A PRAGMATIC APPRECIATION OF MAJOR TRAUMA: DEFINING MAJOR TRAUMA AND EARLY IDENTIFICATION OF THE OLDER ADULT AT RISK OF MORTALITY FROM TRAUMA

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ABSTRACT

Title: A pragmatic appreciation of major trauma: defining major trauma and early identification of the older adult at risk of mortality from trauma.

The existing literature within the field of trauma care originates primarily from an in-hospital focus. There is no global definition of major trauma or relevant trauma triage tool that can be applied in the prehospital phase of care to help early identification of those older adults at risk of mortality from low energy mechanisms of injury who may benefit from early consultant level assessment and ongoing management. Both of these issues are problematic to prehospital clinicians as well as clinicians who work in the emergency department and this thesis sought to address these questions.

An exploratory study to identify prehospital factors associated with outcomes for major trauma patients in a regional trauma network identified candidate variables (Glasgow Coma Score, respiratory rate and age) that provided the foundations of the entire thesis. Critical analysis and synthesis of the existing literature added further domains and issues worthy of critical consideration which included frailty, comorbidities, medications, male gender, injury patterns, ventilatory support, Body Mass Index and acidosis. Subsequently, a series of linked studies applied a mixed-method approach that variously sought to define major trauma from lived experiences of practitioners, gauge the extent to which consensus existed amongst trauma practitioners, and eventually resulted in the tentative formulation of indices for identifying the older adult at risk of mortality from trauma who may benefit from consultant level assessment. A Dynamic Pattern Synthesis analysis accentuated the complexity of trauma in older adults. Collectively, the outcomes of these studies provided an original, elegant and pragmatic definition of major trauma.

"Perceived significant injury or injuries that have potential to be life-threatening or life-changing sustained from either high or low energy mechanisms which also considers the complexities encountered by the extremities of age".

This thesis concludes by offering a tentative predictive model for use in identifying those older adult trauma patients with a high risk of mortality and a prototype triage tool - the *Northumbria Low Energy Trauma Score* (NLETS). It is hoped that this model will prove of practical utility to all practitioners operating in a prehospital environment.

ACKNOWLEDGEMENTS

As a specialist in major trauma, the role exposes you to scenes that are often unimaginable. Those who share that specialist discipline within prehospital care, emergency departments, operating theatres, trauma wards and rehabilitation have a shared goal which bands us all together in a unique (and often odd) fashion. It is a shared experience which we manage professionally as colleagues as well as socially as friends. We have laughed and cried together, sometimes at the same time. This work is inspired by you all. I am proud to be a tiny cog of the NHS machine that continuously saves lives in such demanding and challenging times.

Without doubt this thesis would not be possible without the tireless support and mentorship of my primary supervisor Doctor Michael Hill. His belief in my abilities and passion to improve clinical care for our older adult trauma patients is unwavering. You made me look at the world differently and you share your passion for research with others in a way that is infectious. I also extend my thanks for the support and guidance to my supervisors Professor Fiona Lecky and Doctor Peter McMeekin. You all took the time to help a very naive clinician on his research journey and I have been humbled by your generosity. I would also like to thank Dr Matthew Kiernan for his guidance in our first study within this thesis (Chapter 6). I am glad I (partially) overcame my fear of technology and software packages which were just the first steps to getting this thesis off the ground with your support.

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A significant volume of data for this thesis was acquired from the Trauma Audit and Research Network (TARN) which is the national trauma registry for England and Wales. The data is generated by a small army of co-ordinators across the nation who are the silent soldiers of the trauma networks to provide this amazing service.

All the Northern Trauma Network members who helped support and participated in the various studies in this project, you know who you are, thank you! You are all legends and always go the extra mile for your patients, colleagues and friends. It is my humble honour to be part of that extraordinary team.

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PUBLICATIONS ARISING FROM THIS THESIS

Full Papers

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Abstracts

Thompson, Hill, Davies, and Shaw (2016). Identifying prehospital factors which influence outcome for major trauma patients in a regional trauma network: an exploratory study. *Emergency Medical Journal,* **33:** e1-e14 http://doi.org/10.1136/emermed-2016-206139.18

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Thompson, Hill, McMeekin, and Shaw (2020) PP11 Defining major trauma in the hyper acute setting. *Emergency Medicine Journal* 2020, **37:**e6. http://doi.org/10.1136/emermed-2020-999abs.11

DECLARATION

I declare that the work contained in this thesis has not been submitted for any other award and that it is my own work. I also confirm that this work fully acknowledges opinions, ideas, and contributions from the work of others.

Any ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the Faculty of Health and Life Sciences Ethics committee at Northumbria University for the relevant studies.

Name: Lee James Thompson

Signature:

Date: 26 May 2022

'I don't know anything about science!'
'Marvellous! Ideal qualification!' said Einstein.
'What?'
'Ignorance is very important! It is an absolutely essential step in the learning process!

-Terry Pratchett (1996) '*Johnny and the Bomb*'

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LIST OF SYMBOLS AND ABBREVIATIONS

Within the context of this thesis the term older adult is synonymous with terms elderly and geriatric. Although the definition of older adults differs throughout contemporary literature, within this thesis the term is used to describe those who are age 65 years and older.

AIS	Abbreviated Injury Scale
BMI	Body Mass Index
CAD	Computer Aided Dispatch
CI	Confidence Interval
CINAHL	Cumulative Index of Nursing and Allied Health Literature
CT	Computerised Tomography
df	Degrees of Freedom
DPS	Dynamic Pattern Synthesis
GCS	Glasgow Coma Score
GOS	Glasgow Outcome Scale
HART	Hazardous Access Response Team
HEMS	Helicopter Emergency Medical Service
HTI-ISS	Hospital Trauma Index-Injury Severity Score
ICISS	International Classification of Disease-9 Injury Severity Score
ICU	Intensive Care Unit
ISS	Injury Severity Score
KPI	Key Performance Indicator
MERIT	Medical Emergency Response Incident Team
MOI	Mechanism of Injury
MTC	Major Trauma Centre
NEAS	North East Ambulance Service
NHS	National Health Service
NISS	New Injury Severity Score
NTN	Northern Trauma Network
OR	Odds Ratio

PH	Prehospital
PTS	Paediatric Trauma Score
QCA	Qualitative Comparative Analysis
RCT	Randomised Controlled Trial
ROC	Receiver Operating Characteristic
RSI	Rapid Sequence Induction
RTC	Road Traffic Collision
RTN	Regional Trauma Network
RTS	Revised Trauma Score
SBP	Systolic Blood Pressure
START	Simple Triage and Rapid Treatment
TARN	Trauma Audit Research Network
TBI	Traumatic Brain Injury
TRISS	Trauma Injury Severity Score
TU	Trauma Unit
TXA	Tranexamic Acid

CHAPTER 1. INTRODUCTION

1.1 Contextual overview

The prehospital environment is complex and challenging and, with the exception of specialised teams, exposure to major trauma is very rare. Although major trauma is the leading cause of death in the UK for adults under 40 years (Moran et al., 2018) there is now a noticeable shift in what was once thought of as a younger adults disease (Kehoe et al., 2015b).

In 2012, regional trauma networks were introduced in England (London were an early implementation region prior to this date). The new trauma networks provided a hub and spoke model where specialist Major Trauma Centres (MTC) hubs with dedicated resources and specialities support satellite (spoke) trauma units (see Figure 1.1). Prehospital clinicians who assess trauma patients as being eligible can bypass local Emergency Departments (ED), which may also be designated as a trauma unit, for definitive care at an MTC. An MTC has 24/7 availability of consultant-level care with access to resuscitation, computerised tomography and operating theatres as well as dedicated major trauma ward, intensive care and rehabilitation services. Trauma units have similar services for immediate resuscitation but if more specialist services are required, immediate transport to the specialist MTC will be undertaken (McCullough et al., 2014).

As the regional trauma networks matured, there was an obvious improvement in patient care with a 19% increase in the odds of survival for major trauma patients who reach hospital alive since their introduction (Moran et al., 2018). As a specialist paramedic working within the Northern Trauma Network (NTN), my perception of major trauma in the early years of the new system was that of a disease affecting the younger/middle aged male population. In addition, injuries were mostly sustained from high energy or violent mechanisms of injury (MOI) and that there was an understanding that major trauma was defined as an Injury Severity Score (ISS) of 15 or greater.

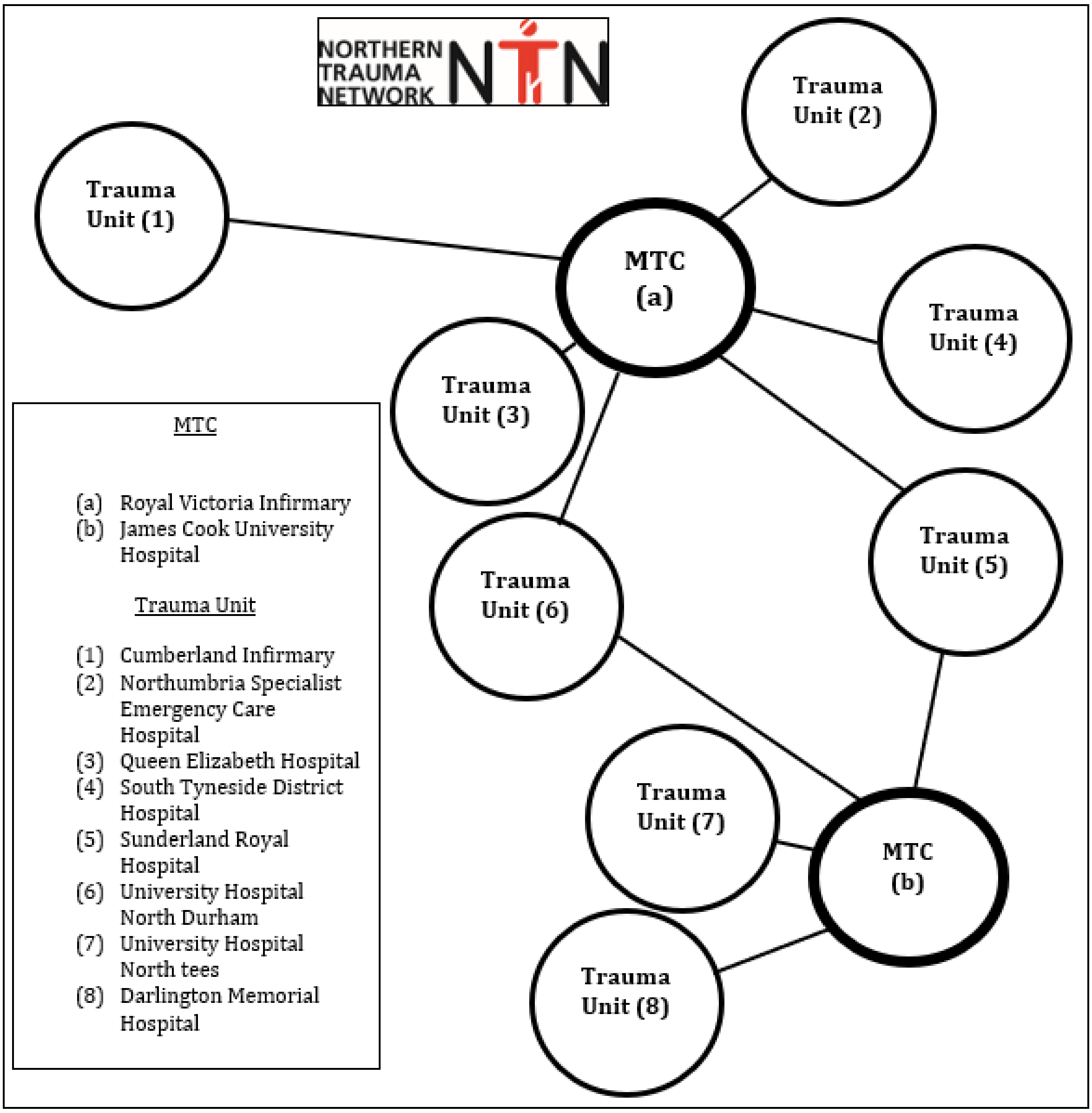

Figure 1. 1 Visual representation of the Northern Trauma Network hub and spoke model.

The ISS is an aggregation of the main injuries from each body region. All injuries receive a code which is generated from the Abbreviated Injury Scale (AIS) dictionary and each body region is scored 1-6 and then squared and the three highest scores added together.

These scores have little utility in the prehospital and hyper-acute settings as accurate AIS codes are only generated after hospital imaging is completed (Trauma Audit and Research Network, 2020). These retrospective scores also do not fully describe major trauma to the non-specialist. Alberdi et al. (2014) highlight that there is no universal definition of major trauma. In the absence of ISS, it is important to be able to define major trauma and provide context to the lay person as well as those who work within the prehospital and hyper-acute phase of care.

There has also been some debate within the NTN about what defines a major trauma patient. To access specialist care at an MTC a major trauma triage tool is utilised to support clinical decision making and identify patients who are eligible. Within the NTN this tool is called the major trauma bypass protocol. The tool utilises physiology, anatomical injuries and special circumstances to identify major trauma (see Figure 1.2) (Northern Trauma Network, 2012). However, the patient must first have a significant MOI which often excludes the older adult falling from less than two metres, which is often not considered as a significant MOI (but may be significant for that individual). Each individual trauma network in the United Kingdom has a bespoke major trauma triage tool for their region to account for local idiosyncrasies, but there is little to differentiate each tool.

Extrapolating regional data from the Trauma Audit and Research Network (TARN), which is the national trauma registry for England and Wales, highlights that trauma patients with an ISS >15 were not necessarily from high energy MOI's or exclusively young adult males. This finding is replicated in the work by Kehoe et al. (2015b) and significantly contributes to the under triage of the older adult highlighted by Hoyle et al. (2020). Throughout this thesis, 'high-energy MOI' will also include violence with or without weapons and penetrating injury of any origin as well as the examples highlighted in Figure 1.2.

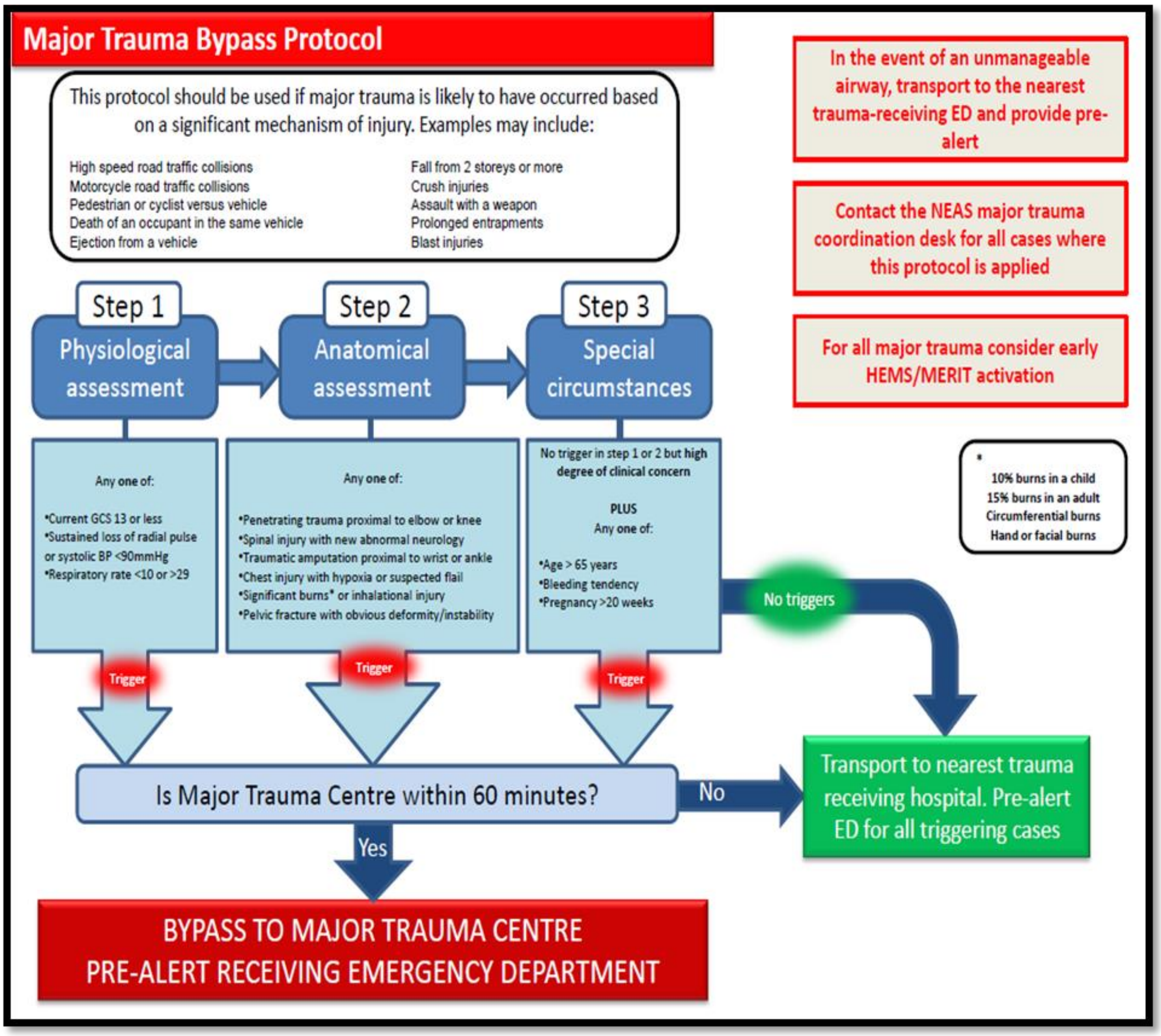

Figure 1. 2 Major trauma triage tool (Northern Trauma Network, 2012).

Based on my clinical experience, it seemed clear that older adults who experience relatively minor/low energy MOI were a significant patient group with considerable injury patterns (and high ISS). When discussing unexpected survivors and unexpected deaths within hospital trauma multi-discipline team meetings there appeared to be a disproportionate number of older adult major trauma patients who were noted as unexpected deaths. As an external specialist who attended multiple meetings at different

NHS Trust hospitals, it was easy to see that there were emerging patterns that stood out with regards to this patient group. Older adult trauma deaths were sustained from relatively low energy MOI, often a fall from standing height, with delayed or unrecognised injuries within the acute phase of care and assessed by relatively junior members of the clinical team. These subsequent delays in recognition and management all contributed to poor outcomes. It is now an acknowledged phenomenon, however, while concluding this thesis a paper by Hoyle et al. (2020) stated that, within the UK, older adults are still at great risk of under triage even within the MTC setting.

The TARN (2017) report into major trauma in older people states that the older adult major trauma group is often complex and preventable harm can result from delays in treatments and that there should be no excuse for discrimination based on age. However, within the NTN it has been acknowledged that identifying those older adults in need of early intervention is challenging and without a recognised older adult trauma triage tool there is a real risk of overwhelming ED's with patients.

Data from TARN highlights that, within the NTN region between April 2012 and March 2017, 56% of eligible patients with significant injuries were due to falls less than two metres. The same dataset shows that 12.5% of patients with an ISS greater than 15 were from falls of less than two metres.

As an operational prehospital specialist, it is also easy to witness the disparity in clinical responses to different types of trauma patients. For example, a pre-alerted stabbing patient being transported to an MTC, which is typically a younger male, would be received by a full trauma team in the resuscitation room. A considerable number of these incidents would require management in the resuscitation room only to see the patient discharged with minimal interventions. They would also not be eligible for entry into the TARN trauma registry (and therefore not receive an ISS). Conversely, I always tell the story of a patient I call George (not his real name) who is in his late 70's and falls down a few steps at home hitting his head, chest and arm. George develops a productive and painful cough and becomes progressively more confused throughout the day. His initial assessment is significantly delayed due to multiple factors within the community and alongside ambulance delays, George is categorised as a low priority. On arrival at hospital, he is seen by a junior clinician. He is reviewed by a senior clinician on the ward the following day and after reviewing notes and further imaging is diagnosed with cerebral haemorrhages and multiple rib fractures. Several days later George dies due to complications of his injuries.

These contrasts in care are also acknowledged in the literature. Although older adult major trauma patients have similar injury patterns to their younger cohorts, they often have a delayed response and assessment and often transported to a local ED rather than a dedicated MTC (Brown et al., 2019b). This pattern of delay in assessment and transport to a local ED, as opposed to a dedicated MTC, is replicated with our own trauma network.

This disparity in response and recognition of injuries between age groups may have multiple contributing factors other than age. It is often compounded by the initial MOI. Anecdotally, high energy transfer within trauma, such as Road Traffic Collisions (RTC) as well as significant violence evokes an emotive response from the initial call whereas a simple fall from standing height does not appear to stimulate a similar response.

The older adult may have many confounders that make an initial assessment after a traumatic incident complex. Comorbidities and polypharmacy can mask their physiological response to trauma, and it is therefore challenging to distinguish between normal and a changing (and often delayed) physiological response for that individual (Fisher et al., 2017).

It is because of the disparity in triage, assessment and ongoing care between the older adult and younger trauma groups that I personally wish to bring an awareness to this issue. I also want to develop a system or tool for early identification of the older adult who may be at risk of adverse outcomes as a result of trauma. I envisage a system that can support clinicians in the acute phase of care and identify those patients who may need urgent senior clinical decision makers involved with their immediate and ongoing management and ideally prevent poor outcomes. Within the context of major trauma a senior clinical decision maker is categorised as a consultant level doctor (Trauma Audit and Research Network, 2021). The initial concept was to potentially design a model that potentially reflected the National Early Warning Score (NEWS) that has been so effective in identifying critically ill or deteriorating medical patients who need interventions (National Institute for Health and Care Excellence, 2020).

1.2 Research Aims and Objectives

The research aims of this thesis are twofold:

- To define major trauma in a pragmatic way that is appropriate to the prehospital and hyper-acute setting; and,
- To develop an elegant predictive triage tool to identify older adults who experience trauma and at risk of mortality and who may potentially benefit from early consultant level assessment and management.

Objectives:

- Critically review the existing literature to explore definitions of major trauma;
- Critically review existing literature to explore the phenomenon of older adult trauma to highlight potential variable predictive of mortality;
- Critically explore prehospital clinicians' perspectives of major trauma and its definition;
- Critically explore the degree of consensus with regards to defining major trauma amongst an expert group; and,
- Identify and extrapolate critical variables and indices that have potential utility in developing an assessment tool for the early identification of older adult major trauma patients at significant risk of mortality who may potentially benefit from early consultant level assessment and management.

Both the definition of major trauma and assessment tool should provide an elegant solution to the aims of this thesis. Abersek (2015) explains the concept of elegance within science where there is potential for infinite complexity which can be interpreted by many as dull and mundane but is a *'refinement'* to provide *'unusual effectiveness and simplicity'*. When the complexity is conceptualised and distilled to its simplest form to express the essence of the issue, it can provide a potent yet elegant solution. It is worth noting that elegance within science does not detract from the complex nature of scientific endeavour but articulates that complexity in a deep and meaningful way which is often viewed as parsimonious.

1.3 Structure of the Thesis

This thesis is a presentation of a series of linked studies. Each chapter could be regarded as an independent study, although, each chapter is intrinsically linked to every other chapter with a narrative that aligns with the aims and objectives highlighted above. While conventionally written in what appears to be a chronological order for the reader, the studies were often undertaken concurrently or out of sequence. Within the final thesis the studies are presented in an order that preserves the main narrative of my argument throughout and not necessarily the order in which they were carried out.

In April 2012, after reports identifying the need for specialist trauma care, regional trauma networks were introduced across the UK which enabled ambulance services to bypass local ED’s and transport severely injured patients direct to definitive care at specialist MTC’s (National Confidential Enquiry into Patient Outcome and Death, 2007, National Audit Office, 2010).

Following the introduction of the NTN, a regional prehospital trauma registry was created which, since its conception, evolved into the NTN prehospital database. This data was combined with outcome data from the national trauma registry maintained by TARN. TARN data allows networks, major trauma centres, trauma units, ambulance services and individual clinicians to benchmark their trauma service with other providers across the country. The combination of TARN with the NTN prehospital database enabled the creation of a meaningful dataset and allowed for a more comprehensive exploration of factors relating to prehospital trauma care. The original study within this thesis (see Chapter 6) explored the epidemiology within the NTN whilst considering the unique geographical features and demographics. This exploratory study intended to provide a baseline against which future performance can be evaluated with the goal of improving patient outcomes.

During the course of this study, it became apparent that there was a disparity between prehospital patients managed as major trauma and those entered into the TARN registry. Prehospital major trauma patients within the NTN region prehospital trauma database were predominantly high energy MOI as dictated by the prehospital trauma triage tool (Figure 1.2) and NTN region TARN eligible patients were more likely to be older and/or originating from lower energy MOI. In their recent paper, Hoyle et al. (2020) highlight the issue of this disparity between younger and older trauma patients. The main issue noted was the under-triage of the older adults and that low energy MOI in this group can lead to severe injury patterns.

Following the completion of the study in Chapter 6, it became apparent that two themes needed further exploration. The first being that if both younger and older major trauma patients have similar injury severity how can we identify those older adults to prevent under-triage, an issue highlighted by Hoyle et al. (2020). The second raises questions over the definition of major trauma given the disparities between young and old.

The ability to identify major trauma patients needing transport to a MTC for definitive care has been associated with improved outcomes (Moran et al., 2018). With this in mind, the first stage in defining major trauma was undertaken in Chapter 2 which is a systematic review of the literature to explore the contemporary definition(s) of major trauma.

ISS is often used by trauma registries such as TARN to describe severity of injury. TARN data must be submitted within 25 days post-incident and scores then attributed to patients based on an aggregation of the main injuries from each body region (Trauma

Audit and Research Network, 2020). These scores have little utility in the prehospital and hyper-acute settings as accurate AIS codes are only generated after hospital imaging is completed.

In the absence of scoring systems and acknowledging the significance of considerable injury originating from low energy MOI, there are conflicting views of what defines major trauma. The systematic narrative literature review in Chapter 2 aimed to provide an understanding of definitions of major trauma used in contemporary literature that would be applicable to prehospital, hyper-acute and early phases of care. The lack of consensus in relation to what constitutes a useful or standard definition of major trauma can make transport decisions challenging. Chapter 2 noted that one approach to defining major trauma involves retrospective scoring of injuries (Thompson et al., 2019b). Unfortunately, as injury scoring systems are often calculated after all imaging and interventions are completed, they are impractical in the prehospital phase of care which, therefore, requires other indices to define major trauma. In the absence of ISS, it is important to be able to define major trauma and provide context to those working in the prehospital and hyper-acute phase of the patient journey as well as non-specialists.

Chapter 4 went on to develop the ideas highlighted in the systematic narrative literature review (Chapter 2) to explore perspectives and definitions of major trauma with a sample of prehospital trauma care providers which included NHS and non-NHS emergency services and first responders.

The proposed research question was: ‘In the absence of retrospective scoring systems can a meaningful definition of major trauma be applied to the prehospital environment?’

This study was conducted as the cumulation of the output of three separate focus groups. It provided rich data from the participants from their lived experiences of working within the prehospital trauma environment. Various themes emerged from very personal accounts to give a prehospital definition of major trauma. The combination of the conclusions of the focus group study and the systematic narrative literature review provided the foundations for a Delphi study to define major trauma. Chapter 5 employed the Delphi process to gauge the degrees of consensus and disagreement amongst expert panel members and utilise their views to provide an expert consensus definition of major trauma.

Jones and Hunter (1995) characterised the Delphi technique as part of a larger group of 'consensus methods' which allow for the harnessing of expert insights. These are derived from appropriate individuals with expert knowledge of the research topic under consideration, in this instance major trauma. The collective output of this expertise can then be shared with all participants and provides a rich resource for all members of the subject expert group to digest (Okoli and Pawlowski, 2004). Further methodological features include:

- Participant anonymity (from one another);
- Iteration – allowing expressed views to be modified at each stage of the process;
- Controlled feedback – in which participants are provided with a summary of their own previous responses at the previous stage; and,
- Statistical group response – in which summary group responses are provided in addition to their own previous responses.

(Jones and Hunter, 1995, Rowe and Wright, 1999)

Delphi techniques have previously been used to seek expert consensus in prehospital care matters (Borger van der Burg et al., 2019, Dippenaar and Wallis, 2019, Seymour-Walsh, 2019). Delphi methodology has, however, been subject to criticism on the basis of methodological flaws, most notably: sampling and use of 'experts'; anonymity; and the issue of enforced consensus (Keeney et al., 2001).

The aim of the study was to utilise the Delphi techniques in order to distil subject expert opinion concerning the definition of major trauma and to critically explore the extent of consensus in the definition of major trauma in the absence of ISS. The conclusions of all three studies (Chapters 2, 4 and 5) gave a universal definition of major trauma and allows us to apply this to all our trauma patients regardless of age or MOI.

With this in mind, exploring the phenomenon of older adult major trauma with the understanding that major trauma, as defined by the new definition (or ISS>15), effects all ages, began with a systematic literature review. During the course of undertaking the initial literature review, a seminal paper authored by Sammy et al. (2016) was published. This paper was a systematic review and meta-analysis of *'Factors affecting mortality in older trauma patients'* which used the same search criteria as our own. In Chapter 3 we extended the time period of the Sammy et al. (2016) paper to include any additional pieces of literature that had become available since its publication. There were limited conclusions from this initial systematic review, therefore, a broader rapid evidence review was undertaken to obtain additional concepts and generalisations with regards to the older adult major trauma population. It was hoped that by identifying key clinical variables it may be possible to predict the outcomes of the older adult with regards to major trauma. As such, both the systematic literature review and rapid evidence review were combined into a single chapter (3) to provide a comprehensive view of key clinical variables that are associated with outcomes in the older adult major trauma patient. The output from the combined literature reviews in Chapter 3 provided the bases of the ongoing studies into older adult major trauma.

Coats and Lecky (2017) describe the emerging picture of major trauma as two distinct disease patterns. The first is high energy MOI's with relatively younger age groups and the second is older adults with lower energy MOI's. However, despite the differences in energy transfer within the MOI's, both groups have similar injury patterns. There is a real concern that older adults with significant injuries have a lower prehospital recognition rate with poor conformity to key performance indicators and are less likely to be transferred to an MTC.

Brown et al. (2019a) highlight a demographic of both older and younger trauma patients which reflects Coats and Lecky's work in addressing the issue of major trauma being two separate diseases (with more than half being older than 51 years). Brown et al. (2019b) also state that older adult major trauma patients were less likely to be transported to a MTC leading to an increased in-hospital mortality.

The literature in Chapter 3 provided sparse details of statistically significant variables which identify older adults who are at high risk of poorer outcomes from trauma. This sparsity of significant findings adds to the growing complexity of this patient group. There are multiple guidelines that provide essential tools within the clinical setting that are evidence-based. However, quality measures rarely take into account the complexity of patients (which include multiple co-morbidities, socioeconomics, culture, environment and behaviour) which may also influence patient centred care (Safford et al., 2007). This complexity became apparent within our exploration of the older adult major trauma patient group.

The need for evidence-based medicine is underpinned by the aim of identifying generalizable, end-chain, linear cause and effect relationships to the detriment of both multi-causality and complexity. This arises from Western medicines methodological alliance with Positivism. Not all phenomena of clinical interest (e.g., low energy trauma in the elderly) can be explained in such strictly linear terms. However, complexity science challenges these linear and mechanistic patterns of traditional evidence based medicine (Braithwaite et al., 2018). The traditional hierarchy of evidence which places systematic review and meta-analysis of randomised control trials (RCT) as well as the RCT's themselves at the pinnacle of the evidence pyramid is difficult to challenge. The limitations of this hierarchy and level of evidence are that they only provide linear causality conclusions and other methods need to be considered to explore other potential conclusions (Murad et al., 2016). For example, complexity theory as a research methodology is described by Gear et al. (2018) as an approach to *'capture new insights into complex problems'.*

Haynes (2017) uses a mixed-method approach to complexity theory which combines a quantitative phase, called 'Cluster Analysis', with a qualitative phase, called 'Qualitative Comparative Analysis (QCA)'. When these phases are combined, they create the method called 'Dynamic Pattern Synthesis (DPS)'.

The cluster analysis combines multiple measurements (such as age and outcomes) into case-based groups according to their similarities or differences to create clusters. Patterns within and between the clusters are then explored using QCA. This purposeful sample was used in an attempt to compare small groups of cases with similarities. Once a dynamic pattern is identified within a small sample it is then replicated with another set or sets of different samples.

Chapter 7 aimed to identify dynamic patterns within the complexity of major trauma age groups in the prehospital and hyper-acute settings to identify if clustered variables can assist in predicting those older adults who have a high risk of mortality due to a traumatic event. The study confirmed the complexity of the older adult major trauma population and highlighted the need to explore a model that would more accurately predict older adult major trauma with regards to mortality.

In the previous chapters we have stated there is a significant increase in the volume of older adult major trauma patients who have significant injuries with poor outcomes which is described as the *'The grey tsunami'* by Rehn (2013). This grey tsunami of older adult major trauma predominantly occurs from relatively low energy MOI, such as a fall from standing height, which is a common dispatch criterion for ambulance services (Brown et al., 2019a). It is also difficult for prehospital care providers to identify those older adults who may have significant underlying injuries which may be categorised as major trauma due to the complexity of this patient group which is highlighted in Chapter 7.

Using the new definition of major trauma addressed in the previous chapters (2, 4 and 5) and the potential predictive variables of mortality highlighted in the literature review (Chapter 3) and exploratory studies (Chapters 6 and 7), a further study was undertaken to develop a predictive model. It is obviously preferable to intervene in the older adult major trauma patients' journey of care to prevent a fatal outcome. Therefore, developing a predictive model to identify those individuals who may benefit from early interventions to improve their potential outcome is desirable.

Ranapurwala et al. (2019) explain that predictive models can provide a tool to understand the multidimensionality of health outcomes at an individual level and to improve patients' outcomes. This reflects the complexity and multidimensionality of older adult trauma which is highlighted in Chapter 7 which acknowledged that we can only really identify tendencies with regards to prediction. As such, we are not only dealing with complexity, but also with individuals who are so different that generalisations defy modelling. With these considerations, identifying potential red flags (such as age, gender, physiology, co-morbidities, medications, and injury patterns) may form an initial assessment criterion in early identification of those individuals who may benefit from specialist intervention.

The identification of the older adult who experiences trauma with potentially significant injury requires a predictive model to allow for early intervention to improve their outcome. Building upon the models highlighted above combined with the predictive variables that were identified in previous chapters (3, 6 and 7) it is believed to be the first step in achieving improved outcomes for this patient group.

Using a modified criterion, highlighted by Cardona-Morrell and Hillman (2015), the variables considered within a predictive model that are appropriate within the prehospital and hyper-acute setting should:

(i) be easily collected in routine practice or easily accessed from electronic or paper documents;
(ii) not require special clinical judgement to maintain objectivity; and,
(iii) be sufficient to independently predict mortality.

Within the context of the Cardona-Morrell and Hillman (2015) paper, it is highlighted that using such tools are not meant as a replacement to clinical judgement but are an objective method to supporting clinical decision making.

The overall goal of the older adult major trauma predictive model studied within Chapter 8 is to provide sufficient sensitivity and specificity to identify those at risk of mortality and who may potentially benefit from early consultant level assessment and management. To give an indication of where that patient is within a sliding scale of risk the variables needed to be weighted to reflect the impact they may have on the patient. For example, increasing age, reducing Glasgow Coma Score (GCS), reducing systolic blood pressure (SBP), number of comorbidities, etc. Binary variables were also weighted but eventually reflected the nature of binary variables and limited to zero and one (binary scoring). A good example of a weighted predictive tool is the National Early Warning Score (NEWS) (now NEWS2) (National Institute for Health and Care Excellence, 2020). The tool uses physiological parameters and each parameter is given a score of 0-3 with an increasing score given the further it deviates from normal. The aggregation of these scores then allocates the patient to a level of risk (low to high). The older adult major trauma prediction tool highlighted in Chapter 8 follows a similar weighted criterion and offers a sense of familiarity to prehospital clinicians in a simple to use table (that is being developed as a smartphone/device application). The overall aim of Chapter 8 is to derive a predictive model that can use easily obtained data in the prehospital and/or hyper-acute setting to identify those older adults who have a high risk of mortality due to a traumatic event.

The conclusions of this thesis provide a practical and elegant definition for major trauma and a predictive tool that evolved to become appropriate for all ages experiencing low energy trauma which is heavily weighted for the older adult. I believe that the definition can become the global standard for defining major trauma and the low energy trauma scoring tool can provide a mechanism for identifying the older adult at risk from trauma and improve their outcomes.

1.4 Summary

This series of linked studies has gone some way to providing a pragmatic definition of major trauma as well as developing an elegant trauma triage tool that will identify the older adult at risk of mortality as a consequence of trauma. This has been achieved through a critical review of the existing literature as well as critically exploring perspectives of clinicians through focus groups and expert consensus utilising the Delphi technique to define major trauma. A further critical review of the literature combined with the identification and extrapolation of variables and indices to explore and develop an assessment tool that will identify the older adult who experience low energy MOI who is at risk of mortality. As such the Northumbria Low Energy Trauma Score should provide a means to improve the outcomes of the older adult and potentially reverse a trend of poor assessment and delays in care and ultimately reduce potentially preventable death in this complex patient group.

CHAPTER 2 DEFINING MAJOR TRAUMA: A SYSTEMATIC NARRATIVE LITERATURE REVIEW

2.1 Introduction

Major trauma is a leading cause of death with 5.8 million people dying annually worldwide (Bouzat et al., 2015). Kehoe et al. (2015b) state that major trauma is perceived to be a younger person's disease as it is the leading cause of death and disability for those aged less than 40 years. However, it is now recognised that an increasing proportion of major trauma patients are elderly (Rickard et al., 2021), with significant injuries from relatively low energy MOI's, such as a fall less than two meters (Dixon et al., 2020). However, the recognition of increasing numbers of elderly trauma may be due to multiple reasons. One such example may be improved data collection since the introduction of trauma networks in 2012 (England) which are funded by the best practice tariff (Moran et al., 2018). Also, by 2030 it is projected that number of people aged over 65 will increase by 50% and those over 85 will increase by 100% (TARN, 2017).

Within the NTN it has been debated as to what defines a patient as having major trauma. To access specialist care at a MTC a major trauma triage tool is utilised by clinicians which uses physiology, anatomical injuries, and special circumstances to identify major trauma. Each individual trauma network in the United Kingdom has a bespoke major trauma triage tool for their region to account for local idiosyncrasies, but there is little to differentiate each tool. However, a nuance with the NTN tool (see Figure 1.2) highlights that the patient must first have a significant MOI. Although not an exhaustive list, the tool highlights various examples which has been interpreted within the NTN to exclude low energy mechanisms which may be significant to vulnerable groups such as the older adult falling from less than two metres. Although this was believed to be a local issue, owing to the nature and interpretation of the local major trauma triage tool, the under triage of the older adult trauma patient appears to be a global issue (Alshibani et al., 2021).

Data from TARN, a national trauma registry for England and Wales, highlight that within the NTN, 56% of TARN eligible patients between April 2012 and March 2017 had significant injuries due to falls less than two metres. ISS is often used by trauma registries such as TARN to describe the aggregation and severity of injury. TARN data must be submitted within 25 days post-incident and scores are then attributed to patients based on that data. TARN database entry requires a patient to have experienced trauma and either be admitted to hospital for more than 72 hours and/or require critical care or die as a consequence their injuries. Alberdi et al. (2014) state that there is no worldwide standardised definition for major trauma and therefore retrospective scores (such as ISS) are commonly used to quantify the severity of injury.

Retrospective injury scores are not available during the prehospital and hyper-acute phase of care. In the absence of scoring systems, and acknowledging the significance of considerable injury originating from low energy MOI's, there are conflicting views of what defines major trauma and it has generated our research question: 'In the absence of retrospective scoring systems can a meaningful definition of major trauma be applied to the prehospital environment?'

This systematic narrative literature review aims to provide an overview of existing definitions of major trauma and considers their utility in relation to the prehospital phase of care.

2.2 Methods

The PRISMA reporting method was used throughout this systematic narrative literature review as recommended by Moher et al. (2009). All literature that focused on trauma patients where an explicit definition of major trauma was used was considered for inclusion. An eclectic approach to study designs (S) was adopted, with cohort studies, case reports, systematic reviews, and meta-analysis, as well as expert opinion and commentaries, all considered.

Major trauma as an outcome measure is inconsistently defined with limited evaluation of its quality as an outcome measure. Therefore, a consequence of the limited primary research that focuses on defining major trauma, this systematic narrative literature review takes an eclectic view of the study criteria for inclusion. It was hypothesised that a general overview of the subject area (major trauma) could be synthesised (Green et al., 2006). A systematic search of the literature was performed using CINAHL, Cochrane Library and Web of Science (MEDLINE). No date ranges were set during the search criteria.

Inclusion criteria were developed with the assistance of a research librarian from Northumbria University, and included all patients, regardless of age, with Boolean search terms 'major' and 'trauma' with the truncation 'defin*' to capture all the variations of the word definition (define, defined, definitions, etc.). The additional criteria of: a) text in English; and, b) peer reviewed were also incorporated. No other inclusion/exclusion criteria were considered.

All abstracts identified within the search were reviewed to ensure the literature contained discussion around the definition of major trauma. A shortlist of abstracts was reviewed in full text and included. The sole criteria for inclusion in the final list was the presence of a definition of major trauma within the body of the article, regardless of whether it originated from another source (e.g., circular citations). The intention therefore was to obtain and review multiple perspectives/frequencies of major trauma definition.

The search was complimented by additional texts identified via reference lists of the original articles and relevant grey literature known to myself.

This review has elements of both a systematic review and narrative review. The systematic search procedures associated with systematic reviews did not undertake meta-analysis because of the wide variation in methods of the source material and therefore findings are presented narratively.

2.3 Results

The initial search identified 5118 papers which were reviewed in full to obtain a short list of relevant documents. Those texts that did not provide a definition for major trauma (n=4976) were excluded from the review, as were duplicates (n=21). A total of 121 texts were considered to be appropriate for this review (see Figure 2.1).

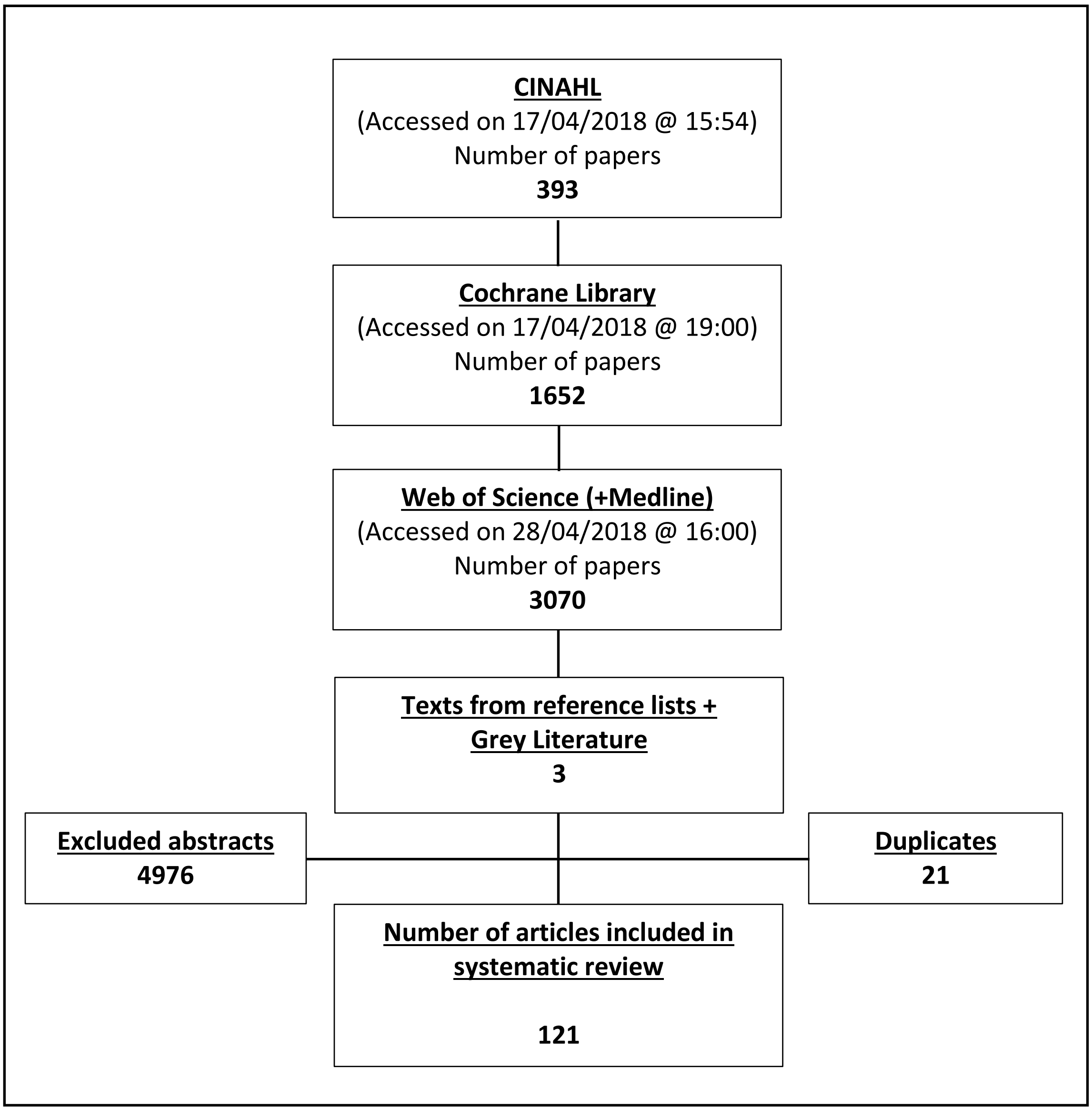

Figure 2. 1 Results of systematic narrative literature search and selection process.

Each document was examined to determine which variables were used in the definition of major trauma. Many documents used multiple variables to define major trauma. NVivo qualitative data analysis software (QSR International Pty Ltd., Version 11, 2015) was used to code the texts and identify trends and commonality of definitions across all the literature reviewed. Table 2.1 summarises all identified individual variables that were used within the literature to define major trauma.

Table 2. 1 Summary of individual variables identified within the literature for defining major trauma.

Criteria for defining major trauma	*(n)*
Injury Severity Score (ISS)	103
Fatal outcome	21
Injury type/pattern	16
Intensive Care Unit (ICU) admission	12
Requires surgical intervention	12
Mechanism of injury (MOI)	9
Haematocrit decrease	7
Abbreviated Injury Scale (AIS)	6
New Injury Severity Score (NISS)	6
Requiring ventilation	5
Receiving blood products	4
Deranged physiology	2
Revised Trauma Score (RTS)	2
Trauma Injury Severity Score (TRISS)	1
International Classification of Diseases-derived ISS (ICISS)	1
Hospital Trauma Index ISS (HTI-ISS)	1
Paediatric Trauma Score (PTS)	1
Prehospital index greater than 3	1

Some texts used combinations of criteria but most often, they used retrospective scoring systems such as ISS, with the common consensus that a score greater than 15 was the standard for defining major trauma.

Injury type or patterns were key defining variables in 16 articles. Injury type/region are also the foundation of retrospective scoring methods (such as ISS). Articles by Blacker and Wijdicks (2004), Furrer et al. (1995), Paffrath et al. (2014), Rowell et al. (2011), Sapan et al. (2016), Shahim et al. (2006) and Stuke et al. (2013a) all use multiple injuries/fractures as part of their definition of major trauma. Although two or more injuries were a sufficient criteria in itself for Paffrath et al. (2014), Shahim et al. (2006), and Stuke et al. (2013a) the other studies necessitated additional criteria, such as a certain level of ISS or admission to ICU. Barrera et al. (2013) also state the need to have deranged physiology in addition to multiple injuries to qualify as major trauma. Other articles are more specific in mentioning individual injuries such as pelvic fracture, spinal fractures, chest or abdominal injuries (Bressan et al., 2015, Burbridge et al., 1991, Cox et al., 2011, Shahim et al., 2006, Stuke et al., 2013b, Voth et al., 2017). It is important to note that these texts, almost exclusively, report case series that examine specific sub-groups of patients who experience polytrauma. Although they list individual or multiple injuries in their definition of major trauma, they also state other variables such as ISS. However, being cognisant of developing a definition that is appropriate, these variables need to be appropriate and easily identified by prehospital clinicians (Table 2.2).

Table 2. 2 Potential prehospital variables identified as defining major trauma.

Variables	**(n)**
Fatal outcome (for patient)	21
Injury type/pattern	16
Intensive Care Unit (ICU) admission (perceived need)	12
Requires surgical intervention (perceived need)	12
Mechanism of injury (MOI)	9
Haematocrit decrease (not routinely available)	7
Requiring ventilation	5
Prehospital index	4
Receiving blood products	4
Deranged physiology	2
Revised Trauma Score (RTS)	2
Paediatric Trauma Score (PTS)	1

Haematocrit point of care testing was identified in seven articles but is not routinely available in the NTN region for prehospital crews. The need for blood products can potentially be anticipated by prehospital teams as there are existing protocols which are used by some prehospital teams (Vuorinen et al., 2020). However, haemodynamics do not appear to be predictive of need (Mix et al., 2018) and the evidence for using prehospital blood products is of low quality (Scott and Sutton, 2016). To a similar extent, there is potential for the perceived need for surgical intervention and intensive care unit (ICU) admission, although this may be difficult in some instances with little to no evidence to support this (Mulholland et al., 2005, Mulholland et al., 2008). Within the NTN region, the criteria for requiring blood products are the same as for tranexamic acid (TXA) administration and therefore prehospital teams could use the administration of TXA as a potential indication for needing blood products (carried by our Helicopter Emergency Medical Service – HEMS). However, there appears to be a significant discrepancy about the protocols for prehospital transfusion of blood products (Thies et al., 2020, van Turenhout et al., 2020).

The Revised Trauma Score (RTS) (Cummings and Mayes, 2007) and prehospital index (Lavoie et al., 2010) use deranged physiology as indicators for major trauma and are already part of our existing regional major trauma triage tool and therefore appropriate to prehospital teams. The Paediatric Trauma Score (PTS) (Narotam et al., 2006) also uses deranged physiology (systolic blood pressure and mental status) in addition with weight, airway status, fractures and wounds, as part of the scoring matrix. Although specific to paediatrics, these factors can be applied to defining major trauma within in the prehospital environment.

There were nine articles from the 121 texts identified in the review that highlight MOI when attempting to define major trauma (see Tables 2.3 – 2.5). The Oxford Centre for Evidence-Based Medicine (OCEBM) score was calculated after critical appraisal of the evidence by a single researcher and checked by a second researcher (Howick et al., 2011, Barry et al., 2019).

Table 2. 3 Defining major trauma using mechanism of injury (MOI) (a).

Authors	Aim	Sample	Method	Location	Definition of major trauma/comments	OCEBM Level of Evidence Score*
Barrera et al. (2013)	To assess the effects of thromboprophylaxis in trauma patients on mortality and incidence of deep vein thrombosis and pulmonary embolism. To compare the effects of different thromboprophylaxis interventions and their effects according to the type of trauma.	16 RCT studies were included in this systematic review (n = 3005).	Systematic review of randomised controlled trials.	Various, including UK, continental Europe and USA.	For purposes of inclusion major trauma defined broadly, e.g., physiological: penetrating or blunt trauma with more than two organs and unstable vital signs; anatomical: people with an ISS higher than 9; mechanism: people who are involved in a 'high energy' event with a risk for severe injury despite stable or normal vital signs. *Comments:* Authors did not seek to define major trauma as a primary objective of this study, but only as an operational means of assessing the clinical efficacy of thromboprophylaxis in trauma patients. The adoption of a wide operational definition is perhaps a function of the need to include sufficient articles in this systematic review.	1a
Bond et al. (1997)	To explore if combined trauma scores improve the sensitivity and specificity over that of individual scores.	3147 trauma incidents which identified the nature of injury (MOI)	Prospective cohort study combining PHI and ISS where MOI is identified.	City of Calgary, Canada.	ISS > 16. Authors concluded that combining prehospital index with mechanism can identify ISS > 16. Authors note that not all 'major trauma' can be identified this way.	2b
Boyle et al. (2008)	To determine if MOI alone is a useful predictor of major trauma in prehospital trauma triage.	4571 trauma incidents in which MOI was used as a basis of assessment.	Retrospective cohort study using secondary data analysis of existing trauma case records.	Victoria, Australia.	Authors claim that individual MOI criteria have no clinical or operational significance in prehospital trauma triage of patients who have an absence of physiological distress and significant patterns of injury.	2b

Table 2. 4 Defining major trauma using mechanism of injury (MOI) (b).

Authors	Aim	Sample	Method	Location	Definition of major trauma/comments	OCEBM Level of Evidence Score*
Cooper et al. (1995)	To investigate the appropriateness of MOI as an exclusive indicator for trauma centre triage.	112 clinician questionnaires.	A prospective cohort study utilising clinician reported data questionnaires.	South Carolina, USA.	MOI alone had a positive predictive value of only 6.9%. MOI may not, by itself, justify bypass of local hospitals in favour of trauma centres.	2b
Kubat et al. (2015)	To define minor and major trauma and to analyse the likelihood of fatal outcome if Vertebral Artery Injury (VAI) is present.	150 publications reviewed resulting in (n = 241) trauma cases where VAI was present.	Narrative review. Secondary data analysis of retrospective case reports.	Various, including USA, Canada, Japan, UK, continental Europe.	The authors employ no concrete definition of major trauma but advise that MOI (with radiological screening) allow for differentiation between major and minor trauma.	4
Lossius et al. (2012)	To investigate the effects of different definitions of major trauma on perceived over- and under-triage rates.	'Approximately' 360 cases.	Retrospective cohort study using secondary data analysis of existing trauma case records.	Stavanger, Norway.	Authors identify ISS > 15 and NISS > 15 as defining major trauma but also identify extended definitions, which include the mechanism of proximal penetrating injury. Authors claim that defining major trauma in terms of mechanism alone drastically increases risk of over-triage.	2c

Table 2. 5 Defining major trauma using mechanism of injury (MOI) (c).

Authors	Aim	Sample	Method	Location	Definition of major trauma/comments	OCEBM Level of Evidence Score*
Magnone et al. (2017)	To analyse the association between MOI and 'major trauma' as defined by ISS > 15.	1575 case records.	Retrospective cohort study using secondary data analysis of existing trauma case records.	Bergamo, Italy.	Over half of patients taken to trauma centres based on mechanism alone are discharged from the emergency department. Authors acknowledge the need for separate protocols for older adults.	2b
Potter et al. (2013)	To assess the sensitivity of the Wessex Triage Tool against cases where ISS > 15.	171 TARN database records.	Retrospective cohort study using secondary data analysis of existing TARN database records.	Plymouth, UK.	Authors identify ISS > 15 as definitive of major trauma but state that prehospital triage tools using MOI would exclude many defined major trauma patients, especially older adults.	2b
Stuke et al. (2013a)	To review a single centre experience with past and present national triage criteria to determine which MOI predicts trauma centre need.	3569 case records.	Retrospective cohort study using secondary data analysis of existing trauma case records.		Significant predictors of Trauma Centre Need included death in the same passenger compartment, ejection from vehicle, extrication time of > 20 minutes, fall from > 20 feet, and pedestrian thrown/run over.	2b

*Based on the scoring matrix of the Oxford Centre for Evidence-Based Medicine (2009).

Barrera et al. (2013) are the only authors to use a 'high energy event' with a risk of severe injury as a definition for major trauma. No other articles use MOI to define major trauma. However, Bond et al. (1997) use mechanism in combination with prehospital index to identify major trauma with an ISS > 16 but recognise this may exclude some major trauma.

Lossius et al. (2012) specifically use the mechanism of proximal penetrating trauma in their extended definition of major trauma. Stuke et al. (2013a) do not use mechanism to define major trauma but use death in the same passenger compartment, ejection from vehicle, extrication time of more than 20 minutes, fall from more than 20 feet, and pedestrian thrown/run over as indicative of trauma centre need (but not as a specific definition of major trauma).

The majority of articles that discuss MOI in defining major trauma either suggest that MOI does not identify all major trauma (Bond et al., 1997, Cooper et al., 1995, Potter et al., 2013, Stuke et al., 2013a) or that by using MOI there is high potential for over-triaging major trauma (Lossius et al., 2012, Magnone et al., 2017). For example, Boyle (2007) categorically states that MOI should not be used to identify major trauma and that, in the absence of deranged physiology or specific injury patterns, it has no clinical significance. The Magnone et al. (2017) MOI article is interesting in that they state that older adults should have their own field triage tool to identify those major trauma patients who require expertise in managing their ongoing care to influence their outcomes.

2.4 Discussion

Within the context of this systematic narrative literature review the main criteria for defining major trauma is by applying a retrospective scoring system with ISS being the most common method and essentially an aggregation of the patients' injuries and frequently referred to within the trauma community.

The ISS (Baker et al., 1974) originated in order to identify (and provide some equivalence between) anatomically different injuries of equal severity and developed from two years of RTC data (n = 2128) which included motorists, passengers, pedestrians and other road users. Data were first classified in accordance with an existing AIS for each body region and severity of injury (see Table 2.6) ranging from 1 (minor) to 6 (non-survivable). The pre-dominant score from each body region (head or neck, face, chest, abdomen, extremity or pelvis, external) is squared and the three highest scoring body regions added together to calculate the ISS (Trauma Audit and Research Network, 2020).

Table 2. 6 Abbreviated Injury Scale (AIS)

1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Non-survivable

However, retrospective scores, such as ISS, are not helpful for a prehospital clinician trying to triage an acutely injured major trauma patient. Furthermore, even at its inception, it was noted that discrepancies in the use of ISS existed between receiving hospitals and the ISS was noted to be particularly problematic when considering children and older adults. In relation to the latter point, the original authors acknowledged that *'increased mortality in the elderly is most pronounced when the injuries are least severe'* (emphasis in original document by Baker et al. (1974)). In the original paper, an ISS<10 was rarely an indication of mortality and an ISS between 10 and 50 was deemed to be *'important evaluative indices'*. Although this seminal paper describes the levels of injury and their potential implications, it is difficult to accurately pinpoint when an ISS>15 became a surrogate marker for major trauma, although it is often attributed to Boyd et al. (1987). Palmer (2007), states that this scoring mechanism is '*arbitrary'*, *'changeable'*, and *'one dimension[al]'*.

The difficulties in dealing with the cumulative effects of polytrauma, where ISS was recorded in accordance with the most severe injury observed, regardless of the extent of more minor concurrent injuries, were only partially resolved by use of the scoring system outlined above. Further problems included the fact that no sensitivity or specificity analysis was undertaken in relation to this scale. Moreover, the scale was based exclusively upon RTC data, and therefore trauma as a consequence of high energy transfer. While these data may therefore usefully translate into similar MOIs, such as falls from a significant height, their use in mechanisms such as stabbing, gunshot wounds or low energy falls may be more problematic. MOI is explicitly referenced in the literature when defining major trauma only to highlight that, in isolation, MOI is not appropriate to identify or define major trauma (note how this is embedded into ISS through its historic development).

An ISS ≥ 15 is, however, the pre-dominant definition for major trauma from the literature highlighted within this review (n=103). It is a universally accepted 'measure' of major trauma based on injury types, body area and the aggregation of those injuries. This scoring system was not designed to prospectively identify possible major trauma and therefore MOI, physiology, haematocrit levels and age become irrelevant when providing a score to identified injuries. These scoring systems are potentially complex and not easily applied in the prehospital phase of care, where there is limited diagnostic equipment, and other criteria may be appropriate to define major trauma for the early hyper-acute phase of care. While progress in medical diagnostic technologies and classification systems such as ISS have (arguably) improved healthcare delivery (OECD, 2016), authors such as Lu (2016) have argued that this statement cannot be observed to be universally true. As clinicians become increasingly reliant upon scoring and measurement to inform (and perhaps even shape) clinical decision-making, it is arguable that there is a subsequently decreasing reliance upon clinical examination and history taking which is potentially deskilling practitioners (Verghese and Horwitz, 2009). Although Verghese and Horwitz (2009) highlight this potential for deskilling they advocate for the ritualistic bedside physical assessment to guide data gathering and support clinical decision making.

Epner et al. (2013) have suggested that an orthodox account of the role of diagnostic scoring in clinical situations would suggest that: (a) diagnosis arises primarily from history and physical examination; and (b) diagnostic testing/scoring is used merely to confirm clinical diagnosis. However, diagnostic testing and measurement have expanded in parallel with technological advances, and this can also be argued to have been accompanied by a 'rising tide' of diagnostic testing in areas such as prehospital care. In most instances, the value of such testing is assessed in its own terms, for example measures of laboratory efficiency and internal consistency, rather than in terms of actual patient outcomes.

Multiple injuries are a common feature of defining major trauma, but it is noted that individual injuries in the presence of deranged physiology can also be indicative of major trauma. Fatalities due to trauma are also regularly referred to in the literature as major trauma.

A fatal outcome from trauma, which is often referred to in the literature as major trauma, can be applied to any setting and should therefore be applied to the prehospital definition of major trauma. However, it should also be noted that fatalities of medical origin are often the primary causal factor of, for example, RTCs. The practice of recording these fatalities in trauma statistics probably represents a significant source of data contamination, as any concurrent injuries, however severe, are often not the cause of death.

The literature indicates that deranged physiology (low blood pressure, reduced consciousness, low or high respiration rates) are indicative of the body's response to major trauma and are commonly identified within an initial assessment (Kim et al., 2017). Deranged physiology is also a key component of the prehospital index, RTS and PTS.

Prediction of potential ICU admission, surgical intervention, need for blood products or ventilation (predicted or ongoing) are all potentially identifiable by prehospital teams and are variables routinely used to define major trauma in the literature. However, it has already been noted that there is great variability in identifying patients within these groups (Thies et al., 2020, van Turenhout et al., 2020) and should therefore be considered as subjective variables unless clear protocols are identified.

Limitations

Within this literature review all articles were identified and assessed using an eligibility criterion with obvious heterogeneity in patient groups and variables. To allow for the reproduction of this systematic narrative review, the method has been carefully described. Only peer-reviewed articles have been used.

Conclusions

The most common definition of major trauma in contemporary and historical use is that of 'an ISS greater than 15'. However, in the prehospital environment, retrospective scoring systems are not available and other variables must be considered. Based upon this review, a meaningful definition of major trauma is suggested as: 'A traumatic event resulting in fatal injury or significant injury with either: appropriate prehospital triage scores (prehospital index, RTS, PTS), deranged physiology, regardless of MOI, or potential requirement for significant treatment sequelae such as ICU admission, ventilation, surgical intervention, or the administration of blood products.'

CHAPTER 3 OLDER ADULT TRAUMA: A COMBINED SYSTEMATIC LITERATURE REVIEW AND RAPID EVIDENCE REVIEW

3.1 Introduction

The Trauma Audit and Research Network (2017) acknowledge that the balance between risk and benefit in the older trauma patient is often complex. Trauma team activation and early activation of geriatric specialists can improve outcomes in the older adult trauma patients although there is an age bias by prehospital teams because of its complex nature and relatively low energy mechanisms and perceived futility of treatment (Eichinger et al., 2021). However, within the NTN it is acknowledged that identifying those older adults in need of early intervention is challenging and, without a recognised older adult (low energy) trauma triage tool, there is a real risk of overwhelming ED's or transporting patients over great distances to specialist MTC's, which may not be appropriate or potentially detrimental to the long-term care of this complex patient group.

Chapter 6 looks at multiple factors that influence outcome (mortality) in major trauma (Thompson et al., 2017). A clear contrast between what prehospital teams manage as major trauma and what is recorded within TARN data emerged as a consequence of the study. Although age was a key variable within the study prehospital data, which focused on high energy MOI, was significantly different from the TARN data which highlights all eligible patients and their injuries regardless of MOI. TARN data had more older adults and more low energy MOI which was omitted from the prehospital dataset as the current major trauma triage tool excludes low energy MOI (see Figure 1.2). As a consequence, further research is required to identify any prognostic indices for future clinical practice to potentially identify the older adult who may have significant injury and poor outcomes within the prehospital phase of care.

To understand the phenomenon of older adult trauma, a systematic literature review was undertaken. During the course of undertaking the review a seminal paper authored by Sammy et al. (2016) was made available. This paper was a systematic review and meta-analysis of *'Factors affecting mortality in older trauma patients'* which used the same search criteria as our own. However, the systematic literature review provided a limited volume of data from which to understand the phenomenon fully or provide sufficient variables that may provide data to explore a potential predictive model. This chapter will combine: (i) a systematic review of the literature using the same criteria as Sammy et al. (2016), with, (ii) a rapid evidence review which explores a more diverse overview of defining major trauma.

Within the context of developing a predictive tool to identify older adults who are at risk of mortality from trauma and therefore may benefit from early intervention variables need to be identified so they can be explored, tested, and validated to provide robust data. It was hypothesised that by undertaking a combined systematic literature review and rapid evidence review key variables would be identified to support the development of a predictive tool.

Therefore, the aim of this combined systematic literature review and rapid evidence review is to highlight potential variables predictive of mortality in the older adult trauma patient group within the prehospital phase of care. As such, this may potentially lead to early identification of those individuals who may benefit from early consultant level assessment and ongoing management.

3.2 Methods

A systematic literature review (Phase A) was supplemented by a rapid evidence review (Phase B) which followed the principles highlighted by Collins et al. (2015). Both phases were performed using CINAHL, Cochrane Library, Medline, Nursing and allied health and EMBASE databases.

Although the older adult is referred to those aged greater than 65 years throughout this thesis, the inclusion criteria for both phases included all ages greater than 55 years. This was to ensure the capture of literature that may use different age groups within their own criteria of older adult. All databases were explored initially using the Boolean search terms within the abstract with first line of the search string as: 'elder*' OR 'older' OR 'geriatric*'), with the second line as: 'trauma', and third line as: 'survival' OR 'mortality' OR 'morbidity' or 'fatal'.

For the systematic literature review (Phase A), studies included would be prospective multi-centred cohort studies with the additional criteria of: 'text in English' and 'peer reviewed'. Dates were limited to literature generated after the Sammy et al. (2016) and therefore between March 2015 and July 2019. For the rapid evidence review (Phase B) the same criteria was utilised but omitted the limitation of prospective multi-centred cohort studies within the time frame January 2004 and July 2019. The PICO research criteria are listed in Table 3.1.

Table 3. 1 PICO research criteria

Population	Older adults who experience major trauma
Intervention	Timings (on-scene, transport, overall prehospital phase) and/or physiology and/or clinical interventions,
Comparator	Patients outside the included characteristics
Outcome	Mortality

The search was complimented by the addition of literature identified via the reference lists of the original articles identified in the search process as well as the addition of grey literature or documents known to the authors.

Rayyan, the online application for systematic reviews, was utilised to manage the literature (Ouzzani et al., 2016).

The results will be tabled as:

Phase A: Systematic literature review, and,

Phase B: Rapid evidence review.

3.3 Results

3.3.1 Phase A: A systematic literature review

The initial search identified 1,096 abstracts (see Figure 3.1 for PRISMA flow diagram). During the course of undertaking the review a seminal paper authored by Sammy et al. (2016) was made available. This paper was a systematic review and meta-analysis of *'Factors affecting mortality in older trauma patients'* and used the same search criteria as our own. Therefore, our review will discuss the above paper and limited to the subsequent literature that has become available since March 2015 which was the end point within the final analysis to be completed by Sammy et al. (2016). No secondary analysis of the materials generated by and prior to the Sammy paper were undertaken and therefore a limitation of this review.

Abstracts were screened for inclusion and exclusion criteria and a total of three papers were considered to be appropriate for this review (see Table 3.2).

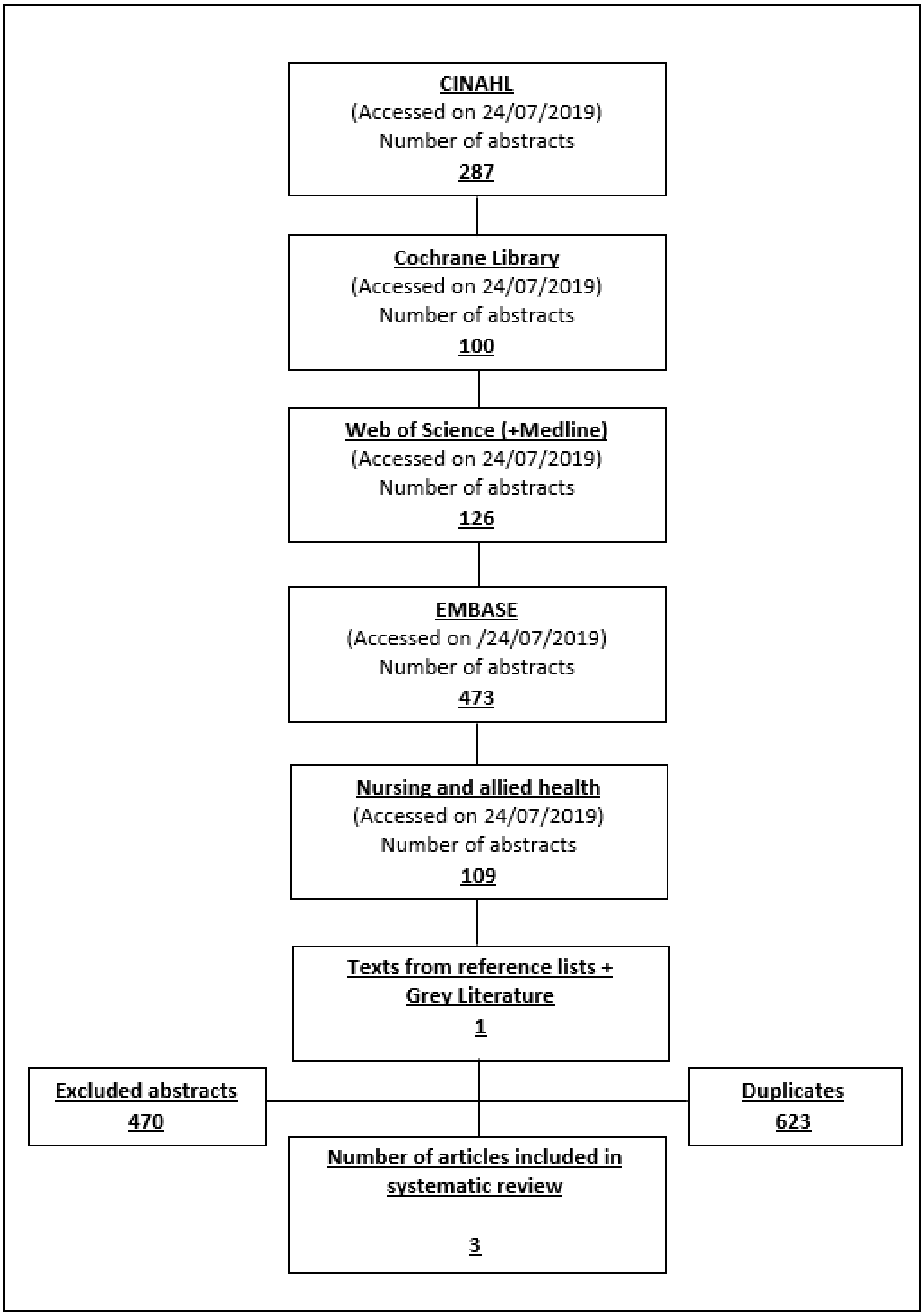

Figure 3. 1 Results of systematic literature review (PRISMA flow diagram)

Table 3. 2 Papers included within systematic review.

Paper	Year of publication	Database	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (95% CI)
(Sammy et al.) A systematic review and meta-analysis of the research literature to identify the risk factors associated with increased mortality in older people suffering major trauma	2016	Grey literature known to authors	Older adult trauma (≥ 65 years). 15 studies included in meta-analysis. (n=596,049 – for those recorded)	variable	Do differences in demographic, clinical and injury characteristics alter risk adjusted mortality in older patients, 65 years and above, who have presented to the Emergency Department or Emergency Services with major trauma	Meta-analysis of the impact on gender on mortality in older people with major trauma 1.51 (1.37, 1.66) (higher mortality in males. Meta-analysis of the impact of number of injuries on mortality in older people with major trauma 1.08 (1.04, 1.12) (higher mortality with more injuries). Meta-analysis of the impact of mechanism of injury on mortality in older people with major trauma 2.88 (1.26, 6.60) (higher mortality with falls). Meta-analysis of the impact of pre-injury warfarin use on mortality in older people with major trauma 1.32 (1.05, 1.66) (higher risk with Warfarin). Multiple factors contribute to mortality risk in older trauma patients. The relation between these factors and mortality are complex, and a fuller understanding of the contribution of each factor is needed to develop a better predictive model for trauma outcomes in older people.
(Sawa et al.) Risk factors for adverse outcomes in older adults with blunt chest trauma: A systematic review	2018	CINAHL	Older adult trauma (≥ 65 years). 13 studies (n=79,313)	Variable	To systematically review the published literature for risk factors associated with adverse outcomes in older adults sustaining blunt chest trauma	Blunt chest wall trauma in older adults is relatively common, the literature on prognostic factors for adverse outcomes in this patient population remains inadequate due to a paucity of high-quality studies and lack of consistent reporting standards.
(Ludi et al.) Geriatric trauma in Santa Cruz, Bolivia	2019	EMBASE	Older adult trauma (≥ 65 years). (n=7,896)	18-64 years	ED disposition, ITU admission and mortality	The results of this study provide a snapshot of the burden of trauma in a proportion of the geriatric population in Santa Cruz, Bolivia. It also highlights important but remediable limitations of the trauma registry as it currently functions, areas for possible injury prevention interventions, and quality improvement initiatives. The geriatric population is physiologically different from their younger counterparts, and it is essential to take their unique needs into consideration when appropriating funding, triaging care, and strengthening facility capacity.

3.3.2 Phase B: A rapid evidence review.

The initial search identified 1098 papers from database searching and papers known to the authors. Duplicates were removed (n = 623) and remaining papers screened for inclusion/exclusion (n = 475) by a single reviewer and read in full for relevance to the subject area. This review considered key variables that may potentially be identified within the prehospital environment to predict mortality within the older adult population who are exposed to trauma. A total of 56 papers were included within this review (see Figure 3.2 and Tables 3.3 – 3.14).

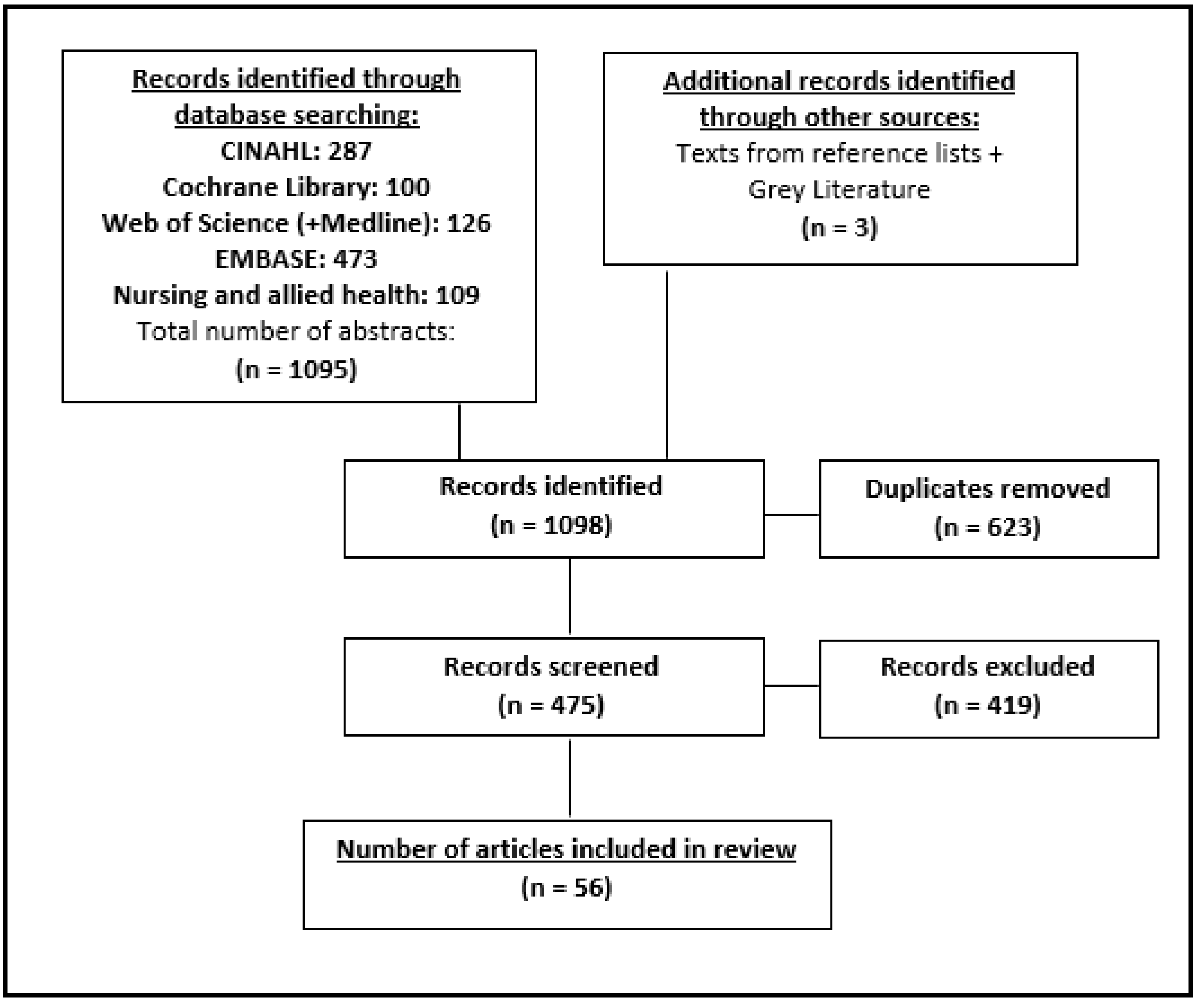

Figure 3. 2 Results of rapid evidence review search (PRISMA flow diagram)

Table 3. 3 Papers included within rapid evidence review (a)

	Paper	Year of publication	Database	Main aim of study	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (appropriate to prehospital)	Relevance for older adult
1	Aitken et al. (2010). Characteristics and Outcomes of Injured Older Adults After Hospital Admission	2010	CINAHL	To describe the seriously injured adult population Aged 65 and older; compare the differences in injury characteristics and outcomes in three subgroups aged 65 to 74, 75 to 84, and 85 and older; and identify predictors of death, complications, and hospital discharge Destination.	(n =6069) aged 65 years and older	65-74 years (n = 2291) 75-84 years (n = 2265) 85+ (n = 1513)	Outcome variables included mortality, complications, and discharge destination (usual residence, rehabilitation, nursing home, convalescence). Predictive factors incorporated demographic details, injury characteristics, and acute care factors.	Predictors of death: 1. Older age, 2. Male sex, 3. Injury caused by fall, 4. Two or more injuries.	Older age Male Falls 2 or more injuries
2	Allen et al. (2015). Causes of death differ between elderly and adult falls.	2015	CINAHL	To test the hypothesis that falls among the elderly are related to patient, rather than to injury factors when compared with falls among younger adults.	(n = 7293)	Adults <65 years (n = 5216)	The proportion of fall admissions in the elderly is growing in this trauma system. Elderly age is the strongest independent predictor of mortality following a fall. In those who die, death is less likely a direct effect of the fall.	Predictors of death: 1. Older age,	Older age
3	Barry and Thompson (2016). Outcomes after rib fractures in geriatric blunt trauma patients	2016	EMBASE	In this study, we sought to determine the mortality rate for geriatric patients with rib fractures. We also wanted to investigate the impact of the number of rib fractures on the need for mechanical ventilation, ICU length of stay, and overall length of hospital stay.	(n = 255) Blunt trauma patients aged 65 years and older		Mortality rate for geriatric patients with rib fractures.	Predictors of death: 1.Male sex, 2. GCS 3, 3. Hypotension, 4. Bilateral pnuemothoraces, 5. First rib fractures, 6. More than 5 ribs fractured.	Male GCS Hypotension Bilateral pnuemothoraces 1st rib fracture Multiple rib fractures
4	Bauza et al. (2008). High mortality in elderly drivers is associated with distinct injury patterns: analysis of 187,869 injured drivers.	2008	CINAHL	Age-related differences in injury severity, outcome, and patterns of injuries	(n = 187,869) injured drivers five age groups (<26, 26-39, 40-54, 55-69, 70+ years)	five age groups (<26, 26-39, 40-54, 55-69, 70+ years)	Mortality and morbidity (and ISS)	Predictors of death: 1.Increasing age (per decade) 2. aspirin 3. Warfarin	Older age Antiplatelet anticoagulant

Table 3. 4 Papers included within rapid evidence review (b)

	Paper	Year of publication	Database	Main aim of study	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (95% CI) (appropriate to prehospital)	Relevance for older adult
5	Benko et al. (2019). Short- and Long-Term Geriatric Mortality After Acute Traumatic Subdural Hemorrhage	2019	EMBASE	The objective of the present study was to analyse short- and long-term mortality data after acute traumatic subdural haemorrhage in the geriatric population as well as review the impact of associated clinical variables including mechanism of injury, pre-morbid antithrombotic use, and need for surgical decompression on mortality rates.	(n = 455) Age >65 years		Mortality	Predictors of death: 1.Increasing age 2. Anti-throbotics	Older age anticoagulant
6	Bhattacharya et al. (2016). The older they are the harder they fall: Injury patterns and outcomes by age after ground level falls.	2016	EMBASE	To analyse ground level falls injury patterns and outcomes stratified by decade of Life.	(n = 5088) of which (n = 3990) aged >60 years.	<60 (n = 1085) 60-69 (n = 638) 70-79 (n= 908) 80-89 (n= 1683) 90+ (n= 768)	Mortality	Predictors of death: 1.Increasing age 2. Head injury 3. Chest injury 4. Unrestrained elderly drivers	Older age Head injury Chest injury Unrestrained passenger
7	Bohnen et al. (2016). Low baseline (pre-injury) blood pressure predicts inpatient mortality in elderly trauma patients: A bi-institutional study.	2016	CINAHL	To identify the independent impact of baseline systolic blood pressure (SBP) on inpatient mortality among elderly trauma patients.	(n = 4233)	Low SBP (<110 mm Hg) Normal SBP (110-139 mm Hg) High SBP (>139 mmHg.)	Mortality	Predictors of death: 1.Low baseline pre-trauma SBP (<110 mmHg) (Threefold.) 2. Pre-existing hypertension controlled with low SBP.	Low baseline SBP Controlled hypertension
8	Camilloni et al. (2008). Mortality in elderly injured patients: the role of comorbidities.	2008	CINAHL	To evaluate the association between pre-existing chronic conditions and risk of death among older trauma patients.	(n = 8145) Age $\geq$65 years	65-69 years 70-74 years 75-79 years 80-84 years 85+ years	Mortality	Predictors of death: 1.increases with number of co-morbidities 2. mortality highest amongst co-morbidities and moderate injuries	Co-morbidities

Table 3. 5 Papers included within rapid evidence review (c)

	Paper	Year of publication	Database	Main aim of study	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (95% CI) (appropriate to prehospital)	Relevance for older adult
9	Caterino et al. (2011). Modification of Glasgow Coma Scale Criteria for Injured Elders.	2011	Known to authors	To determine if a field GCS of 14 is an appropriate cut off to initiate transport to a trauma centre among injured elders.	(n = 52,412		Mortality	Elders with GCS 14 have greater odds of mortality and TBI than adults with GCS 13.	GCS 14
10	Caterino et al. (2010). Identification of an age cut off for increased mortality in patients with elderly trauma.	2010	Known to authors	The goal of this study was to identify at what age mortality truly increases for older victims of trauma.	(n = 75,658) Age > 16 years		Mortality	Predictors of death: 1.Increased age especially from age 70 years	Older age (70)
11	Chalya et al. (2012). Geriatric injuries among patients attending a regional hospital in shinyanga Tanzania.	2012	EMBASE	The objective of this study was to determine the prevalence, injury characteristics and outcomes of geriatric injury among patients at Shinyanga Regional Hospital in Tanzania.	(n = 94)		Mortality Length of stay	Predictors of death: 1.Increased age 2. co-morbidities 3. High ISS 4. Severe head injury 5. Ventilatory support	Older age Co-morbidities Severe head injury Ventilatory support
12	Cortez (2018). Geriatric trauma protocol	2018	MEDLINE	Objective was to implement a geriatric trauma protocol (GTP) based on American College of Surgeons recommendations to improve patient outcomes.	(n = 77) Age ≥65 years		Complications Discharge home Rehabilitation Re-admission Mortality	Variables considered: 1.ISAR tool (which reflects the frailty score) 2. Anticoagulation 3. Polypharmacy	Frailty Anticoagulants polypharmacy
13	Criddle (2009). 5-year survival of geriatric patients following trauma center discharge.	2009	CINAHL	To quantify the influence of injury on geriatric five-year survival and examine the relationship between five-year survival and various patient and injury characteristics.		Predicted life expectancy.	Mortality	Predictors of death: 1. Increasing age 2. Male sex 3. increases with number of co-morbidities/body system dysfunction.	Older age Male Co-morbidities

Table 3. 6 Papers included within rapid evidence review (d)

	Paper	Year of publication	Database	Main aim of study	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (appropriate to prehospital)	Relevance for older adult
14	de Vries et al. (2019). Older polytrauma: Mortality and complications.	2019	EMBASE	This study aimed to describe the mortality pattern of older polytrauma patients, its associated risk factors, and the role and aetiology of in-hospital complications.	(n = 380) poly trauma patients age ≥65 years		Mortality	Predictors of death: 1. Increasing age 2. Coagulopathy 3. Acidosis 3. Low GCS 4. large subdural Haematoma 5 ISS	Older age Anticoagulants Acidosis GCS Large subdural (head injury)
15	Etehad et al. (2015). Impact of road traffic accidents on the elderly	2015	CINAHL	The aim of this study was to show pattern of road traffic injuries in this special aging group.	(n= 1306) >60 years		Injury pattern and mortality	Predictors of death: 1. Increasing age 2. pedestrian RTC 3. motorcycle RTC	Older age Pedestrian motorcyclist
16	Evans et al. (2012). Comorbidity-Polypharmacy Scoring Facilitates Outcome Prediction in Older Trauma Patients.	2012	CINAHL	To determine the association between comorbidity–polypharmacy score (CPS) and clinical outcomes in a large sample of older trauma patients, focusing on outcome prognostication.	(n = 469)		ISS Mortality Length of stay Functional outcome measure	Predictors of death: 1. Increasing age 2. increases with number of drugs (polypharmacy). 3. increases with number of co-morbidities.	Older age Co-morbidities Polypharmacy
17	Grandhi et al. (2008). Anticoagulation and the elderly head trauma patient.	2012	EMBASE	To determine the effect of anticoagulation therapy on outcomes in elderly patients with closed head injury.	(n = 491) age ≥65 years with closed head injury	Warfarin (n=52) Non-warfarin (n=439)	Mortality	The warfarin group experienced greater mortality after trauma.	Anti-coagulants
18	Fletcher et al. (2017) Pre-trauma Functional Independence Measure Score Predicts Survival in Geriatric Trauma.	2017	Nursing and Allied Health	This study hypothesizes that pre-trauma admission FIM scores can be used to predict morbidity. and mortality in the geriatric trauma population.	(n = 941)		Mortality	Predictors of death: 1. Increasing Functional Independence Measure (FIM). 2. Increasing Body Mass Index (BMI) (with each point). 3. Revised trauma score (RTS) on arrival.	Frailty BMI RTS on arrival

Table 3. 7 Papers included within rapid evidence review (e)

	Paper	Year of publication	Database	Main aim of study	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (appropriate to prehospital)	Relevance for older adult
19	Grisoni et al. (2008). Simultaneous bilateral hip fractures in a level I trauma center.	2008	CINAHL	To study the relationship between bi-lateral hip fracture and outcome	(n = 8)	<65 years (n= 4) ≥65 years (n= 4)	Mortality Length of stay	Age >65 years have higher incidence of mortality and longer stay.	Older age
20	Hadjizacharia et al. (2014). Lower extremity fractures in falls.	2014	Nursing and Allied Health	The aim of this study was to evaluate the incidence and outcomes of associated injuries in victims of falls with lower extremity fractures.	(n = 512) All age falls	Age, ISS Area of injury	Mortality Morbidity	Predictors of death: 1. Increasing age 2. Injury pattern	Older age Injury patterns
21	Hamidi et al. (2019). Frailty as a prognostic factor for the critically ill older adult trauma patients.	2019	EMBASE	Aim to assess the impact of frailty on critically ill older adult trauma patients.	(n = 34,854)	Frail (n=17,427) Non-frail (n=)17,427	Primary outcome measure was in-hospital complications. Secondary outcome measures included mortality and discharge disposition.	Critically ill frail patients are more likely to have higher morbidity and mortality.	Frailty
22	Harrington et al. (2010). Factors Associated with Survival Following Blunt Chest Trauma in Older Patients: Results from a Large Regional Trauma Cooperative.	2010	Nursing and Allied Health	Hypothesized that patient factors, injury patterns, and therapeutic interventions influence outcomes among older patients incurring traumatic chest injuries.	(n = 1621) Age >50 years with at least one rib fracture.		Mortality	Predictors of death: 1. Admission to high volume MTC 2. Increasing age 3. Pre-existing congestive heart failure 4. Intubation	Older age Heart failure Intubation (ventilatory support) Improved at high volume MTC
23	Hicks et al. (2014). Association between race and age in survival after trauma	2014	CINAHL	To determine whether racial disparities in trauma survival persist in patients 65 years or older.	(n = 1,073,195)	1. Black v White 2. 16-64 years (n = 502,167 v ≥65 years (n = 571,028)	Mortality	Elderly white trauma patients have a higher incidence of mortality compared to Black patients aged >65 years. This is paradoxical to those aged <65 years where there is a higher incidence of mortality in black patients.	Whites
24	Icer et al. (2016). Factors affecting mortality in geriatric patients with head trauma.	2016	EMBASE	Aim to investigate the factors influencing the prognosis and mortality of geriatric patients with head trauma	(n = 1060) age >65 years	Sex: Male (n=500) Female (n=560)	Mortality	Predictors of death: 1. Male sex 2. Cranial pathologies	Male Head injury

Table 3. 8 Papers included within rapid evidence review (f)

	Paper	Year of publication	Database	Main aim of study	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (appropriate to prehospital)	Relevance for older adult
25	Inamasu et al. (2012). Influence of warfarin and low-dose aspirin on the outcomes of geriatric patients with traumatic intracranial haemorrhage resulting from ground-level fall.	2012	EMBASE	To evaluate whether the use of warfarin/low-dose aspirin (LDA) is predictive of unfavourable outcomes in geriatric patients who sustain a fall-induced traumatic intracranial haemorrhage (TICH).	(n = 76) age >65 years	1.Warfarin (n=12) 2. Low dose aspirin (n=21) 3. Nether 1 or 2	Unfavourable outcomes (Glasgow outcome score of 1-3).	Significant prediction of TICH with warfarin.	Anti-coagulants
26	Kahl et al. (2013). The changing nature of death on the trauma service.	2013	CINAHL	Hypothesized that this increase in elderly injured patients may have combined with recent care innovations to alter the causes of death after trauma.	(n = 819)	All ages	Mortality	Predictors of death: 1. Co-morbidities	Co-morbidities
27	Kani et al. (2019). Thoracic cage injuries.	2019	CINAHL	The goals of this article are to review the anatomy, mechanisms of injuries, classification, imaging evaluation, treatment and long-term complications of osseocartilaginous injuries of the thoracic cage.	N/A	All ages	N/A	Predictors of death: 1. Multiple rib fractures (especially in elderly)	Multiple rib fractures
28	Kocuvan et al. (2016). Evaluation of major trauma in elderly patients - a single trauma center analysis.	2016	EMBASE	The objective of the study was to gather information about elderly major trauma patients admitted to one particular Slovenian trauma centre.	(n = 532) All ages	Age $\geq$65 years Age <65 years	Mortality Morbidity	Predictors of death: 1.Older ($\geq$65 years) 2. Head injuries *ISS was similar in all age groups	Older age Head injuries

Table 3. 9 Papers included within rapid evidence review (g)

	Paper	Year of publication	Database	Main aim of study	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (appropriate to prehospital)	Relevance for older adult
29	Konda et al. (2018). Use of the STTGMA Tool to Risk Stratify 1-Year Functional Outcomes and Mortality in Geriatric Trauma Patients.	2018	CINAHL	To determine whether a novel inpatient mortality risk assessment tool designed to be calculated in the emergency department setting can risk stratify patient-reported functional outcomes and mortality at 1 year.	(n = 685) >55 years	demographics, injury severity, and functional status	Mortality, EQ-5D questionnaire, and percent return to baseline function since their hospitalization at 1-year after hospitalization.	The STTGMA risk score is also a valuable tool to stratify risk of mortality up to 1 year after discharge.	Older age STTGMA Comorbidities vital signs, anatomic injuries
30	Konda et al. (2017). How Does Frailty Factor into Mortality Risk Assessment of a Middle-Aged and Geriatric Trauma Population?	2017	MEDLINE	The aim of this study was to investigate whether the addition of additional frailty variables to the STTGMA tool would improve risk stratification of a middle-aged and elderly trauma population.	(n = 1486) >55 years		Mortality	The STTGMA risk score is also a valuable tool to stratify risk of mortality. (Comparing with STTGMAFRAILTY).	Older age STTGMA Comorbidities vital signs, anatomic injuries
31	Kuhn et al. (2018). Outcomes of Subdural Hematoma in the Elderly with a History of Minor or No Previous Trauma.	2018	EMBASE	To describe the functional outcomes and mortality of SDH in an elderly population and to identify potential prognostic factors.	(n = 671) Low velocity trauma in elderly		Mortality, length of stay, and discharge Glasgow Outcome Score.	Predictors of death: 1. Lower GCS on admission 2. Increased age (over 80) 3. Antiplatelet use	Older age GCS antiplatelet
32	Lukin et al. (2015). Triaging older major trauma patients in the emergency department: an observational study.	2015	CINAHL	The objective of this study was to compare the triage category assigned to older trauma patients with younger trauma patients upon arrival to the emergency department.	(n = 6923)	All ages	ISS	The older trauma patient was significantly more likely to be under-triaged compared to younger patients with similar ISS.	Older age

Table 3. 10 Papers included within rapid evidence review (h)

	Paper	Year of publication	Database	Main aim of study	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (appropriate to prehospital)	Relevance for older adult
33	Marini et al. (2019). Predictors of mortality in patients with rib fractures.	2019	Nursing and Allied Health	The aim of this study was to identify risk factors for morbidity and mortality in patients with rib fractures with focus on identifying a more exact age-dependent cut-off for increased morbidity and mortality.	(n = 1188) all ages	Male (n=800) Female (n=388) MVC/RTC (n=735) Falls (n=364) Other (n=89)	Morbidity Mortality	Predictors of death: 1.Increase at age 65 years 2. Second increase at age 80 years	Older age
34	McMahon et al. (2012). Diurnal variation in mortality in older nocturnal fallers.	2012	Nursing and Allied Health	To examine the independent effects of age, time and mechanism of injury on survival from trauma at 30 days.	(n = 137,521)		Mortality	Predictors of death: 1.Age > 65 years 2. Presenting between 00:00 and 08:00 3. Falls <2m	Older age Out of hours Falls
35	Meisler et al. (2011). Age-related differences in mechanism, cause, and location of trauma deaths	2011	EMBASE	The goal of this study was to describe age-related differences in trauma type, mechanism, cause and location of death in a well-defined European region.	(n = 2923)		Mortality	Predictors of death: 1.Increase with age 2. Head injuries 3. Spinal injuries	Older age Head injuries Spinal injuries
36	Miller et al. (2017). Predicting Mortality and Independence at Discharge in the Aging Traumatic Brain Injury Population Using Data Available at Admission.	2017	CINAHL	To develop a predictive tool using variables available at admission to predict outcomes related to severity of brain injury in aging patients.	(n = 57,588) age >50 years with isolated Traumatic Brain injury (TBI).	50-59 years 60-69 years 70-79 years 80-89 years ≥90 years	Mortality Independent living	Predictors of death: 1. Increasing age Per decade from age 50 years	Older age
37	Neideen et al. (2008). Preinjury beta blockers are associated with increased mortality in geriatric trauma patients.	2008	EMBASE	Hypothesized that preinjury beta blockade would increase mortality in geriatric trauma patients, given beta-blockers inhibit patient's physiologic responses to hypovolemic shock.	(n = 1479) Age >65 years		Mortality	Predictors of death: 1.Comorbidities 2. prescription medications (Inc beta blockers)	Comorbidities polypharmacy

Table 3. 11 Papers included within rapid evidence review (i)

	Paper	Year of publication	Database	Main aim of study	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (appropriate to prehospital)	Relevance for older adult
38	Newgard et al. (2016)	2016	Known to authors	(1) define the high-risk injured older adult using prognostic differences associated with different injury patterns; and (2) derive alternative field trauma triage guidelines that mesh with current national guidelines to improve identification of high-risk elderly trauma patients.	(n = 33,298) injured adults ≥65 years		In-hospital mortality	1. Positive under current field criteria. 2. Field GCS $\leq$14 3. Abnormal vital signs (SBP $\leq$110 or $\geq$200 mmHg, Respirations $\leq$10 or $\geq$24 per min, or Heart rate $\leq$60 or $\geq$110 beats per min). Caveat that over triage will occur.	GCS Abnormal vital signs
39	Nijboer et al. (2009). The Value of the Trauma Mechanism in the Triage of Severely Injured Elderly.	2009	Nursing and Allied Health	To evaluate whether current trauma triage criteria are appropriate in severely injured elderly patients.	(n = 191)	High energy trauma (n=84) Low energy trauma (n=107)	Triage Treatment	Predictors of death: 1.High and low energy trauma 2. Need to consider Age, co-morbidities and likelihood of TBI).	High and low energy Older age Comorbidities Head injury
40	Pandit et al. (2014). Shock index predicts mortality in geriatric trauma patients: An analysis of the National Trauma Data Bank.	2014	CINAHL	The aim of this study was to assess the utility of Shock Index (SI) (heart rate/systolic blood pressure) in predicting outcomes.	(n = 217,190)		Mortality. Secondary outcome measures were need for blood transfusion, need for exploratory laparotomy, and development of in-hospital complications.	Predictors of death: 1. Shock Index of $\geq$1	shock
41	Patel et al. (2014a). Association of a Modified Frailty Index with Mortality After Femoral Neck Fracture in Patients Aged 60 Years and Older.	2014	Nursing and Allied Health	Objective was to develop a modified frailty index, adapted and truncated from the Canadian Study of Health and Aging, and demonstrate a relationship to femoral neck fracture mortality.	(n = 481) Age >60 with femoral neck fracture		Mortality	Patients who have a modified frailty index with clinical deficits including mobility, respiratory, renal, malignancy, thyroid, and impaired cognition have a higher risk of death after femoral neck fracture.	Frailty comorbidities

Table 3. 12 Papers included within rapid evidence review (j)

	Paper	Year of publication	Database	Main aim of study	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (appropriate to prehospital)	Relevance for older adult
42	Pelet-Del-Toro et al. (2019). Morbidity and mortality patterns of pedestrian injuries by age at the Puerto Rico Trauma Hospital from 2000 to 2014.	2019	EMBASE	This study evaluates morbidity and mortality patterns of 2,093 pedestrian injuries at the Puerto Rico Trauma Hospital during 2000-2014 by age.	(N/R) Pedestrian related trauma		Mortality Injury pattern	Predictors of death: 1.Age 65-74 years 2. Age > 84 years	Older age
43	Pracht et al. (2011). Survival advantage for elderly trauma patients treated in a designated trauma center.	2011	CINAHL	Analysis of the effectiveness of designated trauma centres (DTCs) in Florida concerning reduction in the mortality risk of severely injured elderly trauma victims	Aged >65 years	65-74 years 75-84 years 85+ years	Mortality	Improved survival if seen at a designated trauma centre.	Improved at MTC
44	Rupprecht et al. (2017). The geriatric polytrauma: Risk profile and prognostic factors.	2017	CINAHL	The aim of this study was to present clinical results and a risk profile for geriatric polytrauma patients.	(n = 140) Age >65 years		Mortality	Predictors of death: 1. Increasing age 2. Low GCS 3. Low SBP (<80 mmHg)	Older age GCS Low SBP
45	Scheetz (2010). Prehospital factors associated with severe injury in older adults.	2010	EMBASE	The purpose of this paper is to review prehospital factors associated with severe injuries amongst older adults	(n = 21) Literature review		Severe injury: defined as a maximum Abbreviated Injury Score (MAIS) >= 3 or an injury severity score >= 16, including fatal injury.	Predictors of death: 1. Increasing age 2. male sex 3. Lower GCS 4. Anti-coagulated (anti-platelets)	Older age Male GCS Anti-coagulants
46	Shifflette et al. (2010). Should Age Be a Factor to Change from a Level II to a Level I Trauma Activation?	2010	EMBASE	Should patients older than 60 years with multiple injuries and/or a significant mechanism of injury be considered as part of the criteria for Level I activation? Would these patients benefit from a higher level of activation?	(n = 802,211)	Age $\geq$60 years Age <60 years	Mortality	Predictors of death: 1. Age $\geq$60 years	Older age

Table 3. 13 Papers included within rapid evidence review (k)

	Paper	Year of publication	Database	Main aim of study	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (appropriate to prehospital)	Relevance for older adult
47	Siram et al. (2011). Does the pattern of injury in elderly pedestrian trauma mirror that of the younger pedestrian?	2011	EMBASE	Aimed at evaluating the pattern of injury in the elderly pedestrians and how it differs from younger patients.	(n = 79,307) Pedestrian trauma	Age 15-24 (reference group), 25-34, 35-44, 45-54, 55-64, 65-74, 75-84, and 85-89	Mortality Injury pattern	Predictors of death: 1. Increasing age	Older age
48	Thayer et al. (2018). Concomitant Upper Extremity Fracture Worsens Outcomes in Elderly Patients with Hip Fracture.	2018	EMBASE	To determine whether patients with concurrent upper extremity and hip fractures have worse outcomes than patients with hip fractures alone.	(n = 231,299) Hip fracture patients age 65-100 years		Mortality Length of stay, Discharge disposition.	Predictors of death: 1. Concomitant upper extremity fractures (in combination with hip fracture).	Concomitant injuries
49	Utomo et al. (2009). Predictors of in-hospital mortality and 6-month functional outcomes in older adults after moderate to severe traumatic brain injury.	2009	EMBASE	This population-based study investigated predictors of mortality and longer-term functional outcomes following serious TBI in older adults.	(n = 428) Age >64 years old		Mortality Functional outcomes	Predictors of death: 1. Increasing age 2. Decreasing GCS 3. Lowering systolic blood pressure 4. Brainstem injury	Older age GCS Low SBP Brain stem injury
50	Vu et al. (2017). The frail fail: Increased mortality and post-operative complications in orthopaedic trauma patients.	2017	EMBASE	To identify patients with increased risk of mortality and morbidity. This paper investigates the utility of the Modified Frailty Index (mFI) as a predictor of morbidity and mortality in orthopaedic trauma patients.	(n = 36,242)		Mortality Morbidity	Predictors of death: 1. Modified frailty index (mFI)	frailty
51	Werman et al. (2011). Development of State-wide Geriatric Patients Trauma Triage Criteria.	2011	Nursing and Allied Health	This paper describes the development of geriatric-specific field destination criteria for the state of Ohio.	(n = 90,597) age ≥16 years	Adults age ≥16 years to 69 years Age >69 years	Mortality	Data suggested that elderly patients with specific co-morbidities be given strong consideration for evaluation in a trauma centre.	Older age comorbidities

Table 3. 14 Papers included within rapid evidence review (l)

	Paper	Year of publication	Database	Main aim of study	Patient group (Inc. sample size [n])	Comparator (Inc. sample size [n])	Main outcome measure	Main findings (95% CI) (appropriate to prehospital)	Relevance for older adult
52	Werman et al. (2017). Do Trauma Patients Aged 55 and Older Benefit from Air Medical Transport?	2017	CINAHL	The purpose of the current investigation was to evaluate mortality benefits of air transport in adult trauma patients ≥ 55 years of age.	(n = 8421) Trauma patients age ≥55 years	Trauma patients transported by: Ground (n=7739) Air (medical) (n=682)	Mortality	Improved survival benefit with air medical transport	Improved with HEMS
53	Wilson et al. (2016). Early Predictors of Mortality in Geriatric Patients with Trauma.	2016	CINAHL	To identify variables that predict mortality in geriatric patients with trauma.	(n = 147) Trauma patients age ≥65 years		Mortality	Predictors of death: 1. Increasing age 2. Lower GCS 3. Lower energy mechanisms	Older age GCS Low energy
54	Wong et al. (2008). The effects of clopidogrel on elderly traumatic brain injured patients.	2008	CINAHL	To study mortality or morbidity from anticoagulants in elderly patients with traumatic brain injuries (TBI).	(n = 3817) of which (n = 131) on clopidogrel, aspirin or warfarin and evidence of traumatic intracranial bleeding.	Frequency matched control (n = 178)	Mortality, Hospital/ICU duration and discharge disposition.	Clopidogrel use has increased risk of long-term disability and mortality in TBI when compared to other anticoagulants or non-anticoagulant use.	Clopidogrel
55	Wong et al. (2015). The Low Fall as a Surrogate Marker of Frailty Predicts Long-Term Mortality in Older Trauma Patients.	2015	Nursing and Allied Health	Hypothesized that the low fall from less than 0.5 metres, including same-level falls, is a surrogate marker of frailty and predicts long-term mortality in older trauma patients.	(n = 8111)	Low falls, Other blunt trauma, Higher fall heights	Mortality	The low fall mechanism can optimize prediction of long-term mortality after moderate and severe injury and may be a surrogate marker of frailty.	fall
56	Yeung et al. (2008). High risk trauma in older adults in Hong Kong: A multicentre study	2008	EMBASE	The objectives of this study are firstly to describe the epidemiology of high-risk trauma in older patients in Hong Kong, and secondly to identify predictors of trauma mortality.	(n = 810) Aged >55 years		Epidemiology Mortality	Predictors of death: 1. Increasing age 2. Decreasing GCS 3. ISS 4. co-morbidities	Older age GCS ISS comorbidities

The variables highlighted in the 56 papers are represented as frequency distribution in Figure 3.3 and Table 3.15.

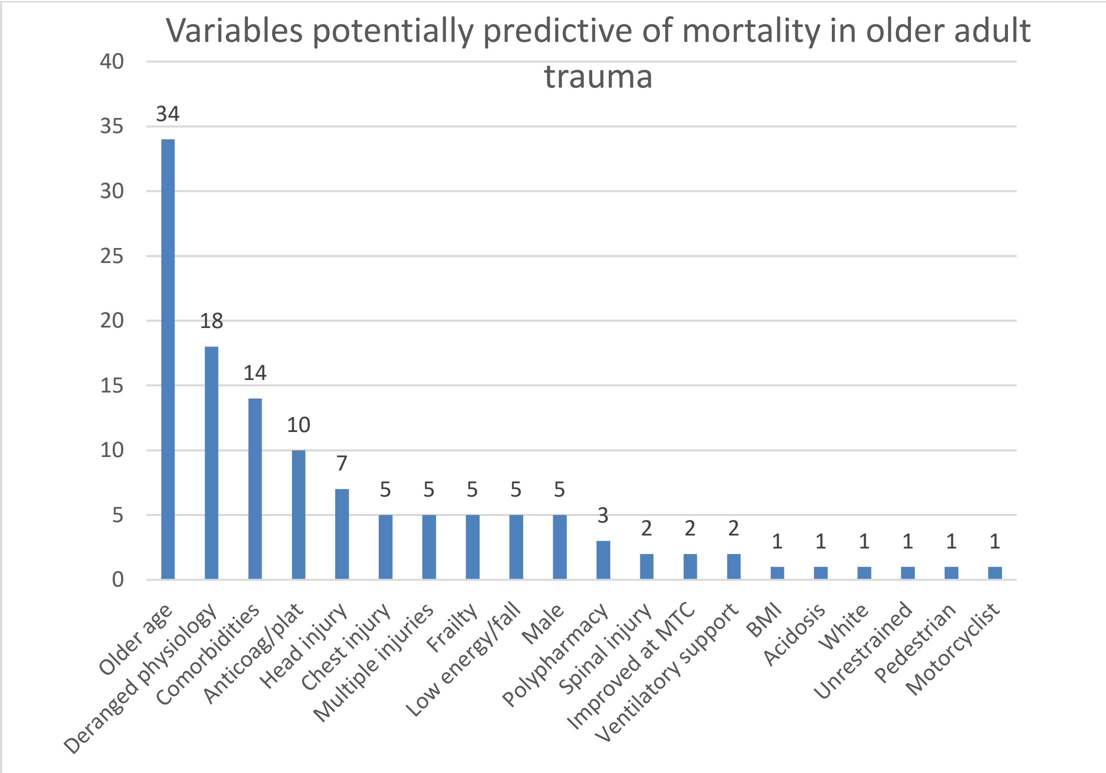

Figure 3. 3 Frequency distribution of variables potentially predictive of mortality in older adult trauma

Table 3. 15 Variables potentially predictive of mortality in older adult trauma

Variable	n (%*)
Older age	34 (28)
Deranged physiology	18 (15)
Comorbidities	14 (11)
Anticoagulant/platelet	10 (8)
Head injury	7 (6)
Chest injury	5 (4)
Multiple injuries	5 (4)
Frailty	5 (4)
Low energy/fall	5 (4)
Male	5 (4)
Polypharmacy	3 (2)
Spinal injury	2 (2)
Improved at MTC	2 (2)
Ventilatory support	2 (2)
BMI	1 (1)
Acidosis	1 (1)
White	1 (1)
Unrestrained	1 (1)
Pedestrian	1 (1)
Motorcyclist	1 (1)
Total	123 (100)

*rounded

3.4 Discussion

3.4.1 Phase A

Within the systematic literature review the main findings from Sammy et al. (2016) highlight that mortality risk in older adults experiencing trauma is complex and a deeper understanding of these factors needs to be researched to develop a predictive model for older trauma patients. Some key variables included an increase of age and severity/number of injuries alongside co-morbidities which are all indicative of increased early mortality. In older adults, gender, mechanism of injury, and medications affect their outcome in comparison to younger patients. Also, predictive factors such as deranged physiology in the younger trauma patient may need a different assessment criterion for the older adult. Most studies within this meta-analysis noted an increase in mortality with those aged greater than 65 years but also noted a secondary sharp increase at those aged over 75 years and again with those older than 85 years.

It was also highlighted that independently both pre-injury warfarin and steroid use increase trauma mortality in older adults and that there may be some protective element to pre-injury statin use. It was unclear if gender is true independent variable, but it is suggested that there is a higher mortality risk with older male trauma patients. Compared to younger trauma patients, the older adult also has a higher trauma risk from falls rather than from RTCs. Higher mortality rates were also seen in older adults who presented with a lower GCS or lower SBP.

The Sawa et al. (2018) paper is another systematic review looking at 'Risk factors for adverse outcomes in older adults with blunt chest trauma. Its limitations within this review with regards to our own review is it only explored studies specifically looking at blunt chest trauma in the older adult. The main findings noted that an increase in age and an increase in number of rib fractures are associated with adverse outcomes. However, no meta-analysis was attempted due to the heterogeneity of the studies and how variables were measured between studies. Prognostic models were therefore not possible to due to the lack of reporting standards within the studies included in their review.

The Ludi et al. (2019) paper looked at older adult trauma patients aged greater than 65 years within six emergency departments in Bolivia which is a low resource setting. Although this paper gives an overall snapshot of older adult trauma in Bolivia there is limit utility in the data, they present to provide any prognostic modelling for older adult trauma patients.

Our systematic literature review highlighted that there is limited robust evidence to develop a predictive model to assist in identifying the older adult trauma patient at risk of mortality and may require early consultant level assessment and interventions. As a consequence, an alternative approach using a less restricted method to provide a rapid evidence review with the inclusion of grey literature was adopted as phase B with the intention of combining with the existing results of the systematic literature review (phase A) to provide a meaningful dataset. This combination is believed to provide a broader insight into potential variables that may be considered for use within a predictive model that is appropriate for the prehospital environment which can be tested against an existing dataset.

The significant topic of discussion within the systematic literature review is the lack of substantial evidence to develop a predictive model to identify those older adults at high risk of mortality from trauma. The Sammy et al. (2016) paper provides valuable insights but concludes that the interaction of key variables are complex and more research is required to develop predictive models for older adult trauma.

3.4.2 Phase B

1. Deranged physiology

Deranged physiology (GCS or SBP or heart rate) was also used as a predictor of mortality in 18 (15%) of the papers within the rapid evidence review in phase B.

1.a. GCS

The lowering of baseline GCS being a common predictor of mortality in the older adult. Many of the variables highlighted as being significant for the older adult, such as lowering of GCS or SBP are, however, also applicable to the younger trauma patient. This may be relevant if a predictive model / triage tool/score focuses on low energy MOI rather than a specific older adult trauma triage tool where age may be a weighted variable.

Caterino et al. (2010) and Newgard et al. (2016) both suggest that even a GCS of 14 is predictive of mortality in the older adult trauma patient. This relatively higher GCS (when compared to the lower GCS of 13 being a trigger for many major trauma triage tools) is highlighted by Kehoe et al. (2015a). They identified that older patients with severe isolated head injuries often present with higher GCS compared to younger trauma patients and therefore triage tools for this patient group should take this relatively high variable into consideration. This often adds to the complexity of the initial assessment of the older adult and the under-triage of their evolving injury or injuries (Hoyle et al., 2020).

1.b. SBP

Within the context of NTN, trauma patients with a significant MOI who have a SBP of less than 90mmHg are candidates for bypass to a Major Trauma Centre (MTC) for ongoing specialist management (see Figure 1.2). A falling SBP is equally indicative of poor outcomes for both the older and younger trauma patient but is a high risk variable for the older adult which may be underplayed due to a presumed association with effects of the patient taking hypertension medications. Ringen et al. (2019) highlight studies that recommend that standard trauma triage criteria for identifying those older adults at risk should raise the SBP measure (red flag/triage trigger) from 90mmHg to up to 110mmHg which may potentially mitigate this phenomenon. Brown et al. (2015) also suggest that older adult trauma patients with a SBP of less than 110 mmHg have a similar risk of mortality to patients who are positively triaged under the existing guidance of a SBP of

90mmHg. Within their study there was no mention of MOI other than to say that the older adult experienced a higher incidence of blunt trauma than their younger trauma patients. This may be a significant factor when applied to the existing NTN major trauma triage tool which excludes minor MOI even when other physiological or anatomical indices are present which also highlights the need to consider low energy MOI within trauma triage tools.

1.d. Acidosis

Acidosis was highlighted by de Vries et al. (2019) as being predictive of mortality which may not be easily tested in many prehospital settings due to limited diagnostic equipment. However, within the NTN region specialist vehicles are routinely dispatched to major trauma who have the resources to obtain a bedside lactate reading. The only caveat to this is that, as we have seen from the literature above, a significant volume of older adult major trauma arises from low energy mechanisms and, therefore, the specialist (critical care) resources may not always be sent to what may initially be perceived as minor trauma. If a predictive model were to be explored within clinical practice, the use of point of care testing for acidosis would need to be considered and explored as to how practical and diagnostic it would be whilst also being a financially viable option.

2. Injuries

Anatomical injuries, which is a key aspect of the STTGMA tool, is addressed within the NTN major trauma triage tool (Figure 1.2) although the NTN tool limits these to penetrating injuries, pelvic instability/deformity and chest injuries. Multiple papers within the rapid evidence review highlight specific injury groups such as:

- Rib fractures (Barry and Thompson, 2016, Kani et al., 2019);
- Chest injury (Bhattacharya et al., 2016, Barry and Thompson, 2016);
- Head injury (Bhattacharya et al., 2016, Icer et al., 2016, Kocuvan et al., 2016, Meisler et al., 2011, Nijboer et al., 2009, Chalya et al., 2012);
- Brain stem injury (Utomo et al., 2009); and,
- Spinal injuries (Meisler et al., 2011).

There are also several papers (n=5) that state that two or more injuries are predictors of older adult mortality.

With regards to rib fractures, there appears to be evidence that an increase in age alongside increased numbers of rib fractures is a mortality risk for the older adult. A systematic review by Craxford et al. (2019) state that there is no validated outcome measure for rib fracture patients. As there has been a marked increase in invasive rib fixation methods they recommend the development of a patient reported outcome measure for rib fixation to provide more robust data for accurately reporting actual outcome. The presence of chest injury and number of potential rib fractures or flail chest may be a consideration within any predictive model to identify if early intervention is required. However, identifying the number of rib fractures may not be possible with the limited diagnostic equipment available within the prehospital phase of care and should therefore be considered as a retrospective variable.

3. Age

Within the rapid evidence review a significant volume of the literature (n=34) highlight that increasing age is, in itself, an independent variable that is predictive of mortality within the older adult trauma patient group. An incremental increase in age appears to correlate with increasing risk of mortality.

Many of the studies/papers reviewed have a clear distinction of when older age is a factor in mortality and age 65 years and older appears to be the baseline for most studies. Some papers looked at all age groups to provide comparison and several begin their identification of older adults being at risk as early as age 50 years (Chang, 2010, Miller et al., 2017). Essentially the consensus of the papers highlights that as age increases the risk of mortality increases.

Aitken et al. (2010), Bhattacharya et al. (2016) & Miller et al. (2017) use increasing decades of age as indicators of increasing risk predictors with Pelet-Del-Toro et al. (2019) identifying bimodal age predictors of traumatic mortality primarily at ages 65 to 74 years and then at ages older than 84 years. When developing predictive models, increasing age should therefore be an obvious variable to consider. There was no indication of how this variable may be weighted within any existing predictive tools although evidence from TARN (2017) should be able guide the weighting of this variable.

An insightful observation by Evans et al. (2012) states that, *"Chronological age does not necessarily correlate well with physiological age".* This would also contribute to the complexity of the older adult group who are often encountered by prehospital crews. There is also an assumption that frailty increases with chronological age but again the complex nature of this patient group defies assumptions. A patient who is chronologically old may not necessarily be physiologically old or frail. Conversely there may be patients who have a relatively 'young' chronological age but who are physiological old and/or frail.

4. Frailty

Although there is often an association with frailty being directly linked to aging this is not exclusively so. Bonner and Lone (2016) highlight that the younger frail patients account for a quarter of critically ill ICU patients were classified as young and frail within their prehospital assessment. They were typically categorised as patients who present with '*a loss of physiological and cognitive function'* which leave them vulnerable to what are regarded as minor stressors such as Trauma, surgery and infection often with poor outcomes. There were five papers within this review which identify that frailty was a potential predictor of mortality with the older trauma patient, although, the Score for Trauma Triage in the Geriatric and Middle-Aged (STTGMA) tool (Konda et al., 2017) was not improved in predicting mortality when frailty scores were added to the tool. Two papers use retrospective data analysis to identify if frailty is a variable that predicts mortality in trauma. Hamidi et al. (2019) analysed 34,854 critically ill trauma patients and concluded that the modified frailty index was an objective measure and predictor of mortality. Vu et al. (2017) also used retrospective analysis of 36,424 trauma patients (limited to pelvic and extremity fractures) and also concluded that the modified frailty index is a significant predictor of mortality.

5. Comorbidities

Numerous papers identified that comorbidities within the older trauma population are predictive of mortality (n=14). Although various papers identified specific conditions that were associated with poorer outcomes within the older trauma patient group, the overall consensus appears to reflect that the risk of mortality increases with the presence of existing comorbidities and increases with additional comorbidities.

Konda et al. (2017) and Konda et al. (2018) evaluate the STTGMA tool with and without frailty scores. The tool uses a combination of age, comorbidities, vital signs (physiology) and anatomical injuries. The later paper states that the addition of frailty scores did not improve the specificity of the tool but the combination of the above stated variables were predictive of mortality within the older adult trauma group.

Within the older adult major trauma population, alongside the prevalence of comorbidities (Camilloni et al., 2008, Chalya et al., 2012, Evans et al., 2012, Kahl et al., 2013, Neideen et al., 2008, Nijboer et al., 2009, Patel et al., 2014b, Werman et al., 2011, Yeung et al., 2008) there is an obvious parallel with the use of medications for those comorbidities and outcome such as:

- Polypharmacy (Cortez, 2018, Evans et al., 2012, Neideen et al., 2008);
- Anti-coagulant (Bauzá et al., 2008, Benko et al., 2019, Cortez, 2018, de Vries et al., 2019, Grandhi et al., 2012, Inamasu et al., 2012, Scheetz, 2010); and
- Anti-platelets (Bauzá et al., 2008, Wong et al., 2008).

6. MoI

It has been highlighted by Magnone et al. (2017) that MOI in isolation is a poor predictor of outcome and that major trauma triage tools, like Figure 1.2, often only highlight high energy MOI. However, the rapid evidence review noted that low energy MOI (n=5), (and in particular low-level falls), were suggested as being potentially predictive of mortality within the older adult trauma patient group. This may reflect the high incidence of low-level falls within this particular demographic as well as highlighting that low energy MOI should not be dismissed when developing predictive models for the older adult trauma demographic.

There were some individual papers that did highlight other MOI that were predictive of mortality in the older adult trauma group that were not low energy MOI:

- Unrestrained passenger (RTC) (Bhattacharya et al., 2016);
- Pedestrian (Etehad et al., 2015); and,
- Motorcyclist (Etehad et al., 2015).

MOI is a much-debated topic within the NTN as it is argued that there needs to be a significant MOI for a clinician to consider using the major trauma triage tool. As a consequence, falls from a low height (and usually from standing height) are not often considered for direct transport to an MTC even if the patient meets other physiological or anatomical criteria. There are often multiple and complex confounders for older adults with low energy MOI who eventually have significant injuries and associated high ISS who therefore remain within local trauma units for their initial and ongoing management. As such, these confounders and complex issues should be acknowledged and addressed when developing predictive models / triage tools for the older adult. Although this was believed to be a local issue it appears to be a encountered in other regions and nations Brown et al. (2019b).

7. Gender

Male gender was a predictor of mortality within the older trauma patient group in several papers within the rapid evidence review (n=5). This is a significant finding with uncertain conclusions as to the reasons behind this phenomenon with Scheetz (2010) suggesting pre-menopausal women exert some form of protective processes. The Trauma Audit and Research Network (2017) report *'major trauma in older people'* highlight the incidence of major trauma across genders. They state that major trauma is a disease that affects the male population, who occupy a much greater percentage of all trauma with an ISS >15 until the age of 80-89 years old when the percentages meet and reverse with women then being the significant percentage of major trauma who have an ISS >15. A potential explanation for this phenomenon may be due to the natural longevity of women who, in certain countries outlive the men by over a decade and therefore form a greater percentage of the overall population within that age group (Regan and Partridge, 2013).

8. Ventilatory support

Harrington et al. (2010) and Chalya et al. (2012) identified that the older adult trauma patient requiring ventilatory support was also a predictor of mortality for this patient group. This variable is an obvious indicator of how sick these patients are and that multiple confounders may be present, but nevertheless, it was an independent variable associated with mortality. Again, this would be a trigger for any age group within its own right but would also be dependent on the mechanism of injury with the existing NTN major trauma triage tool.

9. Ethnicity

Although not transferable to the NTN region due to the regional demographics, Hicks et al. (2014) highlighted that older adult trauma patients who were of a white ethnicity were significantly more likely to have a poorer outcome than black trauma patients of the same age. This is in complete contrast to younger trauma patients highlighted within their study which concluded that further research was needed to explore this disparity further as it was unclear as to why the results identified this phenomenon.

10. BMI

Within this combined review a single paper identified higher Body Mass Index (BMI) as being predictive of mortality in the older adult trauma patient (Fletcher et al., 2017). This may be of increasing relevance as our population is getting older with the over 75 year olds predicted as being the largest major trauma patient group (Kehoe et al., 2015b) as well as becoming more obese within the same age groups (Nazarko, 2017).

Although it was outside of the remit of this review it was interesting to note that two papers (Pracht et al., 2011, Harrington et al., 2010) stated that mortality was reduced for the older adult trauma patients who were directly transported to an MTC. With this in mind, it is a focus of this review to help identify those patients at risk of mortality who may potentially benefit from specialist interventions within an MTC. Currently older adult trauma patients are much less likely to be transported to an MTC (Brown et al., 2019b). Eichinger et al. (2021) highlight that outcomes for the older adult trauma patient are improved when directly transported to an MTC and under triage is complex. They cite many barriers such as insensitive triage criteria, unrecognised injuries which may be contributed to cognitive impairment or delirium and a focus on MoI (typically low energy).

Limitations

Within this combined systematic literature review and rapid evidence review, all articles were identified and assessed using an eligibility criterion with obvious heterogeneity in patient groups and variables. To allow for the reproduction of this combined review, the method has been carefully described. Only peer-reviewed articles have been used. There was no assessment of quality of the papers. This was an intentional strategy within the review due to the eclectic nature of the search criteria and casting a wide net to capture 'potential' variables that could be later tested within a model. However, upon reflection this was a serious omission that undermines a robust and systematic approach which potentially impacts upon the development of a model. As part of my personal development as a researcher, future systematic reviews will always include an assessment of the papers under review.

Conclusions

There is currently no robust older adult major trauma predictive model/triage tool that is widely used by prehospital care providers to identify those at risk of mortality and may therefore potentially benefit from early consultant level assessment and intervention.

The systematic literature review highlighted that GCS and SBP (with potential triage triggering criteria of 110 mmHg) and a positive covariance with increasing age are potential predictors of mortality for the older adult trauma patient. The results from the rapid evidence review would also confirm these findings with additional potential prediction modelling variables that would include GCS of 14, SBP (with a trigger of 110mmHg), increasing age, comorbidities, frailty, specific injury patterns (Head, chest and spine), medications (including polypharmacy / anticoagulants / antiplatelets) and male gender. There would also be consideration to other indices such as ventilatory support, BMI and acidosis (which may be a point of care test available to some prehospital crews).

There are potentially many complex issues that may suggest that combinations of variables may be greater than the sum of their individual parts. This review also highlights that further research is still required to understand the complexities of predicting outcomes for older adult major trauma.

CHAPTER 4 DEFINING MAJOR TRAUMA: A PREHOSPITAL PERSPECTIVE USING FOCUS GROUPS

4.1 Introduction

Preface

The conclusions of the literature review in chapter 2, which discussed the definition of major trauma, highlighted that retrospective scoring systems were the common methods of definition. Within the discussions that followed, multiple factors could be considered for the definition of major trauma which should be applicable to all patients regardless of their location during their journey of care but more specifically to the prehospital or hyper-acute setting. With this in mind, understanding the perspectives of prehospital clinicians with regards their understanding of major trauma and its potential definition became of interest. This was to be my first qualitative project which was outside of my natural comfort zone as I believed I was naturally inclined to quantitative methodologies. However, it was suggested that qualitative data would provide context and a depth of understanding that may not be available through other methodologies. Upon reflection, this was a very time-consuming project, which was due to my inexperience more than any other factor, but it did add a rich narrative which influenced ongoing chapters through its conclusions and discussions.

Background

With the exception of specialist teams, prehospital exposure to trauma is rare. In their paper highlighting prehospital critical care resources responding to trauma in Scotland, Maddock et al. (2020) highlights this lack of exposure to major, moderate and minor trauma for Paramedics which equates to 0.3% of annual incident volume. Although major trauma is the leading cause of death in the UK for adults under 40 years (Moran et al., 2018), Kehoe et al. (2015b) highlight that major trauma patients are now more likely to be elderly and sustain significant injuries from relatively minor MOI. From our own experiences within the NTN, MOI and injury severity do not correlate very well which is also corroborated by Magnone et al. (2017), Potter et al. (2013) and Stuke et al. (2013a).

It is important to identify patients needing transport to a MTC for definitive/specialist care. Current trauma triage tools have been shown to identify patients who are eligible for direct transfer to a MTC and this has been shown to improve outcomes (Moran et al., 2018). UK ambulance services use major trauma triage tools similar to that shown in Figure 1.2 to assist in this clinical decision making. However, a lack of consensus exists in relation to what constitutes a useful or standard definition of major trauma (Alberdi et al., 2014).

This chapter utilises focus group methods to explore perspectives and definitions of major trauma with a sample of prehospital trauma care providers which included NHS and non-NHS emergency services and first responders. The proposed research question was: In the absence of retrospective scoring systems can a meaningful definition of major trauma be applied to the prehospital environment?

4.2 Methods

Qualitative approach and research paradigm

Focus group research entails organised discussion(s) with a selected group of individuals to gain information about their views and experiences of a topic in which the key data output is interaction between participants (Morgan, 1997). Focus groups have been variously described as: organised discussions (Kitzinger, 1994), collective activities

(Powell et al., 1996) and even social events (Goss and Leinbach, 1996). Powell et al. (1996) recommended that '*a group of individuals [are] selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research*.' The primary reason for using a focus group approach in this instance was as an attempt to capture collective thoughts, feelings, and experiences in relation to meaningful definitions of major trauma in prehospital care. (Race et al., 1994) asserted that focus groups are particularly useful methodology for obtaining several perspectives about a topic and investigating collective understandings of a concept. Although individual interviews were considered, the number of potential participants, limited resources, time restraints and practicality discounted this option. It was also believed that comments by one individual may stimulate responses from other participants which may not have occurred through individual interviews (Jackson, 1998). Jackson (1998) also highlights that focus groups may not explore issues to the same depth as individual interviews and they may be more difficult to control but they do make up that deficit by the richness of the interaction between participants.

Three focus groups were undertaken to take into account the considerable geographical area of the NTN region to facilitate attendance from all areas of the network and reduce traveling times for participants. After the initial call for participants, it was appreciated that there was significant interest with a total sample of 45 NTN prehospital trauma care providers attending and spread across the three focus groups. With such a large sample size there were concerns it may be difficult to control the groups. With limited resources, the researcher remained cognisant of obtaining rich meaningful data while retaining control of the groups. In the context of this project many participants wished to attend, of which, the majority were paramedics, and all were from a single trauma network. Upon reflection after the event, the relatively large number of participants at each focus group (n=15) were easily managed and data saturation occurred within 60 minutes at each group although more time was available. This perhaps reflects the nature and character of the participants who were self-selecting within this study.

Recruitment was undertaken through direct application after advertising the focus groups (as part of a larger trauma workshop) through social media, email groups, service bulletins (internal and external) and word of mouth. Inclusion criteria was limited to participants being exposed to trauma patients either remotely (telephone triage/dispatch) or on-scene as an ambulance resource or first responder. No exclusions were placed on age, experience, or area of practice.

Each focus group was organised in a different location to capture any potential geographical idiosyncrasies and was conducted using semi-structured questions lasting approximately 40-60 minutes (More time was available, but data collection reached saturation within 60 minutes). An informal organic approach to the focus group discussion was adopted to minimise interruption and allow conversations to take its natural course. To help guide conversations that may be hesitant various topics highlighted in the literature review (Chapter 2) (Thompson et al., 2019b) were used as prompts to simulate the group discussions. In practice the prompts (highlighted in data collection methods) were helpful, but conversations naturally highlighted the topics and therefore not always needed.

The conversations were digitally recorded and transcribed verbatim. During transcription process, participants were given codes to provide basic information to support the analysis process. Within this chapter direct quotes are simply attributed to participants alphabetically as to not identify any individual and, unless otherwise stated, all quotes used in this chapter originated from NHS clinicians.

Researcher characteristics and reflexivity

Another research clinician helped to facilitate the focus groups alongside the lead author. Both are experienced specialist paramedics for trauma and familiar with the research topic but not experienced with focus group research. As such, practice sessions with more experienced colleagues and continuous reflection and peer debriefing with the wider research team were undertaken throughout the project. Variance in participant experience, profession, education, and history suggested that the semi-structured format would be suitable to explore complex issues and provide the reflexivity to probe for further information or clarification (Bryman, 2016). There were naturally quieter members within each group, however, it was made clear in the introductions that everyone's view should be heard and, to aid transcription as well as ensuring every participant who wished to contribute, could do so. Having an observational facilitator to highlight any issues minimised the risk of single participants dominating group dynamics and biasing the views of others within the group. The facilitator also highlighted when a quieter participant potentially indicated they wished to contribute. The facilitator was also beneficial in recording non-verbal interactions as well as checking transcriptions and lead researcher's interpretations during the analysis of data as recommended by Jackson (1998).

Sampling strategy

A purposive sample (Etikan et al., 2016) of prehospital trauma care providers were selected for their experience in the prehospital setting. The participants were recruited by virtue of their membership of a prehospital trauma workshop group with members originating from different sources (see results, Table 4.1) and organised throughout the NTN region at separate locations to ensure any potential local idiosyncrasies were accounted for (such as rural/urban, differences in co-responding services e.g., different police and fire and rescue services).

There are a series of tensions regarding what constitutes ‘best practice’ in the conduct of focus groups (Freeman, 2007). One such tension concerns the optimal size of the group(s). Recommendations for the ideal group size in focus group studies vary e.g. Six to ten (MacIntosh, 1993); Up to 15 (Goss and Leinbach, 1996); and four (Kitzinger, 1995). One guiding principle in focus group sample selection is the number of participants should be small enough for everyone to contribute, yet be large enough to develop and share diverse opinions across the group (Krueger and Casey, 2000) .

A further concern relates to whether group membership should be homogenous (and perhaps known to each other) or heterogeneous e.g., drawn from a number of differing backgrounds. In the latter context, participants may be unwilling to express themselves – especially if status differentials exist between participants. However, as Freeman (2007) identified, the difficulty of bringing participants together (especially in a busy organisational context) necessitates practicality and, therefore, the contingencies posed within a particular study setting may demand pragmatic compromise.

The research team involved with this focus group study were aware of these issues, including the fact that, at 15 participants, the composition of the focus groups was at the higher end of the literature recommendations. However, the researchers felt that the size could be justified given that the topic for discussion was one of a technical/professional nature as opposed to being an emotive/sensitive topic. Larger groups are typically difficult to moderate, however, in the eventuality, all the focus groups worked well and resulted in enthusiastic discussions and rich data. As Barbour and Kitzinger (1999) noted, the degree of control that researchers actually have over the relevant characteristics of individuals in their groups is best accounted for in terms of circumstance rather than exact planning.

Similarly, there is a clear lack of guidance or recommendation as to the length of focus group interviews. Within the context of our study, it was believed that three focus groups lasting approximately 60 minutes would provide data for analysis but if saturation was not achieved additional time would be given or further iterations would be undertaken.

Ethical issues pertaining to human subjects.

The protocol for the study was reviewed and approved by Northumbria University Ethics Committee (ref. 5714) (see Appendix 1). Each participant received a participant information sheet (Appendix 2) prior to the focus group and consented on the day (Appendix 3). No financial/gift incentives were offered but training and education in advanced trauma care was provided along with refreshments during the session as part of an extended trauma workshop. The participants were recruited by virtue of their membership of the prehospital trauma workshop group with members originating from different sources and not because they were members of an NHS institution and therefore this study did not require HRA approval. Although this was a pragmatic approach to recruiting participants there is a possible inherited bias as all participants have already declared an interest in major trauma.

Data collection methods

A semi-structured interview format was followed chosen on the basis that it is well suited for the exploration of perceptions and opinions of participants regarding complex matters and potential to probe for further information or clarification. The varied professional, educational and personal histories of participants precluded the use of a standardized interview schedule and the semi-structured format accommodated these differences. The following question domains were addressed (but not limited to):

- How would you personally define major trauma?;
- Does the major trauma bypass (triage) tool have a role to play?;
- Does MOI play a role in defining major trauma?;
- Should major trauma be defined by actual injuries present at time of incident?;
- Does initial physiology play a role in defining major trauma?;
- Should older adult trauma patients ($\geq$ 65 years) be managed differently to the 18 to 64-year-old group?;
- Should younger trauma patients (<18 years) be managed differently to the 18 to 64-year-old group?;
- Should age be irrelevant when defining major trauma?;
- Are co-morbidities or medications relevant?; and
- Can we make generalisations to identify (define) major trauma?

Two electronic dictation devices were used to record the sessions. Digital recordings of the conversations were transcribed verbatim and anonymised using alpha numeric codes prior to coding and analysis. A second research clinician compiled notes throughout the focus groups while the lead author chaired the sessions.

Data analysis

Analysis began after the first focus group which influenced and ran concurrently with each iteration of the focus groups.

The transcripts were managed and explored with NVivo qualitative data analysis software; QSR International Pty Ltd. Version 11, 2015. Coding was undertaken and reviewed to identify emerging themes (Saldaña, 2013) (including theoretical and conceptual). As data were collected concurrently, constant comparison was undertaken throughout and new codes identified for qualitative thematic analysis. The data analysis framework approach recommended by Pope et al. (2000) was used throughout the study.

4.3 Results

Between February and March 2018, three focus groups were undertaken and a total of 45 participants attended (Table 4.1). All participants work/volunteer within the NTN region and are exposed to trauma within the context of their individual roles and are familiar with the major trauma triage tool (see Figure 1.2). Participants were predominantly NEAS Paramedics which included specialist Hazardous Area Response Team (HART) Paramedics. Also included were Helicopter Emergency Medical Service (HEMS) (and former HEMS) Paramedics, emergency dispatch officers, emergency call takers, voluntary sector ambulance technicians, police authorised firearms officer tactical team medics and fire and rescue firefighters. Although invited to participate (and usually regular attendees/presenters at the workshop) no doctors or nurses attended any of the focus groups). Participants varied on the basis of age, role and experience. Route of entry into the Paramedic profession was not ascertained for those Paramedics who attended.

Experience, (for clinicians) ranged from less than one year's front-line experience (post qualification/registration) to over 25 years' experience (mean of 12.5 years calculated for a single focus group only). There were limited numbers of sub-groups of participants, therefore, to minimise identifying individuals, subgroups were labelled as: Paramedic, non-UK trained Paramedic, non-registered clinician and non-clinician.

Table 4. 1 Focus group participants.

Role	Focus Group 1	Focus Group 2	Focus Group 3	Total
Paramedic (NHS)	13	11	9	33
Ambulance Technician/care assistant (NHS)	2	2	-	4
Ambulance Technician (non-NHS)	-	-	2	2
Police	-	-	2	2
Firefighter	-	2	-	2
Emergency Dispatcher/call taker	-	-	2	2
Total	15	15	15	45

There were three overarching themes when participants were determining the definition of major trauma: clinician factors, patient factors, and situation factors.

Clinician factors

There were five overlapping sub-themes that emerged from the clinician factors identified during the focus groups (Table 4.2).

Table 4. 2 Clinician factors in defining major trauma.

Sub-theme	Factors
Experience	• Exposure to (or lack of); • Identifying injuries and ongoing care needs; • Specific patient group needs; • Intuition/instinct; and, • Includes all the other themes below.
Clinical Concern	• Linked to experience and potential injuries.
Difficulties	• Communication issues; • Environmental factors; • Adrenaline rush (effecting decision making); • Distracting factors; and, • Limited information.
Index of suspicion	• Based on MOI and potential for injury.
Potential for injury	• Suspicion based on experience and mechanism of injury and assessment.

The overarching theme is based on a clinician's experience, exposure to trauma and how they instinctively/intuitively identify major trauma.

Participant A: *"…you've just got to use your clinical judgement at times………you have just relied upon your experience and your knowledge and understanding……your gut instinct is always the best instinct…"*

Participant B: *"It's a big worry ……. but I [think] nine times out of ten your gut feeling is normally the right one."*

It was acknowledged that a high degree of clinical concern, based on experience and exposure, influences clinical decision making when identifying potential major trauma patients. Multiple factors are considered and, therefore, each patient is unique and should be managed as such with bespoke care.

Participant C: *"Every life matters.......individual care, bespoke care………. every person is different."*

A consensus highlighted there is a balance between knowledge and experience when identifying major trauma patients. It was suggested that a high degree of clinical concern is not often considered when discussing patients with clinicians within hospital ED's who do not meet the strict criteria for direct access to the MTC. This theme often arose when discussing lower energy MOI where patient injuries and physiology generated that high degree of clinical concern. This is an often-voiced criticism of the existing NTN major trauma triage tool (Figure 1.2) which requires a significant MOI before it can be applied for bypass purposes.

Many factors influence a clinician's index of suspicion and it is often based on the unique circumstances (and available/limited resources) presented at that moment in time with many complex and potentially conflicting variables which form their perception of the situation. Examples included communication issues such as: the dementia patient, the child that has not yet acquired language skills, intoxicated patients, non-verbal patients or those whose primary language is different.

Being able to communicate with colleagues via the emergency operations centre or directly with the MTC was acknowledged as being extremely beneficial. It supports clinical decision making and helps identify those individuals who should be managed as major trauma. However, this system can also cause difficulties and frustrations:

Participant D: *"……the clinician (at other end of phone) may still be really inexperienced…..and getting through to them ……is quite difficult."*

Patient factors

Several sub-themes discussed within all the focus groups centred on patient factors when it came to defining major trauma (Table 4.3).

Table 4. 3 Patient factors in defining major trauma.

Sub-theme	Factors
Physiology	• Altered physiology.
Outcome measures	• Apparent injuries; • Life changing; • Need for surgical intervention; and, • Rehabilitation.
Pre-trauma Factors	• Age; • Previous medical history; • Medications; and, • Co-morbidities.

It was widely accepted that patients who experience any form of trauma and have deranged physiology (reduced consciousness, falling blood pressure or altered respiratory rate/pattern) should be managed as major trauma. However, it was also noted to be helpful to understand the patient's normal physiological parameters (prior to trauma) so comparisons can be made and consequential management determined. Also, knowing a patient's previous medical history and medications will also influence ongoing management (e.g., medications that increase the likelihood of haemorrhage or make the patient susceptible to injury).

> **Paramedic E***: "….again, individual care…….specific to that person. So, the 12-year-old whose had the same mechanism, got the same presentation, but the little nanna*

who is on ten drugs, osteoporotic, curvature of the spine and stuff. You're going to kind of manage them…….a bit…..[different]."

One of the main sub-themes discussed were specific to various age groups. It was obvious within the age groups discussions that trauma involving children is very emotive. Specific paediatric trauma triage tools were also discussed. However, most clinicians stated that they were inclined to rapidly transport paediatric trauma to the MTC without referring to a major trauma triage tool. This again relates to a lack of exposure to paediatric trauma and over triage of that age group which is a recognised phenomenon (Engum et al., 2000).

Participant F: *"……they could sit there looking a bit alright but have come out of this awful mechanism, you wouldn't want just say they are probably fine, they look alright, they are probably fine [but] you would want them to be seen."*

Participant G (Non-UK trained)**:** *"The problem is that because the ambulance service is exactly the same in [country] as they over triage the kids."*

Participant H (in relation to rare exposure to paediatrics)**:** *"……..you need that expert advice to start with [via MTC direct line]. So you are making those correct decisions."*

Older adult and frail patient discussions identified that a significant volume of trauma cases involve older adults who have a relatively minor MOI. They often present with no obvious significant injury at the time of incident but are later diagnosed (after advanced diagnostic imaging) with significant injuries. It was acknowledged that this is a challenging patient group as there is a real risk of overwhelming EDs with older adults who have simple falls with potential injuries that are difficult to assess due to multiple factors that include comorbidities, medications, existing frailty, dementia or even the stoicism of the individual patient.

> **Participant I:** *"Age, it doesn't matter ……….. It's all about the injury or potential injury."*

> **Participant J:** *"I think your index of suspicion is going to be higher [in the older adult]. They have a potential for more to be wrong and not show any symptoms compared to younger ones."*

> **Participant K:** *"……. stabbings for example……. you ask for an enhanced care team………helicopters……come out because, it's a sexy trauma. Its [name] who has fallen in the back garden……. they are not going to come out to her."*

A surprisingly minor focus of discussions regarding patient factors were the actual patient outcomes. These seemed to be, in the main, identifiable injuries especially those injuries that are life or limb threatening or require rehabilitation. Observing these discussions, it was easy to conclude that the clinicians were happy to define patients as major trauma where obvious significant injuries were identified. This included injuries that would require interventions (surgical or otherwise) within the patients ongoing journey of care. However, from the limited discussions around this theme it was difficult to identify specific examples. As such, there was no articulated differentiation made between, for example, complex polytrauma surgical interventions and fixation of an isolated wrist. Upon reflexion this was an oversight which may have been amended subsequent focus groups if identified in the first discussions.

What the participants uncovered and what made defining major trauma difficult was the subtle or occult injuries that may later develop and difficult to diagnose without advanced imaging. This was further complicated when talking about the older or frail trauma patient. There was also a real concern for missing potential injury that is not apparent in the initial assessment.

Situation factors

Several sub-themes discussed within all focus groups centred on situational factors (Table 4.4).

Table 4. 4 Situation factors in defining Major Trauma.

Sub-theme	Factors
Bespoke	• Every patient, environment, situation is unique and requires a bespoke management plan.
Mechanism of Injury	• Low energy; • High energy; and, • Influence of alcohol.
Triage	• Tools have a role to play; and, • Triage tools make generalisations but potentially miss many patients.

There were some enlightened discussions throughout the focus groups which commented upon individual factors that need to be placed into context and when combined are often greater than the sum of their individual parts.

> **Participant L:** *"You need a holistic view to see everything……. It's individual to that patient [and] how they present to you at that moment."*

Participant M: *"Every person is different……….you can have the same injury on two different people and that body will react in different ways."*

The consensus of the discussions was that every situation is unique and that there is a need to provide individual care for a specific patient at a specific time combining multiple factors to define that patient as major trauma.

MOI was an interesting area of discussion where all groups stated that high energy MOI heightened their suspicion of injury. However, it was also argued that trauma from minor/low energy MOI were equally as important as they may cause significant injury especially in those rendered vulnerable by virtue of their existing comorbidities, frailty and/or age.

Participant N*: "….mechanism is something you need to consider. And you need to take [it] into account……."*

Participant O: *"…..the 16-year-old fallen over is probably going to bounce and get up, but an 82-year-old, might have a serious injury due to underlying medical conditions….."*

There was a general acknowledgement at all focus groups, when discussing triage, that the use of triage tools was important in highlighting potential major trauma patients. However, it was also acknowledged by many participants that patients they believed were major trauma, did not fit within the parameters of the current NTN major trauma triage tool:

Participant P: *"…..the trauma triage tool has a role to play but it's not necessarily accurate……[in identifying all major trauma]…."*

Participant Q: *"……[the major trauma triage tool] It's not the be all and end all, it is about the suspicion of injury…….."*

Participant R (non-clinician)**:** *"from a personal perspective I had a few injuries a couple of years ago. And I don't see on [major trauma triage tool] that I would be [major trauma] and would have thought I was majorly traumatically injured."*

Participant S: (pointing to triage tool)*"…… it's a good starting point…….You don't necessarily have to agree with it. But it is a good prompt…..[and] a good reference when you're in a high stress situation."*

4.4 Discussion

It was obvious that participants thought experience plays a significant role in identifying and managing major trauma. Although relating to out of hospital cardiac arrest (OHCA) Weiss et al. (2018) highlight that experience and exposure has a direct influence on outcomes on these rare and stressful incidents. Maddock et al. (2020) highlight that lack of exposure to trauma for Paramedics within Scotland and also suggest that specialist teams who are more often exposed to (and specifically train for) trauma can improve trauma patient outcome (30-day mortality).

A lack of exposure to trauma for many clinicians may influence clinical decision making which may be complicated by patient factors such as age, MOI, previous medical history and altered physiology. It is apparent that our understanding of major trauma in England is changing and there is a need to improve our identification, assessment and management especially for the older adult who experiences major trauma from relatively minor MOI such as a fall from standing height (Kehoe et al., 2015b).

Cioffi (1997) explored the value of intuition within clinical decision making. The heuristic approach to decision making (highlighted by Cioffi as a nursing approach) contrasts with the positivist (medical) paradigm and, as a consequence, is often dismissed. However, the value of intuition is based on past experiences and significantly contributes to clinical decision making especially in complex situations where limited information is available. Intuition, in the context that Cioffi explores, draws on a clinician's experience to recognise patterns in patient presentations and/or events that is sensitive to subtle changes. It is this intuition and experience used to describe major trauma that was evident within all the focus groups. However, Choudhry et al. (2005) highlight in their systematic review that there is conflicting evidence that a physicians quality of care may is linked to experience and note that there is a potential risk of poor quality of care with increased experience (with regards to time) and advocate for continuous professional/personal development to mitigate this risk.

Children experiencing major trauma is a very rare event and, of those who are severely injured (n=1,511 between January 2013 and December 2014 in England and Wales), only 56% are transported by ambulance services (Trauma Audit and Research Network, 2015). As these incidents are extremely rare it is understandable that clinicians are anxious about managing these highly emotive cases. Although paediatric trauma is emotive and often over triaged there is clear need for guidance within high stress environments to minimise human error by obtaining skilled advice remotely and/or using age specific trauma triage tools. Although specific to regions within the Netherlands, van Rein et al. (2020) studied the trauma triage process and highlighted there was low compliance with regards to following the paediatric triage and that a clinicians experience and judgement played a significant role in the decision making process. This phenomenon was a commonly held view/experience within all focus groups as well as an anecdotal finding from various NTN clinical advisory groups.

Triage tools and checklists have an acknowledged role to play and may provide reassurance for clinicians when dealing with rare events that are potentially highly stressful (Clay-Williams and Colligan, 2015). However, these tools are very poor in identifying older adults who have significant injuries from low MOI (Potter et al., 2013). Trauma within the UK is changing as the older adult is now the emerging focus of major trauma (Kehoe et al., 2015b). As such, bespoke older adult major trauma triage tools need to be developed to identify those older adults who need early intervention to influence/improve their eventual outcome. Linking in with the themes of intuition and experience is clinical judgement. Within their literature review Mulholland et al. (2008) found there was no clear evidence to support clinical judgement of paramedics to triage blunt trauma patients accurately (including prediction of injury severity). This may go some way to supporting the argument of developing clinical decision-making tools to be used alongside a clinician's intuition. Within the Delphi study in Chapter 5 it was highlighted that, although it did not meet the predetermined consensus level, 60% of respondents believed that an experienced clinician's index of suspicion (intuition) could determine if a patient was major trauma.

A notable concern from many participants was the disparity of patients who have significant injury from low energy MOI and those with similar injuries from high energy MOI. It is also acknowledged that, in isolation, MOI is a very poor indicator of outcome and should only be used in identifying major trauma when other factors, such as deranged physiology, are present (Boyle, 2007). If MOI is used in isolation it is likely to over triage major trauma (Lossius et al., 2001, Magnone et al., 2017). We have a culture of using MOI as an indicator of trauma which is perhaps no longer appropriate and should be addressed within academia and clinical practice. Linking in with age specific and bespoke care, Magnone et al. (2017) recommend that when utilising MOI, the older adult major trauma patient should have an age specific triage tool to assist in identifying those who require specialist interventions.

The definition that emerged from the focus groups interestingly emphasised the end results of the injury rather than the system requirements to treat the injury (which was the focus of chapter 3).

Limitations

All participants were all members of a regular trauma workshop and therefore a self-selecting group which may bias their views on current trauma related concepts and practices. All the participants within the focus groups worked within a single trauma network and their views may potentially differ from other regions or nations although the concepts should be generalisable and transferable to other trauma networks/systems. Although doctors (prehospital and non-prehospital) and nurses were invited as participants none were able to attend the dates of the focus groups. As such the results may not truly reflect the views of the wider network within the region.

Within group discussions there is a risk that single participants can dominate the group and therefore bias the views of others within the group. It is believed that having more than one focus group that are well facilitated will have minimised any individual dominating and biasing the data collected. A second researcher also facilitated the focus groups to observe and take notes. This was based on the recommendations of Jackson

(1998) which also allowed the 'observing' facilitator to indicate if any participants were overshadowing the quieter participants and allowing those quieter participants to contribute.

Focus group discussions present the participants view of reality and there may be differential understandings and perspectives between researcher and participant. Within the context of this research, the lead researcher (LT) is an experienced paramedic which should minimise misinterpretation of the data. Initial transcription and original coding and interpretation were cross checked by the observing facilitator who is also an experienced paramedic who was present during all focus groups. However, as experienced paramedics specialising in trauma, the researchers who facilitated the focus groups may have unintentionally biased the content and direction of the discussions. To minimise the risk of researcher bias, semi-structured questions were used to focus the content of each group discussion and participant checking of the original transcripts for accuracy was also completed. It is believed that participant checking of transcripts enhances the trustworthiness of the study materials (Birt et al., 2016)

Conclusions

Major trauma was felt by the participants to be unique for every clinician/provider and patient when viewed from their individual experience which potentially requires a bespoke management strategy.

MOI can raise the index of suspicion that major trauma has occurred, however, low energy MOI, such as a fall from standing height, should not be discounted when defining major trauma. Older adults and children are both challenging patient groups when undertaking an assessment for major trauma. Children provoke very emotive responses and older adults often present with occult injuries that are complicated by comorbidities and medications. Age specific triage tools should therefore be explored further.

Intuition and heightened clinical concern when identifying major trauma is multifaceted. This aspect of intuition appears to be dependent on a clinician's relative exposure and experience in managing major trauma suggesting the need for specialist clinicians to be available on-scene or remotely to support clinical decision making.

Many variables clearly impact on the prehospital identification and definition of major trauma. It was also acknowledged that combinations of factors are often greater than the sum of their individual parts when defining major trauma which is complex and requires bespoke patient centred care.

In the absence of retrospective scores and using the output from the focus groups a suggested definition of major trauma is:

'Any apparent injury (or injuries) that have the potential to be life-threatening or life-changing including those sustained from low energy mechanisms. It should take account those who are rendered vulnerable by the extremities of age, comorbidities or frailty and those with significant physiological compromise i.e. haemodynamic instability, reduced or fluctuating consciousness or respiratory compromise and/or significant anatomical abnormality that may require immediate intervention.'

The potential definition that has been extrapolated from the output of the focus groups is lengthy and wordy. Therefore, additional research is required to provide a more elegant solution to our definition of major trauma. The definition should be expressed simply in non-technical language that can be applied to any setting which is appropriate to both specialists and non-specialists. It is believed that by seeking out a consensus from experts in trauma care may contextualise and distil the definition of major trauma into a more elegant solution. The Delphi study within Chapter 5 explores this method of consensus further.

CHAPTER 5 DEFINING MAJOR TRAUMA: A DELPHI STUDY.

5.1 Introduction

Preface

The literature review in chapter 2 helped shape and inform the topics discussed within the focus groups of chapter 4. In turn the discussions and conclusions of the focus groups provided a rich narrative of the lived experiences of major trauma from a prehospital perspective. The themes and conclusions were able to provide a number of topics that could potentially be discussed by experts within the field of major trauma. It was believed that this data could be shared with experts to distil their combined understanding to define a common definition of major trauma. As such the data generated from both the literature review and focus groups influenced the content of the Delphi study highlighted within this chapter.

Background

Within the last 100 years human life expectancy has changed and we are now living longer where men can be expected to live until 79.3 years and women 82.9 years with the overall population in England and Wales increasing by 64% within that period. The causes of death over this period have shifted dramatically from infections as the primary cause in 1915 to a more complex distribution throughout a century of medical, industrial and social innovation. For all ages, ischaemic heart disease and dementia and Alzheimer's disease is a common cause of death with cancers and ischaemic heart disease more apparent in the older age groups. The very young (1-4 years) mostly die from congenital malformations, deformations, and chromosomal abnormalities. Deaths in older children through to middle age include suicide, injury and poisoning as the main causes (Office for

National Statistics, 2019). For the last 20 years, injury is the most common cause of death for women aged 10 to 30 years and for men aged 15 to 35 years (Lecky et al., 2020).

As we have seen in previous chapters, major trauma remains a relatively rare cause of death and the lack of Paramedic exposure to major trauma can cause anxiety and our perception of what is classified as major trauma is potentially complex. Major trauma triage tools assist prehospital clinicians to identify major trauma patients who may be suitable for primary transfer to specialist care at an MTC. The triage tool highlighted in Figure 1.2 utilises physiological criteria that are present in other triage tools such as the Simple Triage and Rapid Treatment (START) triage tool and Revised Trauma Score (RTS), all of which can be used in the prehospital phase of care. The START tool is primarily for multiple casualty/major incident /disaster events and can be used by both medical and non-medical personal for rapid triage (Badiali et al., 2017) although it does have a high incidence of over triage (Kahn et al., 2009). The RTS also has its limitations and is not as sensitive to predicting outcomes (Meena and Mehta, 2019). Essentially these tools are used for triage purposes and are limited in their ability to define major trauma. However, they are commonly used within established trauma networks to identify trauma patients who need immediate management.

The study within this chapter employed a Delphi process in order to gauge the degrees of consensus and disagreement amongst expert panel members, their views and definition of major trauma.

The research question assumed an exploratory focus:

"Which factors do subject experts and current prehospital care practitioners identify in defining major trauma in the absence of injury severity scores?"

The specific aims of the study included:

- To distil subject expert opinion concerning the definition of major trauma; and,
- To critically explore the extent of consensus in the definition of major trauma in the absence of ISS.

5.2 Methods

Study design and setting

A two-round modified Delphi technique (with a potential third) was employed in order to explore subject-expert consensus and identify in-situ use of variables to define major trauma in the absence of ISS. This is facilitated through systematically collecting, analysing, coding, and presenting questionnaire responses to the original expert panel participants with the explicit instruction to reflect upon their own individual responses in light of the collective group response. Participants are then invited to submit a revised response to the questionnaire should they wish to do so. Collectively this process might be referred to as one of iteration with controlled feedback. However, Scheibe et al. (1975) identified that when faced with collective group responses, individual respondents have three options: to ignore the feedback, to maintain their views or to adapt a more extreme response to that originally expressed. Using experimental methods, these authors contended that the means by which the feedback is presented has the potential to introduce a distorting influence into the Delphi process in a way which is both difficult to predict and control for. The initial questionnaire can be found in Appendix 8 along with the anonymised feedback/round 1 results in Appendix 9.

The exploratory nature of the Delphi study allowed for feedback to be provided to the expert panel using group responses. To prevent any bias, and to ensure rigor throughout the process, all responses were anonymised and sent to all participants prior to undertaking round two with clear and precise instructions on how to manage the data and respond (Paré et al., 2013). The feedback combined all the results of round 1 as simple graphs to illustrate all responses as well as a summary of the free text used throughout the questionnaire which summarised individual definitions of major trauma (see Appendix 9). This was believed to provide new information that may generate new perspectives to achieve a group consensus.

The survey was designed to reflect the outcomes of the literature review in Chapter 2 (Thompson et al., 2019b) and the output from three focus groups highlighted in Chapter 4 (Thompson et al., 2019a). This included the domains:

- Clinician factors, such as experience and exposure;
- Patient factors, such as physiology, outcome measures and pre-trauma factors; and,
- Situational factors, such as mechanism of injury.

Questions were designed around the domains highlighted above and included variables from both the literature review and focus groups (Chapters 2 and 4) in order to ascertain potential clustering factors including both observable (e.g., profession, experience, and age) and unobservable factors (e.g., values, attitudes, opinions and preferences). Although the domains were known to the authors, these were not explicitly labelled within the survey instrument and therefore may not have been immediately apparent to participants. The questionnaire(s) for subsequent rounds were intentionally unchanged from the initial questionnaire to aid analysis and to compare any significant changes in responses after the feedback had been provided to the participants. As such only minor amendments were made for clarification and to correct any inconsistencies, grammar, and spellings.

Grant et al. (2018) recommend that the Delphi process should conclude after predetermined multiple iterations or when consistency between rounds is stable with unchanging opinion.

Definition of consensus

Mubarak et al. (2019) highlight that 100% agreement can seldom be achieved among experts and that an arbitrary percentage should be set prior to undertaking the study. Within our Delphi design, Likert type scales were used which give the option of a neutral response. With this in mind, a 70% (positive or negative) agreement was set as subject-expert consensus where the neutral score was not considered. This was based upon the recommendations of von der Gracht (2012) and Stewart et al. (2017) who state that there is no set standard of consensus although 70% is commonly reported as a targeted reference point for consensus. The exception to this would be if the group agreement were more than or equal to a 70% neutral response. The main issue with including a mid-point/neutral option is that it becomes an easy option when the other options are potentially socially undesirable/controversial. Within the study design, whilst omitting the mid-point/neutral option was contemplated, it was ruled out on the basis that this may have led to further undesirable consequences. The initial concept of omitting a mid-point/neutral option would force the participant to choose the theoretical nearest positive or negative response from the neutral option. Chyung et al. (2017) explored literature that concluded that when the neutral option is removed from Likert type scales the responses are distributed to the nearest alternative option but, many respondents simply did not respond leaving that question unanswered. With this in mind, several questions within our study presented themselves for a simple binary response which may partially mitigate any neutral response. Dolnicar and Grün (2007) highlight that this method provides an acceptable alternative to ordinal scales that may also improve the efficiency of the questionnaire.

Sampling of study participants (expert panel)

The expert panel members, who will be referred to as participants within this study, were from a broad range of professional groups who are exposed to and manage major trauma patients within their everyday workplace. The use of the term 'expert' is commonplace in the lexicon of Delphi methodology and literature but does not imply expert status in the vernacular sense: It simply implies that panel members are purposively selected on the basis of a privileged knowledge base or experience. In this instance, panel members were purposively selected based upon diversity of experience and expertise within a single trauma network. Weinstein (1993) explains there are two kinds of expertise: expertise in knowing (epistemic expertise) and expertise in doing (performance expertise). Bourne et al. (2014) explore the potentially abstract concept of expertise within elitism and cite exemplar individuals who are undoubtedly experts within their own domain and 'one of a kind'. However, they also acknowledge the expert who is such due to their accumulation of hard work as well as ability. One of the strengths (and limitations) of this study was to capture the views of participants who were experts by virtue of their understanding and hard work at the patient interface within a single trauma network. Although this was a pragmatic approach to access regional expertise there was a risk of bias from such a homogenous group. Huybrechts et al. (2012) highlight that differences between regions include confounders such as intensity, exposure and prevalence which all have potential biases which should be acknowledged. However, Roller and Lavrakas (2015) explain that homogenous groups are potentially necessary for group dynamics but may produce single minded *'group think'* ideas and that heterogenous groups may create new viewpoints. Within the context of this study the expert panel were required to have first-hand experience of the hyper-acute trauma setting to which a definition of major trauma can be applied.

Whilst there are no absolute guidelines as to the number of participants that may contribute to the Delphi process (Keeney et al., 2001), the aim was to have at least three individuals from each relevant professional group within the Northern Trauma Network (NTN) which covers the North East and Cumbria areas of England.

Data collection and management

Ethical approval was granted through the Integrated Research Application System (IRAS project ID: 237977).

A Delphi method with two iterations of questionnaires was utilised (with a potential third which was not required). The survey was conducted using the online system SurveyMonkey Inc. (San Mateo, California, USA). Panel members remained anonymous to one another throughout the data collection and analysis process. The Delphi study commenced on 12 December 2018 and ran through to 5 November 2019 (this time frame is discussed within the study limitations).

All data collected were stored electronically in a secure and password protected folder and anonymised prior to analysis.

Validity and Reliability

Sackman (1974) suggested that the Delphi processes fail to meet standards of reliability and validity '*normally set for scientific methods*.' However, careful scrutiny of Sackman's assertions reveal that his concerns relate more to the methodological shortcomings of particular studies rather than overall methodological approach *per se*.

Anonymised results are believed to prevent attrition of panel members who may have a minority opinion (Sinha et al., 2011) and minimises bias that certain individuals may create as well as contributing to the overall rigor of the study (Paré et al., 2013). A short pilot study was carried out to refine the wording of the survey instrument and to remove potential ambiguities and ensure reliability of responses. All responses of the proceeding questionnaires were anonymised and peer reviewed prior to any analysis and sharing with the expert panel members between survey iterations.

Data Analysis

All quantitative data analysis was undertaken using the Statistical Package for the Social Sciences (SPSS; Version 26, IBM Inc.; Armonk, NY, USA). The level of statistically significance was predetermined as a *p* value of ≤ 0.05 (Kennedy-Shaffer, 2019).

After initial descriptive analysis of variables, Kruskal-Wallis tests were used to determine statistically significant differences ($p \leq 0.05$) in response to the Delphi statements between the professional groups within the sample e.g., Doctors, Paramedics, Nurses and others which included managers, academics and administrators. The term 'other' was used to prevent unique individuals within specialised professional groups from being easily identified.

The Kruskal–Wallis test is a statistical method for ascertaining the significance of differences between the median values for *K+* sub-groups from within the same sample, sometimes referred to as 'ANOVA by Ranks': this is the test of choice when analysing ordinal data such as that generated by the Delphi instrument.

No consistent patterns of opinion emerged in relation to professional group membership (Doctor / Paramedic / Nurse / other). The statistical parameters for the use of Kruskal Wallis suggest a minimum group membership of 5 (Minitab, 2019). Whilst the 'other' group failed to meet this parameter (n=2), there was no theoretical basis to combine this group with any other.

Because no consistent patterns of difference emerged based upon professional group membership, a hierarchical cluster analysis was undertaken in order to identify patterns of similarity and difference of response within the data. Yim and Ramdeen (2015) identified that '*Cluster analysis refers to a class of data reduction methods used for sorting cases, observations, or variables of a given dataset into homogeneous groups that differ from each other.*' Cases (individual participants) are clustered based upon chosen characteristics – in this instance, similarity in the way they scored selected Delphi statements – *and NOT their professional grouping*. Cases in each specific cluster share many characteristics but are also dissimilar to those not belonging to that cluster. A three-cluster solution provided membership in each group of a size that would allow for further meaningful statistical comparison in order to determine qualitative differences in response patterns between the clusters. This was calculated using Ward's method and squared Euclidian distance as a means to determine cluster membership whilst minimising variance within each cluster.

Therefore, in the current study, the cluster membership was based upon similarity in response to the Delphi statements. Arranging response patterns together and classifying these as belonging to different broader groups provides a means of applying some organisation to individual Delphi responses, which at first sight might appear highly individualised or even chaotic. The technique of cluster analysis originated in biology and ecology (Sokal and Sneath, 1963) and although the technique has been reasonably widely employed in social science analysis, it has not (to date) gained the same level of application in health research. As such, distinguishing characteristics between clusters using an interpretive analysis and allocating sub groupings was undertaken (Vaismoradi et al., 2016). Using this interpretive approach, the application of current triage practices was applied to each cluster which differentiated each clusters approach to triage/levels of risk acceptance.

Free text data generated by questionnaire responses were managed and analysed using NVivo qualitative data analysis software (QRS International Pty Ltd., Version 11, 2015). Data were coded and reviewed to identify emerging themes (Saldaña, 2013).

A grounded theory approach to qualitative analysis of the free text data allowed for potentially multiple iterations of the Delphi process to be influenced by the generated data and themes identified. This inductive approach allowed for theoretical insights to be generated as the process was undertaken rather than testing preconceived hypotheses (Chapman et al., 2015). Within the context of this study, it allowed for a thematic framework to distil variables into their most common denominators to provide generalisable themes appropriate to both the expert and layperson. This is not to imply *statistical* generalisation, but rather the type of qualitative *moderatum* generalisation identified by Williams (2000).

5.3 Results

Figure 5.1 highlights the Delphi study process and the frequency of responses throughout.

A text version of the questionnaire can be found in Appendix 8. The results of round 1 which were used as feedback to the expert panel/participants can be found in Appendix 9.

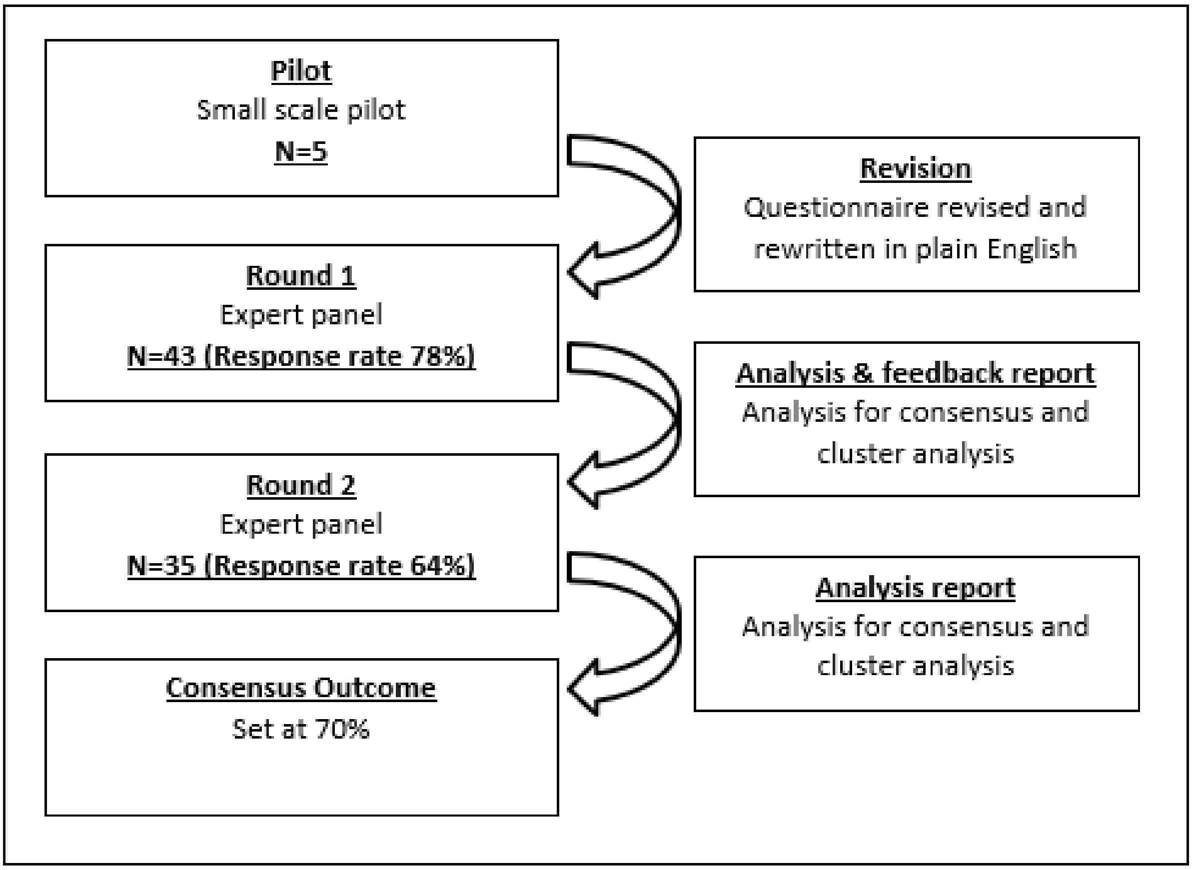

Figure 5. 1 Study Process.

Table 5.1 describes the frequency of responding participants professional group alongside experience in years, including range and mean.

Table 5. 1Delphi participants by professional group and experience.

Professional group Round 1 (n)	Experience in years Range (mean)*
Doctor (20)	6 - 21+ (14)
Paramedic (16)	6 - 20 (14)
Nurse (5)	0 – 21+ (12)
Other (2)	Not recorded
Total (43)	0 – 21+ (13)
	*Rounded

Due to the level of expertise within very specific professional disciplines which specialise in major trauma, participants were placed into generic professional groups to prevent identifying individuals and potential bias. These groups were used within the context of the cluster analysis to identify differences between specific group responses. Table 5.2 highlights the response rates to each round of the study by professional group.

Table 5. 2 Delphi participants by professional group and response rates.

Invited to participate by professional group (n)	Round 1 n (Response %)	Round 2 n (Response %)
Doctor (20)	20 (100)	14 (70)
Paramedic (20)	16 (80)	16 (80)
Nurse (10)	5 (50)	3 (30)
Other (5)	2 (40)	2 (40)
Total (55)	43 (78)	35 (64)

Round 1

Because no consistent patterns of opinion emerged in relation to professional group membership (Doctor / Paramedic / Nurse), a cluster analysis was performed in order to identify patterns of similarity of response within the data (whilst ignoring whether responses were made by professional group). Participants who did not complete all sections of the questionnaire (n = 7) were excluded from the cluster analysis (missing data addressed within limitations). Figures 5.2 and 5.3 highlight the distribution of participants by cluster (three cluster solution).

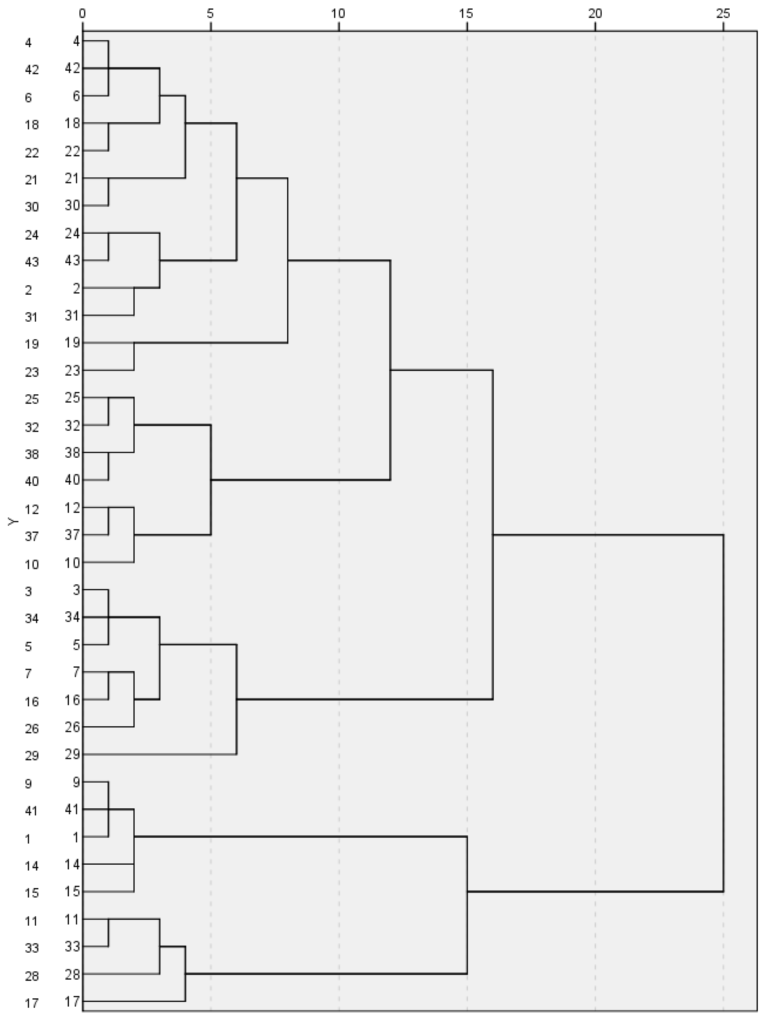

Figure 5. 2 Dendrogram using Ward Linkage.

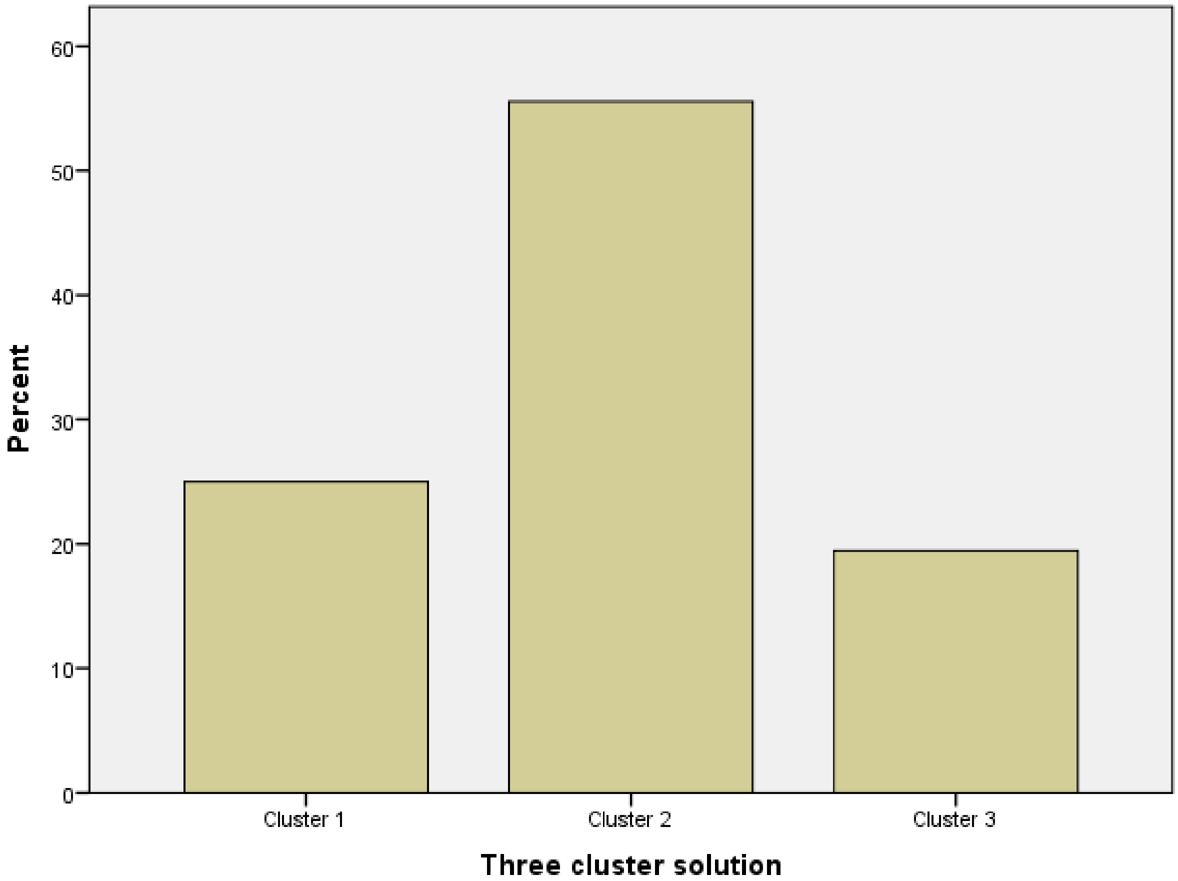

Figure 5. 3 Percentage of clusters (cluster 1 = 'Trauma Minimisers, cluster 2 = 'Middle Ground', and cluster 3 'Risk Averse').

Three distinctive clusters were identified and their composition by professional group is highlighted in Table 5.3.

Table 5. 3 Composition of clusters.

Cluster	N (%)	Composition (%)
1	9 (25)	4 Doctors (44) 4 Paramedics (44) 1 Nurse (11)
2	20 (56)	10 Doctors (50) 7 Paramedics (35) 3 Nurses (15)
3	7 (19)	5 Doctors (71) 1 Paramedic (14) 1 Nurse (14)
Total	36 (100)	19 Doctors (53) 12 Paramedics (33) 5 Nurses (14)

Clusters 2 and 3 were closely linked together and all clusters produced a normal distribution pattern.

Cluster 1 were coded as "Trauma Minimisers" owing to their answers indicating a high threshold for identifying major trauma. In relative terms, from a given number of trauma patients, cluster 1 participants would identify a very low percentage as major trauma.

Cluster 2 were coded as "The Middle Ground". This cluster represented the majority of the Delphi participants as well as their respective professional groups. Cluster 2 identified what would be considered an appropriate proportion of major trauma based upon existing criteria used within the NTN major trauma triage tool (Figure 1.2).

Cluster 3 were coded as "Risk Averse" as their answers indicated a very low threshold for identifying major trauma. From a given number of trauma patients cluster 3 would identify a high percentage as major trauma.

Table 5.4 highlights the areas of consensus within the first round Delphi questionnaire that was predetermined as $\geq$70% agreement (see Appendix 8 and 9 for questionnaire and participant feedback/results).

A single question within the survey instrument (question 23- Appendix 8) presented participants with a list of factors that could be acknowledged as the main variables in defining major trauma. This list was distilled from a comprehensive review of existing literature and earlier focus group research with practitioners. Respondents were asked to identify factors they viewed as relevant with a binary "yes" / "no" answer. Table 5.5 highlights the key variables from that list that achieved consensus from the Delphi participants.

Table 5. 4 Consensus on variables (Delphi round 1)

Variable	Consensus (≥70%)	%
Actual injuries*	Yes	100 (>med)
Only high energy mechanisms should be considered	Yes	97.5 (>disagree)
Physiology*	Yes	97.44 (>med)
Need for blood products*	Yes	92.3 (>med)
Age (>65 years) special consideration*	Yes	89.75 (>med)
Experienced clinicians are able to identify major trauma patients	Yes	89.74 (>agree)
Need for ventilatory support*	Yes	89.47 (>med)
Intoxication makes triage difficult	Yes	87.5 (>agree)
Age (paediatric)*	Yes	87.18 (>med)
Age has no relevance	Yes	85 (>disagree)
Low energy mechanisms should be considered	Yes	85 (>Agree)
Elderly require different assessment/management	Yes	85 (>agree)
Need for surgical intervention*	Yes	84.61 (>med)
Triage tools always identify major trauma	Yes	82.5 (>disagree)
Mechanism of injury (MOI)*	Yes	82.5 (>med)
Scoring systems are the only way to identify major trauma	Yes	76.92 (>disagree)
Paediatrics require different assessment/management	Yes	77.5 (>agree)
Identified by clinical assessment (as opposed to mechanism of injury)	Yes	77.5 (>agree)
Can only be defined by retrospective scores	Yes	75 (>disagree)
Perceived need for Intensive Care Unit admission	Yes	75 (>agree)
Triage tools can identify patients who would benefit from MTC care	Yes	75 (>agree)
Outcome measures (e.g., injury severity scores) *	Yes	71.8 (>med)
Pre-existing frailty should be considered	Yes	70 (>agree)
Need for tranexamic acid (TXA)*	No	69.22 (>med) 30.77 (Low)
Need for pelvic binding*	No	64.1 (>med) 35.9 (low)
Perceived need for surgical intervention	No	62.5 (>agree) 22.5 (neutral) 15 (Disagree)
Major trauma can only be managed at an MTC	No	62.5 (>disagree) 15 (neutral) 22.5 (agree)
Need for spinal immobilisation*	No	61.54 (low) 38.47 (>med)
Clinicians high index of suspicion can identify major trauma without imaging	No	60 (>agree) 15 (neutral) 25 (disagree)
Burns should have a separate protocol	No	57.9 (>agree) 26.32 Neutral) 15.79 (disagree)
Previous medical history*	No	56.41 (low) 43.59 (med)
Burns should be included in major trauma triage	No	55.27 (>agree) 7.89 (Neutral) 36.85 (disagree)
Pre-existing co-morbidity should be considered	No	51.28 (>agree) 25.64 (neutral) 23.08 (disagree)

*Refers to multi-variable choice within question 1 (see Appendix 8).

Table 5. 5 Key variables highlighted by participants in round 1.

Variable identified	Consensus (≥70%)	%
Life threatening injuries	Yes	95
Limb threatening	Yes	92.5
Major blood loss	Yes	87.5
Suspected abdominal injury with haemodynamic instability	Yes	80
Injury causing reduced consciousness	Yes	72.5

Free text responses within the questionnaire were coded and subject to thematic analysis. Questions 21 and 22 (see Appendix 8) asked for free text descriptions of the participants personal and, if appropriate, workplace definitions of major trauma. This emergent grounded theory analysis allowed for subtle adjustment to the survey instrument prior to iteration 2 of the Delphi process. Table 5.6 provides a summary overview of these coded themes.

Table 5. 6 Frequency of variables highlighted in qualitative analysis of free text.

Variable	Round 1 n
Significant injury/Polytrauma	24
Life threatening/changing/disability	18
Mechanism of Injury (MOI)	14
Specialist input	12
Physiological changes	10
Prolonged treatment/Rehab	8
Age	6
Previous medical conditions	3
Bespoke/patient specific care	2
ISS	1
Total	98

Round 2

Of the original 43 respondents from the first round, 35 participants completed the second round of the Delphi. Several members had since left their original place of work and were unable to be contacted (discussed in limitations).

The survey instrument utilised in round 2 remained relatively unchanged from the initial instrument used in round 1 (i.e., the structure of the instrument did not change at all and subtle wording changes were influenced by participants' prior qualitative responses). This was intentional to aid analysis and to compare any significant changes in response due to the feedback provided in Appendix 9. Non-parametric related-samples Wilcoxon Signed rank test was utilised to analyse difference in responses with the significance level set at ≤ 0.05.

There were only modest changes in overall responses between iterations 1 and 2. Five statements moved from non-consensus to consensus status, with only a single statement moving from consensus to non-consensus (Table 5.7). None of the consensus changes (summarised in Table 5.7) proved statistically significant in their own right but their combined effect was sufficient to alter the overall consensus. A single statistically significant change was 'major trauma patients can only be managed at an MTC' which, although statistically significant it still did not meet the agreed consensus level of 70% and therefore did not change its overall status.

Table 5. 7 Changes in consensus between rounds 1 and 2 (questions 1-20)

Variable	Consensus (≥70%)	Round 1 %	Round 2 %	Related Samples Wilcoxon Signed Rank Test
Pre-existing frailty should be considered	Changed to No	70 (>agree)	63.64 (>agree) 21.21 (neutral) 15.15 (>disagree)	0.142
Need for tranexamic acid (TXA)*	Changed to Yes	69.22 (>med) 30.77 (Low)	79.41 (>med)	0.124
Need for pelvic binding*	Changed to Yes	64.1 (>med) 35.9 (low)	76.47 (>med)	0.432
Perceived need for surgical intervention*	Changed to Yes	62.5 (>agree) 22.5 (neutral) 15 (Disagree)	70.59 (>agree)	0.218
Clinicians high index of suspicion can identify major trauma without imaging	Changed to Yes	60 (>agree) 15 (neutral) 25 (disagree)	70.59 (>agree)	0.084
Burns should have a separate protocol	Changed to Yes	57.9 (>agree) 26.32 (neutral) 15.79 (disagree)	76.47 (>agree)	0.325

The single change from consensus to non-consensus concerned the statement 'Injury causing reduced consciousness' which moved from a 72.5% agreement to a below consensus agreement of 65 %. This variable was one of multiple options that a participant could choose from to help support their definition of major trauma (question 23- Appendix 10).

The results of Delphi results were distilled further as part of a reductive strategy (grounded theory/thematic analysis) to provide an elegant and generalisable definition of major trauma. Table 5.8 highlights the themes produced by the results of Tables 5.4, 5.5 and 5.6. The reductive coding was undertaken by multiple members of the research team to help validate our interpretation and groupings and establish inter-coder reliability of the themes (Castleberry and Nolen, 2018). This, however, creates a '*generality*' that may be subjective (Vaismoradi et al., 2016). As such, it can be argued that the themes within the potentially life threatening and potentially life changing sections could be interpreted as (and reduced further to): 'requirement for specialist treatment'.

Table 5. 8 Factors identified as definitive components of major trauma.

Reductive Coding	Table 5.4 Variables	Table 5.5 Variables	Table 5.6 Variables
Potentially Life Threatening	Deranged physiology	Life threatening injuries	Life threatening injuries
		Suspected abdominal injury with haemodynamic instability	Physiological changes
		Injury causing reduced consciousness	
	Need for blood products	Major blood loss	
	Need for ventilatory support		
	Potential need for ICU		Specialist input required
Potentially Life Changing	Need for surgical intervention	Limb threatening injuries	Life changing injuries
			Significant injury/polytrauma
			Prolonged treatment/rehabilitation
Other	Actual injuries		
	Clinical experience/skills/perception		
	MOI (high and low energy)		
	Age (paediatrics and older adults		
	Frailty		
	Interventions (TXA, Pelvic binding)		
	ISS/scoring/triage		

5.4 Discussion

Statement of principle findings

Abersek (2015) explains the concept of elegance within science as the distilling of potentially infinite complexity, which can be interpreted by many as dull and mundane, into seemingly simple answer. This distilled complexity conceptualises the topic into its simplest form to express the essence of the issue, which can provide a potent yet elegant solution. It is worth noting that elegance within science does not detract from the complex nature of scientific endeavour but articulates that complexity in a deep and meaningful way which is often viewed as simple. The thematic analysis highlighted in Table 5.8 visualises this process which may be an oversimplification of our definition of major trauma. However, at its very foundation are the generalisable building blocks to defining major trauma that can be applied to all from expert to non-specialist/layperson alike. There are nuances in every field of practice and, as such, these foundations can be built upon to make generalisable concepts specific to individuals or professional groups by the addition of individual/professional group idiosyncrasies. An insightful comment by one participant highlighted their concern with regards to definitions needing context depending upon area of practice, '*How you define it will be based on where in the patient journey that patient is. End [diagnosis] after 3 weeks in hospital with access to complex imaging and specialist input is different to how it will be at the ED front door or in the prehospital setting'.* As such, the underlying disease should not change based upon the stage within the patient journey and therefore a definition should be appropriate to the entirety of the patient journey.

The areas of consensus highlighted in Table 5.5 were replicated throughout the study in the free text as well as reflecting the association with other key variables highlighted within the results and summarised in Table 5.8. They highlight that life and limb threatening injuries are without doubt the variables that define major trauma. Included within that table are major blood loss, abdominal injury with haemodynamic instability and reduced consciousness which could be addressed under deranged physiology. Deranged physiology could also be argued to highlight life and limb threatening injuries. It was also noted that only using high energy mechanisms should be discounted.

The participants within this study do not significantly change their opinions between rounds with the exception of those highlighted above. Furthermore, during the cluster analysis there was no clear difference in response between individual disciplines and each cluster had an even distribution of professional groups.

In the main, consensus was achieved in many variables highlighted within the study. Within round 1 several aspects did not meet the agreed consensus level such as the need for TXA, pelvic binding and 'potential need' for surgical intervention (as opposed to actual need) round 2 responses provided a shift in agreement and these variables consequently met the agreed 70% consensus. Although two burns-related statements were presented to the participants, a non-consensus reaching majority in iteration 1 (which became a consensus agreement after iteration 2) and paradoxically asserted that burns should have a separate protocol from the major trauma triage tool and yet also be included in the major trauma triage tool. These conflicting statements may be due to the wording and placement of the statements within the instrument, but other than this no strong conclusions can be drawn from this change in consensus status.

Again, the majority of participants, but not meeting the prespecified consensus level, disagree that major trauma can only be managed at an MTC. This may reflect the views of the regional specialists that are distributed throughout the trauma units or that sub-groups of patients may be best managed locally.

A low percentage of agreement on whether to consider comorbidities and previous medical history in identifying potential major trauma may be reflective of the composition of the participants within the Delphi study. Owing to the nature of the research topic, in the context of defining major trauma in the hyper-acute phase of care, there was an obvious lack of participants from the rehabilitation and long-term care disciplines. These sub-acute disciplines may have an alternative perspective with regards to the variables that should be considered in defining major trauma.

It is perhaps reassuring and a testament to the specialist/expert participants that a patient's actual injuries are a primary focus in identifying major trauma and also based on that patient's individual circumstances. However, within the prehospital phase of care many injuries may be obvious, but, as highlighted within the focus group work in chapter 4, without imaging many injuries may be hidden and difficult to identify. As such this may reflect the composition of the expert group which consisted of a majority of primarily hospital-based doctors and nurses. A bespoke model for identifying major trauma should take into account the unique nature of an individual patients' episode of care that includes their age and expected physiology and that not all mechanisms are equal based on an individual's unique response. It is also noted that experts within the hyper-acute trauma setting do not agree with triage tools and scoring systems being able to identify all major trauma. This may reflect the wealth of experience and exposure to major trauma within the participant group and a common theme that ran through the study was that major trauma is unique to the individual at that time where injury/injuries threaten life or limb. However, it may also reflect the commonly held belief that trauma triage tools have poor accuracy and have potential for great variation in under/over triage (Fuller et al., 2021, Gianola et al., 2021, Voskens et al., 2018).

Strengths and weaknesses of the study

The Delphi study provided a technique to gain consensus on defining major trauma by the experts within that specialist area across disciplines. Delphi techniques have previously been used in order to seek expert consensus in prehospital care matters (Borger van der Burg et al., 2019, Dippenaar and Wallis, 2019, Seymour-Walsh, 2019). However, Delphi methodology has been subject to criticism on the basis of methodological flaws, most notably: sampling and use of 'experts'; anonymity; and the issue of enforced consensus (Keeney et al., 2001).

Throughout the study the authors remained cognisant of these criticisms during the design phase of this study. The title of expert is also very subjective and relies on the context within which supposed expertise lies. Within the context of this study, it was a conscious decision to use experts with current lived experiences of working predominantly within the trauma setting in a hands-on clinical context. This may be considered both a strength and weakness of the study and the regional specific expertise may produce its own idiosyncrasies.

There was a significant drop out rate between both rounds (round 1 n=43, round 2 n=35), however, this is not uncommon in relation to repeated administrations of the same survey. The dropout rate may partially be contributed to the long-time frame over which the study was conducted. Unfortunately, the two lead researchers had family members with acute illness and consequential bereavement which had a significant impact on the overall timeframes that could not be avoided.

Within the cluster analysis there was no obvious distinguishing characteristic between groups such as age, experience or speciality of the participants. However, if participant responses were applied to the major trauma triage tool criteria (Figure1.2) it allowed for a pragmatic criterion in which to compare difference between the clusters consequently named *'trauma minimisers'*, *'the middle ground'* and *'risk averse'*. This method was believed to contextualise the participant cluster responses.

The regional trauma network and the individuals who work within it are a very close community. There may be a risk of unintentional homogenous thinking due to the isolated nature and familiarity within the group. There is also a risk of excluding the views and perceptions of those who are not specialists or who work in the sub-acute disciplines within the region although it is believed that the definition of major trauma will be transferable and generalisable within all settings. It is an intentionally broad definition in its application to provide an elegant solution from a complex process to allow it to be appropriate to all. However, each professional group may have their own idiosyncrasies and therefore additional criteria may be added to their own specific definition of major trauma which would then exclude other groups. As a general definition it stands alone but is also enhanced by the addition of discipline specific variables which complement their unique definition of major trauma.

Complete case analysis was undertaken which omitted missing data with the assumption missing data was random (Pigott, 2001). Upon reflection this method may have created issues as small volumes of missing data from an already small dataset may not reflect the true participant population. As such other methods should be utilised to account for missing data. The Markov Model has been used for large datasets (Mirkes et al., 2016) and maximum likelihood, multiple imputation and bootstrapping (Schomaker and Heumann, 2018) may also be utilised.

Strength and weaknesses in relation to other studies, discussing important differences in results.

The authors are unaware of any prior consensus study which has attempted to define major trauma in the absence of ISS or other scoring mechanisms (although there are examples that relate to defining polytrauma (Butcher et al., 2014) and prehospital tools that explore triage such as START (Badiali et al., 2017) and RTS (Meena and Mehta, 2019)). It is therefore difficult to compare this study to other studies or literature.

Meaning of the study

This Delphi study highlights the group consensus of the expert panel to the definition of major trauma in the hyper-acute setting. It was interesting that although clusters were created (trauma minimisers, the middle ground, and the risk averse) there was no real difference in composition within those clusters highlighting that differences were not based on profession. It is hoped the concluding definition can provide a reference for non-specialists, academics and/or clinicians where retrospective scoring systems provide little context or meaning.

Unanswered questions and future research

The definition of major trauma from this Delphi study is partly subjective and therefore open to interpretation. ISS or other scoring systems provide an objective measure but have very limited utility within the hyper-acute setting. Future research may be able to identify objective measures that consider the principles within this study.

Conclusions

Based upon the previous literature review, focus groups and the output of this Delphi study, major trauma may be potentially defined as: *"Perceived significant injury or injuries that have potential to be life-threatening or life-changing sustained from either high or low energy mechanisms which also considers the complexities encountered by the extremities of age"*. This parsimonious, single sentence definition is a concise solution which can be complimented by additional criteria to make it specific for various professional groups or to reflect the patients position within their overall journey of care.

CHAPTER 6 IDENTIFYING PREHOSPITAL FACTORS ASSOCIATED WITH OUTCOME FOR MAJOR TRAUMA PATIENTS IN A REGIONAL TRAUMA NETWORK: AN EXPLORATORY STUDY.

6.1 Introduction

Preface

The project in this chapter was conceived in 2014 and the consensus in the UK at that time was that major trauma was a sequalae of factors that effected relatively younger adults. It was my first experience of undertaking a project as a researcher and although labelled as chapter 6, chronologically it was the first step which influenced the other chapters within this thesis.

Background

In April 2012, after reports identifying the need for specialist trauma care, regional trauma networks were introduced across the UK which enabled ambulance services to bypass local emergency departments and transport severely injured patients direct to specialist/definitive care at specialist MTC's (National Confidential Enquiry into Patient Outcome and Death, 2007, National Audit Office, 2010).

Following the introduction of the local NTN, a regional prehospital trauma registry was created and of which, the author of this thesis is the architect. This data was combined with outcome data from the national trauma registry maintained by the TARN. TARN is a national organisation that collects and processes data on moderately and severely injured patients in England and Wales. TARN data allows trauma networks, MTC's, trauma units, ambulance services and individual clinicians to benchmark their trauma service with other providers across the country. The combination of TARN outcome data with the NTN prehospital database enabled the creation of a meaningful dataset and allowed for a more comprehensive exploration of factors relating to prehospital trauma care. A key consideration in this analysis was understanding the epidemiology of a trauma system whilst taking into account the unique geographical features and demography of the NTN region. Understanding the local regional major trauma epidemiology through this preliminary and exploratory study, with the intention of providing a baseline from which to evaluate future performance, would potentially identify trends and ultimately improve patient outcomes.

The aim of this study was to explore the prehospital casualty and response factors associated with major trauma outcomes within the NTN.

6.2 Methods

The study analysed combined data from TARN and NTN prehospital database for the North East (England) Ambulance Service NHS Foundation Trust producing a comprehensive dataset of regional major trauma patients. The entry criteria for patient inclusion within the NTN prehospital database can be seen in Figure 6.1. Ethical approval for the study was granted via Northumbria University Research Ethics Review Panel (HLS-PHW141411- see Appendix 11). Reporting of the study followed the STROBE guidelines (Vandenbroucke et al., 2007).

Study period and population

The sample comprised of data collected between 1st of April 2012 and 30th September 2012 with each patient record (case) within the dataset containing 69 variables. The study identified two groups of variables: 'Casualty Characteristics' obtained from patient care records, which included physiological measurements, age, MOI etc.; and 'Response

Characteristics' obtained from Computer Aided Dispatch (CAD) records, which included response and transport times, crew skill mix and triage practices.

Within the sample there was a small number (n=36, 3.5%) of casualties who were not classified as major trauma at initial triage but were retrospectively included into the sample because they were later identified as meeting major trauma criteria. All 'under-triaged' patients managed at the MTC's or trauma units were subsequently entered into the database.

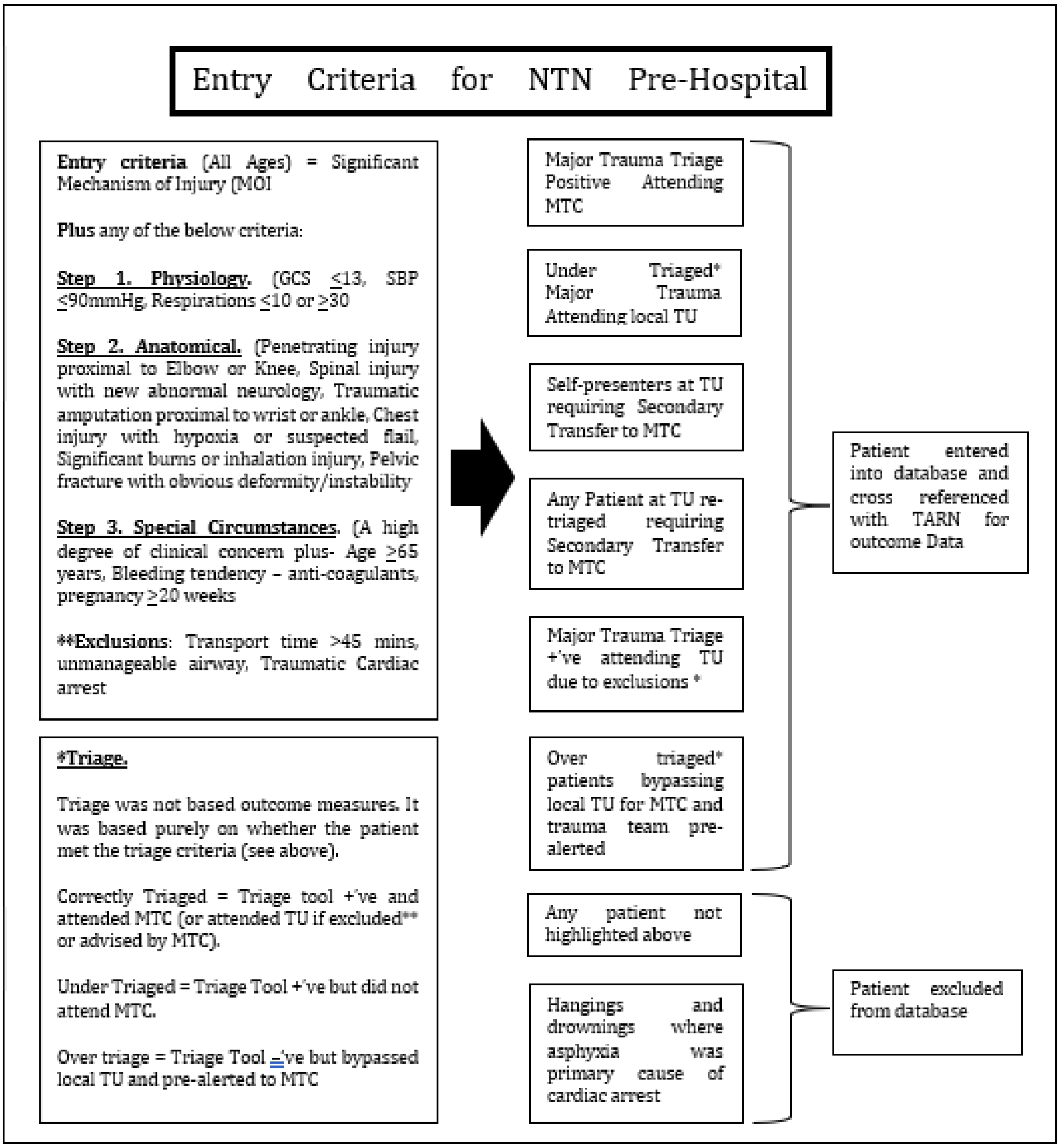

Figure 6. 1 Criteria for patient entry into prehospital database

The North East Ambulance Service (NEAS) NHS Foundation Trust covers an area of 8,365 square kilometres serving over 2.71 million people in a mixed geography of rural and urban areas and receives over 1.5 million emergency and urgent calls per annum. The NTN, at the time of the study, had nine trauma units (now eight) and two MTC's. There are two Helicopter Emergency Medical Service (HEMS) bases within the region which are charity-funded and each aircraft is staffed by Doctors qualified in Prehospital Emergency Medicine (20 part-time doctors and four in training) and Paramedics (11 full-time equivalents). These aircraft do not fly at night, or when weather restricts visibility, but HEMS crews are able to respond to calls via a rapid response vehicle during these times. At the time of this study HEMS teams were available to respond on a Friday and Saturday night utilising a rapid response vehicle (now Thursday to Sunday night).

NEAS paramedics within the NTN are trained and educated to carry out multiple interventions for trauma patients. These interventions include advanced airway management (endo-tracheal tube intubation and supraglottic airways), needle decompression of pneumothoraces and intravenous and intraosseous access. The application of haemorrhage control devices (tourniquets, haemostatic gauze) as well as Tranexamic Acid (TXA) and immobilisation / splinting devices are also available to prehospital paramedics.

HEMS doctors within the region are also trained to manage cardiothoracic trauma up to and including resuscitative thoracotomy, peri-mortem C-section, rapid sequence induction (RSI) and the administration of blood products (although blood products were not on the aircraft at the time of this study).

Hazardous Area Response Team (HART) Paramedics are also available within the NTN region to access patients at height, in water or in remote or difficult locations. At the time of the study there were 58 ambulance stations throughout the region with over 500 Paramedics who work alongside emergency care assistants and ambulance technicians.

Data analysis

Descriptive statistics were used to characterise the study sample in terms of casualty and response characteristics. Categorical and ordinal variables were expressed as proportions and continuous variables expressed as means with standard deviations.

The primary outcome measure used in causal analysis was 'Status at Discharge' (alive/deceased). Independent variables were loosely grouped into two sets:

(i) casualty characteristics e.g., age and physiological indices; and,

(ii) response characteristics e.g., skill mix and transport time.

Whilst there were multiple recordings of physiological indices for most patients within the study, the set employed for analysis purposes were the observations used by the attending crew expressed within their pre-alert to the receiving unit or alternatively, those observations that prompted the use of the major trauma triage tool shown in Figure 1.2. Preliminary bivariate analysis was undertaken in order to explore relationships between these factors and outcome 'Status at Discharge' (alive/deceased).

To adjust for collinearity and potential amplification bias a binary logistic regression analysis was undertaken with the outcome 'Status at Discharge' (alive/deceased) as the dependant variable. Only independent variables that were individually associated with the outcome 'Status at Discharge' (alive/deceased), at a predetermined $p \leq 0.05$ level were entered into the binary logistic regression model. All candidate predictor variables were entered into the model using a forward stepwise method, and each variable's contribution to the overall fit was estimated using likelihood ratio tests. Analyses were undertaken using the Statistical Package for the Social Sciences (SPSS; Version 22, IBM Inc; Armonk, NY, USA).

6.3 Results

The study sample consisted of 1033 patient (case) records that met the prehospital major trauma triage tool criteria, as shown in Figure 1.2. Table 6.1 highlights descriptive analysis of demographic characteristics of the sample group and key emergency response characteristics.

Bivariate analysis revealed that a number of variables were significantly associated with outcome 'Status at Discharge' (alive/deceased) shown in Table 6.2.

In order to address problems of collinearity and the potential for amplification bias, binary logistic regression was undertaken for 571 casualties using outcome 'Status at Discharge' (alive/deceased) as the dependant variable. Analysis proceeded on the basis of 'listwise' exclusion, and this resulted in a total of 462 cases being excluded from the analysis sample (N=1033). Variables were entered into the model on the basis of the 'forward stepwise' method. All candidate variables considered for inclusion in the binary logistic regression model were individually associated with the outcome 'Status at Discharge' (alive/deceased) at the $p \leq 0.050$ significance level.

A test of the full model against a constant only model was statistically significant, indicating that the predictors as a set reliably distinguished between alive or deceased ($\chi 2 = 103.862$, $p \leq 0.000$). Collectively, all seven candidate predictors "explained" 94% of the variability in 'Status at Discharge' (alive/deceased).

Table 6. 1 Demographics, crew attendance, timings, and triage

Age in years		**Years [SD] (95% CI)**
	Mean	38.5 [21.5] (37-40)
	Missing	86
Adult / Child <17		**n (%)**
	Adult	853 (82.6)
	Child <17	133 (12.9)
	Missing	43 (4.2)
Sex		**n (%)**
	Male	708 (68.5)
	Female	298 (28.8)
	Missing	23 (2.2)
Prehospital Traumatic Cardiac Arrest (TCA)		**n (%)**
– Active Resuscitation		30
	Died on scene	7 (23)
	Transported to hospital	23 (77)
	Alive at discharge	3 (10)
	Died in hospital	18 (60)
	Missing	2 (7)
In hospital deaths from prehospital major trauma (Not prehospital TCA)		**n (%)** 43 (4)
Attended by		**n (%)**
	HEMS	168 (16.3)
	Land Crews	844 (81.7)
	Missing	17 (1.6)
Crew arrival times		**Minutes [SD] (95% CI)**
	Mean	12 [13.5] (11 - 13)
	HEMS	14 [11.5] (12 - 16)
	Land Crews	11.5 [13.5] (10.5 - 13)
On scene times		**Minutes [SD] (95% CI)**
	Mean	36 [19.5] (35 - 37.5)
	HEMS	51.5 [21.5] (48 - 55.5)
	Land Crews	33.5 [18] (32.5 - 35)
Transport time		**Minutes [SD] (95% CI)**
	Mean	17 [11.5] (16 - 17.5)
	HEMS	13 [9.5] (11 - 14.5)
	Land Crews	17.5 [12] (16.5 - 18.5)
Time to definitive care (999 call to arrival at receiving facility)		**Minutes [SD] (95% CI)**
	Mean	65 [27] (63 - 66.5)
	HEMS	78 [23] (73.5 - 81.5)
	Land Crews	62.5 [27] (60.5 - 64.5)
Triage		**n (%)**
	Correct triage	744 (72.0)
	Under triage	36 (3.5)
	Over triage	248 (24)
	Missing	5 (0.5)

Table 6. 2 Relationship of Independent variables associated with outcome 'Status at discharge' (Alive/Deceased), obtained using bivariate analysis.

Independent Variable	**Test Statistic**	***df.***	**p**	**Mean Difference**	**95% CI(Lower)**	**95% CI(Upper)**
GCS	t = -10.222	44.15	$p \leq 0.000$	7.28 scale points	5.845	8.715
Respiratory Rate	t = -5.241	43.55	$p \leq 0.000$	8 per min.	5	12
Systolic BP at Scene	t = -3.027	37.52	$p \leq 0.004$	11.4 mmHg	11.46	57.7
Age	t = -5.464	738	$p \leq 0.000$	17.8 years	11.47	24.24
Transport Time	t = -2.085	685	$p \leq 0.037$	-3.78 minutes	-7.14	- 0.21
Skill Mix	u = 18,239	-	$p \leq 0.036$	-	-	-
Triage	u = 19,959		$p < 0.000$	-	-	-

Step 1 Nagelkerke's R^2 (45.8%) the model included 'GCS' score only and indicated a moderate relationship between prediction and grouping.

Step 2 Nagelkerke's R^2 (59.8%) the model included 'GCS' score and 'Age' and indicated a stronger relationship between prediction and grouping.

Step 3 the final model included 'GCS', 'respiratory rate', and casualty's 'age' and indicated that these factors are significant predictors of outcome 'Status at Discharge' (alive/deceased) ($\chi 2= 155.902$, $p < 0.000$) (see Table 6.3). The other four candidate predictors, 'transport time', 'triage', 'skill mix' and 'systolic BP', were not significant.

Table 6. 3 Results from binary logistic regression analysis of predictor variables for outcome 'Status at Discharge' (alive/deceased).

	Significant Variables within the predictive model			
	Variable	***Wald***	***P***	***Odds Ratio***
Step 3	**GCS**	39.662	$p \leq 0.000$	1.587 (95% CI: 1.374 – 1.833)
	Age	25.097	$p \leq 0.000$	0.923 (95% CI: 0.894 – 0.952)
	Respiratory Rate	11.553	$p \leq 0.001$	1.165 (95% CI: 1.067 – 1.272)

'GCS', 'age' and 'respiratory rate' were all significant at the 5% level ('GCS' – $p < 0.000$; 'age' - $p < 0.000$; 'respiratory rate' - $p < 0.001$).

The odds ratio (OR) were as follows: 'GCS' was 1.587 (95% CI: 1.374 – 1.833); 'Age' was 0.923 (95% CI: 0.894 – 0.952); 'respiratory rate' was 1.165 (95% CI: 1.067 – 1.272). The model correctly predicted 99.3% of the variability of an 'Alive' outcome, and 67.6% of 'Deceased' outcome at discharge, giving an overall percentage correct prediction rate of 97.4%.

6.4 Discussion

The findings of this study suggest that physiological measures taken at the scene are of greater predictive utility than are emergency services response characteristics. Specifically, GCS, respiration rate, and age formed significant elements of the predictive model. Further analysis suggested that as people age, outcomes from major trauma significantly worsened. This finding is consistent with existing research highlighting the relationship between trauma in older adult patients and poorer outcomes (Cox et al., 2014, Kehoe et al., 2016, Kehoe et al., 2015b).

Almost all previous studies with regard to physiology and trauma were exclusive to the in-hospital setting (Lin et al., 2011, Victorino et al., 2003, Ocak et al., 2009, MacLeod et al., 2004). The evaluation of prehospital tools using physiological variables in part as predictors of trauma outcome have high variation in sensitivity and specificity (Gianola et al., 2021) However, it should be noted that the inherent complexity of physiological indices (and their significance) potentially complicates their predictive utility e.g., whilst a SBP of < 90 mmHg serves as a trigger for bypass to a MTC, the utility of this observation is nullified in cases of Traumatic Brain Injury (TBI). Recent research (Spaite et al., 2017) has identified that each 10mmHg reduction in SBP is associated with an 18% increase in mortality when SBP falls below 120mmHg. These findings should make us reconsider the hypotensive threshold for the isolated TBI patient group. Comparing the findings of in-hospital data (see chapter 3) with our own prehospital findings, the conclusions with regards to SBP are very similar.

Emergency services response characteristics most often form the basis for Key Performance Indicators (KPI's) for ambulance service delivery and evaluation: For example, the UK Department of Health requires ambulance services within England to respond to Red (life threatening calls) within 8 minutes regardless of rural or urban location (Turner et al., 2006). The 8 minute response time as a KPI is easy to measure but studies are conflicting and challenge the validity of this arbitrary time which does not correlate well with outcomes (Al-Shaqsi, 2010). The rise of evidence-based medicine has brought with it the unintentional consequence of 'therapeutic nihilism' (Starr, 1976), in which failure to establish supporting evidence for an intervention is (incorrectly) interpreted as a warrant for therapeutic inertia. Within medicine there is a familiar saying that *'absence of evidence is not evidence of absence'* (Altman and Bland, 1995). A classic example of this paradox is the work by Smith and Pell (2003) titled *'Parachute use to prevent death and major trauma related to gravitational challenge: systematic review of randomised controlled trials'.* Their research (to prove a point) highlighted there was no empirical evidence to support the use of parachutes to prevent death or major trauma related to gravitational challenge. The pressures to 'do nothing' are further exacerbated during times of fiscal austerity, where being unable to unequivocally establish an evidence base can underpin the further erosion of service standards such as crew response times.

In terms of the current study, it would appear that (abnormal) physiological measurements, possibly as a reflection of the severity of trauma and nature of the physiological insult, underpin the most accurate predictive model of mortality outcomes.

Existing research considering the impact of timings and skill mix is markedly limited to consideration of on-scene times and predominately focused on the impact of physician led teams in prolonging 'on-scene' times (Carr et al., 2006, Carr et al., 2008, Di Bartolomeo et al., 2007, Dissmann and Le Clerc, 2007). These studies have typically added fuel to the 'stay and play' or 'load and go' debate and highlight the 'golden hour' of immediate care (Harmsen et al., 2015, Lerner and Moscati, 2001). Abhilash and Sivanandan (2020) describe the golden hour as the immediate assessment and resuscitation of a patient which must be undertaken concurrently to optimise any ongoing management. However, the typical lack of standardisation in how 'on-scene' times are defined/calculated and recorded raises valid questions concerning the potential generalisability of these findings beyond the context in which individual studies were undertaken. In the context of our study, HEMS teams took longer to arrive on scene (from the initial call being made), compared to land-based resources, had extended 'on-scene' times and longer overall mean time from emergency call to arrival at receiving facility. As previously noted, HEMS teams have a wider scope of practice and are able to initiate additional interventions such as RSI. More widely, the huge variation in scope of practice between professions in different regions and countries (Eckstein et al., 2000) makes direct comparisons difficult. Although prehospital timings were extended for HEMS teams, compared to land based teams, this study did not examine whether the presence of HEMS improved timings for ongoing management such as time to theatre or time to Computerised Tomography (CT) scan (Garner et al., 2015).

Within this study it was noted that those major trauma casualties who were correctly triaged were more likely to have poorer outcomes which may reflect that severe major trauma is likely to be more obvious and therefore potentially have poorer outcomes. This finding may suggest that crews are using existing triage practices to correctly classify trauma severity. Whilst some patients are incorrectly over-triaged and transported to a MTC and some major trauma patients inappropriately under-triaged and transported to local hospital emergency departments, these eventualities did not appear to be statistically associated with significantly adverse outcomes. The tendency to over-refer casualties to MTC's is perhaps a reflection of the precautionary principal in action.

Limitations

The study was conducted during the spring and summer months and does not account for seasonal variations which may have affected MOI, available flying time (daylight in northern UK is 18 hours in the hight of summer and six hours in winter) and driving conditions due to adverse weather during the winter months (snow and ice). There is a strong likelihood of ecological and confounding relationships within the current data set. Whilst bivariate analysis such as is reported above can reveal interesting associations, the large number of degrees of freedom involved, the potential for collinearity and amplification bias by means of multiple comparisons using the same variables would risk Type I errors.

As is the case with all uses of secondary data, analysis is constrained by the fact that data are collected for purposes other than the researcher's intentions (Bulmer, 1980). Furthermore, the large number of personnel involved in data collection inevitably potentiates the risk of poor inter-rater reliability (Cicchetti, 1976). Whilst mortality data serves as an absolute binary outcome measure, morbidity data is less tangible (Bowling and 2004). Further research is required to understand the utility of the predictor variables considered in this paper in predicting morbidity outcomes, especially in the case of life-changing morbidity.

The area of main area of concern while undertaking this study was the issue of disparity between patients in the two databases which were partially combined and used within the analysis. The first database, the prehospital major trauma database, uses the major trauma triage tool (see Figure 1.2) as the criteria for entering the data. The prehospital dataset is then cross referenced with the TARN data to obtain outcome data for those specific prehospital cases only. It is only when looking at both data sets independently that there is an obvious difference in patient groups.

The data within this study has been shown to have patients originating from high energy MOI (with no statistically significant correlation with mortality). This is partly due to the major trauma triage tool excluding low energy MOI. As such the mean age within this NTN prehospital data was 38.5 years. When viewing all the TARN data the average major trauma patient is now an older adult experiencing low energy MOI (Coats and Lecky, 2017).

From the data used within this analysis only 55% of cases had outcome data matched from the TARN dataset. Within the UK, best practice tariffs (financial incentives) are awarded to TARN eligible patients, provided that key performance indicators are met. Therefore, as a tool to identify patients who would be eligible for TARN (and best practice tariff) it has limited sensitivity/specificity.

Since this study was first undertaken there has been a growing understanding that major trauma has now two distinctly separate modalities: high energy (including violence) and low energy MOI's. There is also a corelation between lower energy MOI and the older adult age groups (Coats and Lecky, 2017). With this in mind, major trauma triage tools should be explored further to identify those patients who have significant injury from low energy MOI who are, at present, excluded. This exploration will obviously be focused on the older adult (who experiencing lower energy MOI) and ensure they are not excluded from potentially improving their outcome through early identification and management as part of a collaborative trauma system. Coats and Lecky (2017) acknowledge that the low energy/older adult trauma patient is complex, and that ongoing management may need to be different to that of the younger trauma patient. They also state that this may be the case because of conscious or unconscious ageism although financial incentives (such as best practice tariff) may become potent drivers for change.

The disparity in what is perceived as major trauma within the NTN prehospital dataset and that recorded within TARN also raises the question of what defines major trauma (highlighted in Chapters 2, 4 and 5). If major trauma is to be regarded as the severely injured that are eligible for inclusion within the TARN data (and best practice tariff) then existing prehospital triage tools are not fit for purpose as they will exclude the older adults who predominantly originate from low energy MOI. Further research is required to explore the phenomenon of low energy MOI and its association with major trauma and the potential for developing a low energy trauma triage tool.

Conclusions

This study data identifies that within the NTN, prehospital major trauma predominantly affects the male population with the mean age of 38.5 years and that the physiological indices of GCS and respiration rate have a significant correlation with outcome. Although there is a large and growing body of evidence with regards to the correlation between age and trauma outcomes, further research is required in order to more fully understand the predictive utility of age, in combination with other variables, to determine outcomes and ongoing needs from low energy trauma in the prehospital environment. This may possibly allow for the generation of age-specific variables as part of a low energy trauma triage criteria to support the early identification of patients requiring consultant level assessment and ongoing management.

This study identified that there is greater predictive utility in relation to outcome from physiological measures taken at the scene than emergency services response times which, paradoxically, comprise key performance indicators for service delivery. Rather than interpreting this finding as a warrant for the therapeutic nihilist instruction to abandon targets, it was concluded that further analysis is required to establish the value of response characteristics in relation to morbidity outcomes and the alleviation of suffering.

CHAPTER 7 IDENTIFYING POTENTIAL PREDICTORS OF MORTALITY IN THE OLDER ADULT TRAUMA PATIENTS USING DYNAMIC PATTERN SYNTHESIS

7.1 Introduction

The previous chapters have identified the difference in major trauma mechanisms and outcomes which reflect the work of Coats and Lecky (2017) who describe the emerging phenomenon that major trauma is now clearly two different disease patterns. The first being high energy mechanisms with relatively younger age groups and the second being older adults with lower energy mechanisms. However, despite the differences in energy transfer within the mechanisms of injury both groups have similar ISS. It is acknowledged that older adults with significant injuries have a lower prehospital recognition rate with poor conformity to key performance indicators and are less likely to be transferred to a major trauma centre (MTC).

In Chapter 6 the conclusions of prehospital factors that are associated with outcome acknowledged that there was a statistically significant correlation between increasing age and mortality (Thompson et al., 2017). The limitations in Chapter 6 acknowledged that the NTN prehospital data did not fully represent the older adult trauma patient within that dataset. This is due to the existing major trauma triage tool (Figure 1.2), which requires a *'significant mechanism of injury'* which has been interpreted locally to exclude trauma that originates from low energy MOI which is the predominant MOI of the older adult. This may be a regional anomaly although Brown et al. (2019a) highlight a similar demographic which also reflects Coats and Lecky's work in addressing the issue of major trauma being two separate diseases (with more than half of cases being older than 51 years). Brown et al. (2019b) also state that older adult major trauma patients were less likely to be transported to an MTC with an increased in-hospital mortality.

The literature in Chapter 3 provides sparse details of statistically significant variables which would identify older adults who are at high risk of poorer outcomes from trauma which adds to the growing complexity of this patient group. However, beyond these general tendencies to fare less well than their younger counterparts, few specific factors have been identified that unequivocally underpin these general tendencies.

There are multiple guidelines that provide essential tools within the clinical setting that are based on evidence-based care. However, quality measures rarely take into account the complexity of patients which may also influence patient centred care (Safford et al., 2007).

Evidence-based medicine usually describes a linear correlation between cause and effect, although, complexity science is challenging these mechanistic patterns (Braithwaite et al., 2018). Evidence based medicine is underpinned by the aim of identifying generalizable, end-chain, linear cause and effect relationships to the detriment of both multi-causality and complexity. This arises from Western medicine methodological alliance with Positivism. As in most disease patterns, not all phenomena of clinical interest (e.g., low energy trauma in the elderly) can be explained in such strictly linear terms. The traditional hierarchy of evidence which places systematic review and meta-analysis of randomised control trials (RCT) as well as the RCT's themselves at the pinnacle of the evidence pyramid and it is difficult to challenge this long-established order. However, this level of evidence only provides linear causality conclusions and other methods need to be considered to explore other potential conclusions (Murad et al., 2016).

Complexity theory as a research methodology is described by Gear et al. (2018) as an approach to *'capture new insights into complex problems'.* Haynes (2017) uses a mixed-method approach to complexity theory which combines the quantitative phase (cluster analysis) with Qualitative Comparative Analysis (QCA) to be called Dynamic Pattern Synthesis (DPS). The cluster analysis combines multiple measurements into case-based groups according to their similarities or differences. Patterns within and between the clusters are then explored using QCA. The sample is purposeful in an attempt to compare small groups of cases with a similarity. Once a dynamic pattern is identified within a small sample it is then replicated with another set of cases.

The aim of this chapter is to identify dynamic patterns within the complexity of major trauma age groups within the hyper-acute prehospital setting to identify if clustered variables can assist in identifying those older adults who have a high risk of mortality due to a traumatic event.

7.2 Methods

Study period and population.

A retrospective analysis of data from TARN, the national database for both England and Wales was undertaken for the period between 1 April 2012 and 31 March 2017. The data includes prehospital and in-hospital timings, physiology, interventions and outcomes. Data was obtained from TARN specifically for the NTN region. The NTN covers the North East of England from the Scottish boarders to North Yorkshire and includes North Cumbria. It has three NHS ambulance service providers and a Helicopter Emergency Medical Service (HEMS) based at two locations with nine Trauma Units during most of the study sample timeframe (now eight) and two Major Trauma Centres (MTC).

Data analysis.

Using the methods described by Haynes (2017), a modified DPS method was applied to the sample to account for a single episode of care for each case (as opposed to a longitudinal study). The prehospital data was extrapolated from the TARN dataset and the Statistical Package for the Social Sciences (SPSS; Version 26 IBM Inc.; Armonk, NY, USA) was used for initial analysis of data.

Simple descriptives of the initial data will explore the demographics of age and gender as well as the outcomes of mortality and injury severity score (ISS).

During the analysis period of the study the COVID-19 pandemic was ongoing and as a consequence the extremely large database could not be effectively utilised on the available IT resources and, in keeping with the ethos of DPS and using smaller purposeful sample sizes, a 10 percent random sample was taken from the original dataset.

An initial cluster analysis was run using a binary variable of age (age <65 and age ≥65 years) and outcome as mortality (dead/alive) to give a four-cluster grouping. Cluster analysis is one methodological approach to potentially identify patient subgroups that differentiate based on their characteristics from a dataset which may influence treatment and/or prognosticate (Kent et al., 2014).

Distribution tables were generated to identify frequencies of key variables identified in Chapter 3 across all four clusters which include:

- Age;
- Gender;
- Outcome (mortality, Glasgow outcome score);

- Airway/breathing support (including intubation/ventilation);
- Deranged physiology (shock, respiration rate, GCS, SBP);
- Injury (body region and/or multiple injury);
- MOI (high/low energy); and,
- Skill mix (of attending crew).

The DPS methodology states that means of scaled variables should have the mean calculated as thresholds prior to conversion to a binary Crisp Set (0 = below threshold, 1 = above threshold). Within the context of this study, clinical thresholds were determined based on previous research highlighted in Chapters 3 and 6 (e.g., SBP <110mmHg). This gave Crisp Sets for our data that were obtained by applying relevant clinical knowledge and not just a mathematical mean. This was believed to have more relevance to the clinical focus of the study. Interventions/injuries were also converted to binary No/Yes (0 = No, 1 = Yes) responses.

Random quota samples were then extrapolated from the SPSS data. Initially this was undertaken using a random one percent per sample of all cases using the random sample size percentage function embedded within SPSS. However, the still considerable dataset caused issues with obtaining samples that included sufficient numbers of all four clusters. For example, the sample may have contained data entirely from a single cluster and omit any data from the three remaining clusters. To overcome this issue four random cases from each cluster using the same random sample size function but with 'exact cases' to isolate the required number. This generated random quota samples that had equal composition across each cluster. Etikan and Bala (2017) highlight that this type of non-probability random sampling provides a convenient method to achieve a desired number of cases that display the required characteristics for inclusion. The limitations of this method are that it may not reflect the general population as the clusters may have an uneven composition and therefore unevenly distributed throughout all cases but should provide sufficient data to discuss a small cluster within that population which was evident within our data. Forcing balanced clusters may suggest an even composition of clusters throughout the complete dataset when this is not the case. Severe class imbalance between majority and minority classes (clusters) within the dataset may lead to bias and false outcomes (Hasanin et al., 2019, Prati et al., 2015).

The final samples were converted to a Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, WA, USA. Version: Office 365, 2018) for analysis using QCA. This sample is described as a *'Truth Table'* by Haynes (2017). All cases within each individual cluster which have prime implicants (all 0's or all 1's) for a given variable were logged and summarised using Boolean algebra (upper case depicting above threshold and lower case below threshold). Within our own research this method was found to be cumbersome and difficult to interpret due to the large number of repeated samples. Therefore, the technique was modified to produce sub-tables (Tables 7.7 to 7.16) and frequency tables (Tables 7.17 and 7.18) which proved to be easier for the lead researcher to analyse and interpret which may reflect his familiarity with number patterns rather than word patterns which may not be transferable to other researchers' methods/techniques.

Means and/or standard deviations (mean ± SD) are reported for continuous variables. Frequencies and percentage are reported for categorical variables.

A p value of <0.05 was predetermined as the level of statistical significance.

7.3 Results

Between 1 April 2012 and 31 March 2017 there were 16,558 TARN eligible patients for the NTN region of which 7,392 were aged 65 years or older. Age ranged from new-born (0 years) to 106 years with a mean of 59 years. Females were 45.5% (n=7,534) of the sample, males 54.5% (n=9,024). The mean ISS was 13 (SD 9.172).

Outcome was determined as mortality (dead/alive) and for data collected between 1 April 2012 and 31 March 2017 mortality was recorded by TARN at hospital discharge or within hospital at 30 days (The Trauma Audit Research Network, 2019). The sample (all ages) mortality rate was 6.5% (n=1,071) (age $\geq$65 = 9.4% n=693). Table 7.1 highlights all age demographics.

Table 7. 1 All age demographics

	All ages	**<65 years**	**$\geq$65 years**
N	16558	9166	7392
Age			
Mean, (Range)	59 (0-106)	41 (0-65)	81 (65-106)
ISS			
Mean, (SD)	13 (9.172)	14 (9.855)	12 (8.114)
Mortality, n, (%)	1071 (6.5)	378 (4.1)	693 (9.4)
Gender			
Male, n, (%)	9024 (54.5)	6185 (67.5)	2839 (38.4)
Female, n, (%)	7534 (45.5)	2981 (32.5)	4553 (61.6)

The 10% random sample from the original data generated 1641 cases which was then converted into four clusters based on age (<65 years and $\geq$65 years) and mortality. Table 7.2 to 7.6 shows the frequencies of variables across all four clusters (inclusive of Chi Square [X^2] test) and the interpretation of the data. The individual clusters where grouped based on their characteristics and named as:

- Cluster 1: Younger Alive (age <65 years);
- Cluster 2: Older Alive (age ≥65 years);
- Cluster 3: Older Dead (age ≥65 years); and,
- Cluster 4: Younger Dead (age <65 years).

Table 7. 2 Frequencies of variables across sample clusters (a)

	Cluster 1 Young Alive n (%)	**Cluster 2 Older Alive n (%)**	**Cluster 3 Older Dead n (%)**	**Cluster 4 Young Dead n (%)**	**Total N (%)**	***X^2* Asymptotic sig. (*df*)**	**Interpretation**
Age Range						**0.000 (3)**	Statistically significant. A significant higher volume of older adults die compared to younger patients
<65	830(95.2)	0 (0)	0 (0)	42 (4.8)	872 (100)		
Residual	+389	-373.6	-35.1	+19.7			
≥65	0 (0)	703 (91.4)	66 (8.6)	0(0)	769 (100)		
Residual	-389.0	+373.6	+35.1	-19.7			
Gender						**0.000 (3)**	Statistically significant. Higher relative number of elderly female survivors from expected compared to older males and younger females. Less expected frequency of deaths in elderly females than elderly males as opposed to observed deaths within the *Chi Squared* frequency analysis
Female	279 (37.2)	475 (57)	31 (4.1)	12 (1.6)	749 (100)		
Residual	-99.8	+106.1	+0.9	-7.2			
Male	551 (61.8)	276 (30.9)	35 (3.9)	30 (3.4)	892 (100)		
Residual	+99.8	-106.1	-0.9	+7.2			
Outcome						**0.000 (3)**	Statistically significant. A significant higher volume of older adults die compared to younger patients
Dead	0 (0)	0 (0)	66 (61.1)	42 (38.9)	108 (100)		
Residual	-54.6	-46.3	+61.7	+39.2			
Alive	830 (54.1)	703 (45.9)	0 (0)	0 (0)	1533 (100)		
Residual	+54.6	+46.3	-61.7	-39.2			
ISS						**0.000 (3)**	Statistically significant. There were similar patterns between older and younger groups which reflects the findings of the TARN 'Major trauma in older people' report (Trauma Audit Research Network, 2017). Very similar injury patterns and ISS despite differences in mechanism of injury (high/low energy).
<15	539 (49.4)	519 (47.5)	27 (2.5)	7 (0.6)	1092 (100)		
Residual	-13.3	+51.2	-16.9	-20.9			
>15	291 (53)	184 (33.5)	39 (7.1)	35 (6.4)	549 (100)		
Residual	+13.3	-51.2	+16.9	+20.9			

Table 7. 3 Frequencies of variables across sample clusters (b)

	Cluster 1 Young Alive n (%)	Cluster 2 Older Alive n (%)	Cluster 3 Older Dead n (%)	Cluster 4 Young Dead n (%)	Total N (%)	X^2 Asymptotic sig. (*df*)	Interpretation
Mechanism (i)						**0.000 (24)**	Statistically significant. There is a distribution of age across most mechanisms of injury. However, there is a clear distinction between the older and younger groups. The younger groups still have significant injuries sustained from low energy mechanisms, but they predominantly sustain injuries from high energy mechanisms. In contrast the older groups still have significant injuries from high energy mechanisms, but most cases are sustained from low energy mechanisms.
Other	24 (53.3)	9 (20)	0 (0)	12 (26.7)	45 (100)		
Residual	+1.2	-10.3	-1.8	+10.8			
Blow(s)	96 (93.2)	5 (4.9)	1 (1)	1 (1)	103 (100)		
Residual	+43.9	-39.1	-3.1	-1.6			
Burns	1 (100)	0 (0)	0 (0)	0 (0)	1 (100)		
Residual	+0.5	-0.4	0	0			
Crush	8 (88.9)	1 (11.1)	0 (0)	0 (0)	9 (100)		
Residual	+3.4	-2.9	-0.4	-0.2			
Falls <2m	321 (34.6)	544 (58.7)	50 (5.4)	12 (1.3)	927(100)		
Residual	-147.9	+146.9	+12.7	-11.7			
Falls >2m	142 (57)	90 (36.1)	9 (3.6)	8 (3.2)	249 (100)		
Residual	+16.1	-16.7	-1.0	+1.6			
Shooting	1 (100)	0 (0)	0 (0)	0 (0)	1 (100)		
Residual	+0.5	+0.4	0	0			
Stabbing	21 (87.5)	1 (4.2)	0 (0)	2 (8.3)	24 (100)		
Residual	+8.9	-9.3	-1.0	+1.4			
RTC	216 (76.6)	53 (18.8)	6 (2.1)	7 (2.5)	282 (100)		
Residual	+73.4	-67.8	-5.3	-0.2			
Mechanism (ii)						0.000 (3)	Statistically significant. As above
High energy	509 (71.3)	159 (22.3)	16 (2.2)	30 (4.2)	714 (100)		
Residual	+147.9	-146.9	-12.7	+11.7			
Low energy	321 (34.6)	544 (58.7)	50 (5.4)	12 (1.3)	927 (100)		
Residual	-147.9	+146.9	+12.7	-11.7			

Table 7. 4 Frequencies of variables across sample clusters (c)

	Cluster 1 Young Alive n (%)	Cluster 2 Older Alive n (%)	Cluster 3 Older Dead n (%)	Cluster 4 Young Dead n (%)	Total N (%)	X^2 Asymptotic sig. (*df*)	Interpretation
Mechanism (iii)						0.000 (9)	Statistically significant. As above (Table 7.3)
Other	151 (82.5)	16 (8.7)	1 (0.5)	15 (8.2)	183 (100)		
Residual	+58.4	-62.4	-6.4	+10.3			
Fall <2m	321 (34.6)	544 (58.7)	50 (5.4)	12 (1.3)	927 (100)		
Residual	-147.9	+146.9	+12.7	-11.7			
Fall >2m	142 (57)	90 (36.1)	9 (3.6)	8 (3.2)	249 (100)		
Residual	+16.1	+53.0	+6.0	+7.0			
RTC	216 (73.6)	53 (18.8)	6 (2.1)	7 (2.5)	282(100)		
Residual	+73.4	-67.8	-5.3	-0.2			
GOS						0.000 (9)	Statistically significant. This follows a similar pattern to the mortality (Dead/Alive) variable which reflects the design of the analysis. There were considerable differences between observed and expected results. There was one case in the 'older dead' group who is recorded as making a good recovery which may be considered a data recording issue.
Dead	1 (0.9)	9 (7.7)	65 (55.6)	42 (35.9)	117 (100)		
Residual	-59.2	-37.8	+58.9	+38.1			
Severe disability	44 (48.9)	46 (51.1)	0 (0)	0 (0)	90 (100)		
Residual	+-2.3	+10.0	-4.7	-3.0			
Moderate disability	71 (35.1)	131 (64.9)	0 (0)	0 (0)	202 (100)		
Residual	-32.9	+50.1	-10.5	-6.7			
Good recovery	537 (62.4)	322 (37.4)	1 (0.1)	0 (0)	860 (100)		
Residual	+94.5	-22.3	-43.7	-28.5			
Head Injury						0.000 (3)	Statistically significant. Throughout all injury variables there is a similar injury pattern between the older and younger groups. This again reflects the significance of injuries sustained by the elderly from relatively low energy mechanisms.
No	619 (50.7)	548 (44.8)	34 (2.8)	21 (1.7)	1222 (100)		
Residual	+0.9	+24.5	-15.1	-10.3			
yes	211 (50.4)	155 (37)	32 (7.6)	21 (5)	419 (100)		
Residual	-0.9	-24.5	+15.1	+10.3			

Table 7. 5 Frequencies of variables across sample clusters (d)

	Cluster 1 Young Alive n (%)	Cluster 2 Older Alive n (%)	Cluster 3 Older Dead n (%)	Cluster 4 Young Dead n (%)	Total N (%)	X^2 Asymptotic sig. (*df*)	Interpretation
Chest injury						0.098 (3)	Not statistically significant. However, throughout all injury variables there is a similar injury pattern between the older and younger groups. This again reflects the significance of injuries sustained by the elderly from relatively low energy mechanisms.
No	614 (50.3)	525 (43)	55 (4.5)	26 (2.1)	1220 (100)		
Residual	-3.1	+2.4	+5.9	-5.2			
Yes	216 (51.3)	178 (42.3)	11 (2.6)	16 (3.8)	421 (100)		
Residual	3.1	-2.4	-5.9	+5.2			
Spinal Injury						0.366 (3)	Not statistically significant. However, throughout all injury variables there is a similar injury pattern between the older and younger groups. This again reflects the significance of injuries sustained by the elderly from relatively low energy mechanisms.
No	647 (51.3)	534 (42.3)	46 (3.6)	34 (2.7)	1261 (100)		
Residual	+9.2	-6.2	-4.7	+1.7			
Yes	183 (48.2)	169 (44.5)	20 (5.3)	8 (2.1)	380 (100)		
Residual	-9.2	+6.2	+4.7	-1.7			
Multiple injuries						0.052 (3)	Not statistically significant. However, throughout all injury variables there is a similar injury pattern between the older and younger groups. This again reflects the significance of injuries sustained by the elderly from relatively low energy mechanisms.
No	525 (49.5)	475 (44.8)	40 (3.8)	21 (2)	1061 (100)		
Residual	-11.6	+20.5	-2.7	-6.2			
Yes	305 (52.6)	228 (39.3)	26 (4.5)	21 (3.6)	580 (100)		
Residual	+11.6	-20.5	+2.7	+6.2			
PH spinal support						0.000 (3)	Statistically significant. There is a higher-than-expected use of prehospital spinal support in the younger alive group compared to the older alive group which is much less than expected. This may reflect the high energy transfer mechanisms in the younger group compared to low energy transfer in the older group which should be a consideration as it is noted that the older group have a high volume of spinal injuries.
No	658 (48.1)	626 (45.8)	56 (4.1)	27 (2)	1367 (100)		
Residual	-33.4	+40.4	+1.0	-8.0			
Yes	172 (62.8)	77 (28.1)	10 (3.6)	15 (5.5)	274 (100)		
Residual	+33.4	-40.4	-1.0	+8.0			
PH Ventilation sup.						0.708 (1)	Not statistically significant with insufficient numbers to make any interpretation.
No	1 (12.5)	0 (0)	0 (0)	7 (87.5)	8 (100)		
Residual	+0.1	0	0	-0.1			
Yes	0 (0)	0 (0)	0 (0)	1 (100)	1 (100)		
Residual	-0.1	0	0	+0.1			

Table 7. 6 Frequencies of variables across sample clusters (e)

	Cluster 1 Young Alive n (%)	Cluster 2 Older Alive n (%)	Cluster 3 Older Dead n (%)	Cluster 4 Young Dead n (%)	Total N (%)	X^2 Asymptotic sig. (*df*)	Interpretation
PH GCS						0.000 (3)	Statistically significant. It was surprising that so few cases within the older and younger dead groups had a GCS ≤14. There was an obvious lack of prehospital data on GCS recorded (n=858, 52%). In the younger alive group, there were less observed cases than expected with a reduced GCS and more cases than expected in the deceased group.
15	300 (47.2)	305 (48)	28 (4.4)	3 (0.5)	636 (100)		
Residual	-4.7	+27.0	-4.6	-17.8			
≤14	111 (50)	70 (31.5)	16 (7.2)	25 (11.3)	222 (100)		
Residual	+4.7	-27.0	+4.6	+17.8			
PH SBP						0.000 (3)	Statistically significant. There were relatively few cases across all groups were a prehospital SBP was less than 110 mmHg. There was a surprising low expected number of cases with PH SBP <110 mmHg within the older and younger dead groups with an increase in those actually observed residual of +4.9 and +3.4 respectively).
≥110mmHg	769 (50)	677 (44)	57(3.7)	36 (2.3)	1539 (100)		
Residual	-9.4	+17.7	-4.9	-3.4			
<110mmHg	61 (59.8)	26 (25.5)	9 (8.8)	6 (5.9)	102 (100)		
Residual	+9.4	-17.7	+4.9	+3.4			
PH skill mix						0.079 (18)	Not statistically significant. The NTN region has a diverse number of responders but predominantly it will be paramedics who attend trauma incidents. In Chapter 6 it was argued that doctors within our region are only sent to the most severe cases of major trauma to provide enhanced prehospital care outside the scope of paramedic practice. As a consequence, they have a dispatch criterion and will therefore not attend many low energy trauma incidents which may be reflected within the distribution of the case they attend.
Advanced Paramedic	4 (66.7)	2 (33.3)	0 (0)	0 (0)	6 (100)		
Residual	+1.1	-0.6	-0.3	-0.2			
Doctor (ambulance)	6 (75)	2 (25)	0 (0)	0 (0)	8 (100)		
Residual	+2.1	-1.5	-0.4	-0.2			
Doctor+ Snr Nurse	16 (61.5)	5 (19.2)	2 (7.7)	3 (11.5)	26 (100)		
Residual	+3.5	-6.4	+0.7	+2.2			
Doctor Immediate Care	19 (67.9)	8 (28.6)	0 (0)	1 (3.6)	28 (100)		
Residual	+5.5	-4.3	-1.4	+0.1			
Paramedic (ambulance)	319 (48.3)	291 (44)	33 (5)	18 (2.7)	661 (100)		
Residual	+0.7	+1.1	+0.7	-2.5			
Paramedic (RRV)	3 (42.9)	4 (57.1)	0 (0)	0 (0)	7 (100)		
Residual	-0.4	+0.9	-0.3	-0.2			
Technician (ambulance)	37 (35.9)	56 (54.4)	6 (5.8)	4 (3.9)	103 (100)		
Residual	-12.6	+10.8	+1.0	+0.8			

*PH = Prehospital

The data was then further reduced into 10 samples which each contained four random cases from each cluster to form a 16-case truth table for each of the samples with the prime implicants shaded grey (Tables 7.7 to 7.16). Tables 7.17 and 7.18 summarise the combined frequencies of the prime implicants for each variable within each cluster for all truth tables. The Boolean algebra was recorded for truth table (a) (seen in Table 7.7) as:

(Abbreviations: ISS = Injury Severity Score, PH = Prehospital, GCS = Glasgow Coma Score, SBP = Systolic Blood Pressure and GOS = Glasgow Outcome Scale. Upper case indicates positive prime implicants and lower case indicated negative prime implicants).

Cluster 1 Younger Alive: age 65 * iss * MORTALITY * chest injury * abdominal injury * other injury * airway * airway support * respiration rate * PH GCS ≤13 * PH SBP <90 * PH SBP <100 * PH SBP <110 * spinal support * PH SKILL MIX * mortality index

Cluster 2 Older Alive: AGE 65 * MORTALITY * intubation * abdominal injury * spinal injury * pelvic injury * other injury * airway * breathing * airway support * spinal support * SKILL MIX

Cluster 3 Older Dead: AGE 65 * mortality * gos * intubation * shock * facial injury * abdominal injury * spinal injury * other injury * airway * breathing * airway support * breathing support * respiratory rate * PH GCS ≤ 13 * PH SBP <90 * PH SBP <100 * PH SBP <110 * spinal support * SKILL MIX

Cluster 4 Younger Dead: SITE * age 65 * mortality * gos * abdominal injury * pelvic injury * PH SBP <90 * PH SBP <100 * PH SBP <110

The Boolean algebraic term * abdominal injury * was common across all four clusters.

As highlighted in the methods, the Boolean algebraic record was difficult to interpret by the author and was thought to be too unwieldy when comparing across multiple samples and therefore sub-tables were generated below each truth table (Tables 7.7 to 7.16). The combined frequencies of these numerical representations of what would have been a Boolean algebraic record are recorded as Table 7.17 and Table 7.18.

Table 7. 7 Qualitative Comparative Analysis Truth Table (a)

Case	Site	Age65	Gender	ISS	Mortality	GOS	Intubation	Shock	Head Injury	Face Injury	Chest Injury	Abdo Injury	Spinal Injury	Pelvic Injury	Limb Injury	Other Injury	Multiple Injury	PH Airway	PH Breathing	PH Airway Supp.	PH Breath Supp.	PH Resp. Rate	PH GCS ≤14	PH GCS ≤13	PH SBP ≤90	PH SBP ≤100	PH SBP ≤110	PH Spine Supp.	PH Skill Mix	Mech High/Low	Mortality Index	Cluster
8.228E+11	1	0	1	0	1	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	1	0	1
8.228E+11	1	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	1	1	1	1	0	1	1	0	1
8.228E+11	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.566E+11	0	0	0	0	1	1	0	1	0	0	0	0	1	1	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.228E+11	1	1	1	0	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	1	1	2
8.228E+11	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1	1	0	1	0	0	2
8.566E+11	0	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	1	0	0	2
8.566E+11	0	1	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	2
8.2049E+11	1	1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	1	0	3
8.86E+11	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	1	3
8.568E+11	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.566E+11	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	0	1	0	0	3
8.2049E+11	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	1	1	1	1	0	1	0	4
8.228E+11	1	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4
8.228E+11	1	0	1	1	0	0	1	0	0	0	1	0	0	0	0	1	1	0	1	1	1	0	0	0	1	1	1	0	1	1	0	4
8.228E+11	1	0	0	1	0	0	1	1	1	1	1	0	1	0	0	0	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	4

C1. Young Alive		0		0	1						0	0				0		0		0		0		1	1	1	1	0	1		0	
C 2. Older Alive		1			1		0					0	0	0		0		0	0	0								0	1			
C 3. Older Dead		1			0	0	0	0		0		0	0			0		0	0	0	0	0		1	1	1	1	0	1			
C 4. Young Dead	1	0			0	0						0		0											1	1	1					

Table 7. 8 Qualitative Comparative Analysis Truth Table (b)

Case	Site	Age65	Gender	ISS	Mortality	GOS	Intubation	Shock	Head Injury	Face Injury	Chest Injury	Abdo Injury	Spinal Injury	Pelvic Injury	Limb Injury	Other Injury	Multiple Injury	PH Airway	PH Breathing	PH Airway Supp.	PH Breath Supp.	PH Resp. Rate	PH GCS ≤14	PH GCS ≤13	PH SBP ≤90	PH SBP ≤100	PH SBP ≤110	PH Spine Supp.	PH Skill Mix	Mech High/Low	Mortality Index	Cluster
8.2E+11	1	0	1	0	1	1	0	0	1	0	0	0	1	0	1	0	1	0	0	0	0	0	1	1	1	1	1	1	1	0	0	1
8.23E+11	1	0	1	1	1	1	0	1	0	1	1	1	0	0	0	0	1	0	0	0	1	0	1	1	1	1	0	0	1	1	0	1
8.23E+11	1	0	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	0	1
8.23E+11	1	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.59E+11	0	1	1	0	1	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2
8.2E+11	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.2E+11	1	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.84E+11	0	1	0	0	1	1	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	2
8.2E+11	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.57E+11	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	3
8.23E+11	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	1	0	1	0	0	3
8.57E+11	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.23E+11	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4
8.23E+11	1	1	1	1	0	0	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	0	0	0	0	0	1	0	1	1	4
8.23E+11	1	0	1	1	0	0	1	1	0	1	0	0	0	0	1	0	1	0	1	1	1	0	0	0	0	0	0	0	1	1	0	4
8.23E+11	1	0	0	1	0	0	1	1	1	1	1	0	1	0	0	0	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	4

C1. Young Alive	1	0	1		1	1	0							0		0		0	0	0		0	1	1	1	1			1		0	
C 2. Older Alive		1			1	1	0	0		0	0	0		0		0		0	0	0	0	0		1	1	1	1		1			
C 3. Older Dead		1		1	0	0	0	0	1	0	0	0	0	0	0			0	0	0	0	0			1	1	1		1			
C 4. Young Dead	1			1	0	0	1									0																

Table 7. 9 Qualitative Comparative Analysis Truth Table (c)

Case	Site	Age65	Gender	ISS	Mortality	GOS	Intubation	Shock	Head Injury	Face Injury	Chest Injury	Abdo Injury	Spinal Injury	Pelvic Injury	Limb Injury	Other Injury	Multiple Injury	PH Airway	PH Breathing	PH Airway Supp	PH Breath Supp	PH Resp. Rate	PH GCS ≤14	PH GCS ≤13	PH SBP ≤90	PH SBP ≤100	PH SBP ≤110	PH Spine Supp.	PH Skill Mix	Mech High/Low	Mortality Index	Cluster
8.86E+11	0	1	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.57E+11	0	1	1	0	1	1	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	0	1	1	1	1	1	0	1	0	0	1
8.57E+11	0	0	1	1	1	1	0	0	0	0	1	0	1	0	0	1	1	0	0	0	1	0	1	1	1	1	1	1	1	1	0	1
8.57E+11	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	0	1
8.2E+11	1	1	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	1	2
8.57E+11	0	1	0	0	1	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.23E+11	1	1	0	1	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.57E+11	0	1	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.2E+11	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.23E+11	1	1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.23E+11	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.84E+11	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	3
8.23E+11	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1	0	1	1	0	4
8.23E+11	1	0	1	1	0	0	1	1	1	0	1	1	0	0	0	1	1	0	0	0	0	0	1	1	1	1	1	0	1	1	0	4
8.23E+11	1	0	1	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	0	1	1	4
8.58E+11	0	0	1	1	0	0	1	0	1	0	1	0	1	0	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	4

C1. Young Alive	0				1	1	0	0	0			0		0				0	0	0		0	1	1	1	1	1		1		0	
C2. Older Alive		1			1	1	0		0	0		0	0			0		0	0	0	0	0	1	1	1	1	1	0	1			
C3. Older Dead		1		1	0	0	0	0		0		0				0		0	0	0	0	0		1	1	1	1	0	1	0	0	
C4. Young Dead		0	1	1	0	0										1						0			1	1	1			1		

Table 7. 10 Qualitative Comparative Analysis Truth Table (d)

Case	Site	Age65	Gender	ISS	Mortality	GOS	Intubation	Shock	Head Injury	Face Injury	Chest Injury	Abdo Injury	Spinal Injury	Pelvic Injury	Limb Injury	Other Injury	Multiple Injury	PH Airway	PH Breathing	PH Airway Supp.	PH Breath Supp.	PH Resp. Rate	PH GCS ≤14	PH GCS ≤13	PH SBP ≤90	PH SBP ≤100	PH SBP ≤110	PH Spine Supp.	PH Skill Mix	Mech High/Low	Mortality Index	Cluster
8.2E+11	1	0	1	0	1	1	0	1	0	0	0	1	0	0	0	1	1	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1
8.2E+11	1	0	0	0	1	1	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.23E+11	1	0	1	0	1	0	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1
8.57E+11	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.86E+11	0	1	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	2
8.2E+11	1	1	0	0	1	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.23E+11	1	1	0	0	1	0	0	1	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.56E+11	0	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0	2
8.23E+11	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	0	1	0	1	0	1	0	0	0	1	1	1	1	0	1	1	3
8.23E+11	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.23E+11	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.57E+11	0	1	1	1	0	0	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.86E+11	0	0	1	1	0	0	0	1	1	0	1	1	1	1	1	0	1	0	1	0	0	0	0	0	1	1	1	1	1	1	1	4
8.23E+11	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4
8.57E+11	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4
8.84E+11	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4

C1. Young Alive		0		0	1		0		0	0				0				0	0	0	0		1	1	1				1		0	
C2. Older Alive		1	0		1		0			0		0				0		0	0	0	0	0			1	1		0	1	0	0	
C3. Older Dead		1			0	0						0				0		0		0		0			1	1	1					
C4. Young Dead		0		1	0	0			1	0						0		0		0	0	0			1	1	1		1			

Table 7. 11 Qualitative Comparative Analysis Truth Table (e)

Case	Site	Age65	Gender	ISS	Mortality	GOS	Intubation	Shock	Head Injury	Face Injury	Chest Injury	Abdo Injury	Spinal Injury	Pelvic Injury	Limb Injury	Other Injury	Multiple Injury	PH Airway	PH Breathing	PH Airway Supp.	PH Breath Supp.	PH Resp. Rate	PH GCS ≤14	PH GCS ≤13	PH SBP ≤90	PH SBP ≤100	PH SBP ≤110	PH Spine Supp.	PH Skill Mix	Mech High/Low	Mortality Index	Cluster
8.86E+11	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.23E+11	1	0	1	1	1	1	0	0	0	0	1	1	0	0	1	1	1	0	0	0	1	0	1	1	1	1	1	1	1	1	0	1
8.58E+11	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.56E+11	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.23E+11	1	1	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.84E+11	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	0	2
8.84E+11	0	1	0	0	1	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.84E+11	0	1	0	1	1	1	0	1	1	0	1	0	1	1	1	1	1	0	0	0	0	0	1	1	1	0	0	1	1	1	1	2
8.2E+11	1	1	1	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.23E+11	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.57E+11	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.84E+11	0	1	1	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	3
8.2E+11	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4
8.23E+11	1	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	4
8.23E+11	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1	1	1	1	0	4
8.57E+11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4

C1. Young Alive		0			1	1	0	0		0			0	0				0	0	0		0	1	1	1	1	1		1		0	
C2. Older Alive		1	0		1	1	0					0						0	0	0	0	0	1	1	1				1			
C3. Older Dead		1			0	0	0		0		0			0		0		0	0	0	0	0			1	1	1	0	1	0	0	
C4. Young Dead		0			0	0				0		0	0	0															1			

Table 7. 12 Qualitative Comparative Analysis Truth Table (f)

Case	Site	Age65	Gender	ISS	Mortality	GOS	Intubation	Shock	Head Injury	Face Injury	Chest Injury	Abdo Injury	Spinal Injury	Pelvic Injury	Limb Injury	Other Injury	Multiple Injury	PH Airway	PH Breathing	PH Airway Supp.	PH Breath Supp.	PH Resp. Rate	PH GCS ≤14	PH GCS ≤13	PH SBP ≤90	PH SBP ≤100	PH SBP ≤110	PH Spine Supp.	PH Skill Mix	Mech High/Low	Mortality Index	Cluster
8.23E+11	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	1
8.23E+11	1	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.23E+11	1	0	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	0	1
8.84E+11	0	0	1	0	1	1	0	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	1	1	1	1	1	0	1	1	0	1
8.2E+11	1	1	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.2E+11	1	1	0	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	0	2
8.23E+11	1	1	0	0	1	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2
8.58E+11	0	1	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	0	2
8.2E+11	1	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	1	1	1	0	1	1	1	3
8.84E+11	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	3
8.57E+11	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.57E+11	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	0	1	0	0	3
8.2E+11	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4
8.2E+11	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	1	1	1	1	0	1	0	4
8.23E+11	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	4
8.23E+11	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	1	1	1	0	1	1	0	4

C1. Young Alive		0	1	0	1		0	0	0			0		0		0		0	0	0	0	0	1	1	1	1	1				0	
C2. Older Alive		1	0		1	1	0		0	0		0		0				0	0	0	0	0	1	1	1	1	1		1			
C3. Older Dead		1			0	0		0		0	0	0		0	0			0	0	0	0	0		1	1	1	1	0	1			
C4. Young Dead	1	0		1	0	0				0	0	0	0	0	0		0					0			1	1	1				0	

Table 7. 13 Qualitative Comparative Analysis Truth Table (g)

Case	Site	Age65	Gender	ISS	Mortality	GOS	Intubation	Shock	Head Injury	Face Injury	Chest Injury	Abdo Injury	Spinal Injury	Pelvic Injury	Limb Injury	Other Injury	Multiple Injury	PH Airway	PH Breathing	PH Airway Supp.	PH Breath Supp.	PH Resp. Rate	PH GCS ≤14	PH GCS ≤13	PH SBP ≤90	PH SBP ≤100	PH SBP ≤110	PH Spine Supp.	PH Skill Mix	Mech High/Low	Mortality Index	Cluster
8.86E+11	0	**0**	1	**1**	**1**	**1**	0	**0**	1	1	0	**0**	**0**	**0**	0	**0**	1	1	1	1	1	**0**	0	0	**1**	**1**	**1**	1	**1**	0	0	1
8.86E+11	0	**0**	0	**1**	**1**	**1**	0	**0**	1	0	0	**0**	**0**	**0**	0	**0**	0	0	0	0	0	**0**	1	1	**1**	**1**	**1**	0	**1**	0	0	1
8.2E+11	1	**0**	1	**1**	**1**	**1**	1	**0**	1	1	0	**0**	**0**	**0**	1	**0**	1	0	0	0	1	**0**	0	1	**1**	**1**	**1**	0	**1**	1	1	1
8.23E+11	1	**0**	0	**1**	**1**	**1**	0	**0**	0	0	1	**0**	**0**	**0**	1	**0**	1	0	0	0	0	**0**	1	1	**1**	**1**	**1**	0	**1**	0	0	1
8.59E+11	0	**1**	1	0	**1**	1	**0**	**0**	**0**	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	0	**0**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	2
8.23E+11	1	**1**	1	1	**1**	0	**0**	**0**	**0**	**0**	1	**0**	0	**0**	0	**0**	0	**0**	1	**0**	1	**0**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	2
8.23E+11	1	**1**	0	0	**1**	0	**0**	**0**	**0**	**0**	0	**0**	0	**0**	1	**0**	0	**0**	0	**0**	0	**0**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	2
8.56E+11	0	**1**	0	0	**1**	0	**0**	**0**	**0**	**0**	0	**0**	1	**0**	1	**0**	1	**0**	0	**0**	0	**0**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	2
8.23E+11	1	**1**	0	0	**0**	**0**	0	0	0	0	**0**	**0**	0	**0**	1	**0**	0	**0**	**0**	0	1	**0**	1	1	**1**	**1**	**1**	0	**1**	1	**0**	3
8.57E+11	0	**1**	1	1	**0**	**0**	1	0	1	0	**0**	**0**	1	**0**	0	**0**	1	**0**	**0**	1	1	**0**	0	0	**1**	**1**	**1**	1	**1**	0	**0**	3
8.57E+11	0	**1**	1	1	**0**	**0**	0	0	1	1	**0**	**0**	0	**0**	0	**0**	1	**0**	**0**	0	0	**0**	1	1	**1**	**1**	**1**	0	**1**	0	**0**	3
8.58E+11	0	**1**	0	0	**0**	**0**	0	1	0	0	**0**	**0**	0	**0**	1	**0**	0	**0**	**0**	0	0	**0**	1	1	**1**	**1**	**1**	0	**1**	0	**0**	3
8.2E+11	1	**0**	1	**1**	**0**	**0**	**1**	0	1	1	0	**0**	0	1	0	0	1	0	0	0	0	0	1	1	1	1	1	0	**1**	**1**	0	4
8.2E+11	1	**0**	1	**1**	**0**	**0**	**1**	0	0	0	0	**0**	0	0	0	1	0	0	1	1	1	0	0	0	1	1	1	0	**1**	**1**	0	4
8.23E+11	1	**0**	1	**1**	**0**	**0**	**1**	1	1	1	1	**0**	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	1	**1**	**1**	1	4
8.58E+11	0	**0**	0	**1**	**0**	**0**	**1**	0	0	0	0	**0**	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1	0	**1**	**1**	0	4

C1. Young Alive		0		1	1	1		0				0	0	0		0						0			1	1	1		1			
C2. Older Alive		1			1		0	0	0	0		0		0		0		0		0		0	1	1	1	1	1	0	1	0	0	
C3. Older Dead		1			0	0					0	0		0		0		0	0			0			1	1	1		1		0	
C4. Young Dead		0		1	0	0	1					0																	1	1		

Table 7. 14 Qualitative Comparative Analysis Truth Table (h)

Case	Site	Age65	Gender	ISS	Mortality	GOS	Intubation	Shock	Head Injury	Face Injury	Chest Injury	Abdo Injury	Spinal Injury	Pelvic Injury	Limb Injury	Other Injury	Multiple Injury	PH Airway	PH Breathing	PH Airway Supp.	PH Breath Supp.	PH Resp. Rate	PH GCS ≤14	PH GCS ≤13	PH SBP ≤90	PH SBP ≤100	PH SBP ≤110	PH Spine Supp.	PH Skill Mix	Mech High/Low	Mortality Index	Cluster
8.59E+11	0	1	0	0	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0	1
8.2E+11	1	0	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	0	0	0	0	1	1	1	1	1	0	1	1	1	1
8.23E+11	1	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.57E+11	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.23E+11	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.23E+11	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	1	2
8.57E+11	0	1	0	0	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	1	2
8.57E+11	0	1	1	0	1	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	1	1	0	1	1	1	2
8.2E+11	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	1	3
8.2E+11	1	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.57E+11	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.56E+11	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.2E+11	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4
8.23E+11	1	1	1	1	0	0	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	0	0	0	0	0	1	0	1	1	4
8.57E+11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4
8.56E+11	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4

C1. Young Alive					1	1				0		0		0		0		0	0	0	0	0	1	1	1			0	1			
C2. Older Alive		1			1		0			0	0	0						0	0	0	0	0	1	1	1	1	1	0	1			
C3. Older Dead		1			0		0			0	0	0		0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1			
C4. Young Dead					0	0				0						0																

Table 7. 15 Qualitative Comparative Analysis Truth Table (i)

Case	Site	Age65	Gender	ISS	Mortality	GOS	Intubation	Shock	Head Injury	Face Injury	Chest Injury	Abdo Injury	Spinal Injury	Pelvic Injury	Limb Injury	Other Injury	Multiple Injury	PH Airway	PH Breathing	PH Airway Supp.	PH Breath Supp.	PH Resp. Rate	PH GCS ≤14	PH GCS ≤13	PH SBP ≤90	PH SBP ≤100	PH SBP ≤110	PH Spine Supp.	PH Skill Mix	Mech High/Low	Mortality Index	Cluster
8.23E+11	1	0	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	1	1	0	1
8.23E+11	1	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0	1
8.23E+11	1	0	1	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0	1	1	1	1	1	0	1	0	0	1
8.84E+11	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	0	1	0	0	1
8.86E+11	0	1	0	1	1	1	0	0	0	0	1	0	1	0	1	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.59E+11	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	1	1	1	1	1	0	1	0	0	2
8.84E+11	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	1	1	0	1	0	0	2
8.57E+11	0	1	0	0	1	1	0	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2
8.2E+11	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	1	3
8.57E+11	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.9E+11	0	1	0	1	0	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	1	1	3
8.56E+11	0	1	1	0	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	1	1	1	1	0	1	1	0	0	3
8.23E+11	1	0	1	1	0	0	1	0	1	1	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4
8.23E+11	1	0	1	1	0	0	1	0	1	0	1	1	0	1	0	1	1	1	1	1	1	0	0	0	1	1	1	1	0	1	1	4
8.84E+11	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	4
8.84E+11	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	4

C1. Young Alive		0			1					0	0	0		0		0		0		0		0			1	1			1		0	
C2. Older Alive	0	1			1	1	0	0	0			0		0		0		0		0		0			1	1	1		1			
C3. Older Dead		1			0	0	0			0	0	0				0		0	0	0	0	0		1	1				1			
C4. Young Dead					0	0		0					0									0			1	1	1					

Table 7. 16 Qualitative Comparative Analysis Truth Table (j)

Case	Site	Age65	Gender	ISS	Mortality	GOS	Intubation	Shock	Head Injury	Face Injury	Chest Injury	Abdo Injury	Spinal Injury	Pelvic Injury	Limb Injury	Other Injury	Multiple Injury	PH Airway	PH Breathing	PH Airway Supp.	PH Breath Supp.	PH Resp. Rate	PH GCS ≤14	PH GCS ≤13	PH SBP ≤90	PH SBP ≤100	PH SBP ≤110	PH Spine Supp.	PH Skill Mix	Mech High/Low	Mortality Index	Cluster
8.86E+11	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.2E+11	1	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.23E+11	1	0	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	0	1	1	0	1
8.57E+11	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	1
8.2E+11	1	1	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.2E+11	1	1	0	0	1	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	2
8.2E+11	1	1	0	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	0	2
8.57E+11	0	1	0	0	1	1	0	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2
8.2E+11	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	1	3
8.86E+11	0	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.84E+11	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	3
8.57E+11	0	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	3
8.23E+11	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1	0	1	1	0	4
8.23E+11	1	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	4
8.23E+11	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1	1	1	1	0	4
8.58E+11	0	0	1	0	0	0	0	1	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	4

C1. Young Alive		0			1	1		0		0	0	0	0	0		0	0	0	0	0		0		1	1	1	1	0	1		0	
C2. Older Alive		1			1	1	0		0			0	0			0		0	0	0	0	0	1	1	1	1	1		1			
C3. Older Dead		1		1	0	0	0	0	1		0	0	0	0		0		0	0	0	0	0		1	1	1	1	0	1			
C4. Young Dead		0			0	0				0		0	0																1			

Table 7. 17 Qualitative Comparative Analysis truth table frequencies within clusters (a)

Cluster	**Site**		**Age65**		**Gender**		**ISS**		**Mortality**		**GOS**		**Intubation**		**Shock**		**Head Injury**		**Face Injury**		**Chest Injury**		**Abdo Injury**		**Spinal Injury**		**Pelvic Injury**		**Limb Injury**		**Other Injury**	
	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C1. Young Alive	1	1	**8**	0	0	2	3	1	0	**10**	0	**6**	5	0	5	0	3	0	5	0	3	0	7	0	3	0	9	0	0	0	7	0
C2. Older Alive	1	0	0	**10**	3	0	0	0	0	**10**	0	**6**	10	0	3	0	5	0	6	0	2	0	10	0	3	0	5	0	0	0	7	0
C3. Older Dead	0	0	0	**10**	0	0	0	3	**10**	0	**9**	0	7	0	5	0	1	2	6	0	7	0	9	0	3	0	6	0	3	0	8	0
C4. Young Dead	0	3	**7**	0	0	1	0	5	**10**	0	**10**	0	0	2	1	0	0	1	5	0	1	0	5	0	4	0	3	0	1	0	3	1

Table 7. 18 Qualitative Comparative Analysis truth table frequencies within clusters (b)

Cluster	**Multiple Injury**		**PH Airway**		**PH Breathing**		**PH Airway Supp.**		**PH Breath Supp.**		**PH Resp. Rate**		**PH GCS ≤14**		**PH GCS ≤13**		**PH SBP ≤90**		**PH SBP ≤100**		**PH SBP ≤110**		**PH Spine Supp.**		**PH Skill Mix**		**Mech High/Low**		**Mortality Index**	
	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C1. Young Alive	1	0	**9**	0	**7**	0	**9**	0	3	0	9	0	0	6	0	**8**	0	10	0	8	0	6	3	0	0	9	0	0	8	0
C2. Older Alive	0	0	**10**	0	**8**	0	**10**	0	7	0	9	0	0	6	0	**7**	0	9	0	8	0	7	5	0	0	10	**2**	0	2	0
C3. Older Dead	1	0	**10**	0	**9**	0	**9**	0	8	0	10	0	0	1	0	**6**	0	10	0	9	0	9	6	0	0	9	**2**	0	3	0
C4. Young Dead	1	0	**1**	0	0	0	**1**	0	1	0	4	0	0	0	0	0	0	5	0	5	0	5	0	0	0	4	0	**2**	1	0

7.4 Discussion

Exploring the demographics for all ages within the NTN region TARN data highlights that mortality is more than double for older trauma patients (age ≥65 years = 9.4% vs. age <65 = 4.1%). Giannoudis et al. (2009) highlighted a similar trend within their research at a UK level one trauma unit (what was to be known as an MTC). Sammy et al. (2016) explore the older adult group further and state that this level of mortality is exponential as the *'oldest old'* have the highest mortality rates. There was almost an exact converse image for gender which switched from 67.5% male (32.5% female) for those aged <65 years to 38.4% male (61.6% female) in those aged ≥65 years which is a 29.1% shift in composition. There appears to be little evidence within the literature about this phenomenon to this extent and may be unique to the NTN region. However, the Trauma Audit and Research Network (2017) report into major trauma in older people do describe the changing demographic of older gender balance. Within the ISS >15 group they show the liner increase in percentage of the older female trauma patient with increasing age groups with the inverse true for the older male groups (see Figure 7.1). A theoretical conclusion in the increased composition of females compared to males within the oldest of the old may relate to the longevity of the female sex who may live up to a decade longer than men in certain countries (Regan and Partridge, 2013). This phenomenon is potentially correlated to sex hormones but remains inconclusive. As such, the male population in the oldest of the old presents as a different composition compared to younger populations. Simply put: men die younger hence reversing the composition at the cross over point within Figure 7.1.

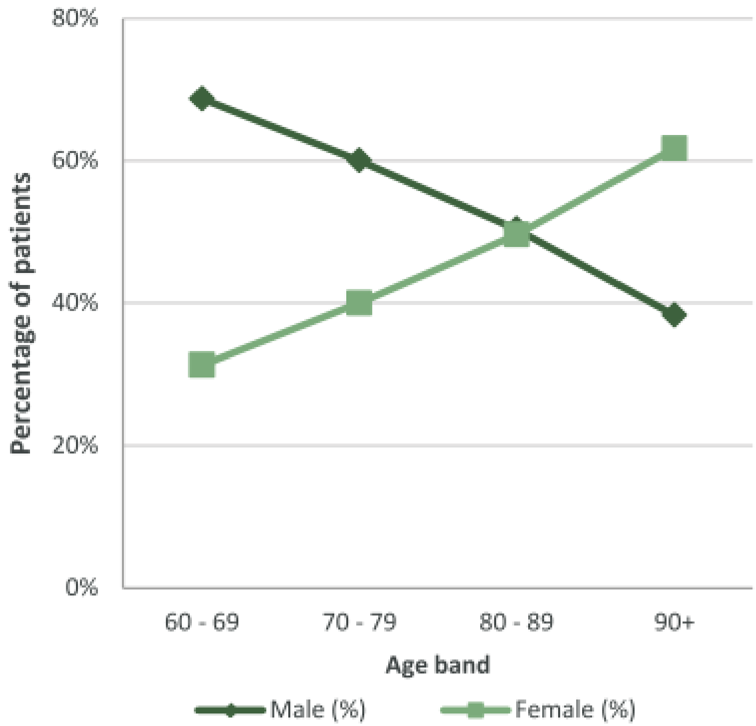

Figure 7. 1 TARN Major trauma in older people (ISS >15) (Trauma Audit and Research Network, 2017)

There was little difference in mean ISS between the age groups, <65 years (mean ISS 14) and ≥65 years (mean ISS 12). The overall ISS mean for all ages was 13. However, within their exploration of the older patient Sammy et al. (2016) noted that older men had significantly higher mortality when compared to older women. There is no conclusive evidence for this reason, but several papers have described the phenomenon of the effect of female gender as a variable that is complex but may involve sex hormones as a protective factor (Deitch et al., 2007, Regan and Partridge, 2013).

Within the younger clusters (1, young alive & 4, young dead) the dominant mechanisms of injury were high energy as opposed to the older clusters (2, older alive & 3, older dead) which were low energy (falls <2m). This is also reflected within the Trauma Audit and

Research Network (2017) report and work by Brown et al. (2019a) which explores a similar dataset in Perth, Australia.

The second stage of DPS consisted of creating binary Crisp Sets using clinical thresholds to determine the cut offs for each variable prior to analysis for prime implicants using a random sample of four cases for each cluster. A total of ten iterations were analysed to identify patterns.

The cluster analysis was run to take into account age (</≥65 years) and mortality (dead/alive), so it is therefore understandable that the four clusters were expressed as younger alive, older alive, older dead and younger dead with high relevant frequencies for those variables within the respective cluster. GOS, which also reflects mortality as well as disability, was also expected to mirror the mortality variable.

Outside of these expected variable results there is sparse consistency between the remaining variables within the truth tables to reflect reliability in patterns and it is difficult to extrapolate any meaning between clusters. Most variables showed some commonality rather than differences across the clusters which may also be a consequence of the sample size and a limitation of the study. However, the DPS method is designed to be used with small sample sizes. It may also reflect the extremely diverse nature of trauma and the complex nature of creating predictive modelling, but it may highlight potential red flags that may need further exploration.

The younger dead cluster appear to have slight variations from the other clusters in that they are noted to have received intubation (in 2/10 truth tables) and less likely to have had no issues with airway and airway support as well as breathing and breathing support. It should be noted that these results are not the same as stating that the younger dead cluster did have issues with airway/breathing and/or support which highlights that absence of evidence is not evidence of absence (Altman and Bland, 1995).

The remaining variable that was contrasting across clusters was that of MOI. Lower energy MOI's (fall <2m/from standing height) are clearly an issue for both the older alive clusters and older dead clusters with high energy MOI's being a variable of concern for the younger dead cluster.

Limitations

The variance and lack of patterns between samples is however a significant finding within itself. It highlights that we can only really identify tendencies with regards to prediction of outcome and that we are not only dealing with complexity but also with individuals who are so different that generalisations defy modelling. However, this may also be a consequence of the methods used within the sampling strategy which led to relatively small sample sizes which limit the opportunity for characteristics to emerge. Although, one of the proposed benefits of this method is its application to small sample sizes. With these considerations, identifying potential red flags may form an initial assessment criterion in early identification of those individuals who may benefit from specialist intervention. Haynes and Books (2018) highlight this phenomenon in their understanding of complexity domains within their description of Dynamic Pattern Synthesis. Table 7.19 highlight these domains and acknowledge where various topics may sit within these domains. With regards to the study within this chapter it would suggest that predicting trauma outcomes within our groups lies within the extreme end of complexity akin to predicting weather patterns. It was with great disappointment (as a novice researcher and PhD student) that more consistent patterns were not found.

The results and interpretation perhaps confirm the complexity, variance, and/or limitations of the current data set with regards to the older adult trauma patient. This is also reflected in the literature review discussed in Chapter 3 which highlighted that there are few robust studies that are able identify predictive variables for the older adult trauma patient. TARN, who supplied the data for this study, are now collecting other data variables, such as comorbidities, that may support further DPS research and analysis to take these new data into account.

Table 7. 19 The complexity domain in research (Haynes and Books, 2018).

	Simple	**Complicated**	**Complex**	**Chaos**
Scientific prediction	Predictable	Bounded prediction	Temporary forecasting	Short term probabilities
Dynamic	Stable	Stable with occasional disruptions	Mix of stability and instability	Unstable
Research evidence	Cause and effect	Linear trends and statistical controls	Pattern analysis	Individual case studies. Event probabilities
Science example	Tide tables	Flying an aircraft	Animal behaviour	Weather
Social science example	National records on the price of alcohol influence national levels of consumption	Local level of alcohol consumption and emergency admission	The use of psychological therapy to manage depression	Employment attendance for excessive consumers of alcohol

Future research within this area should consider sub-sets of older adults. Older age group subsets, which are also acknowledged in the 'Major trauma in older people' report (Trauma Audit and Research Network, 2017), should be explored further to identify specific trends and phenomena within the transition through much older age groups and the relationship with gender and outcome.

Within the context of our study we have created a threshold age of $\geq$65 years. Although this age is commonly referred to within the literature, it is artifact of the study that we have created a threshold that may have been otherwise a different age. As such other age ranges may have been used to differentiate cluster and therefore obtained different results. With this in mind, adaptions to this study should be considered for future research.

Conclusion

As patients cross the artificial threshold of 65 years of age set within this study, there is a higher incidence of mortality and what was once perceived as a male disease can be seen to be an increasingly female disease with greater age. Low energy MOI (i.e., a fall from <2m) is the main mechanism of injury for the older adult which may be a contributing factor to the complexity of older adult predictors in trauma as it is such a common presentation for emergency medical services. The DPS methodology did not identify meaningful dynamic patterns within the complexity of the older major trauma age group. There is huge variance within this complex and challenging patient group which requires further exploration with additional key variables that were not available within the sample dataset.

Research journey

The DPS method is seldom used within healthcare research and prior to undertaking this thesis was unknown to me. However, out of professional respect to my mentors who suggested this method, I explored how it would relate to my own work and understood that it may potentially provide connections that had so far eluded the field of older adult trauma. Although designed to be applied to small sample sizes which can be extrapolated to larger datasets to identify patterns within complex phenomenon, I persevered with many aspects of the DPS method, especially the qualitative comparative analysis and using truth tables to identify patterns. In reality, the recorded data within this chapter does not truly reflect the volume of attempts that were undertaken. Post analysis I did not believe this chapter added to what was already known about older adult trauma except that the DPS method may not be appropriate for this subject area or that the data is too diverse or sample data were not appropriate in size. However, it provided an opportunity to learn about alternative methods of research and contributed to a wider understanding of research methodologies that have the potential to explore complex topics that may not be traditionally utilised within healthcare.

CHAPTER 8 DEVELOPING A PREDICTIVE MODEL TO IDENTIFY OLDER ADULT TRAUMA PATIENTS WITH A HIGH RISK OF MORTALITY: THE NORTHUMBRIA LOW ENERGY TRAUMA SCORE

8.1 Introduction

The evidence from the previous chapters acknowledges that current triage, assessment and ongoing care of the older adult trauma patient potentially compromises their outcome. This is perhaps a reflection that, as a disease, trauma is now *'two separate diseases'* with regards to age (Coats and Lecky, 2017). It is also acknowledged that the older adult major trauma group are complex and challenging when attempting to identify those who require early identification to influence their ongoing care and prevent a fatal outcome. There is also a clear need to develop an older adult/low energy trauma triage tool/score to support clinical decision making for those clinicians that are seldom exposed to trauma. This is now more important than ever due to a significant increase in the volume of older adults who have high a ISS (Kehoe et al., 2015b) which is described as the *'The grey tsunami'* by Rehn (2013). Although the trend of reported cases is rising it may be a consequence of maturing trauma networks within the UK (and globally) with dedicated staff and more robust reporting systems linked to national trauma registries.

The grey trauma tsunami of older adults predominantly occurs from relatively low energy MOI such as a fall from standing height which is a common dispatch criterion for ambulance services (Brown et al., 2019a). It is often difficult for prehospital care providers to identify those older adults who may have significant underlying injuries which may be categorised as major trauma.

Ranapurwala et al. (2019) explain that predictive models can provide a tool to understand the multidimensionality of health outcomes at an individual level and to improve those patients' outcomes. This reflects the complexity and multidimensionality of older adult trauma which was highlighted in Chapter 7 which discussed Dynamic Pattern Synthesis

(DPS) of older adult trauma independent variables. The use of DPS in the previous chapter acknowledged that we can only really identify tendencies with regards to prediction and that we are not only dealing with complexity but also with individuals who are so different that generalisations defy modelling. However, severe class imbalance between majority and minority classes (clusters) within the dataset may have led to bias and similar outcomes (Hasanin et al., 2019, Prati et al., 2015). With these considerations, identifying potential red flags may form an initial assessment criterion in the early identification of those individuals who may benefit from specialist intervention.

Ichwan et al. (2015) compared a modified trauma triage criterion for 'geriatrics' (age >70years) against the standard adult triage criteria (age <70 years) using an ISS of >15 as an outcome measure. The modified tool had additional criterion of:

- SBP of <100mmHg (compared to SBP <90mmHg);
- Glasgow Coma Score (GCS) ≤14 (compared to GCS ≤13);
- Fracture of 1 proximal long bone or injury sustained in 2 or more body regions (compared to 2 or more fractures of proximal long bones); and,
- MOI that includes being struck by a vehicle and fall from any height (no comparator).

The modified criterion does address some of the areas highlighted within the previous chapters and the Ichwan team conclude that the modified triage criteria improved sensitivity in identifying those aged >70 years who have an ISS >15 (and similar patterns with other outcomes including mortality).

Sasser et al. (2012) modified their field trauma triage scheme for the older adult to reflect the high incidence of low energy mechanisms in the elderly and also incorporated a SBP criteria of <110mmHg for those aged >65 years. Another modification to their triage criterion was the addition of patient's anticoagulation, although not specific to the older adult. It was interesting to note their analysis of 10 years of data highlighted that under-triage of the older adult within the Washington State trauma system is a substantial problem.

Bouamra et al. (2015) utilised age and comorbidities within their predictive modelling for true 30-day outcome measures (mortality). Both age and comorbidity were independently associated with mortality and improved their predictive modelling for older trauma patients.

The identification of the older adult who experiences trauma with potential significant injury requires a predictive model to allow for early intervention to improve their outcome. Building upon the models highlighted above combined with the predictive variables that were identified in Chapter 3 is believed to be the first step in achieving improved outcomes for this patient group.

The combined systematic literature review and rapid evidence review in Chapter 3 highlighted variables from contemporary literature that are predictors of mortality within the older adult trauma population. Using a modified criteria, highlighted by Cardona-Morrell and Hillman (2015), the variables considered within a predictive model that are appropriate within the hyper-acute setting should: (i) be easily collected in routine practice or easily accessed from electronic or paper documents; (ii) do not require special clinical judgement; (iii) is sufficient to independently predict mortality; and, (iv) does not employ value judgement (and therefore objective). Therefore, any trauma triage tool/score that is developed must utilise easily available data.

Farrohknia et al. (2011) addressed the scientific evidence behind ED triage scales and concluded that triage scales within the ED have many shortcomings and are based on limited and often insufficient evidence. The evidence suggested that, within the ED, tools which use simple (and readily available) indices, such as physiology, to predict outcome was seldom researched and in the few studies that used these indices the scientific evidence was limited. As a consequence, there were shortcomings within the scientific evidence that current triage scales rely upon. With regards to vital signs, more robust evidence is required to determine which chief complaint and vital signs provide the greatest prognostic values. As such interrater agreement, validity and triage scale safety require further investigation. Also, a head-to-head comparison of all triage scales are required to determine the performance, differences, advantages and disadvantages between each scale. Statistical relevance and clinical relevance often differ and therefore other methods may be considered when attempting to derive conclusions from a clinical setting. This concept is explored to some extent by Murad et al. (2016). Although specific to clinical drug trials, the work of Moncrieff and Kirsch (2015) highlight the relevance of statistical significance compared to clinical relevance which is relevant when using scales/scores where even small changes in the score may be clinically significant Although the hierarchy of evidence elevated empirical evidence it must always applied to the real-world clinical setting and its relevance to the patient.

The overall goal of the older adult/low energy trauma triage tool/score as a predictive model is to provide sufficient sensitivity and specificity to those at risk of a fatal outcome. To give an indication of where that patient is within a sliding scale of risk the variables may need to be weighted to reflect the impact they may have on the patient. For example, increasing age, reducing GCS, reducing blood pressure, number of comorbidities, etc. Dichotomous variables may also potentially be weighted to some extent.

A good example of a weighted predictive tool/score is the National Early Warning Score (NEWS) (National Institute for Health and Care Excellence, 2020). The NEWS uses physiological parameters and each parameter is given a score of 0-3 with an increasing score given the further it deviates from normal. The aggregation of these scores then allocates the patient to a level of risk (low to high). The older adult/low energy trauma triage tool/score will follow a similar weighted criterion bases on the results of the studies in Chapter 6 and 7.

Aim

The aim of this chapter is to derive a prototype triage tool/score prior to validation that can use easily obtained data within the hyper-acute prehospital setting to identify those older adults who have a high risk of mortality due to a traumatic event.

8.2 Methods

Using the PICO format, the population within the study will be the older adult trauma patients within the Northern Trauma Network. The intervention will assess the variables highlighted in Chapter 3 (Table 8.1) and comparisons made between these variables as well as comparing various aspects of those patients age <65 years with those age ≥65 years. The predictor variables in Table 8.1 will be tested against the outcome of mortality.

Study period and population

A retrospective analysis of data from TARN was undertaken for the period between 1 April 2012 and 31 March 2017. Patients entered into the database have experienced trauma and admitted to hospital for more than 72 hours and/or required critical care or died from their injuries.

The data includes prehospital and in-hospital timings, physiology, interventions, and outcomes. Data was obtained from TARN specifically for the NTN region. The NTN covers the North East of England from the Scottish borders to North Yorkshire and includes North Cumbria. It has three NHS ambulance service providers and two Helicopter Emergency Medical Service (HEMS) providers. The NTN has two MTCs and had nine trauma units during most of the sample time frame (now eight) (see Figure 8.1).

Table 8. 1 Identified potential prediction variables.

Variable	SPSS Code
Older age	
(Recoded as)	<65 years
	≥65
Deranged physiology	
GCS (Prehospital)	≤14
SBP (Prehospital)	<110
	≥110
Respiration Rate (Prehospital)	<10, 10-30, >30
Comorbidities[1]	Not in TARN[1]
Anticoagulant/platelet[1]	Not in TARN[1]
Injuries	
Head injury	Yes/No
Chest injury	Yes/No
Spinal injury	Yes/No
Multiple injuries	Yes/No
Frailty[1]	Not in TARN[1]
Male	Yes/No
Polypharmacy[1]	Not in TARN[1]
MTC	Yes/No
Ventilatory support	Yes/No
Mechanism[2]	
Recorded as	High/Low Energy[2]
	RTC, Falls (+/-2m), Other
Other indices	
BMI[1]	Not in TARN[1]
Acidosis[1]	Not in TARN[1]
White[1]	Not in TARN[1]

Data analysis

Means and standard deviations are reported for continuous variables. Frequencies and percentage are reported for categorical variables.

Mann-Whitney test was used to evaluate continuous variables and Fisher's exact test used for categorical variables. A *p* value of <0.05 was predetermined as the level of significance.

To develop the predictive model/triage tool/score a binary logistic regression analysis was undertaken with mortality as the outcome (adjusting for collinearity and potential

[1] Data not available within the TARN dataset for the sample time period
[2] Mechanism was excluded from the final model owing to low energy being the main focus of the final Northumbria Low Energy Trauma Score

amplification bias). Only independent variables that were associated with mortality where a p value of ≤ 0.05 was predetermined as the level of significance were entered into the binary logistic regression model.

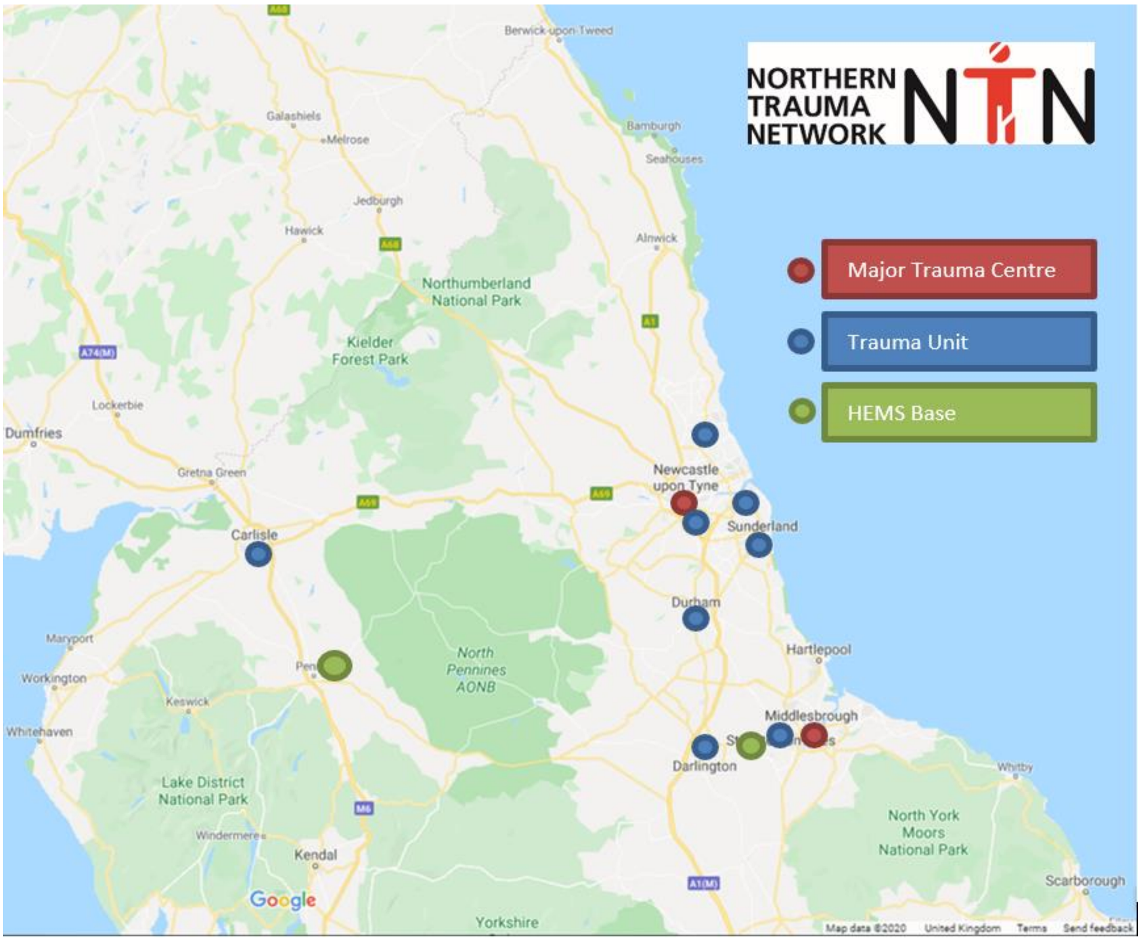

Figure 8. 1 Northern Trauma Network Region

All potential predictor variables were entered into the model using a forward stepwise method, and each variable's contribution to the overall fit was estimated using likelihood ratio tests. Cases were excluded pairwise. Estimates, Confidence intervals (95%), model fit, R squared change, descriptives and part/partial correlations were included. Durbin-Watson statistics were included to test for the presence of autocorrelation and prediction errors within a regression analysis. This was undertaken to identify issues with exaggerated goodness of fit and false positives where statistical significant results are in fact not significant (Field, 2018, Uyanto, 2020). An aggregation of prediction variable scores, that were weighted based on their deviation from normal, were used to create a mortality index which, during the course of the study, evolved to be called Northumbria Low Energy Trauma Score. Using the Northumbria Low Energy Trauma Score against outcome (mortality) created a prediction matrix where the positive prediction value was categorised as 'dead'.

A receiver operating characteristic (ROC) curve was used to assess the accuracy of the predictive model against mortality. A separate dataset that was not used within the development of the predictive model was used to generate the ROC curve. The ROC curve provides a visual representation of the predictive values while incorporating the sensitivity (true positive prediction) and specificity (true negative prediction) (Alemayehu and Zou, 2012).

The Statistical Package for the Social Sciences (SPSS; Version 22, IBM Inc.; Armonk, NY, USA) was used for analysis of the data.

8.3 Results

All ages

Data was obtained from TARN specifically for the NTN region for the dates between 1 April 2012 and 31 March 2017. Within this period there were 16,558 TARN eligible patients of which 6,895 were aged 65 years or older. Age ranged from new-born (0 years) to 106 years with a mean of 59 years. Females were 45.5% (n=7,534) of the sample, males 54.5% (n=9,024). The mean ISS for all ages was 13 (SD 9.172).

Outcome was determined as mortality (dead/alive) and for data collected between 1 April 2012 and 31 March 2017 mortality was recorded by TARN at hospital discharge or within hospital at 30 days (The Trauma Audit Research Network, 2019). The sample (all ages) mortality rate was 6.5% (n=1,071) (Age <65 = 4.1%, n=378 and age ≥65 = 9.4% n=693) (see Table 8.2).

Table 8. 2 NTN region demographics and outcomes

	All ages	**<65 years**	**≥65 years**
N	16558	9166	7392
Age			
Mean, (Range)	59 (0-106)	41 (0-65)	81 (65-106)
Median	62	45	81
ISS			
Mean, (SD)	13 (9.17)	14 (9.855)	12 (8.114)
Mean ISS dead	23 (14.07)	30 (15.36)	20 (11.81)
Mean ISS alive	12 (8.29)	13 (8.93)	11 (7.19)
Median	9	9	9
Mortality, (%)	1071 (6.5)	378 (4.1)	693 (9.4)
Gender			
Male, (%)	9024 (54.5)	6185 (67.5)	2839 (38.4)
Female, (%)	7534 (45.5)	2981 (32.5)	4553 (61.6)

Age ≥65 years

There were 16,558 TARN eligible patients within the NTN region of which 7,392 were aged 65 years or older. Within this older adult group age ranged from 65 to 106 years, with a mean of 81 years. Within the ≥65 years group, females were 61.6% (n=4,553) of the sample and males 38.4% (n=2,939). The mean ISS for those aged ≥65 years was 12 (SD 8.114) (see Table 8.2).

The sample (age ≥65 years) mortality rate was 9.4% (n=693). The mean ISS for those who died age ≥65 years was 20 compared to a mean ISS 30 for those who died age <65 years.

The continuous variables of age, multiple injuries, prehospital respiratory rate, prehospital SBP were assessed using non-parametric Mann-Whitney *U* tests which are highlighted in Table 8.3 using the dependent outcome of mortality (dead/alive).

Table 8. 3 Non-Parametric Mann-Whitney U Test for continuous variables

	N (Mean, SD)	Range	Mann-Whitney U	Z	Asymp. Sig. (2-tailed)
Age	7392 (81, 8.350)	0-106	1804454.5	-9.663	0.000
Dead	693				
Alive	6699				
Multiple injuries	7392 (1, 0.827)	1-8	1931847.0	-8.969	0.000
Dead	693				
Alive	6699				
PH Resp Rate	3864 (19, 5.561)	0-99	717902.5	-.325	0.745
Dead	421				
Alive	3443				
PH SBP	3790 (149, 30.601)	0-250	593607.5	-4.812	0.000
Dead	411				
Alive	3379				

PH = Prehospital. grouping by dead/alive.

Chi square (X^2) and Fisher exact tests were conducted for the independent variables of gender, head injury, chest injury, spinal injury, prehospital ventilatory support, prehospital Glasgow Coma Score (GCS) <15 and prehospital SBP <110mmHg against the dependent variable of mortality (dead/alive) (see Table 8.4).

Table 8. 4 Chi Square (X2) and Fisher exact tests

	N (%)	Dead (%)	Alive (%)	Pearson X^2	*df*	X^2 Asymp Sig. (2-sided)	Fishers exact test
Gender	7392 (100)	693 (9)	6699 (91)	45.087	1	0.000	0.000
Female	4553 (62)	345 (8)	4208 (92)				
Male	2839 (38)	348 (12)	2491 (88)				
Head injury	7392 (100)	693 (9)	6699 (91)	330.939	1	0.000	0.000
No	5428 (73)	307 (6)	5117 (94)				
Yes	1968 (27)	386 (20)	1582 (80)				
Chest injury	7392 (100)	693 (9)	6699 (91)	7.890	1	0.005	0.006
No	5722 (77)	507 (9)	5215 (91)				
Yes	1670 (23)	186 (11)	1484 (89)				
Spinal injury	7392 (100)	693 (9)	6699 (91)	3.804	1	0.051	0.053
No	5538 (75)	498 (9)	5040 (91)				
Yes	1854 (25)	195 (11)	1659 (89)				
PH Vent. Support	20 (0.3)	19 (95)	1 (5)	0.055	1	0.814	1.000
No	19 (0.3)	18 (95)	1 (5)				
Yes	1 (0.01)	1 (100)	0 (0)				
PH GCS <15	3898 (53)	440 (11)	3458 (89)	221.255	1	0.000	0.000
GCS 15	3074 (42)	227 (7)	2847 (93)				
GCS<15	824 (11)	213 (26)	611 (74)				
PH SBP <110mmHg	7392 (100)	693 (9)	6699 (91)	59.654	1	0.000	0.000
SBP>110mmHg	7068 (96)	623 (9)	6445 (91)				
SBP<110mmHg	324 (4)	70 (22)	254 (78)				

Regression analysis

A logistic regression analysis was performed using stepwise approach and excluded cases pairwise. The assumptions of logistic regression are: observations are independent, linear effect on log odds scale between continuous covariates and outcome, no relevant overdispersion and sample size large enough to ensure valid confidence intervals and *p* values (Nørskov et al., 2021). The dependent variable was mortality (dead/alive) and used alongside the independent variables: gender, head injury, chest injury, spinal injury, multiple injuries, age ranges, prehospital GCS <15, prehospital SBP <110mmHg.

There were 47% missing/unrecorded data for prehospital GCS (n = 3,494) and therefore only 3,898 cases were included for analysis of prehospital GCS within the model. The model summary is shown in Table 8.5 alongside the ANOVA results (Table 8.6) and the results of the logistic regression (regression coefficients) with the mortality outcome (dead) in Tables 8.7 to 8.9.

Table 8. 5 Regression model summary

					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.238[a]	.057	.057	.283	.057	234.450	1	3896	.000	
2	.271[b]	.073	.073	.281	.017	69.386	1	3895	.000	
3	.295[c]	.087	.087	.279	.014	59.710	1	3894	.000	
4	.306[d]	.094	.093	.278	.006	27.109	1	3893	.000	
5	.312[e]	.097	.096	.277	.003	14.911	1	3892	.000	
6	.314[f]	.099	.097	.277	.002	7.330	1	3891	.007	
7	.317[g]	.100	.099	.277	.001	6.215	1	3890	.013	
8	.317[h]	.100	.098	.277	.000	.188	1	3889	.664	1.916

a. Predictors: (Constant), PH GCS <15

b. Predictors: (Constant), PH GCS <15, Head injury

c. Predictors: (Constant), PH GCS <15, Head injury, Age Groups

d. Predictors: (Constant), PH GCS <15, Head injury, Age Groups, PH SBP <110mmHg

e. Predictors: (Constant), PH GCS <15, Head injury, Age Groups, PH SBP <110mmHg, Gender

f. Predictors: (Constant), PH GCS <15, Head injury, Age Groups, PH SBP <110mmHg, Gender, Spinal injury

g. Predictors: (Constant), PH GCS <15, Head injury, Age Groups, PH SBP <110mmHg, Gender, Spinal injury, Chest injury

h. Predictors: (Constant), PH GCS <15, Head injury, Age Groups, PH SBP <110mmHg, Gender, Spinal injury, Chest injury, Multiple Injury

i. Dependent Variable: Outcome alive dead

Table 8. 6 ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	18.796	1	18.796	234.450	.000[b]
	Residual	312.342	3896	.080		
	Total	331.138	3897			
2	Regression	24.263	2	12.131	153.976	.000[c]
	Residual	306.875	3895	.079		
	Total	331.138	3897			
3	Regression	28.897	3	9.632	124.101	.000[d]
	Residual	302.241	3894	.078		
	Total	331.138	3897			
4	Regression	30.987	4	7.747	100.477	.000[e]
	Residual	300.150	3893	.077		
	Total	331.138	3897			
5	Regression	32.133	5	6.427	83.651	.000[f]
	Residual	299.005	3892	.077		
	Total	331.138	3897			
6	Regression	32.695	6	5.449	71.044	.000[g]
	Residual	298.443	3891	.077		
	Total	331.138	3897			
7	Regression	33.171	7	4.739	61.865	.000[h]
	Residual	297.967	3890	.077		
	Total	331.138	3897			
8	Regression	33.185	8	4.148	54.144	.000[i]
	Residual	297.952	3889	.077		
	Total	331.138	3897			

a. Dependent Variable: Outcome alive dead
b. Predictors: (Constant), GCS <15
c. Predictors: (Constant), GCS <15, Head injury
d. Predictors: (Constant), GCS <15, Head injury, Age Groups
e. Predictors: (Constant), GCS <15, Head injury, Age Groups, SBP <110
f. Predictors: (Constant), GCS <15, Head injury, Age Groups, SBP <110, Gender
g. Predictors: (Constant), GCS <15, Head injury, Age Groups, SBP <110, Gender, Spinal injury
h. Predictors: (Constant), GCS <15, Head injury, Age Groups, SBP <110, Gender, Spinal injury, Chest injury
i. Predictors: (Constant), GCS <15, Head injury, Age Groups, SBP <110, Gender, Spinal injury, Chest injury, Multiple Injury

Table 8. 7 Results of logistic regression (regression coefficients) with mortality outcome (dead) (a)

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations		
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part
1	**(Constant)**	.942	.005		184.497	.000	.932	.952			
	PH GCS <15	-.170	.011	-.238	-15.312	.000	-.192	-.148	-.238	-.238	-.238
2	**(Constant)**	.958	.005		176.645	.000	.948	.969			
	PH GCS <15	-.131	.012	-.184	-10.945	.000	-.154	-.108	-.238	-.173	-.169
	Head injury	-.092	.011	-.140	-8.330	.000	-.114	-.070	-.212	-.132	-.128
3	**(Constant)**	1.049	.013		81.062	.000	1.024	1.075			
	PH GCS <15	-.133	.012	-.186	-11.162	.000	-.156	-.109	-.238	-.176	-.171
	Head injury	-.091	.011	-.139	-8.331	.000	-.113	-.070	-.212	-.132	-.128
	Age Groups	-.044	.006	-.118	-7.727	.000	-.055	-.033	-.116	-.123	-.118
4	**(Constant)**	1.055	.013		81.480	.000	1.030	1.081			
	PH GCS <15	-.129	.012	-.180	-10.832	.000	-.152	-.105	-.238	-.171	-.165
	Head injury	-.092	.011	-.140	-8.444	.000	-.114	-.071	-.212	-.134	-.129
	Age Groups	-.045	.006	-.120	-7.872	.000	-.056	-.034	-.116	-.125	-.120
	PH SBP <110mmHg	-.113	.022	-.080	-5.207	.000	-.156	-.071	-.090	-.083	-.079
5	**(Constant)**	1.075	.014		77.434	.000	1.048	1.102			
	PH GCS <15	-.126	.012	-.177	-10.664	.000	-.150	-.103	-.238	-.168	-.162
	Head injury	-.087	.011	-.133	-7.950	.000	-.109	-.066	-.212	-.126	-.121
	Age Groups	-.049	.006	-.130	-8.409	.000	-.060	-.037	-.116	-.134	-.128
	PH SBP <110mmHg	-.112	.022	-.079	-5.154	.000	-.155	-.069	-.090	-.082	-.079
	Gender	-.036	.009	-.060	-3.861	.000	-.055	-.018	-.078	-.062	-.059

Table 8. 8 Results of logistic regression (regression coefficients) with mortality outcome (dead) (b)

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations		
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part
6	**(Constant)**	1.084	.014		75.888	.000	1.056	1.112			
	PH GCS <15	-.124	.012	-.174	-10.473	.000	-.148	-.101	-.238	-.166	-.159
	Head injury	-.092	.011	-.139	-8.263	.000	-.114	-.070	-.212	-.131	-.126
	Age Groups	-.050	.006	-.133	-8.576	.000	-.061	-.038	-.116	-.136	-.131
	PH SBP <110mmHg	-.111	.022	-.078	-5.112	.000	-.154	-.068	-.090	-.082	-.078
	Gender	-.035	.009	-.058	-3.701	.000	-.053	-.016	-.078	-.059	-.056
	Spinal injury	-.028	.010	-.042	-2.707	.007	-.048	-.008	-.023	-.043	-.041
7	**(Constant)**	1.091	.015		74.865	.000	1.063	1.120			
	PH GCS <15	-.122	.012	-.171	-10.277	.000	-.146	-.099	-.238	-.163	-.156
	Head injury	-.096	.011	-.145	-8.533	.000	-.118	-.074	-.212	-.136	-.130
	Age Groups	-.050	.006	-.135	-8.725	.000	-.062	-.039	-.116	-.139	-.133
	PH SBP <110mmHg	-.107	.022	-.075	-4.935	.000	-.150	-.065	-.090	-.079	-.075
	Gender	-.031	.009	-.052	-3.295	.001	-.050	-.013	-.078	-.053	-.050
	Spinal injury	-.029	.010	-.043	-2.802	.005	-.049	-.009	-.023	-.045	-.043
	Chest injury	-.027	.011	-.039	-2.493	.013	-.048	-.006	-.033	-.040	-.038

Table 8. 9 Results of logistic regression (regression coefficients) with mortality outcome (dead) (c)

		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations		
Model		**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**Lower Bound**	**Upper Bound**	**Zero-order**	**Partial**	**Part**
8	**(Constant)**	1.092	.015		74.700	.000	1.063	1.120			
	PH GCS <15	-.122	.012	-.171	-10.266	.000	-.145	-.099	-.238	-.162	-.156
	Head injury	-.094	.012	-.143	-7.991	.000	-.117	-.071	-.212	-.127	-.122
	Age Groups	-.051	.006	-.135	-8.731	.000	-.062	-.039	-.116	-.139	-.133
	PH SBP <110mmHg	-.107	.022	-.075	-4.901	.000	-.150	-.064	-.090	-.078	-.075
	Gender	-.031	.009	-.052	-3.313	.001	-.050	-.013	-.078	-.053	-.050
	Spinal injury	-.028	.011	-.041	-2.573	.010	-.049	-.007	-.023	-.041	-.039
	Chest injury	-.025	.012	-.036	-2.149	.032	-.048	-.002	-.033	-.034	-.033
	Multiple Injury	-.005	.011	-.008	-.434	.664	-.027	.017	-.092	-.007	-.007

a. Dependent Variable: Outcome dead/alive

An aggregation of prediction variable scores, that were weighted based on their deviation from normal, were used to create a mortality index which evolved to be called the Northumbria Low Energy Trauma Score (see Table 8.10). A separate data set that was not used in the original modelling was utilised (January 2019 to December 2019, n = 8010). Using the Northumbria Low Energy Trauma Score against outcome (mortality) to produce the ROC curve in Figure 8.2.

Table 8. 10 Northumbria Low Energy Trauma Score for older adult trauma

Predictor	**Score**
Age	
65-74	3
75-84	4
85+	5
Gender	
Female	0
Male	1
Head	
No	0
Yes	1
Chest	
No	0
Yes	1
Spine	
No	0
Yes	1
Multiple injuries	
No	0
Yes	1
GCS <15	
No	0
Yes	1
SBP <110mmHg	
No	0
Yes	1

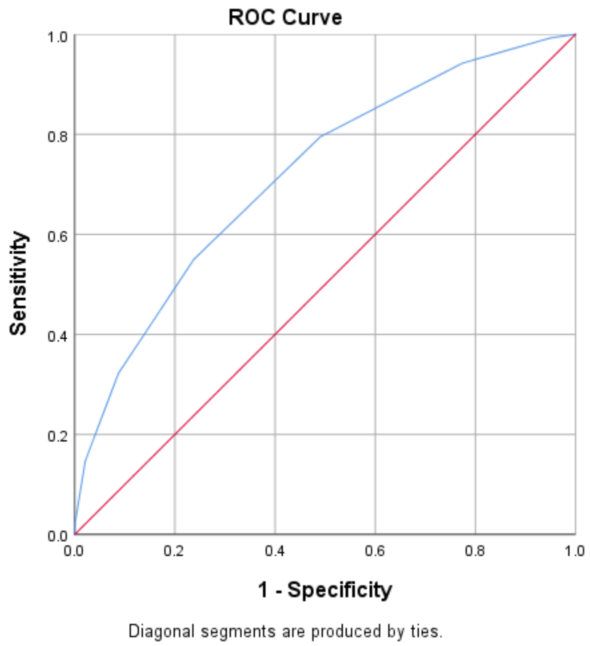

Figure 8. 2 Receiver Operating Characteristic Curve for Northumbria Low Energy Trauma Score with outcome as 'dead'

Table 8.11 describes the area under the curve for the predictive significance of the Northumbria Low Energy Trauma Score against the positive outcome of 'dead'. The coordinates of the curve are described in Table 8.12.

Table 8. 11 Area under the curve for Northumbria Low Energy Trauma Score and outcome 'dead'

			Asymptotic 95% Confidence Interval	
Area	Std. Error[a]	Asymptotic Significance.[b]	Lower Bound	Upper Bound
.719	.010	.000	.699	.739

The test result variable(s): Northumbria Low Energy Trauma Score has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.
a. Under the nonparametric assumption
b. Null hypothesis: true area = 0.5

Table 8. 12 Coordinates of the curve for Northumbria Low Energy Trauma Score and outcome 'dead'

Positive if Greater Than or Equal To[a]	Sensitivity	1 - Specificity
2.00	1.000	1.000
3.50	.993	.950
4.50	.942	.774
5.50	.795	.490
6.50	.550	.238
7.50	.322	.087
8.50	.147	.021
9.50	.046	.005
10.50	.022	.000
11.50	.001	.000
13.00	.000	.000

The test result variable(s): Northumbria Low Energy Trauma Score has at least one tie between the positive actual state group and the negative actual state group.
a. The smallest cut-off value is the minimum observed test value minus 1, and the largest cut-off value is the maximum observed test value plus 1. All the other cut-off values are the averages of two consecutive ordered observed test values.

Different thresholds for Northumbria Low Energy Trauma Score were compared against each other to determine the sensitivity (true positive rate) and specificity (true negative rate) of the threshold. The positive and negative predictive value of the Northumbria Low Energy Trauma Score threshold was also calculated (see Table 8.13).

Table 8. 13 Northumbria Low Energy Trauma Score models for sensitivity, specificity and predictive values

Northumbria Low Energy Trauma Score	**Sensitivity**	**Specificity**	**Positive predictive value**	**Negative predictive value**	**Prevalence**	***X^2***	***Fishers exact test***
≥5	99.3	5.0	9.8	98.5	9.4	0.000	0.000
≥6	94.4	22.1	11.1	97.4	9.4	0.000	0.000
≥7	79.9	47.3	13.6	95.8	9.4	0.000	0.000
≥8	59.5	67.5	15.9	94.2	9.4	0.000	0.000
≥9	43.1	80.3	18.4	93.2	9.4	0.000	0.000
≥10	32.0	89.3	23.6	92.7	9.4	0.000	0.000
≥11	21.4	94.7	29.2	92.1	9.4	0.000	0.000
≥12	12.6	97.6	35.4	91.5	9.4	0.000	0.000
≥13	9.1	98.9	45.7	91.3	9.4	0.000	0.000

8.4 Discussion

Within the NTN data for all ages, males compromised 54.5% which is slightly lower than the national 59%. ISS mean was 13 but had a median of 9 which is the same as the national median. The mean age for all ages is 59 years with a median of 62 years which is higher than the national median of 57 years (Bouamra et al., 2015).

Within our data there is a considerable difference in mortality between the younger (<65 years) and older (≥65 years) groups. When comparing the two groups the older adults (≥65 years) have a lower mean ISS (12 compared to 14) but have a more than double rate of mortality. In those patients who died there was a 10 point mean difference in ISS between the younger (ISS 30) and older groups (ISS 20). This is also reflected in the work by Brown et al. (2019a) who also describe the higher incidence of poorer outcomes in older adult trauma. Their paper highlights that comorbidities and medications, which include anticoagulation, leave the older adult predisposed to poorer outcomes and they appear deceptively uninjured with normal physiology. Within this study comorbidities and medications (anticoagulation/platelet) were not available within the data. This is therefore an obvious limitation to the study and a limitation of the proposed Northumbria Low Energy Trauma Score. This should be taken into consideration for further research into the predictive model/triage tool/score.

There was also a significant shift in gender composition between the older and younger groups. For all age groups within the NTN data, male gender was 54.5% which is much lower than the national data (68-75.5%). When analysing gender between the younger and older groups there is almost a reversal of composition with males composing 67.5% in the younger group and 38.4% in the older group. This appears to be a dramatic shift for our region. In the 'Major Trauma in Older People' report (Trauma Audit and Research Network, 2017), this shift occurs in the ≥90 year group. However, the report does show a reducing male composition for every decade from age 60 which equalises at age 80-89 years (see Figure 7.1). This may have implications for developing a localised predictive model/triage tool/score and its utility in other regions.

Within the sample there were only 20 cases highlighted as ventilatory support (prehospital). In 19 of those cases, it was reported to highlight that ventilatory support was not required leaving only a single case of ventilatory support and therefore providing insufficient data to draw any conclusions from. Missing data is an obvious concern for this parameter for what would potentially be included within a predictive model/triage tool/score and therefore a significant limitation. It must however be a consideration when developing the model/tool/score for use in clinical practice as a potential further research study. Within the same context, prehospital GCS was missing from 47% of the sample and this also needs to be considered within future development of the model/tool/score. Maximum likelihood estimation as highlighted by Fuchs (1982) is a means to look at the missing data and its association with, in our case, outcome to see if it is missing at random. Mack et al. (2018) state that data that is missing completely at random (MCAR) has no systematic difference in cases with missing data and those cases with complete data. In this instance data available for analysis is reduced and therefore reduced statistical power of the analysis although it does not introduce bias. However, data missing at random (MAR) the missing data is systematically related to observed cases but not unobserved cases which may or may not introduce bias. The alternative is when data is missing not at random (MNAR) where data is systematically related to factors not measured and impacts upon estimate effects which will therefore likely be biased. As such, if our data is MNAR it will have implications for the final Northumbria Low Energy Trauma Score. Using simulations to test various methods for missing data, Enders and Bandalos (2001) acknowledge that listwise deletion and pairwise deletion have been applied to missing data by researcher to account for missing data they have no theoretical justification. They go on to state that full information maximum likelihood estimation provides the most efficient method of managing data that is missing at random.

Due to the bimodal nature of respiratory rate (i.e., worsens as it increases or decreases from normal parameters) it was utilised as a binary variable normal/non-normal. The development of the model did not make any difference when switching between binary, normal (0) and non-normal (1), and an incremental weighting of deviation from normal (i.e., score increasing from 0 to 3 as rate increases/decreases). The same was also found to be true for multiple injuries and therefore multiple injuries was utilised as No (0) and Yes (1) rather than using an increasing scale for aggregation of the number of injuries.

Prehospital GCS <15, head injury, age groups (<65, $\geq$65 years), prehospital SBP <110mmHg, gender, spinal injury, chest injury and multiple injury were all included within the binary logistic regression model. The Durbin-Watson test result of 1.92 highlights a normal reading with regards to autocorrelation between variables within the model (0.00-2.00= positive correlation, 2.00-4.00= negative correlation).

Within the model summary the R^2 accounted for 10% variance in the predictiveness of the model. Although this variance is low all other tests are significant and the model remains valid. With the addition of other independent variables that were not included within the data, such as comorbidities, frailty and medications (inc.

anticoagulation/platelet), it is believed the variance in the predictive nature of the model will be greatly improved. Although the data not included is available within the full TARN dataset is was not made available to the research team due to internal issues at TARN. Although not directly relating to issues with the dataset, the issues compromised their ability to provide extended datasets to external groups for research purposes at that time.

When analysing coefficients (Tables 8.7 to 8.9) within the regression analysis, prehospital GCS <15, head injury, age group, prehospital SBP <110mmHg, gender, spinal injury and chest injury all account for their individual association with outcome but also highlight that when combined they are significantly predictive of mortality (p <0.05).

The Northumbria Low Energy Trauma Score is a construct of key variables identified in previous chapters as potentially predictive in their own right and combined as an aggregated group model. It is heavily weighted for the older adult who experiences trauma. The method of weighting scores was also used by Shi et al. (2019) within various AIS components of the ISS to improve prediction of outcome. As the dominant mechanism of injury within this sample group originates from low energy mechanisms, such as a fall from standing height, it has comparative utility as a low energy trauma score (and why the name evolved from the mortality index to its present format). Most trauma triage tools focus on the high energy mechanisms and are widely used throughout the UK (Lecky et al., 2014). Doctor Jac Hardcastle, a consultant in emergency medicine from Northumbria Specialist Emergency Care Hospital (NSECH), defined her older (low energy MOI) trauma as *"stealth trauma"* as they often go unrecognised within the acute healthcare setting and often experience fatal outcomes (Hardcastle, 2018). The Northumbria Low Energy Trauma Score used within this study may support earlier identification of stealth trauma within the prehospital and hyper-acute healthcare setting.

A ROC curve generated a significant positive result for our predictive model using the Northumbria Low Energy Trauma Score. The sensitivity, specificity and predictive values were calculated for each threshold score from $\geq$5 to $\geq$13 all of which were statistically significant but may potentially be improved by additional independent variables (comorbidities, frailty, and medications). It must be noted that positive/negative predictive values as well as sensitivity and specificity may have great variance within disease prevalence (Brenner and Gefeller, 1997)

With the Northumbria Low Energy Trauma Score providing a statistically significant result, the development of a simple prehospital tool/score to identify those patients at risk of mortality is possible. Figure 8.3 highlights a potential model that extends the Northumbria Low Energy Trauma Score used within the analysis. It includes lactate levels, co-morbidities, medications, anticoagulants/antiplatelets, frailty score and body mass index. These additional criteria were identified in Chapter 3 but were unable to be tested within the current data. It is an aspiration of the author to validate the 'Northumbria Low Energy Trauma Score' in his post-doctoral research and apply it within the clinical setting as a smart device application. The lactate levels have been calculated on the results of a study conducted by Bernhard et al. (2020) who looked at the correlation between lactate and mortality. Their findings were used as markers and weighted within the score seen in Figure 8.3.

Northumbria Low Energy Trauma Score						
Indices/Score	**0**	**1**	**2**	**3**	**4**	**5**
Age (years)	<65			65-74	75-84	85+
Gender	Female	Male				
Head injury	No	Yes				
Chest injury	No	Yes				
Spinal injury	No	Yes				
Multiple injuries	No	Yes				
GCS	15	14	13	≤12		
SBP (mmHg)	≥110	110 - 90	<90			
Lactate (mmol/l)	0-1	2-3	4-5	6-7	8-9	10+
Comorbidities (number)	0	1	2	3	4+	
Medications (number)	0	1-2	3-4	5+		
Anticoagulants /antiplatelet	No	Yes				
Frailty score	1-2	3	4-5	6	7	8-9
BMI	Normal	Under/over weight	Obese	Morbidly obese		

Figure 8. 3 Extended Northumbria Low Energy Trauma Score

There is a maximum Northumbria Low Energy Trauma Score of 36 but testing is required to establish zones of clinical response. The concept should highlight patients with a low (green) score who may safely be managed with the community provided safety netting is in place. A moderate (amber) score would indicate patients who need further assessment within a care facility. A high (red) score would indicate patients who need immediate transport to an appropriate facility where consultant level decision makers are located alongside other specialist resources. There may also be a potential 'black zone' which may indicate those patients who, due to the extremis of their injuries and physiological reserve, may be palliated and should be managed appropriately.

Limitations

Regional NTN data may not reflect the national UK data and therefore limit the predictive model's utility outside of the local region, but it is believed that the data should be comparable within the UK setting. The independent variables of comorbidities, frailty and medications were not available within the data and further research is needed to explore these variables within the model to improve R^2 variance and sensitivity and specificity.

The weighted scores were based on the degrees from 'normal' clinical indices which were highlighted in the previous chapters (3, 6 and 7). As such, these weighted scores could potentially be developed further using similar discriminatory methods as used by Shi et al. (2019) who developed alternative weighted AIS to predict outcome from trauma. Missing data in key variables such as ventilatory support and GCS may account for some degree of variance. Ventilatory support data was almost completely missing from the data sample. Ongoing research will need to consider completeness of data and consider missing data and its random/non-random association with outcome.

Conclusions

A model using combining prehospital GCS <15, head injury, age groups (<65 and ≥65 years), prehospital SBP <110mmHg, gender, spinal injury, chest injury and multiple injuries was found to be predictive of mortality from low energy trauma within the prehospital setting. This is believed to be especially applicable to the older adult at high risk of mortality from trauma and may be improved with addition of comorbidities, frailty, and medications as independent variables. There is real potential to ultimately save life with regards to older adults who are described as stealth trauma as they are invisible and hidden and have consequential fatal consequences. The Northumbria Low Energy Trauma Score will raise awareness of those at risk and expedite their ongoing management to a consultant level decision maker within the ED. The main caveat to the Northumbria Low Energy Trauma Score in its current format is that it requires further validation and field testing within a clinical setting to ensure it is appropriate for everyday practice within the prehospital environment. It provides a statistically significant model but must be applied within a clinical setting and ensure it has clinical significance. This ongoing validation and testing will form part of ongoing post-doctoral research in collaboration with NEAS, Northumbria Healthcare Trust, NTN, and Northumbria University.

CHAPTER 9 GENERAL DISCUSSION AND CONCLUSIONS

9.1 Introduction

This thesis is the culmination of several linked studies with the intertwined narrative of what defines major trauma and how we improve the outcomes of older adults who experience major trauma. As a body of work, this thesis has explored the narrative from the perspective of the challenging prehospital environment. However, the empirical outcomes are also applicable to the hyper-acute setting that may include emergency medicine within the ED.

The exploratory nature of the initial study in Chapter 6 (Thompson et al., 2017) coalesced the aims of the overall thesis, namely to define major trauma in a pragmatic way that is appropriate to the prehospital and hyper-acute setting and to develop a predictive triage tool to identify older adults who experience trauma and are at risk of mortality and who may potentially benefit from early consultant level assessment and management.. The study highlighted the predictive values of indices specific to a single trauma network within the prehospital phase of care. However, the limitations of the study acknowledged that there is a disparity between what is manged by prehospital teams as major trauma and what is registered within TARN as major trauma. Existing triage tools appear to exclude low energy trauma (and therefore the majority of older adult trauma) and the older adult is often complex to assess due to delayed or masked physiological triggers. This initial study had the surprising finding that, in isolation, MOI had no significant correlation with outcome which reflected the work of Magnone et al. (2017) which was not published prior to my own research. With this in mind, why do we hold MOI in such regard when describing major trauma where low energy MOI can also lead to significant injury? The findings of this thesis should reinforce the concept that MOI can provide an index of suspicion when assessing trauma patients. However, it should not be considered as an absolute variable to select those who should be defined as major trauma, especially those who are rendered vulnerable by the extremities of age/frailty who are exposed to low energy MOI.

My own research was also corroborated by the recent work of others with regards to the under-triage of the older adult triage patient. Although the older adult/low energy cases are not initially perceived as major trauma, the surrogate marker of an ISS >15 in TARN data makes us question what we consider as major trauma as the older adult is always significantly under-triaged (Hoyle et al., 2020). Although trauma networks have matured we constantly refer to major trauma without a global and universal definition of major trauma within the field of trauma care (Alberdi et al., 2014). With this in mind defining major trauma became a priority of this thesis. Although the initial exploratory study concluded that the physiological indices of GCS and respiration rate have a significant correlation with outcome within the NTN prehospital data, age also has a significant correlation. It also concluded that the utility of existing triage tool indices should be questioned and that a *'load and go and play on the way'* method of intervention should be considered to improve outcomes by minimising on-scene times and expedient transfer to specialist resources.

Phase 1 defining major trauma

With the findings of the exploratory study giving focus for further research, the primary phase of this thesis critically reviewed and explored the definition of major trauma. The overall aim of this phase was to define major trauma in a pragmatic way that is appropriate to the prehospital and hyper-acute setting. The conceptual framework of exploring the definition of major trauma encompassed a review of the literature (Thompson et al., 2019b), alongside prehospital perspectives utilising focus groups (Thompson et al., 2019a), which would provide sufficient data to inform the content of the Delphi study to gain expert consensus to defining major trauma (Thompson et al., 2021). The lack of any standardised definition of major trauma was of some surprise where the use of retrospective scores such as ISS cannot define major trauma in the prehospital or hyper-acute setting and have little meaning to the lay person. Through the course of the three studies in the primary phase, my research refined the definition of major trauma through each consecutive study with each preceding study informing the content of the next. The critical review of the literature and critical exploration of the views and perceptions of prehospital clinicians provided the domains and content of the Delphi study which critically reviewed the degrees of consensus from an expert panel. No literature review, focus group or Delphi study to define major trauma had been undertaken prior to my own research. The qualitative aspect of the focus groups allowed for rich data to be explored which gave unique insights into concept that has not been published elsewhere. The Delphi study exploited the wealth of expertise within the NTN with regards to those who manage major trauma in the real world and was therefore not the abstract construct of academic concepts. Although the Delphi technique is a well-regarded tool in achieving expert consensus of experts within a field of practice it has not previously been applied to defining major trauma. My research has provided an elegant solution to defining major trauma which is applicable to all settings and both the specialist and non-specialist that is globally generalisable and extended to be applicable to idiosyncratic staged of care and different professional groups.

Phase 2 Older adult major trauma

The secondary phase of the thesis critically reviewed and explored the phenomenon of older adult trauma. The overall aim of this phase was to develop a predictive triage tool to identify older adults who experience trauma and at risk of mortality and who may potentially benefit from early consultant level assessment and management. The linked studies within this phase had the objective of identifying critical variables that would support the development of a trauma triage tool that would identify the older adult at significant risk of mortality from trauma.

The critical review of the combined literature/rapid evidence review once again reflected the issue of existing research within the field of older adult trauma care having an in-hospital focus with limited primary research generated from a prehospital or paramedicine origin. This review also noted the complexity of the older adult trauma patient where limited empirical data provides variables that identify the older adult at risk of mortality from trauma. Although the findings of the evidence were limited the combined review did highlight indices that were worthy of consideration within the development of a predictive model.

The DPS methodology was used to critically explore the complexity of the older adult trauma population. This appears to be the only research to use this method for the critical exploration of complexity and dynamic patterns with regards to the older adult trauma patient. Although the comprehensive data was explored using a well-structured and applied framework, I modified the technique further to improve the visualisation of the findings. This modified method may be the product of the specific dataset and/or the idiosyncrasies of my own methods of analysis. However, I do suggest that if applied to future projects using the DPS method it would simplify analysis regardless of the number of test samples. The variables under consideration generated a four-group cluster that after analysis proved inconclusive which was initially disappointing. Upon reflection this finding only reinforces the concept that the complexity of the older adult trauma population defies current modelling and there is huge variance within the NTN data used within this study.

The existing literature within the field of trauma care appears to originate from in-hospital resources or, to a lesser degree, physician led prehospital emergency medicine. The paucity of research that originates from a prehospital perspective highlights why the studies in this thesis are required which address the specific issues within the field of paramedicine and trauma care. The preceding chapters (as individual studies) begin to fill the void of prehospital trauma care research which specifically originates from a paramedic foundation as well as providing the specific focus on older adult trauma care. Although research within this specific area of older adult trauma is lacking, it is somewhat reassuring that related exploratory work has been undertaken by Elizabeth Brown and her colleagues in Australia with similar conclusions (Brown et al., 2019a, Brown et al., 2019b).

The final study within this thesis (Chapter 8) critically explored and applied the fundamental indices that may potentially identify the older adult at risk of mortality from trauma as a predictive model/triage tool. The utility of the combined indices identified were theorised to be greater than the sum of their individual predictive value. This study, which combined the variables, appears to be the first prehospital low energy trauma triage score that is heavily weighted for the older adult. When applying the tool to an existing TARN dataset it is significantly predictive of outcome (mortality). In its current format the 'Northumbria Low Energy Trauma Score' would complement the existing major trauma triage tool within the NTN region to potentially improve outcomes for all trauma patients within the region regardless of age or MOI.

The Northumbria Low Energy Trauma Score has potential implications for the field of trauma care. Using simple to acquire indices within the prehospital phase of care would see this elegant tool being applied to produce a numeric/colour coded score to enhance an initial trauma assessment to identify older adults at risk. Routinely acquired data by prehospital clinicians can now potentially expedite the ongoing care of our most vulnerable older adults and improve their outcomes through identifying those who need early consultant level decision makers involved with their ongoing care.

Both phases of this thesis have applied a systematic and rigorous approach to defining major trauma and developing a tool to identify the older adult at risk of mortality from trauma. The development of the ISS by Baker et al. (1974) must be acknowledged as the current international tool to provide a numerical context to a patients aggregated injury severity. It is a consistent area of relevance throughout this thesis and there are many parallels with its development and that of the development of the Northumbria Low Energy Trauma Score. The ISS was originally designed with minimal data from a single MOI (RTC's). We are now fortunate to have a national database maintained by TARN which has a comprehensive data set of all MOI's that was not available to Baker et al in the 1970's and therefore unfair to provide comparisons. The aim within the development of ISS was to determine if a linear correlation existed between aggregated AIS and mortality existed. It is somewhat humbling to build upon their seminal work by acknowledging and hopefully providing a solution to address their statement: *'increased mortality in the elderly is most pronounced when the injuries are least severe'.* It must also be acknowledged that in the origins of ISS only RTC's were taken into account and they did not consider alternative MOIs, especially low energy MOI such as a fall from standing height.

Future research

Future research will see the refining of the Northumbria Low Energy Trauma Score. The data used with the final study did not include certain indices such as comorbidities, medications, frailty, body mass index (BMI) and lactate additional (identified in Chapter 3) but were unable to be tested within the current data. Therefore, the Northumbria Low Energy Trauma Score will be validated against a new dataset which will soon include these variables. If the validation process is successful, we will apply it to clinical practice within the NTN region as a feasibility study prior to undertaking a much larger multicentre study. The Northumbria Low Energy Trauma Score is currently being developed as a smartphone application that could also be imbedded within current ambulance services electronic patient care records that would automatically pull data that is routinely recorded within the system to trigger a response if the score dictates.

Conclusion

The culmination of this thesis highlights two parsimonious yet elegant contributions to the existing body of research into trauma care. The first is the definition of major trauma: *"Perceived significant injury or injuries that have potential to be life-threatening or life-changing sustained from either high or low energy mechanisms which also considers the complexities encountered by the extremities of age"*. The second is the Northumbria Low

Energy Trauma Score which can be applied in any prehospital or acute care setting to identify the older adult at risk of mortality from low energy trauma who may benefit from early consultant level assessment and management.

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APPENDICES

APPENDIX 1. ETHICAL APPROVAL FOR FOCUS GROUPS (NORTHUMBRIA UNIVERSITY 5714)

Submission

Submission Ref	5714
Status	Approved
Submission Coordinator	Pauline Pearson pauline.pearson@northumbria.ac.uk
Name	lee.j.thompson
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Faculty	Health and Life Sciences
Department	Nursing, Midwifery & Health
Submitting As	PGR - Postgraduate Research studen
Externally Approved	Note: ONLY tick this box if your project has already received full ethical approval from an external organisation
Module Level Approval	*Tick this box if staff and this submission refers to an entire module.*
Module Code	*Type a value* Help
Module Tutor	Find Help Clear
	Titl...
	De...
	Em...
Research Supervisor	Michael Hill Find Help Clear
	Titl... Associate Professor
	De... Health and Life Sciences
	Em... michael.hill@northumbria.ac.uk
Ethical Risk Level	Medium

Risk Level Conditions:

Your ethical risk is **medium**. Your research should only consist of one or more of the following:
- Non-vulnerable adults
- Non-sensitive personal data referring to a living individual
- Secondary data not in the public domain
- Environmental issues
- Commercially sensitive information

Your project proposal has some ethical implications and will be reviewed by one independent reviewer appointed by your Faculty Research Ethics Committee. Some factors to be considered include considering obtaining informed consent forms from organisations or people involved, permission to use data from the Data Controller, as well as confidentiality/anonymity issues.

G1: General Aims and Research Design (Mandatory)

Title

Title of your research project

A focus group to gain perceptions for defining major trauma in the pre-hospital phase of care.

Outline General Aims and Research Objectives

State your research aims/questions (maximum 500 words). This should provide the theoretical context within which the work is placed, and should include an evidence-based background, justification for the research, clearly stated hypotheses (if appropriate) and creative enquiry.

What is the purpose of the study?
Defining Major Trauma:
The last 5 years has seen many advances in trauma care with the introduction of dedicated trauma networks being established within England and now within the rest of the United Kingdom (UK). Many disciplines are involved with each individual trauma patients journey of care from the initial incident in the pre-hospital phase of care to rehabilitation. The term 'Major Trauma' will have a different meaning for each individual and it is poorly defined within the literature.
The National Audit Office 2010 report 'Major trauma care in England' stated that "Major trauma describes serious and often multiple injuries where there is a strong possibility of death or disability" and, along with many other documents, research papers and reports, refer to patients with high injury severity scores as 'Major Trauma'. These scores are given retrospectively after advanced imaging and assessments which are not available in the pre-hospital or hyper-acute phase of patient care.
Major Trauma Triage Tools support the clinical decision making for identifying patients who may be candidates for definitive care at a Major Trauma Centre. However, these tools are limited in their utility and only identify 40% of patients with high injury severity scores.
Throughout the literature and due to the poor specificity of trauma triage tools there is a general lack of consensus existing in regard to defining 'Major Trauma'.
The aim of this focus group is to identify the key aspects of Major Trauma from a pre-hospital perspective that will give a pre-hospital definition for 'Major Trauma'.

G2: Research Activities (Mandatory)

Please give a detailed description of your research activities

Please provide a description of the study design, methodology (e.g. quantitative, qualitative, practice based), the sampling strategy, methods of data collection (e.g. survey, interview, experiment, observation, participatory), and analysis. Do sensitive topics such as trauma, bereavement, drug use, child abuse, pornography, extremism or radicalisation inform the research? If so have these been fully addressed?

Methods: A qualitative study using focus group methodology.
The focus group will systematically collate opinion on what defines major trauma and paramedic perceptions of introducing new spinal motion restriction techniques.
The focus group will comprise of facilitator who will present semi-structured questions to a homogenous group of paramedics. The objective is to obtain accurate data on a limited range of specific issues and within a social context where participants consider their own views in relation to others.
There will be three individual focus group sessions with the expectation of recruiting a minimum of 10 participants per session. Each session will last between 1 and 2 hours.
The sessions will be recorded using digital sound recording equipment which will then be transcribed for analysis.
Why use focus groups:
The main reason to use focus groups over other methods (individual interviews, observation, surveys) is to draw upon participants feelings and beliefs that may be distilled or explored and influenced within the group context (Frey and Fontana, 1991). It also allows for a large amount of data to be collected in a relatively short period of time when compared to other methods. Focus groups can also explore the degree of consensus on a given topic (Morgan, 1997). This is believed to be the overall aim of the focus group, however, group work can be dominated by individual characters and potentially more difficult to control. It will require the facilitator to allow participants to communicate but semi-structured questions can maintain a focus on the subject while allowing productive digressions to flow and develop new ideas and knowledge (DiCicco-Bloom and Crabtree, 2006).
Analysis:
Thematic Analysis for free text will be used (Dick, 2005) utilising the five stage data analysis framework suggested by Pope and Mays, (2006).
Background data will use Cluster Analysis (Mooi and Sarstedt, 2011).
Mann Whitney and Kruskal-Wallis tests will explore differences in opinion.

APPENDIX 2. FOCUS GROUP PARTICIPANT INFORMATION SHEET

Focus Group Participant Information Sheet

Project title:	Focus group to gain consensus for defining major trauma in the pre-hospital phase and perceptions of new spinal motion restriction principles.

Chief Investigator information

Name:	**Lee Thompson**

Faculty:	**Health and Life Sciences**
Department:	**PG Research**
Email: **Tel:**	lee.thompson@neas.nhs.uk **0 (+44) 191 430 2399**
Principal Supervisor (if relevant):	**Dr Michael Hill, Northumbria University.** michael.hill@northumbria.ac.uk **0 (+44) 191 215 6623**
Northumbria University Ethics Sub. Ref. No:	**????**
Please list your co-investigators (if relevant):	**N/A**
IRAS Project ID	**?????**
NEAS R&D No:	**NEAS/2018/????**
Version: **Date:**	**V1.0** **13/01/2018**

FOCUS GROUP INFORMATION SHEET

We would like to invite you to take part in a focus group to gain consensus for defining major trauma in the pre-hospital phase and obtain your perceptions of new spinal motion restriction principles. Before you decide whether or not you would like to take part, it is important for you to consider why the research is being done and what it will involve. Please read this information sheet carefully.

What is a Focus Group?

The focus group technique seeks to obtain consensus on the opinions of the group members through a series of open semi-structured questions. As part of the process, a moderator will facilitate discussions in a purposeful and open way, making sure everyone has the opportunity to take part. The opinions and influences of other members of the group may help shape and inform individuals opinions. This will allow for creative thinking to conceptualise abstract ideas. The responses from each focus group will be summarised in a report to highlight themes and trends. The focus group is therefore part of an iterative multi-stage process designed to combine opinion into group consensus. However, there may be obvious differences of opinion with the group.

What is the purpose of the study?

a. **Defining Major Trauma:**

The last 5 years has seen many advances in trauma care with the introduction of dedicated trauma networks being established within England and now within the rest of the United Kingdom (UK). Many disciplines are involved with each individual trauma patients journey of care from the initial incident in the pre-hospital phase of care to rehabilitation. The term 'Major Trauma' will have a different meaning for each individual and it is poorly defined within the literature.

The National Audit Office 2010 report 'Major trauma care in England' stated that "*Major trauma describes serious and often multiple injuries where there is a strong possibility of death or disability*" and, along with many other documents, research papers and reports, refer to patients with high injury severity scores as 'Major Trauma'. These scores are given retrospectively after advanced imaging, assessments and interventions have been undertaken and, as such, are not available in the pre-hospital or hyper-acute phase of patient care.

Major Trauma Triage Tools/Protocols support the clinical decision making for identifying patients who may be candidates for definitive care at a Major Trauma Centre. However, these tools are limited in their utility and only identify 40% of patients with high injury severity scores (age 16 to 59) (Trauma Audit and Research Network, 2017).

Throughout the literature and due to the poor specificity of trauma triage tools there is a general lack of consensus existing in regard to defining 'Major Trauma'.

b. **Spinal Motion Restriction Feasibility (SMRF) Study:**

The Spinal Motion Restriction Feasibility (SMRF) study is a randomised prospective two centre study comparing patient outcomes between two management options for patients experiencing potential spinal cord injury (SCI).

Within the UK, cervical Spinal Cord Injury (SCI) is a rare event. Traditional three-point immobilisation (rigid collar, head blocks and tape) for spinal stabilisation has been the standard clinical practice for trauma patients with suspected cervical SCI for over 50 years. These practices are based on little more than isolated case studies and limited consensus agreement and have become so engrained within trauma management culture that it is difficult to change current practice.

Contemporary literature and consensus reports are now challenging traditional practices in favour of a pragmatic second generation of supportive techniques that follow patient centred Spinal Motion

Restriction principles. Spinal Motion Restriction principles include moving away from the routine application of rigid collars and back boards, encouraging self-extrication when appropriate, manual in line stabilisation and alternative approaches to Spinal Motion Restriction while improving patient comfort. These principles empower clinicians to tailor their approach to Spinal Motion Restriction and ensure effective and safe patient centred care.

The new Spinal Motion Restriction protocol may cause some concern with existing Emergency Medical Service (EMS) providers as it is a considerable shift from current clinical practice. The focus group gives an opportunity to highlight concerns and gain a pre-hospital perspective of this proposed change in practice.

The aim of this focus group is to identify the key aspects of Major Trauma that will give a definition for 'Major Trauma' through group consensus. It is also the aim to gain a pre-hospital perspective of the new proposed Spinal Motion Restriction protocol.

Why have I been invited to take part?

As an established EMS clinician within this field, the research team wish to gain your views about which variables define a 'Major Trauma' patient within your area of expertise. Specifically, we would like to ask your views on the predictive value of a range of demographic, clinical, and trauma-related variables.

The impact of introducing new Spinal Motion Restriction protocols is unknown and, as it will be implemented by EMS staff, the research team wish to understand the implications of such a change in practice from the very members of staff who will be directly involved. We plan to recruit 30 participants over three focus groups consisting of EMS clinicians who are exposed to Major Trauma.

What will I be asked to do if I take part?

We are inviting you to participate as a focus group panel member. This would involve participating in a group discussion (maximum of 20 people) using open, semi-structured questions which will be facilitated by the lead researcher. It is envisaged that this should take approximately 60 minutes. The focus group will be structured to be very informal in a relaxed environment. You would subsequently receive an update of the findings of the focus group if requested.

Who is organising and funding the research?

This research is part of a PhD studying Major Trauma. There are no conflicts of interest and the study does not receive any funding.

The study is sponsored by North East Ambulance Service NHS Foundation Trust.

The focus group will be conducted by Lee Thompson, a PhD student at Northumbria University and Specialist Paramedic for Trauma with North East Ambulance Service NHS Foundation Trust. The study is supervised by Dr Mick Hill and Dr Peter McMeekin of Northumbria University and Professor Fiona Lecky of Sheffield University.

Confidentiality

No personal information will be collected and group responses will be collated anonymously using an identifying number known only to the lead researcher. Some background information such as area of practice, length of experience in practice and experience within Major Trauma may be used. All responses received during the focus group will be strictly confidential, and your identity will not be divulged. Direct quotes may be used as part of the study report/publication or later iterations of the research area, but these will not be traceable back to you.

Data protection

Focus group responses will be recorded using digital recording equipment and saved in mp3 format. The data will then be transcribed and stored on an encrypted Northumbria University network to allow analysis by the research team. To comply with the Northumbria University research data management policy, data for research projects must be retained in an appropriate format for at least ten years from the end of the project. This is in accordance with Northumbria University's Research Records Retention Schedule.

https://www.northumbria.ac.uk/static/5007/respdf/data-prot_secure_storage.pdf

https://www.northumbria.ac.uk/research/research-data-management/-/media/corporate-website/documents/pdfs/research/research-data-management-policy-version-7.ashx

You have the right to access submitted information in accordance with UK data protection laws.

Research ethics

The proposed focus group has been through a process of ethical review and permission has been granted for this study by Northumbria University Faculty of Health and Life Sciences Ethics Committee.

A copy of the Northumbria University ethics committee application and decision letter is available on request.

All participants will be asked to complete a consent form.

What do I do now?

Thank you for reading this information sheet and for considering taking part in this research. Please let us know whether or not you would like to take part by replying to this email/document. If you wish to participate, we would be very grateful if you could also complete the attached consent form.

If you have any questions or concerns, please do not hesitate to contact me.

Name Lead Researcher:	**Lee Thompson**	**Date:**	**13th January 2018**
Signature:			

APPENDIX 3. FOCUS GROUP PARTICIPANT CONSENT FORM

Focus Group Participant Consent Form

Project title:	Focus group to gain consensus for defining major trauma in the pre-hospital phase and perceptions of new spinal motion restriction principles.

Lead Researcher information

Name:	**Lee Thompson**

Faculty:	**Health and Life Sciences**
Department:	**PG Research**
Email: **Tel:**	lee.thompson@neas.nhs.uk **0 (+44) 191 430 2399**
Principal Supervisor (if relevant):	**Dr Michael Hill, Northumbria University.** michael.hill@northumbria.ac.uk **0 (+44) 191 215 6623**
Northumbria University Ethics Sub. Ref. No:	
Please list your co-investigators (if relevant):	**N/A**
IRS Project ID	
NEAS R&D No:	**NEAS/2017/**
Version: **Date:**	**V0.1** **12/12/2017**

Participant Identification Number for this project

Number:	

	☒
1. I confirm that I have read and understand the participant information sheet explaining the above research project and I have had the opportunity to ask questions about the project.	☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline.	☐
3. I give permission for my anonymised responses to be used during the research process, and to be accessed by members of the research team. I understand that my name will not be linked with the research materials, and I will not be identifiable during the research process or in the reports that result from the research.	☐
4. I agree to take part in the above research project.	☐
5. I understand that the data collected during the focus group discussion may be used for the purposes of both a final report of the above study as well as purposes of subsequent academic publication, further research and teaching.	☐

I wish to be updated as to the outcomes of the study and wish to be sent a copy of the initial report and/or publication.	☐
Email address:	

Name of Participant:		Date:	
Signature:			

Name Lead Researcher:	Lee Thompson	Date:	29/11/2017
Signature:			

Completion:

Please return scanned or electronically completed forms via email to:

lee.thompson@neas.nhs.uk

Or return hard copies to:

Lee Thompson, Trauma Team, Emergency Operations Centre, North East Ambulance Service NHS Foundation Trust, Bernicia House, Goldcrest Way, Newburn Riverside, Newcastle Upon Tyne. NE15 8NY.

Further information: Please do not hesitate to contact the lead researcher if you have any concerns or questions.

Contact details:

Lee Thompson. Tel: 0 (+44) 191 430 2399, email: lee.thompson@neas.nhs.uk

Michael Hill. Tel: 0 (+44) 191 215 6623, email: Michael.hill@northumbria.ac.uk

Copies: Please retain a copy of the completed consent from for your personal records. An additional copy will be held in a North East Ambulance Service secure location for the duration of the research study.

APPENDIX 4. NEAS RESEARCH AND DEVELOPMENT LETTER OF SUPPORT FOR DELPHI STUDY

North East Ambulance Service NHS
NHS Foundation Trust

For Life

Research & Development Department
Ambulance Headquarters
Bernicia House
The Waterfront
Goldcrest Way
Newburn Riverside
Newcastle upon Tyne
NE15 8NY

Tel: 0191 430 2192
Fax: 0191 430 2082

Mr Lee Thompson
NEAS HQ
Bernicia House
Goldcrest Way
Newburn Riverside
Newcastle Upon Tyne
NE15 8NY

11 December 2017

Dear Lee Thompson

Re: Delphi study to gain consensus for defining major trauma and identifying major trauma in the pre-hospital phase

I am writing to inform you that having reviewed the information submitted I am satisfied that there are no outstanding governance requirements at this time.

In my capacity as Research & Development Manager for North East Ambulance Service NHS Foundation Trust, I can confirm that the Research Department support the research application and associated proposal for your research project. I look forward to hearing the results of your research in due course.

Yours sincerely

MJackson

Michelle Jackson
Research & Development Manager

APPENDIX 5. ETHICAL APPROVAL FOR DELPHI STUDY (NORTHUMBRIA UNIVERSITY 4219; IRAS ID 237977)

Submission

Submission Ref	4219
Status	Approved
Submission Coordinator	Pauline Pearson pauline.pearson@northumbria.ac.uk
Name	lee.j.thompson
Email	lee.j.thompson@northumbria.ac.uk
Faculty	Health and Life Sciences
Department	Nursing, Midwifery & Health
Submitting As	PGR - Postgraduate Research studen
Externally Approved	Note: ONLY tick this box if your project has already received full ethical approval from an external organisation
Module Level Approval	*Tick this box if staff and this submission refers to an entire module.*
Module Code	*Type a value* Help
Module Tutor	Find Help Clear
	Titl...
	De...
	Em...
Research Supervisor	Michael Hill Find Help Clear
	Titl... Associate Professor
	De... Health and Life Sciences
	Em... michael.hill@northumbria.ac.uk
Ethical Risk Level	Medium

Risk Level Conditions:

Your ethical risk is **medium**. Your research should only consist of one or more of the following:
- Non-vulnerable adults
- Non-sensitive personal data referring to a living individual
- Secondary data not in the public domain
- Environmental issues
- Commercially sensitive information

Your project proposal has some ethical implications and will be reviewed by one independent reviewer appointed by your Faculty Research Ethics Committee. Some factors to be considered include considering obtaining informed consent forms from organisations or people involved, permission to use data from the Data Controller, as well as confidentiality/anonymity issues.

G1: General Aims and Research Design (Mandatory)

Title

Title of your research project

A Delphi study to gain consensus for defining major trauma and identifying major trauma in the pre-hospital phase.

Outline General Aims and Research Objectives

State your research aims/questions (maximum 500 words). This should provide the theoretical context within which the work is placed, and should include an evidence-based background, justification for the research, clearly stated hypotheses (if appropriate) and creative enquiry.

Aim: To undertake a Delphi study to develop a consensus statement defining what constitutes 'Major Trauma' and how this may be identified in the pre-hospital environment.

Questions:
1. What is the definition of 'Major Trauma'?
2. How can we identify Major Trauma in the pre-hospital environment?

G2: Research Activities (Mandatory)

Please give a detailed description of your research activities

Please provide a description of the study design, methodology (e.g. quantitative, qualitative, practice based), the sampling strategy, methods of data collection (e.g. survey, interview, experiment, observation, participatory), and analysis. Do sensitive topics such as trauma, bereavement, drug use, child abuse, pornography, extremism or radicalisation inform the research? If so have these been fully addressed?

Methods: A mixed methods (quantitative, qualitative) Delphi study.
A Delphi technique will systematically collate expert opinion on what defines major trauma and how it can be identified in the pre-hospital phase.
The technique employs a series of rounds beginning with open questionnaire seeking the opinion of a chosen panel of experts. The open questions will have an opportunity to discuss rationale of answers within free text. It is believed a pilot study will be required to ensure the technique and questionnaire is appropriate.
Levels of agreement of statements or importance of issues between experts will then be analysed along with relevant background information (profession, years experience in Major Trauma and whether they are part of a major trauma team). Feedback from these results will be given to the members of expert panel along with the following round of questionnaires. Three iterations of questionnaires and feedback allows the expert panel to review their previous answers with the information provided by other members of the expert panel. It is believed this method will distil expert opinion to obtain a common consensus of the whole panel.
Closed questions will be scored using a five-point Likert scale.
Online survey software will be used to perform the questionnaires:
https://www.surveymonkey.co.uk/
Analysis:
Thematic Analysis for free text (Dick, 2005).
Background data will use Cluster Analysis (Mooi and Sarstedt, 2011).
Mann Whitney and Kruskal-Wallis tests will explore differences in opinion based on background (e.g. Profession).

Ymchwil Iechyd a Gofal Cymru
Health and Care Research Wales

NHS
Health Research Authority

Mr Lee Thompson
Specialist Paramedic for Trauma
North East Ambulance Service
Ambulance HQ, Emergency Operations Centre
Bernicia House, Goldcrest Way,
Newburn Riverside, Newcastle Upon Tyne
NE15 8NY

Email: hra.approval@nhs.net
Research-permissions@wales.nhs.uk

01 August 2018

Dear Mr Thompson

HRA and Health and Care Research Wales (HCRW) Approval Letter

Study title:	**A Delphi study to gain consensus for defining major trauma and identifying major trauma in the pre-hospital phase.**
IRAS project ID:	**237977**
REC reference:	**18/HRA/0447**
Sponsor	**North East Ambulance Service NHS Foundation Trust**

I am pleased to confirm that **HRA and Health and Care Research Wales (HCRW) Approval** has been given for the above referenced study, on the basis described in the application form, protocol, supporting documentation and any clarifications received. You should not expect to receive anything further relating to this application.

How should I continue to work with participating NHS organisations in England and Wales?
You should now provide a copy of this letter to all participating NHS organisations in England and Wales, as well as any documentation that has been updated as a result of the assessment.

Following the arranging of capacity and capability, participating NHS organisations should **formally confirm** their capacity and capability to undertake the study. How this will be confirmed is detailed in the "*summary of assessment*" section towards the end of this letter.

You should provide, if you have not already done so, detailed instructions to each organisation as to how you will notify them that research activities may commence at site following their confirmation of capacity and capability (e.g. provision by you of a 'green light' email, formal notification following a site initiation visit, activities may commence immediately following confirmation by participating organisation, etc.).

It is important that you involve both the research management function (e.g. R&D office) supporting each organisation and the local research team (where there is one) in setting up your study. Contact details of the research management function for each organisation can be accessed here.

How should I work with participating NHS/HSC organisations in Northern Ireland and Scotland?
HRA and HCRW Approval does not apply to NHS/HSC organisations within the devolved administrations of Northern Ireland and Scotland.

If you indicated in your IRAS form that you do have participating organisations in either of these devolved administrations, the final document set and the study wide governance report (including this letter) has been sent to the coordinating centre of each participating nation. You should work with the relevant national coordinating functions to ensure any nation specific checks are complete, and with each site so that they are able to give management permission for the study to begin.

Please see IRAS Help for information on working with NHS/HSC organisations in Northern Ireland and Scotland.

How should I work with participating non-NHS organisations?
HRA and HCRW Approval does not apply to non-NHS organisations. You should work with your non-NHS organisations to obtain local agreement in accordance with their procedures.

What are my notification responsibilities during the study?
The attached document *"After HRA Approval – guidance for sponsors and investigators"* gives detailed guidance on reporting expectations for studies with HRA and HCRW Approval, including:

- Registration of Research
- Notifying amendments
- Notifying the end of the study

The HRA website also provides guidance on these topics and is updated in the light of changes in reporting expectations or procedures.

I am a participating NHS organisation in England or Wales. What should I do once I receive this letter?
You should work with the applicant and sponsor to complete any outstanding arrangements so you are able to confirm capacity and capability in line with the information provided in this letter.

The sponsor contact for this application is as follows:

Name: Ms Michelle Jackson

Tel: 01914302000

Email: michelle.jackson@neas.nhs.uk

Who should I contact for further information?
Please do not hesitate to contact me for assistance with this application. My contact details are below.

Your IRAS project ID is **237977**. Please quote this on all correspondence.

Yours sincerely

Aliki Sifostratoudaki
Assessor

Email: hra.approval@nhs.net

Copy to: *Mrs Michelle Jackson, North East Ambulance Service NHS Foundation Trust, Sponsor and R&D contact*

IRAS project ID	237977

List of Documents

The final document set assessed and approved by HRA and HCRW Approval is listed below.

Document	*Version*	*Date*
HRA Schedule of Events [237977_SOE_PICs_Assessed by HRA]	1	01 August 2018
HRA Statement of Activities [237977_SOA_PICs_Assessed by the HRA]	1	01 August 2018
IRAS Application Form [IRAS_Form_07012018]		07 January 2018
Letter from sponsor [NEAS letter of support for research]		08 December 2014
Participant consent form [Delphi participant consent for v3.3 190618LT]	3.3	19 June 2018
Participant information sheet (PIS) [Delphi Participant Information Sheet MT v2.3 260618LT]	2.3	26 June 2018
Research protocol or project proposal [Northumbria University research ethics proposal for Delphi Study]	v3.2	05 December 2017
Summary CV for Chief Investigator (CI) [Curriculum Vitae]		03 January 2018

IRAS project ID	237977

Summary of assessment

The following information provides assurance to you, the sponsor and the NHS in England and Wales that the study, as assessed for HRA and HCRW Approval, is compliant with relevant standards. It also provides information and clarification, where appropriate, to participating NHS organisations in England and Wales to assist in assessing, arranging and confirming capacity and capability.

Assessment criteria

Section	Assessment Criteria	Compliant with Standards	Comments
1.1	IRAS application completed correctly	Yes	The Applicant clarified that there will be one site type involved for this study, Participant Identification Centres (PICs).
2.1	Participant information/consent documents and consent process	Yes	No comments
3.1	Protocol assessment	Yes	No comments
4.1	Allocation of responsibilities and rights are agreed and documented	Yes	The Sponsor contact has confirmed that the Statement of Activities and the Schedule of Events will form the agreement between the Sponsor and the research sites. No judgement on the cost attributions has been made.
4.2	Insurance/indemnity arrangements assessed	Yes	The Applicant clarified that as the Sponsor is the North East Ambulance Service NHS Foundation Trust, the management and design of the study will be covered by NHS indemnity and not by the Northumbria University indemnity.
4.3	Financial arrangements assessed	Yes	This study is not receiving external funding.
5.1	Compliance with the Data Protection Act and data security issues assessed	Yes	No comments

Section	Assessment Criteria	Compliant with Standards	Comments
5.2	CTIMPS – Arrangements for compliance with the Clinical Trials Regulations assessed	Not Applicable	No comments
5.3	Compliance with any applicable laws or regulations	Yes	No comments
6.1	NHS Research Ethics Committee favourable opinion received for applicable studies	Not Applicable	No comments
6.2	CTIMPS – Clinical Trials Authorisation (CTA) letter received	Not Applicable	No comments
6.3	Devices – MHRA notice of no objection received	Not Applicable	No comments
6.4	Other regulatory approvals and authorisations received	Not Applicable	No comments

Participating NHS Organisations in England and Wales

This provides detail on the types of participating NHS organisations in the study and a statement as to whether the activities at all organisations are the same or different.

There is one site type involved in this study, PICs. PICs will be responsible for identifying potential participants.

The Chief Investigator or sponsor should share relevant study documents with participating NHS organisations in England and Wales in order to put arrangements in place to deliver the study. The documents should be sent to both the local study team, where applicable, and the office providing the research management function at the participating organisation. Where applicable, the local LCRN contact should also be copied into this correspondence.

If chief investigators, sponsors or principal investigators are asked to complete site level forms for participating NHS organisations in England and Wales which are not provided in IRAS, the HRA or HCRW websites, the chief investigator, sponsor or principal investigator should notify the HRA immediately at hra.approval@nhs.net or HCRW at Research-permissions@wales.nhs.uk. We will work with these organisations to achieve a consistent approach to information provision.

IRAS project ID	237977

Principal Investigator Suitability

This confirms whether the sponsor position on whether a PI, LC or neither should be in place is correct for each type of participating NHS organisation in England and Wales, and the minimum expectations for education, training and experience that PIs should meet (where applicable).
A key contact would be expected to identify potential participants. GCP training is not a generic training expectation, in line with the HRA/HCRW/MHRA statement on training expectations.

HR Good Practice Resource Pack Expectations

This confirms the HR Good Practice Resource Pack expectations for the study and the pre-engagement checks that should and should not be undertaken
No HR arrangements would be expected for the external research team (for PIC sites) as no study activities will be undertaken at these sites.

Other Information to Aid Study Set-up

This details any other information that may be helpful to sponsors and participating NHS organisations in England and Wales to aid study set-up.
The applicant has indicated that they do not intend to apply for inclusion on the NIHR CRN Portfolio.

APPENDIX 6. DELPHI STUDY PARTICIPANT INFORMATION SHEET

Delphi Study Participant Information Sheet

Northumbria University NEWCASTLE

Project title:	Delphi study to gain consensus for defining major trauma and identifying major trauma in the prehospital phase.

Lead Researcher information

Name:	**Lee Thompson**

Faculty:	**Health and Life Sciences**
Department:	**PG Research**
Email: **Tel:**	lee.thompson@neas.nhs.uk **0 (+44) 191 430 2399**
Principal Supervisor (if relevant):	**Dr Michael Hill, Northumbria University.** michael.hill@northumbria.ac.uk **0 (+44) 191 215 6623**
Northumbria University Ethics Sub. Ref. No:	**4219**
Please list your co-investigators (if relevant):	**N/A**
IRAS Project ID	**237977**
NEAS R&D No:	**NEAS/2017/237977**
HRA. Central Booking Service Ref:	**18/HRA/0447**
Version: **Date:**	**V2.2** **13/01/2018**

DELPHI STUDY INFORMATION SHEET

We would like to invite you to take part in a Delphi consensus study. Before you decide whether or not you would like to take part, it is important for you to consider why the research is being done and what it will involve. Please read this information sheet carefully.

What is a Delphi study?

The Delphi technique seeks to obtain consensus on the opinions of experts, termed panel members, through a series of structured questionnaires. As part of the process, the responses from each round are fed back in summarised form to the participants who are then given an opportunity to respond again to the emerging data. The Delphi is therefore an iterative multi-stage process designed to combine opinion into group consensus.

What is the purpose of the study?

The last 5 years has seen many advances in trauma care with the introduction of dedicated trauma networks being established within England and now within the rest of the United Kingdom. Many disciplines are involved with each individual trauma patients journey of care from the initial incident in the prehospital care to rehabilitation. The term 'Major Trauma' will have a different meaning for each individual and it is poorly defined within the literature.

The National Audit Office 2010 report 'Major trauma care in England' stated that "*Major trauma describes serious and often multiple injuries where there is a strong possibility of death or disability*" and, along with many other documents, research papers and reports, refer to patients with high injury severity scores as 'Major Trauma'. These scores are given retrospectively after advanced imaging, assessments and interventions have been undertaken and, as such, are not available in the prehospital or hyper-acute phase of patient care.

Major Trauma Triage Tools/Protocols support the clinical decision making for identifying patients who may be candidates for definitive care at a Major Trauma Centre, however, these tools are limited in their utility and only identify 40% of patients with high injury severity scores (age 16 to 59) (Trauma Audit and Research Network, 2017).

Throughout the literature and due to the poor specificity of trauma triage tools there is a general lack of consensus existing in regard to defining 'Major Trauma'.

The purpose of this Delphi study is to identify the key aspects of Major Trauma that will give us a definition for 'Major Trauma' through group expert consensus. It is believed that a common expert consensus on the definition of 'Major Trauma' will inform, and improve upon existing, clinical decision-making tools to identify those patients who will benefit from definitive care at a Major Trauma Centre.

The aim of this Delphi study is to provide a common definition for 'Major Trauma' through a consensus agreement of expert panel members.

Why have I been invited to take part?

As an established expert in this field, we are keen to gain your views about which variables define a 'Major Trauma' patient within your area of expertise. Specifically, we would like to ask your views on the predictive value of a range of demographic, clinical, and trauma-related features. We plan to recruit 50 participants consisting of Paramedics, Prehospital Emergency Medicine Physicians

Emergency Medicine Physicians, Anaesthetic, Intensive Care and Surgical staff as well as academics who specialise in Major Trauma.

What will I be asked to do if I take part?

We are inviting you to participate as a Delphi panel member. This would involve completing a brief questionnaire, rating possible predictors of 'Major Trauma' using an online survey. It is envisaged that this should take approximately 30 minutes. You would subsequently receive a reminder of your ratings, a summary of the group's responses and a further online questionnaire to re-rate the original list of predictors. This process would continue until a group consensus is achieved or three Delphi rounds have been completed. To allow timely conclusion of the study we would respectfully request a response time of 1 week for completion of each round.

Who is organizing and funding the research?

This research is part of a PhD into Major Trauma. There are no conflicts of interest and the study does not receive and funding.

The study is sponsored by North East Ambulance Service NHS Foundation Trust.

The Delphi study will be conducted by Lee Thompson, a PhD student at Northumbria University and Specialist Paramedic for Trauma with North East Ambulance Service NHS Foundation Trust. The study is supervised by Dr Mick Hill and Dr Peter McMeekin of Northumbria University and Professor Fiona Lecky of Sheffield University.

Confidentiality

No personal information will be collected and survey responses will be collated anonymously using an identifying number known only to the participant and lead investigator. Some background information such as area of practice, length of experience in practice and experience within Major Trauma may be used. All responses received in the study will be strictly confidential, and your identity will not be divulged. Direct quotes to free-text answers may be used as part of the study report or later Delphi iterations or research area, but these will not be traceable back to you.

Data protection

Survey responses will be collected online using a quality-assured survey company, utilising an encrypted internet server. Further information is available from https://www.surveymonkey.co.uk/mp/policy/security/

Results will be downloaded to an encrypted Northumbria University network to allow analysis by the research team. To comply with the Northumbria University research data management policy, data for research projects must be retained in an appropriate format for at least ten years from the end of the project. This is in accordance with Northumbria University's Research Records Retention Schedule.

https://www.northumbria.ac.uk/static/5007/respdf/data-prot_secure_storage.pdf

https://www.northumbria.ac.uk/research/research-data-management/-/media/corporate-website/documents/pdfs/research/research-data-management-policy-version-7.ashx

You have the right to access submitted information according to UK data protection laws.

Research ethics

The proposed Delphi study has been through a process of ethical review and permission has been granted for this study Northumbria University Faculty of Health and Life Sciences Ethics Committee.

A copy of the Northumbria University ethics committee application and decision letter is available on request.

All participants will be asked to complete a consent form.

What do I do now?

Thank you for reading this information sheet and for considering taking part in this research. Please let us know whether or not you would like to take part by replying to this email. If you wish to participate, we would be very grateful if you could also complete the attached consent form.

If you have any questions or concerns, please do not hesitate to contact me.

Name Lead Researcher:	**Lee Thompson**	**Date:**	**13 January 2018**
Signature:			

APPENDIX 7. DELPHI STUDY PARTICIPANT CONSENT FORM

Northumbria University NEWCASTLE

Delphi Study Consent Form

Project title:	Delphi study to gain consensus for defining major trauma and identifying major trauma in the prehospital phase.

Lead Researcher information

Name:	**Lee Thompson**

Faculty:	**Health and Life Sciences**
Department:	**PG Research**
Email: **Tel:**	lee.thompson@neas.nhs.uk **0 (+44) 191 430 2399**
Principal Supervisor (if relevant):	**Dr Michael Hill, Northumbria University.** michael.hill@northumbria.ac.uk **0 (+44) 191 215 6623**
Northumbria University Ethics Sub. Ref. No:	**4219**
Please list your co-investigators (if relevant):	**N/A**
IRS Project ID	**237977**
NEAS R&D No:	**NEAS/2017/237977**
HRA Central Booking Service Ref:	**18/HRA/0447**
Version: **Date:**	**v3.3** **19/06/2018**

Participant Identification Number for this project

Number:	

	☒
1. I confirm that I have read and understand the information sheet explaining the above research project and I have had the opportunity to ask questions about the project.	☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline.	☐
3. I give permission for my anonymised responses to be used during the Delphi process, and to be accessed by members of the research team. I understand that my name will not be linked with the research materials, and I will not be identifiable during the Delphi survey or in the reports that result from the research.	☐
4. I agree to take part in the above research project.	☐
5. I understand that the data collected during the Delphi study may be used for the purposes of both a final report of the above study as well as purposes of subsequent academic publication, further research, and teaching.	☐

I wish to be updated as to the outcomes of the study and wish to be sent a copy of the initial report and/or publication.	☐
Email address: **(if required)**	

Name of Participant:		**Date:**	
Signature:			

Name Lead Researcher:	**Lee Thompson**	**Date:**	**19/06/2018**
Signature:			

Completion:

Please return scanned or electronically completed forms via email to:

lee.thompson@neas.nhs.uk

Or return hard copies to:

Lee Thompson, Trauma Team, Emergency Operations Centre, North East Ambulance Service NHS Foundation Trust, Bernicia House, Goldcrest Way, Newburn Riverside, Newcastle Upon Tyne. NE15 8NY.

Further information: Please do not hesitate to contact the lead researcher if you have any concerns or questions.

Contact details:

Lee Thompson. Tel: 0 (+44) 191 430 2399, email: lee.thompson@neas.nhs.uk

Michael Hill. Tel: 0 (+44) 191 215 6623, email: Michael.hill@northumbria.ac.uk

Copies: Please retain a copy of the completed consent from for your personal records. An additional copy will be held in a North East Ambulance Service secure location for the duration of the research study.

APPENDIX 8. DELPHI STUDY SURVEY ROUND 1

Northumbria University NEWCASTLE

Delphi Study Survey Round 1

1. From the options below rate the items importance with regards to its role in defining major trauma.

	This factor should not be considered	Low importance	Medium importance	High importance	This is the only factor to consider
Mechanism of injury					
Actual injuries sustained					
Physiology (e.g., Glasgow Coma Score, Respiration Rate, Systolic Blood Pressure)					
Age (Paediatric)					
Age (>65 years)					
Previous medical history					
Outcome measures such as Injury Severity Scores (ISS)					
Need for surgical intervention					
Need for ventilatory support					
Need for blood products					
Need for Tranexamic Acid (TXA)					
Need for spinal immobilisation (e.g., Collar, Blocks, Scoop)					
Need for pelvic binding/splinting					
Other: please specify below					

Other:	

2. Major trauma should be identified by a clinical assessment and actual/perceived injury pattern regardless of the Mechanism of Injury (e.g., High energy v Low energy).

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

3. The older trauma patient (aged 65 years +) should be assessed/triaged/managed differently compared to younger adult trauma patients.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

4. Paediatric trauma patients (aged less than 12 years) should be assessed/triaged/managed differently to adult trauma patients.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

5. Age has no relevance in trauma triage.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

6. Burns (in the non-polytrauma patient).

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
Burns should be included within the major trauma triage					
Burns should have a separate protocol/triage from Major Trauma					

7. Pre-existing frailty should be considered when identifying major trauma.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

8. Pre-existing medical conditions (co-morbidities) should be considered when identifying major trauma.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

9. Major trauma can only be defined retrospectively using Injury Severity Scores.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

10. Scoring systems are the only way to identify major trauma.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

11. Experienced clinicians are able to identify major trauma patients.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

12. Only high energy mechanisms of injury should be considered in identifying major trauma.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

13. Major trauma triage tools always identify major trauma patients.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

14. Low energy mechanisms of injury (such as a fall from standing) should be considered within major trauma if injury pattern suggests significant injury.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

15. Intoxicated patients make triage of major trauma difficult.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

16. A clinician with a high index of suspicion can confidently identify major trauma without specialist imaging.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

17. A perceived need for ongoing surgical intervention can be a key factor in identifying major trauma.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

18. A perceived need for Intensive Care Unit (ITU) admission can be a key factor in identifying major trauma.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

19. Major Trauma Bypass Protocols identify patients who would benefit from definitive care at a Major Trauma Centre and not just patients with high Injury Severity Scores.

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

20. Major Trauma patients can only be managed at a Major Trauma Centre (excluding Traumatic Cardiac Arrest, compromised airway, transport time greater than 60 minutes).

Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

21. How would you personally define 'Major Trauma' in your own words? Please include factors you think should be considered and those you think should not be considered.

22. Does your area of practice have a definition for Major Trauma and if so, how do they define Major Trauma?

23. Please tick the variables you would use to define Major Trauma.

Life threatening injuries		Major Trauma is dependent on multiple factors that are unique to the individual patient at a given time	
Limb threatening injuries		Injury Severity Score (>15)	
Any injury that requires specialist intervention		Injury causing new neurology	
Major blood loss		Suspected spinal injury requiring immobilisation	
Injury to more than one limb		Suspected abdominal injury causing haemodynamic instability	
Burns greater than 15% (10% Child)		Suspected pelvic injury requiring splinting	
Injury causing reduced consciousness		Other Please state below:	
High energy mechanism (for example but not limited to: roll over RTC, fall from >2m, Gunshot wound)		Free text:	

The questions on this page will help us identify emerging trends and themes within the context of the multi-disciplined approach to major trauma.

Confidentiality: **No personal information will be collected and survey responses will be collated anonymously using an identifying number known only to the participant and lead investigator. Some background information such as area of practice, length of experience in practice and experience within Major Trauma. All responses received in the study will be strictly confidential, and your identity will not be divulged. Direct quotes to free-text answers may be used as part of the study report or later Delphi iterations or research area, but these will not be traceable back to you.**

24. What is your area of practice with regards to trauma?

HEMS Paramedic	
HEMS Doctor	
Paramedic	
Emergency Medicine (Doctor)	
Intensive Care (Doctor)	
Surgical (Doctor)	
Academic	
Other (please specify below)	
Free text:	

25. Years experience (post qualification)

0-5 years	
6-10 years	
11-15 years	
16-20 years	
21 years +	

26. In which setting do you usually work

Major Trauma Centre	
Trauma Unit	
Rehabilitation	
Prehospital	
Non-trauma status hospital	
Academia	
Administration	
Other (please specify)	
Free text:	

Thank you.

That is the end of the questionnaire. Thank you for taking the time to participate. We will inform you of the findings and ask for your comment on the findings as soon as possible.

The following pages contain General Data Protection Regulation (GDPR) information.

General Data Protection Regulation (GDPR): How participant information may be used for research.

When you agree to take part in a research study, the sponsor will collect the minimum personally identifiable information needed for the purposes of the research project. Information about you will be used in the ways needed to conduct and analyse the research study. NHS organisations may keep a copy of the information collected about you. Depending on the needs of the study, the information that is passed to the research sponsor may include personal data that could identify you. You can find out more about the use of patient information for the study you are taking part in from the research team or the study sponsor. You can find out who the study sponsor is from the information you were given when you agreed to take part in the study. For some research studies, you may be asked to provide information about your health to the research team, for example in a questionnaire. Sometimes information about you will be collected for research at the same time as for your clinical care, for example when a blood test is taken. In other cases, information may be copied from your health records. Information from your health records may be linked to information from other places such as central NHS records, or information about you collected by other organisations. You will be told about this when you agree to take part in the study.

General Data Protection Regulation (GDPR): Keeping information for future research.

Information about you that is collected during a research study may be kept securely to be used in future research in any disease area, including research looking at social and economic factors affecting health. This may include combining it with information about you held by other health or government organisations such as NHS Digital. Usually, the information is combined together by matching information that has the same NHS number. Doing this makes maximum use of the information you have provided and allows researchers to discover more. Researchers may not be able to specify all the possible future uses of the information they keep. It could include providing the information to other researchers from NHS organisations, universities or companies developing new treatments or care. Wherever this happens it will be done under strict legal agreements. The information about you will be depersonalised wherever possible so that you cannot be identified. Where there is a risk that you can be identified your data will only be used in research that has been independently reviewed by an ethics committee. On rare occasions NHS organisations may provide researchers with confidential patient information from your health records when we are not able to seek your agreement to take part in the study, for example because the number of patients involved is too large or the NHS organisation no longer has your contact details. Researchers must have special approval before they can do this.

General Data Protection Regulation (GDPR): Your choices about health and care research

If you are asked about taking part in research, usually someone in the care team looking after you will contact you. People in your care team may look at your health records to check whether you are suitable to take part in a research study, before asking you whether you are interested or sending you a letter on behalf of the researcher. In some hospitals and GP practices, you may have the opportunity to sign up to a register to hear about suitable research studies that you could take part in. If you agree to this, then research nurses, researchers or administrative staff authorised by the organisation may look at your health records to see if you are suitable for any research studies. It's important for you to be aware that if you are taking part in research, or information about you is used for research, your rights to access, change or move information about you are limited. This is because researchers need to manage your information in specific ways in order for the research to be reliable and accurate. If you withdraw from a study, the sponsor will keep the information about you that it has already obtained. They may also keep information from research indefinitely. If you would like to find out more about why and how patient data is used in research, please visit the Understanding Patient Data website. https://understandingpatientdata.org.uk/what-you-need-know Further information is available, depending on where in the UK you live: England In England you can register your choice to opt out via the NHS website. If you do choose to opt out you can still agree to take part in any research study you want to, without affecting your ability to opt out of other research. You can also change your choice about opting out at any time. Northern Ireland If you would like to find out more about how and why your information is used, including for research purposes, please visit the Department of Health website. Scotland Members of the public in Scotland have their rights and responsibilities set out in the Patient's Rights (Scotland) Act 2011. For information on confidentiality of data (including in research) please visit the NHS Inform website. Wales If you would like to find out more about how and why your information is used, including for research purposes, please visit NHS Direct Wales.

APPENDIX 9. DELPHI STUDY RESULTS/FEEDBACK ROUND 1

NHS
North East
Ambulance Service
NHS Foundation Trust

Defining Major Trauma:
A Delphi Study.

<u>Feedback: Delphi study round 1.</u>

Hello all and thank you for taking the time to complete the first round of the Delphi study into defining major trauma it was very much appreciated. The data took some time to analyse and produced some valuable outputs.

The Delphi technique seeks to obtain consensus on the opinions of experts through a series of structured questionnaires. As part of the process, the responses from each round are fed back in summarised form to the participants who are then given an opportunity to respond to the emerging data. The Delphi is therefore an iterative multi-stage process designed to combine opinion into group consensus on the variables that define major trauma.

Based on these outputs we would like you to digest the following data which may influence how you answer the second round of the Delphi Study. The questions themselves have remained relatively unchanged, however, the feedback from the first round is designed to provide you with information that may bring together a common understanding of major trauma and a working definition of major trauma.

Results:

There were three distinct clusters of participants whose answers were similar (clusters 2 and 3 were very closely linked together) and produced a normal distribution pattern.

Cluster 1 were coded as "Trauma Minimisers" owing to their answers indicating a high threshold for identifying major trauma. In relative terms, from a given number of trauma patients, cluster 1 participants would identify a **<u>very low</u>** percentage as major trauma.

Cluster 2 were coded as "The Middle Ground". This cluster represented the majority of the Delphi participants as well as their respective professional groups. Cluster 2 identified what would be considered an appropriate proportion of major trauma based upon existing criteria.

Cluster 3 were coded as "Risk Averse" as their answers indicated a very low threshold for identifying major trauma. From a given number of trauma patients cluster 3 would identify a **<u>high</u>** percentage as major trauma.

Seven participants out of a total of 43 participants did not answer all the questions within the questionnaire and were excluded from the cluster analysis based on the limited availability of data.

Table 1. Composition of clusters.

Cluster	N (%)	Composition (%)
1	9 (25)	• 4 Doctors (44) • 1 Nurse (1) • 4 Paramedics (44)
2	20 (56)	• 10 Doctors (50) • 3 Nurses (15) • 7 Paramedics (35)
3	7 (19)	• 5 Doctors (71) • 1 Nurse (14) • 1 Paramedic (14)

There was an obvious consensus on many of the variables highlighted as defining major trauma. These patterns are clear in the graphs seen in supplementary material 1. There were however some statistically significant variations in agreement between clusters in other variables (level of significance set as p $\leq$0.05).

Table 2. Variables where significant difference occurs between cluster opinions.

Variable	Difference between clusters (C)			p Value*
	Cluster	Differs from	Cluster	
Need for spinal immobilisation (as an identifier for major trauma)	1	-	2	<0.01
Need for pelvic binding (as an identifier for major trauma)	1	-	2 & 3	0.01
Age has no relevance within major trauma	3	-	1 & 2	0.01
Burns should be included within Major Trauma Triage Tool	3	-	1 & 2	<0.01
Burns should have a separate protocol	1	-	2 & 3	<0.01
Pre-existing frailty should be considered (when defining major trauma)	1	-	2 & 3	<0.01
Pre-existing comorbidities should be considered (when defining major trauma)	1	-	2	<0.01

* p value rounded to 2 decimal places (Independent samples Kruskal-Wallis test).

We have included many graphs which represent the distribution of answers given to some of the questions asked within the first round of the Delphi study (supplementary material 1). We have also included the free text of your personal definitions of major trauma (supplementary material 2) and your work base definitions (supplementary material 3).

What now?

Please take your time to digest the information in this document and then click on the link below or scan the QR code with a smart phone to complete the questionnaire. It is almost exactly the same questionnaire as the first, but your answers may now be slightly different or may not change at all.

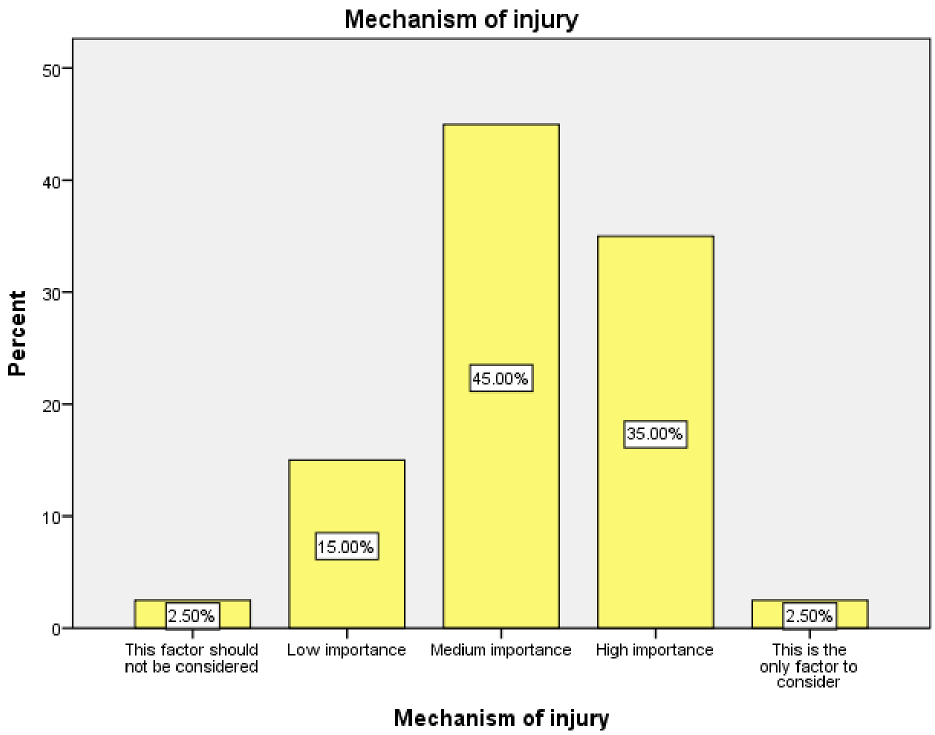
Can I thank you once again for taking the time to read through this information and complete the questionnaire. Without your help this project would not be possible.

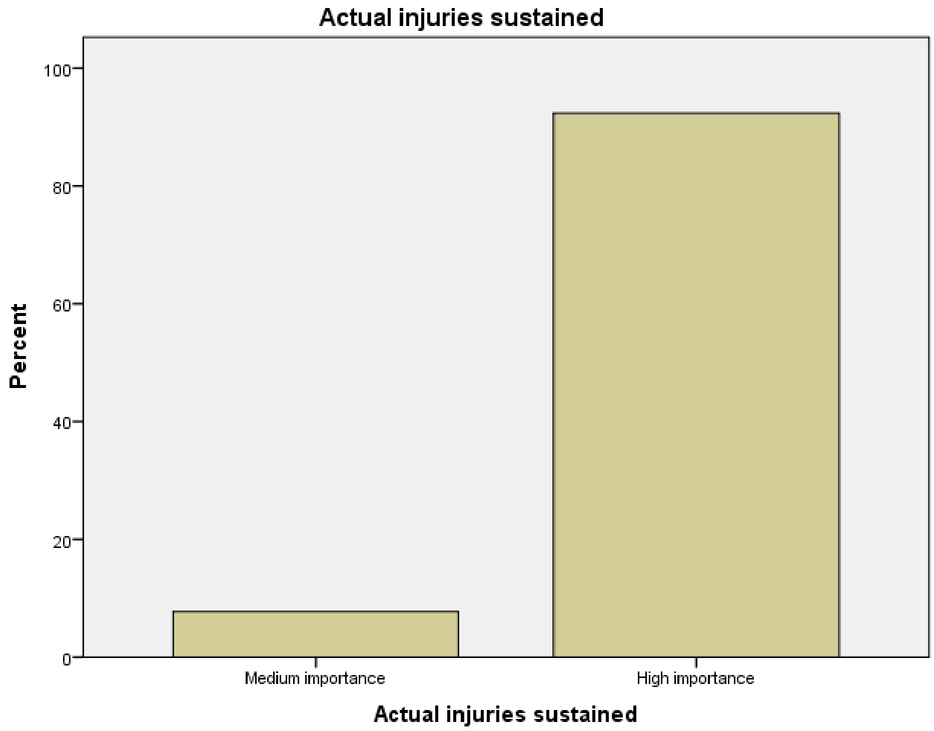
https://www.surveymonkey.com/r/FP39ZGP

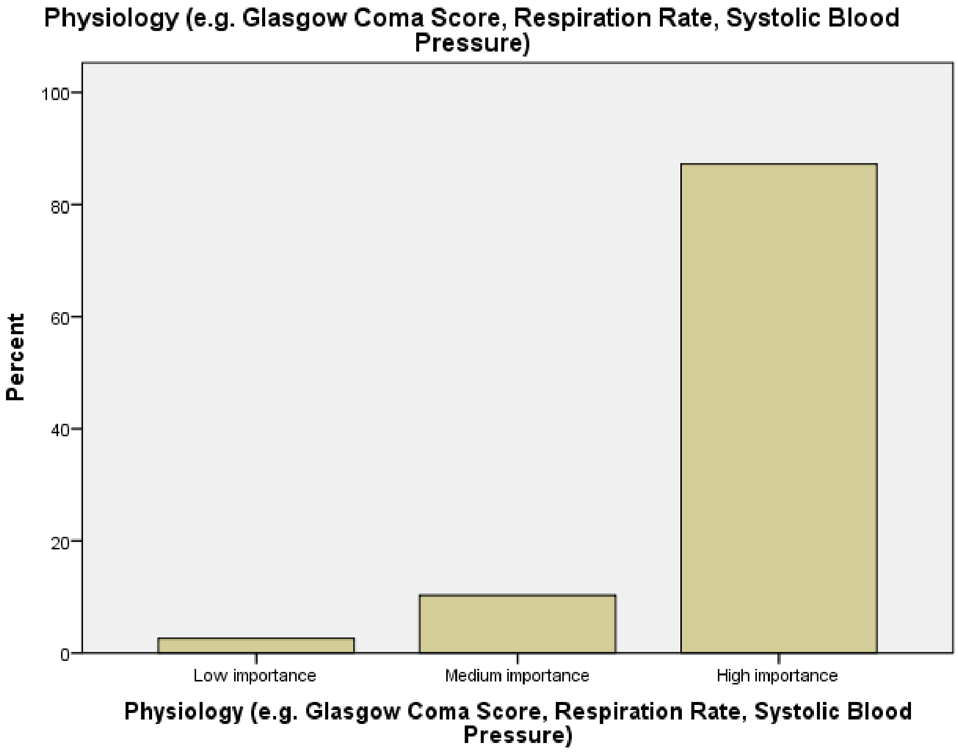
Best regards as always,

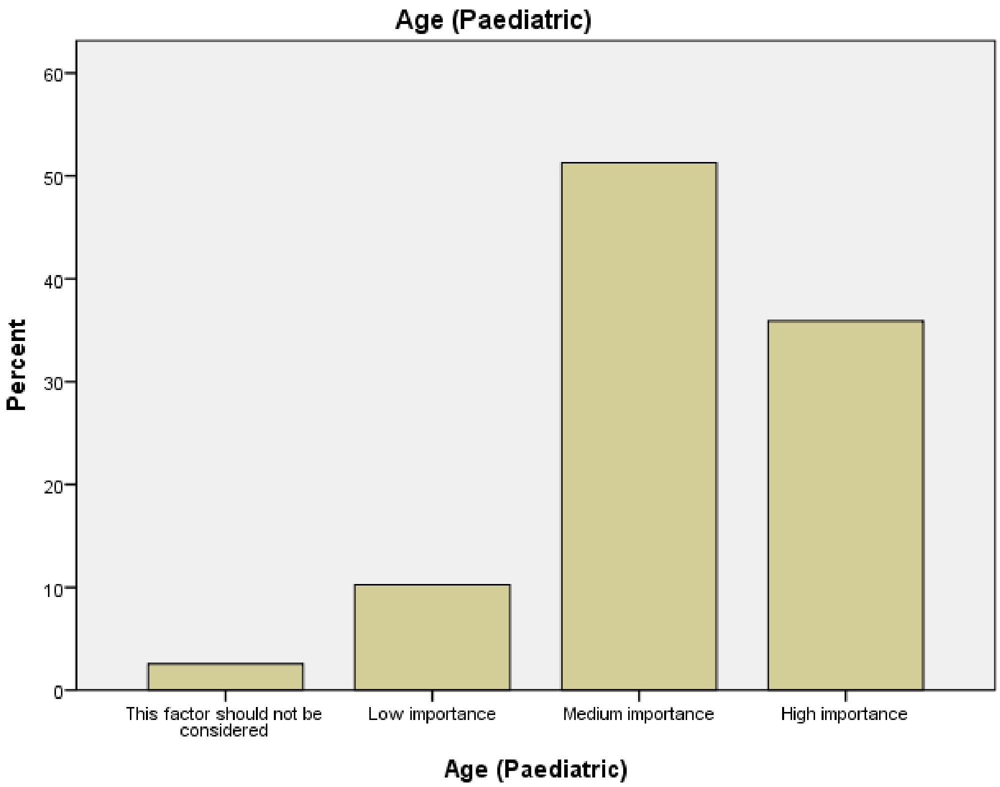
Lee Thompson

<u>Supplimentary material 1:</u> Graphical representation of answers.

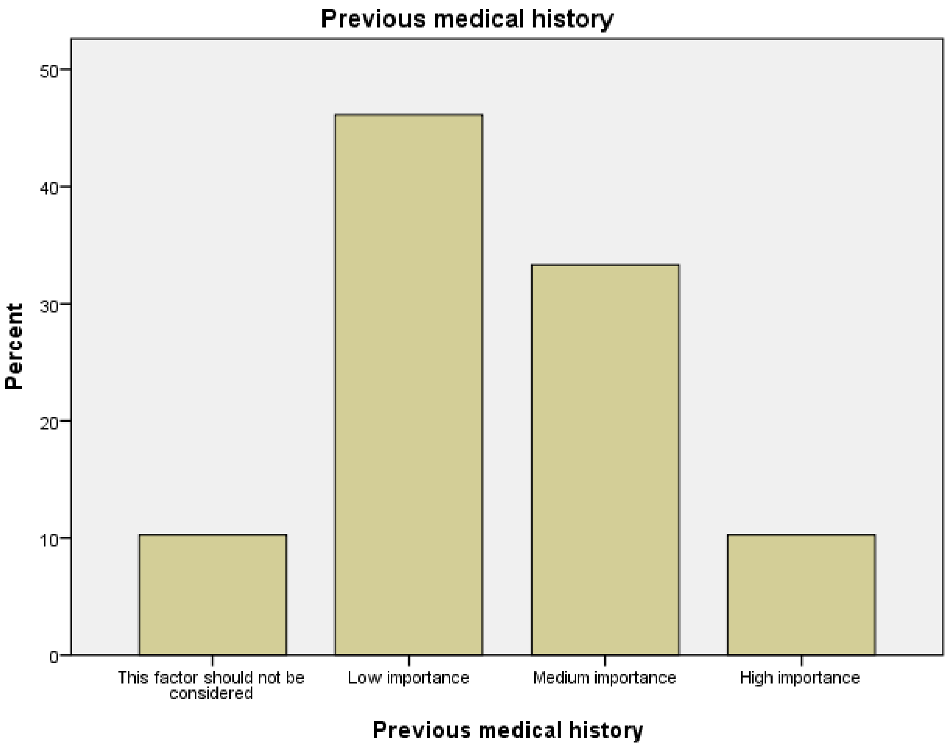


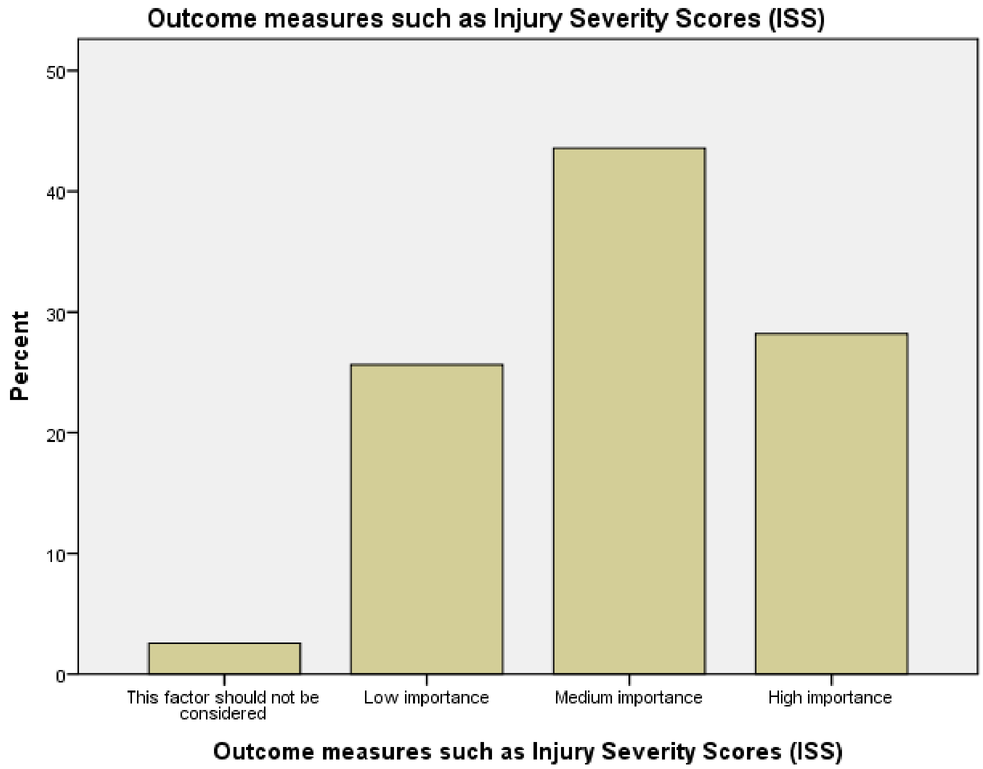


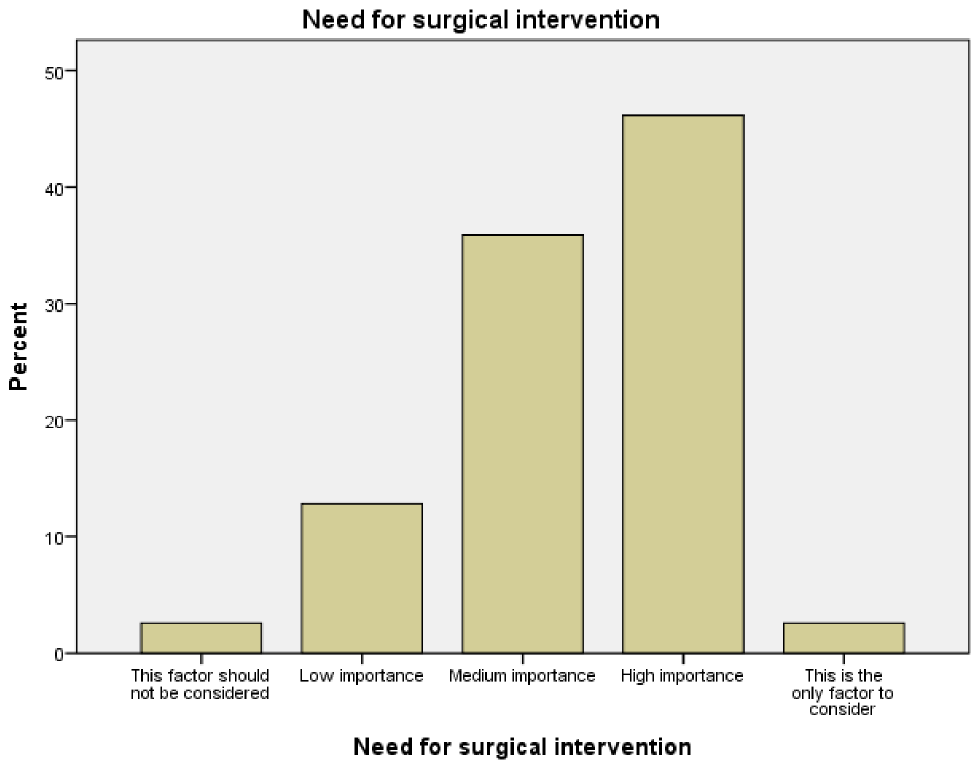

Physiology (e.g. Glasgow Coma Score, Respiration Rate, Systolic Blood Pressure)
Percent
100
80
60
40
20
0
Low importance
Medium importance
High importance
Physiology (e.g. Glasgow Coma Score, Respiration Rate, Systolic Blood Pressure)

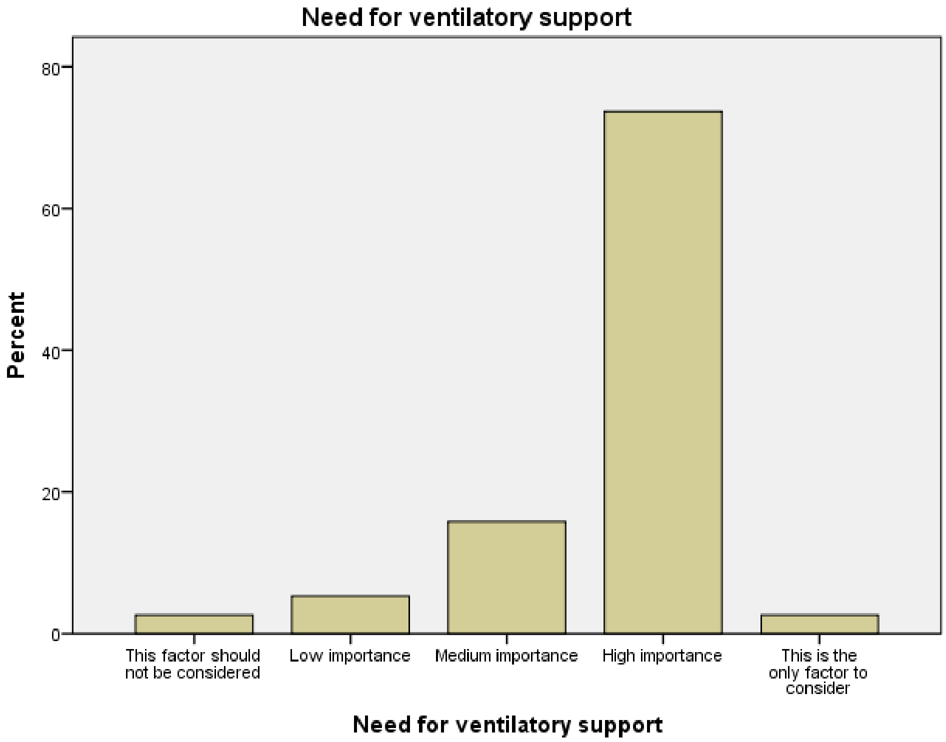

Age (Paediatric)
Percent
60
50
40
30
20
10
0
This factor should not be considered
Low importance
Medium importance
High importance
Age (Paediatric)

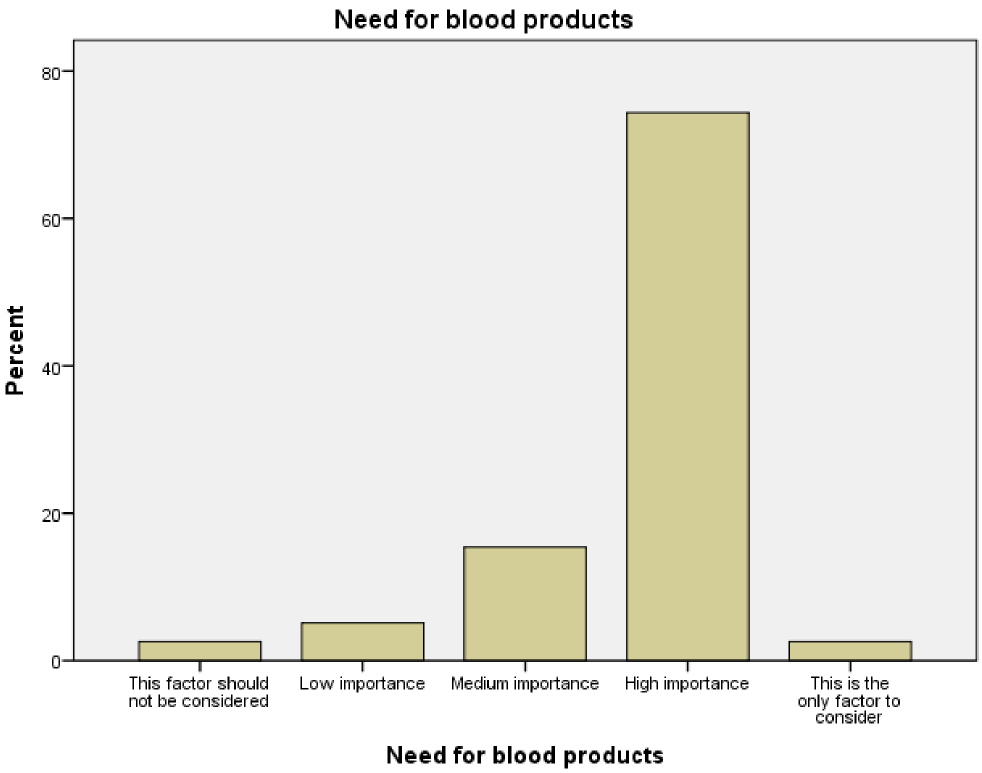

Age (>65 years)
Percent
50
40
30
20
10
0
This factor should not be considered
Low importance
Medium importance
High importance
Age (>65 years)

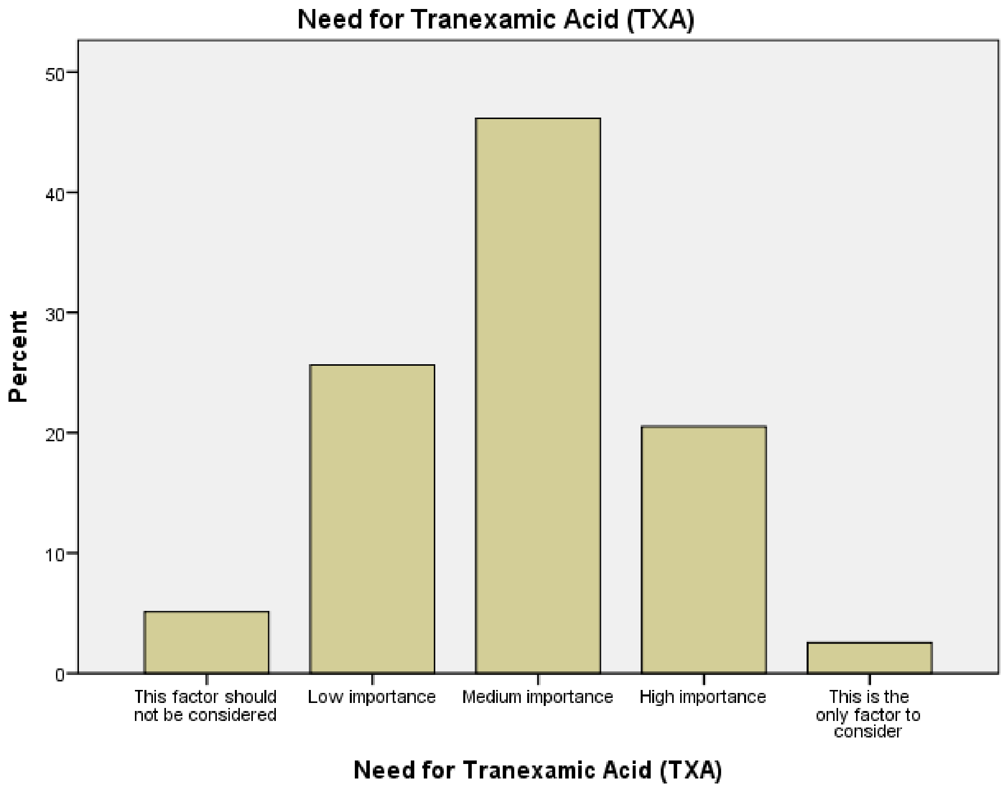

Previous medical history
Percent
50
40
30
20
10
0
This factor should not be considered
Low importance
Medium importance
High importance
Previous medical history


Outcome measures such as Injury Severity Scores (ISS)
Percent
0
10
20
30
40
50
This factor should not be considered
Low importance
Medium importance
High importance
Outcome measures such as Injury Severity Scores (ISS)

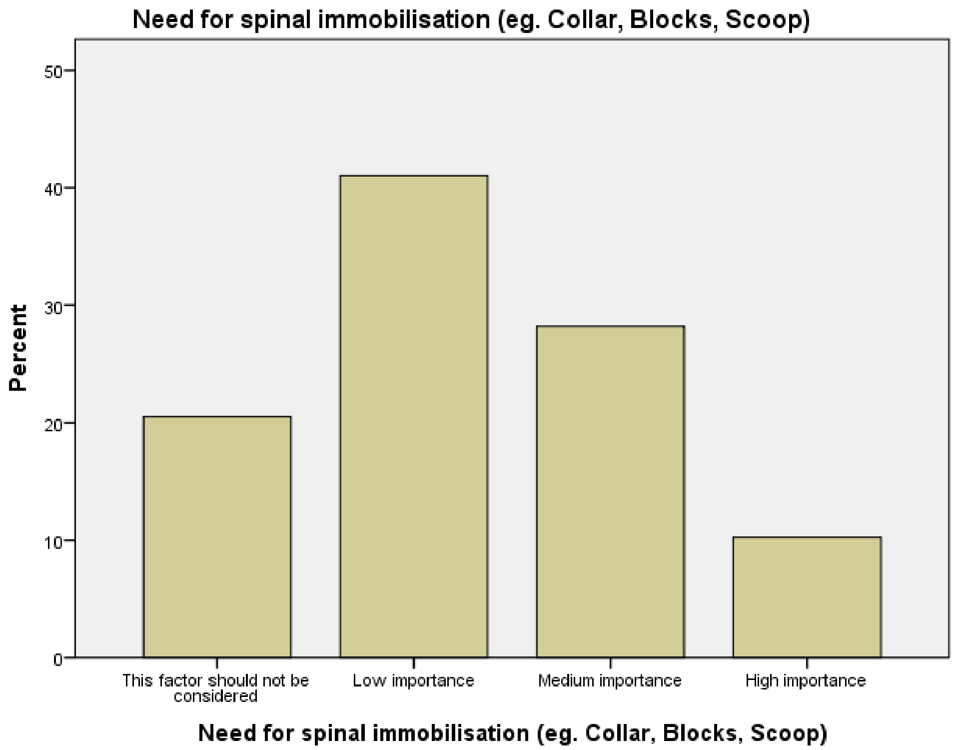

Need for surgical intervention
Percent
0
10
20
30
40
50
This factor should not be considered
Low importance
Medium importance
High importance
This is the only factor to consider
Need for surgical intervention


Need for ventilatory support
80
60
40
20
0
Percent
This factor should not be considered
Low importance
Medium importance
High importance
This is the only factor to consider
Need for ventilatory support

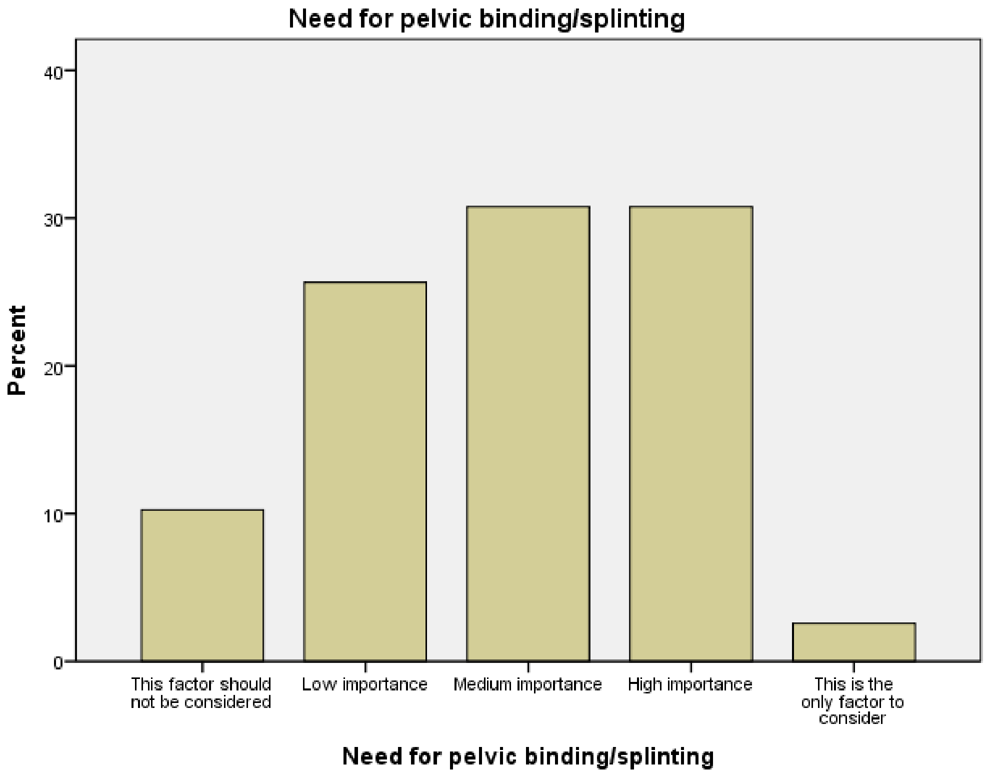

Need for blood products
80
60
40
20
0
Percent
This factor should not be considered
Low importance
Medium importance
High importance
This is the only factor to consider
Need for blood products

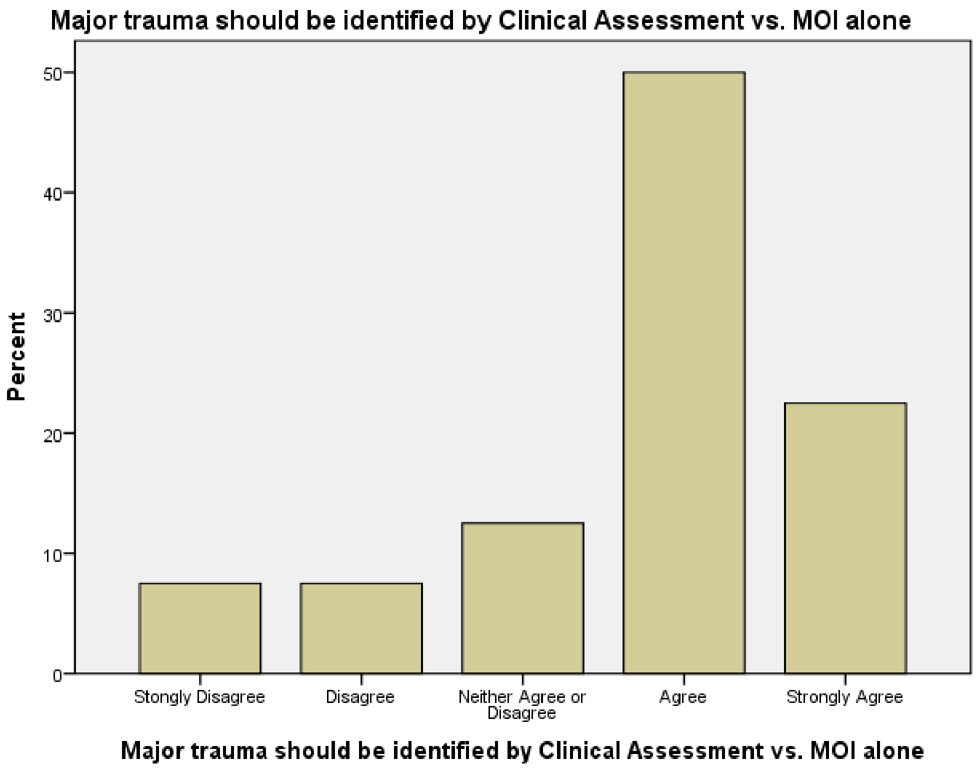


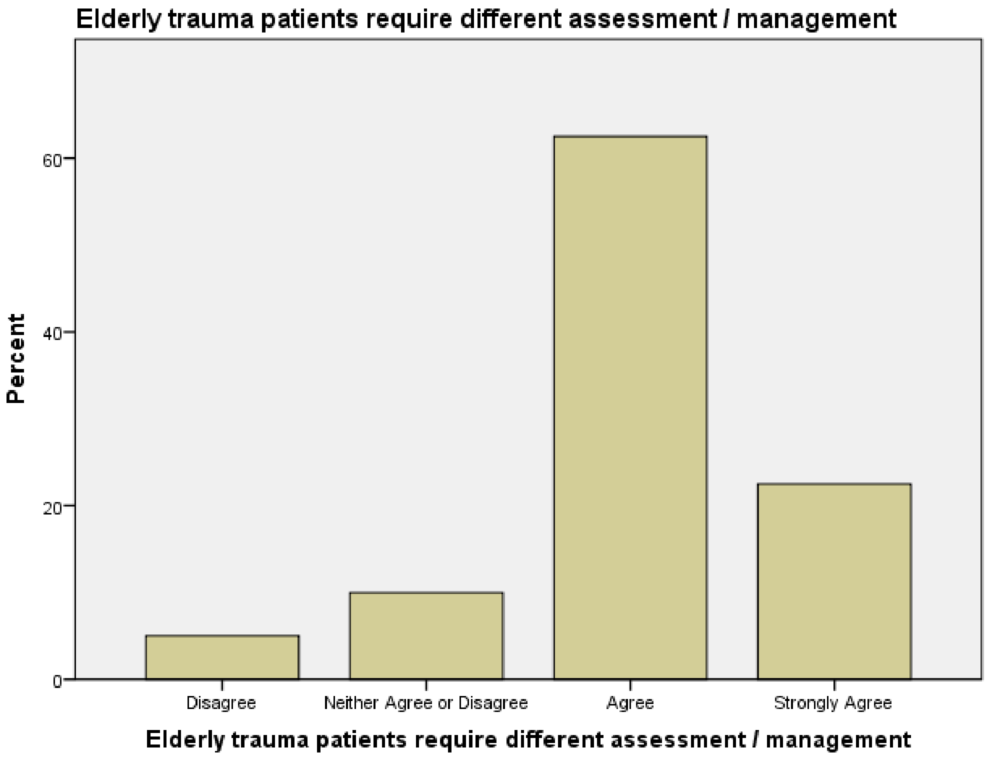
Need for Tranexamic Acid (TXA)
Percent
50
40
30
20
10
0
This factor should not be considered
Low importance
Medium importance
High importance
This is the only factor to consider
Need for Tranexamic Acid (TXA)

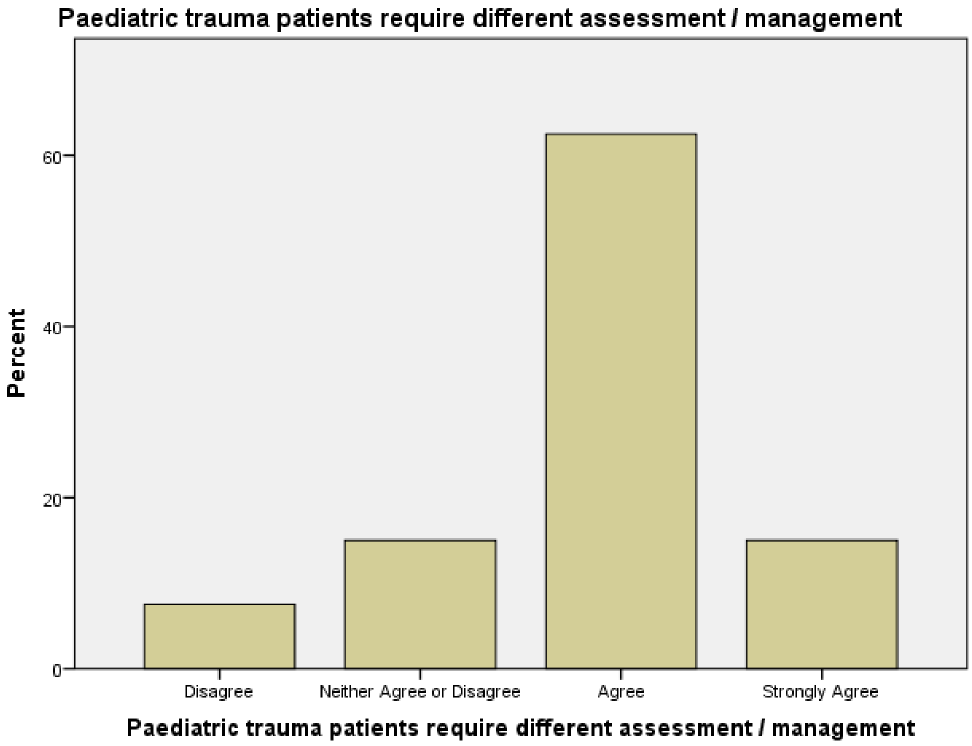


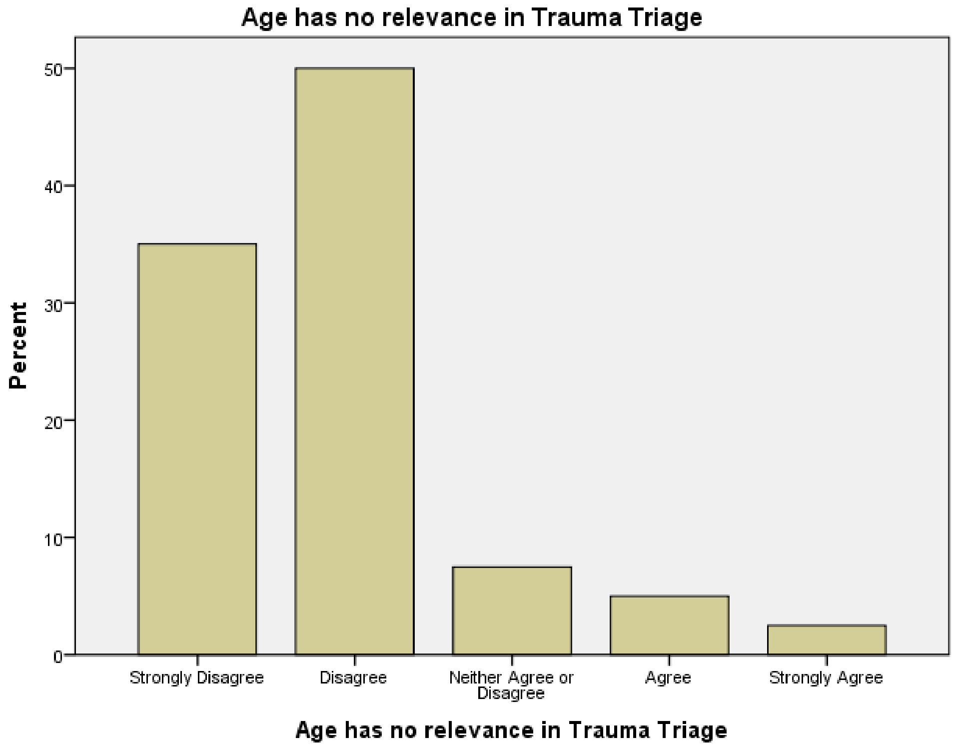
Need for spinal immobilisation (eg. Collar, Blocks, Scoop)
Percent
50
40
30
20
10
0
This factor should not be considered
Low importance
Medium importance
High importance
Need for spinal immobilisation (eg. Collar, Blocks, Scoop)


Need for pelvic binding/splinting
Percent
40
30
20
10
0
This factor should not be considered
Low importance
Medium importance
High importance
This is the only factor to consider
Need for pelvic binding/splinting

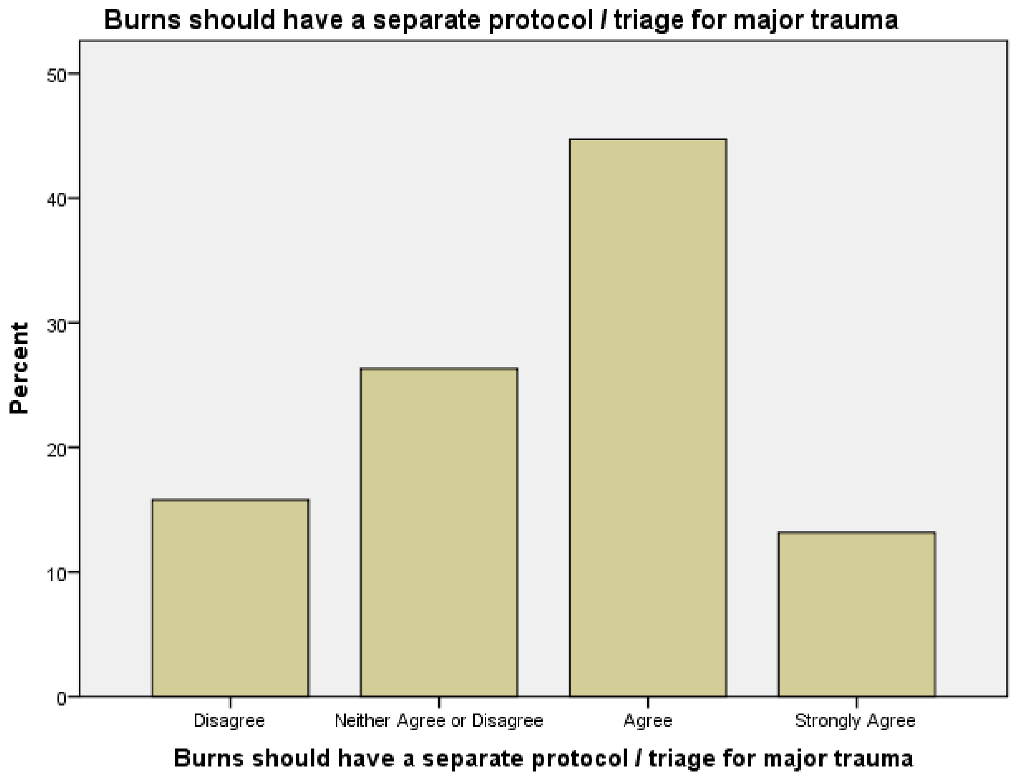

Major trauma should be identified by Clinical Assessment vs. MOI alone
Percent
50
40
30
20
10
0
Stongly Disagree
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Major trauma should be identified by Clinical Assessment vs. MOI alone

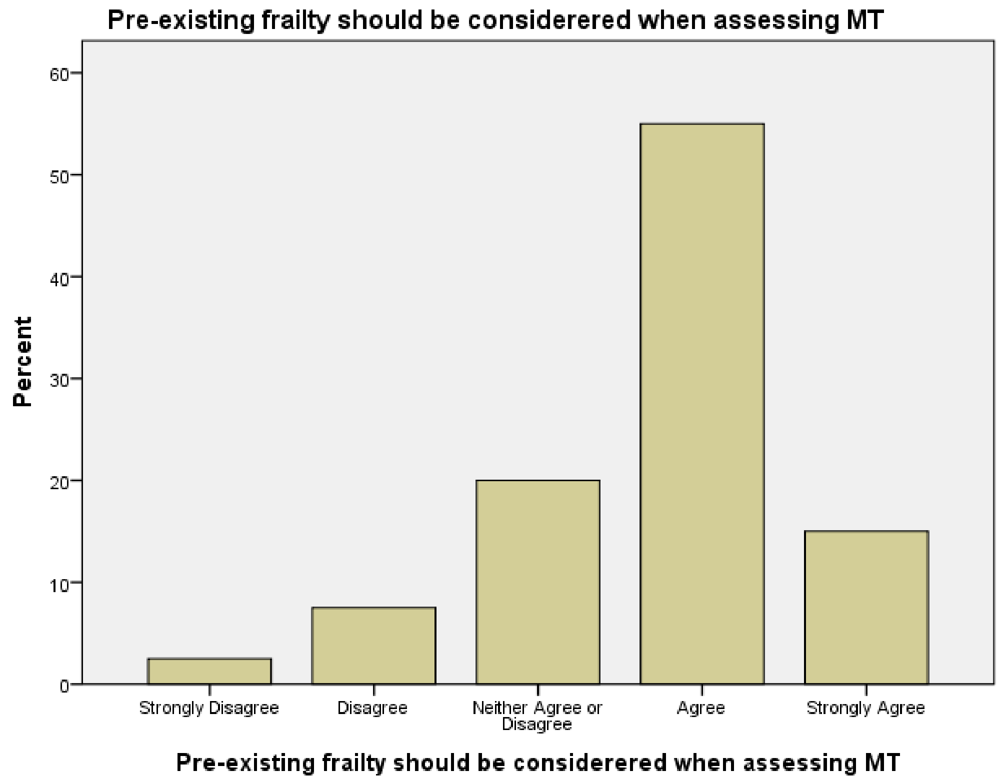

Elderly trauma patients require different assessment / management
Percent
0
20
40
60
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Elderly trauma patients require different assessment / management

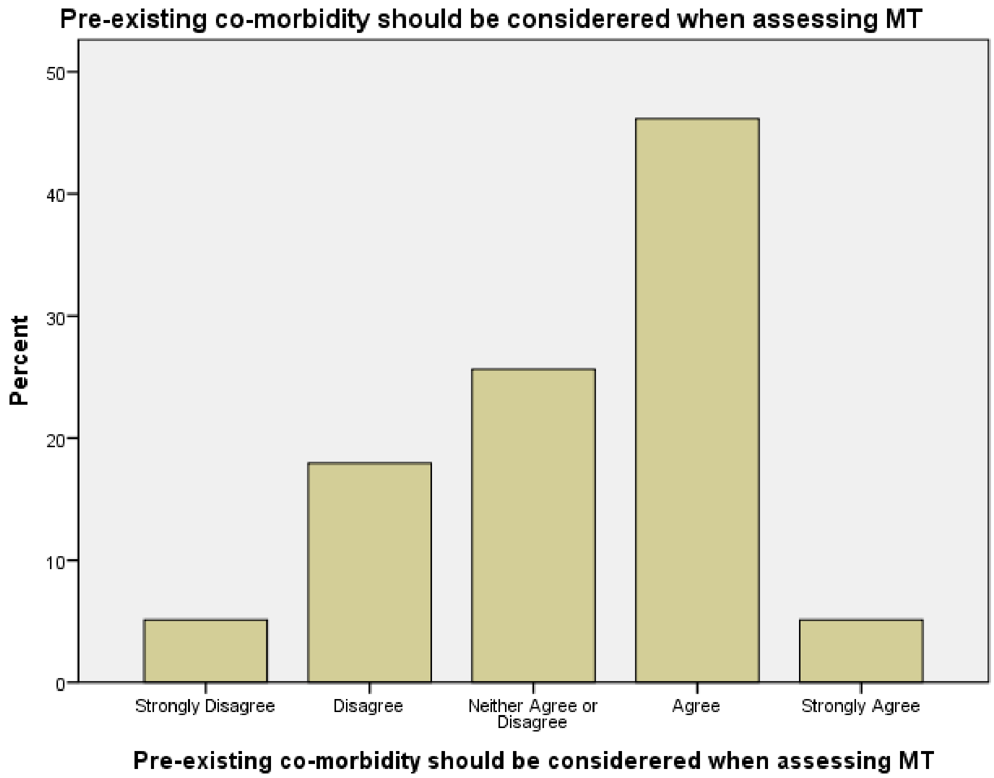

Paediatric trauma patients require different assessment / management
Percent
0
20
40
60
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Paediatric trauma patients require different assessment / management

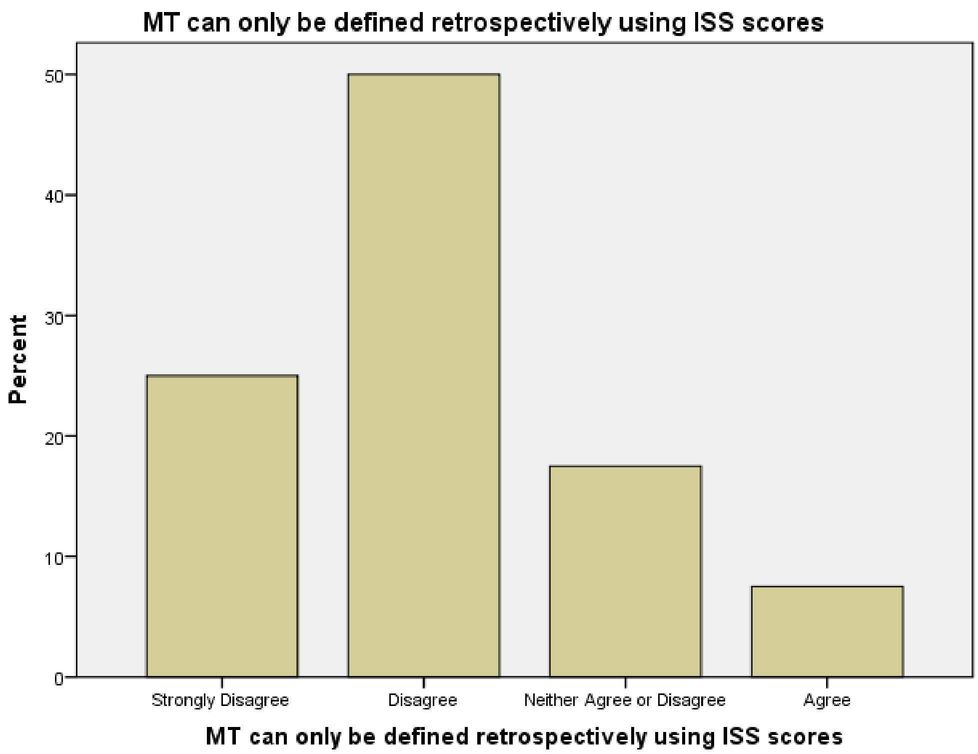

Age has no relevance in Trauma Triage
Percent
50
40
30
20
10
0
Strongly Disagree
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Age has no relevance in Trauma Triage

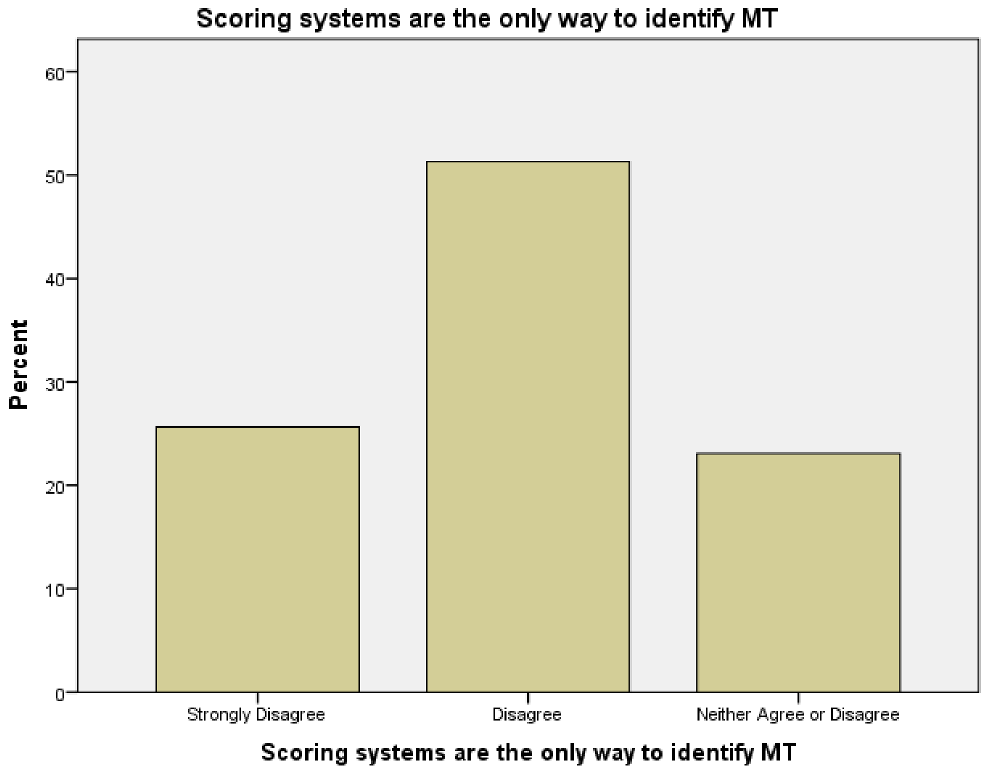

Burns should be included in major trauma triage
Percent
50
40
30
20
10
0
Strongly Disagree
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Burns should be included in major trauma triage

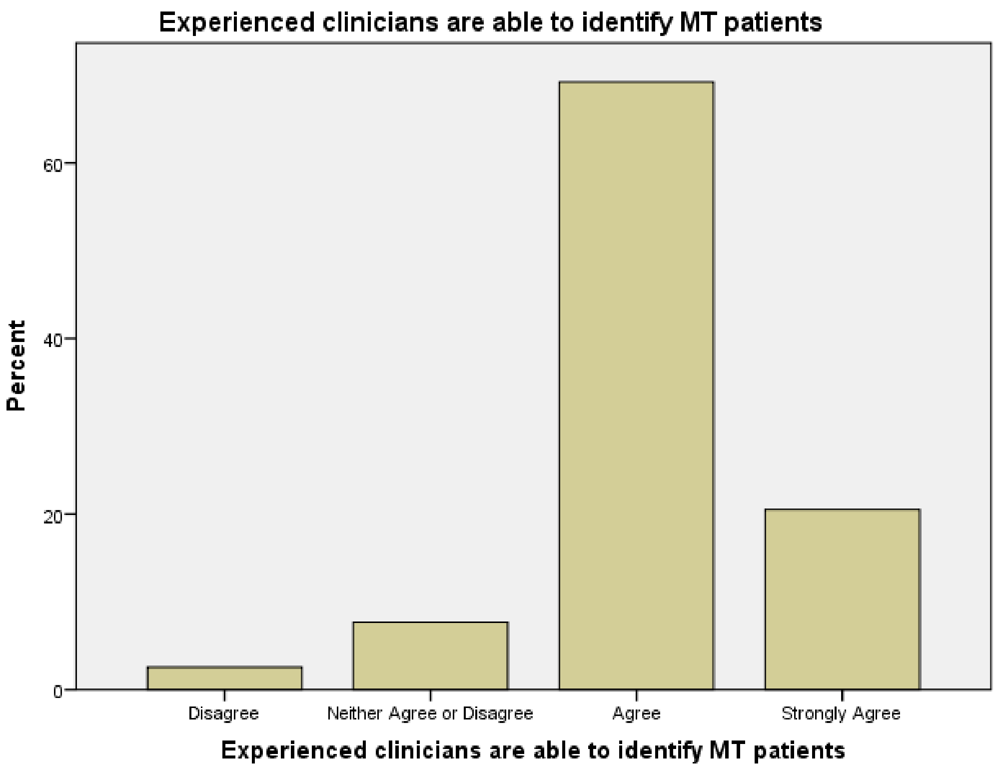

Burns should have a separate protocol / triage for major trauma
Percent
0
10
20
30
40
50
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Burns should have a separate protocol / triage for major trauma

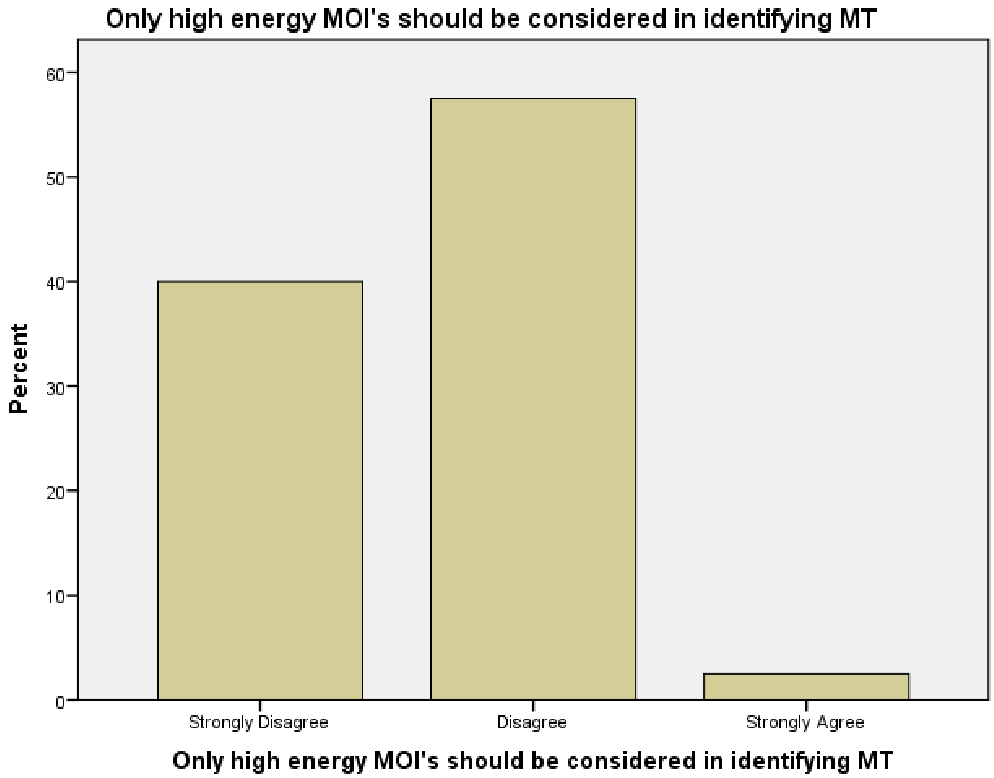

Pre-existing frailty should be considerered when assessing MT
Percent
0
10
20
30
40
50
60
Strongly Disagree
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Pre-existing frailty should be considerered when assessing MT

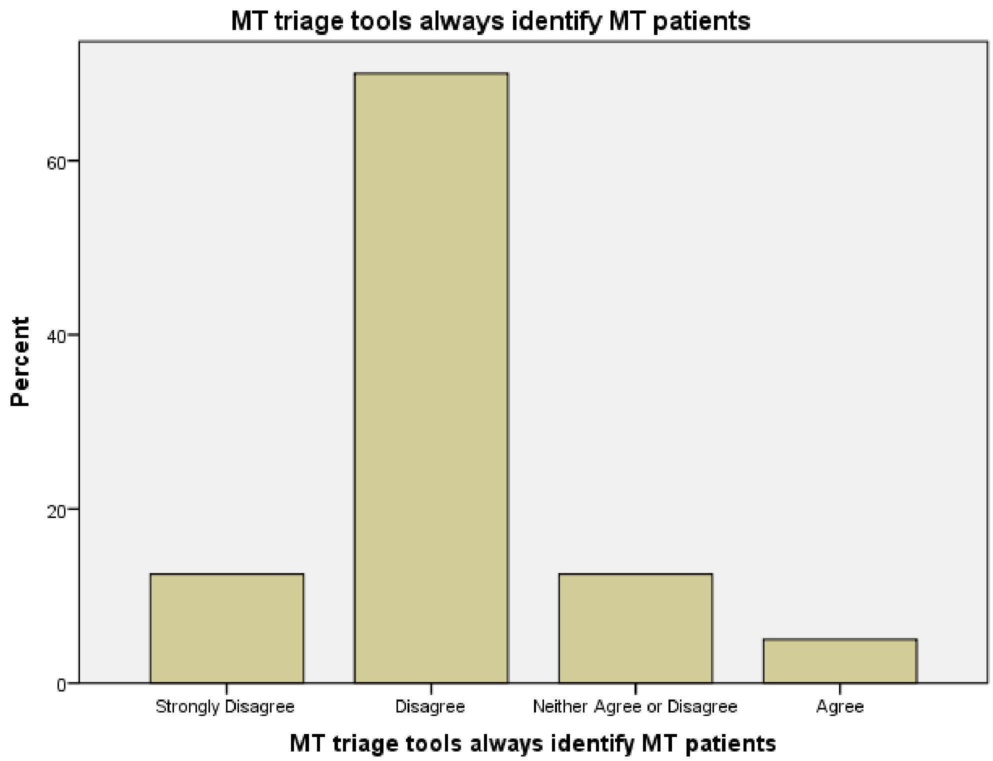

Pre-existing co-morbidity should be considerered when assessing MT
Percent
50
40
30
20
10
0
Strongly Disagree
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Pre-existing co-morbidity should be considerered when assessing MT

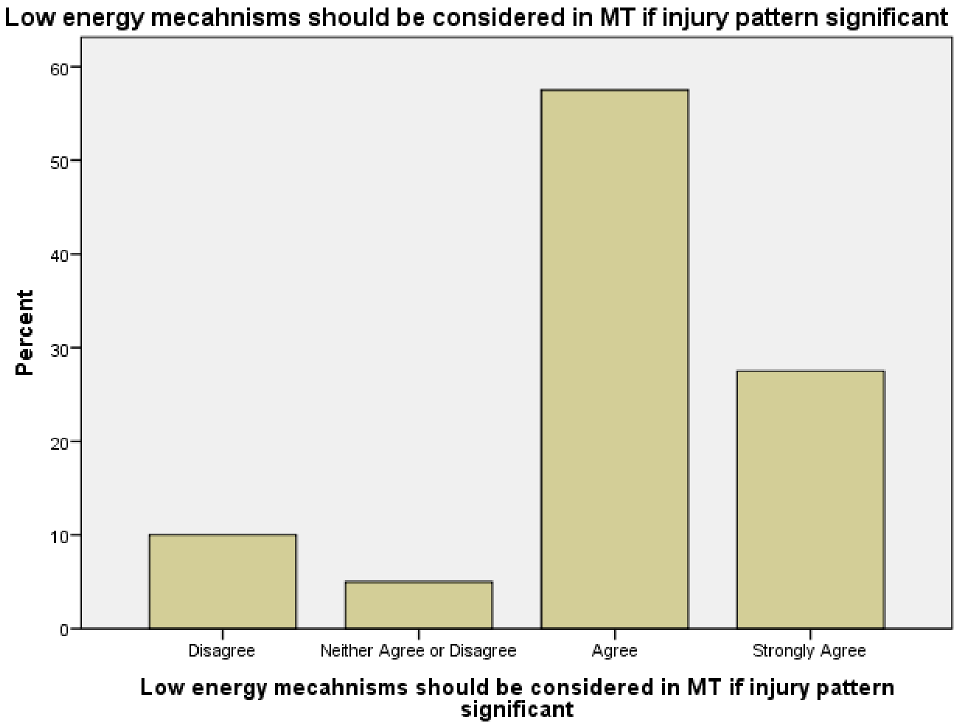

MT can only be defined retrospectively using ISS scores
Percent
50
40
30
20
10
0
Strongly Disagree
Disagree
Neither Agree or Disagree
Agree
MT can only be defined retrospectively using ISS scores

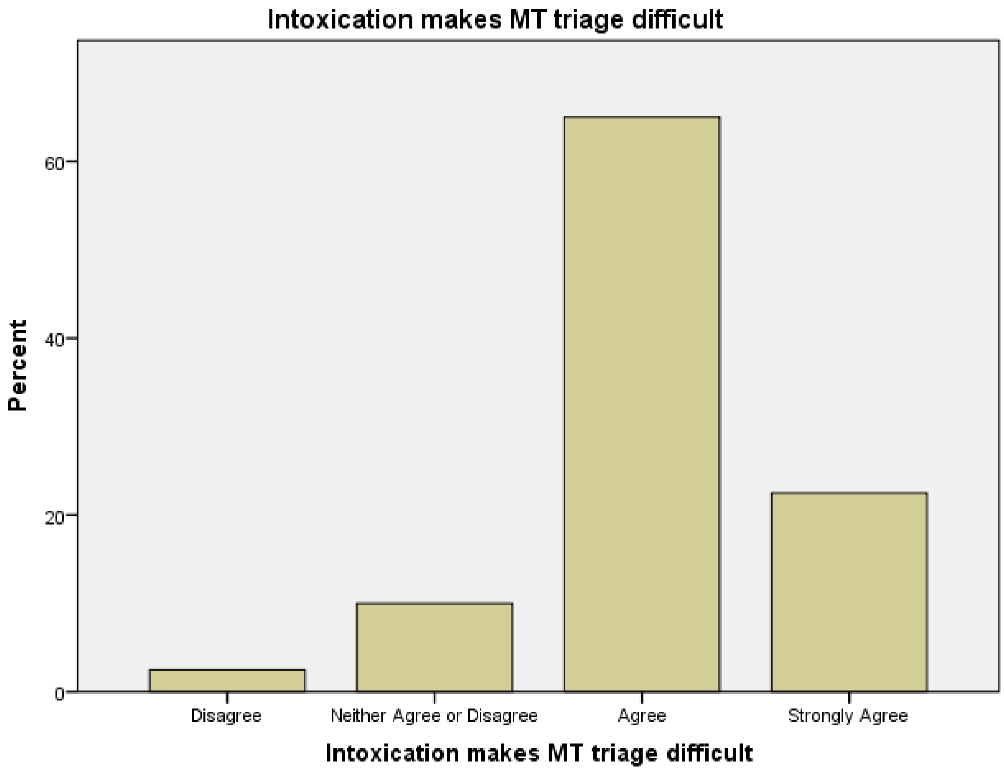

Scoring systems are the only way to identify MT
Percent
60
50
40
30
20
10
0
Strongly Disagree
Disagree
Neither Agree or Disagree
Scoring systems are the only way to identify MT

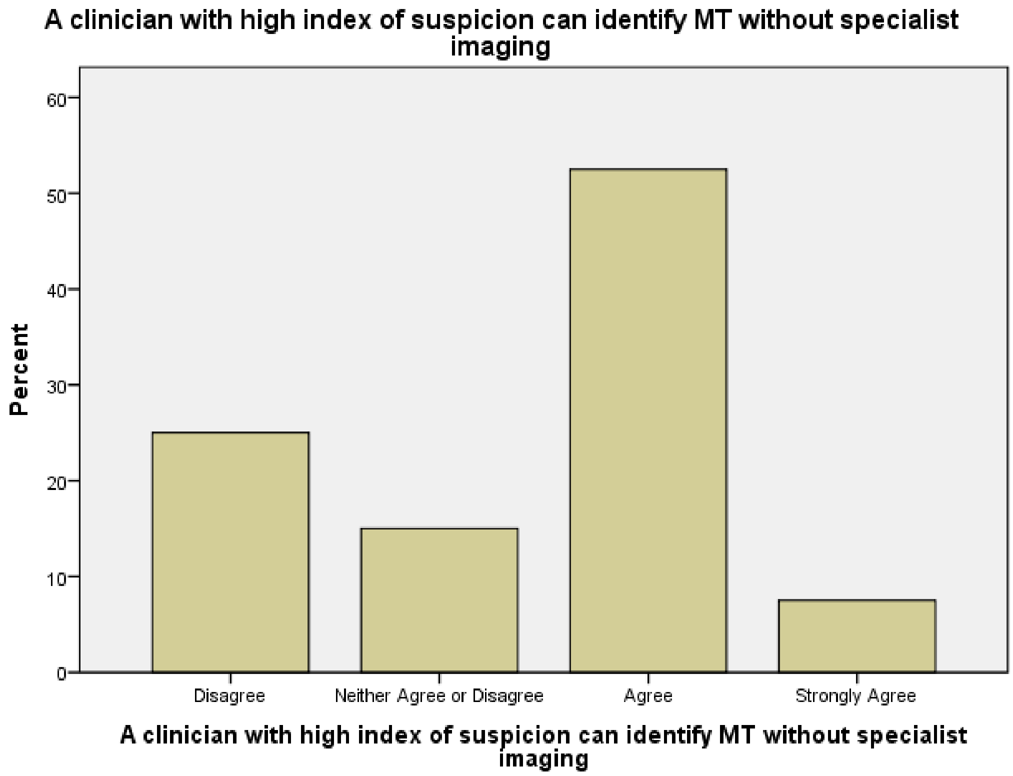

Experienced clinicians are able to identify MT patients
Percent
60
40
20
0
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Experienced clinicians are able to identify MT patients

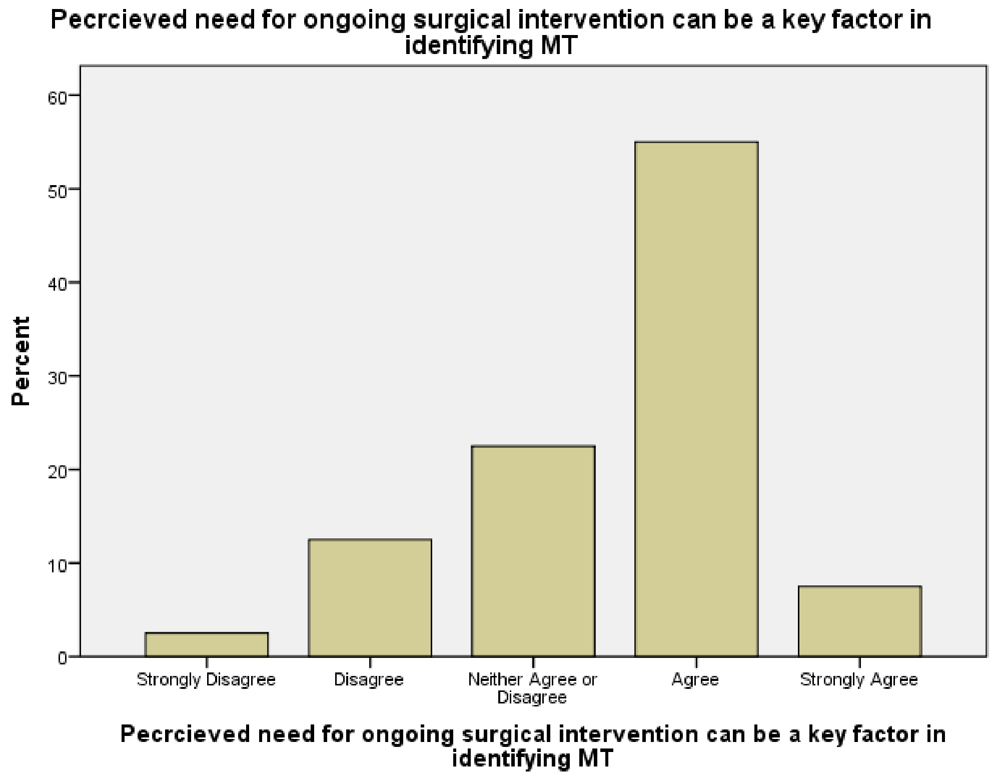

Only high energy MOI's should be considered in identifying MT
Percent
0
10
20
30
40
50
60
Strongly Disagree
Disagree
Strongly Agree
Only high energy MOI's should be considered in identifying MT

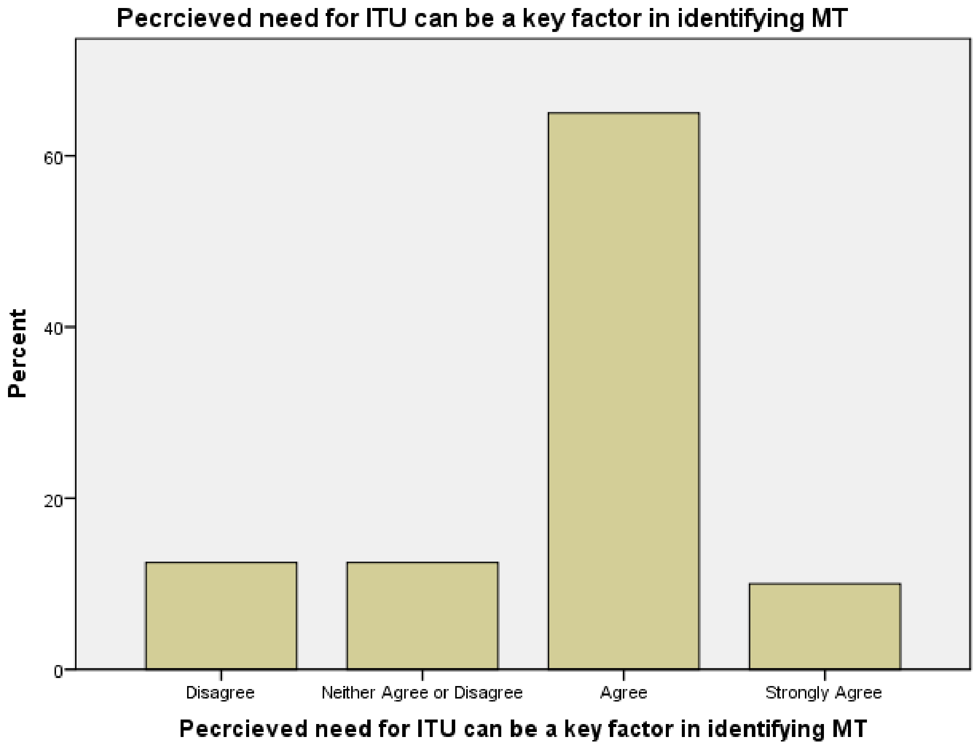

MT triage tools always identify MT patients
Percent
0
20
40
60
Strongly Disagree
Disagree
Neither Agree or Disagree
Agree
MT triage tools always identify MT patients


Low energy mecahnisms should be considered in MT if injury pattern significant
60
50
40
30
20
10
0
Percent
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Low energy mecahnisms should be considered in MT if injury pattern significant

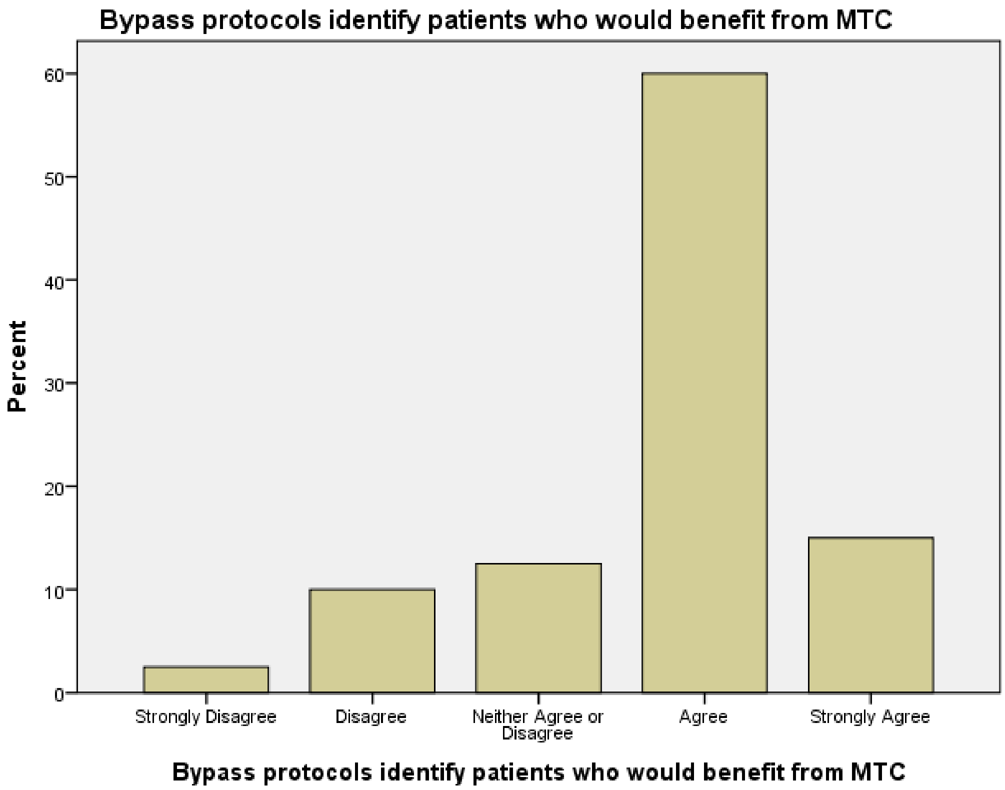

Intoxication makes MT triage difficult
60
40
20
0
Percent
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Intoxication makes MT triage difficult


A clinician with high index of suspicion can identify MT without specialist imaging
Percent
0
10
20
30
40
50
60
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
A clinician with high index of suspicion can identify MT without specialist imaging

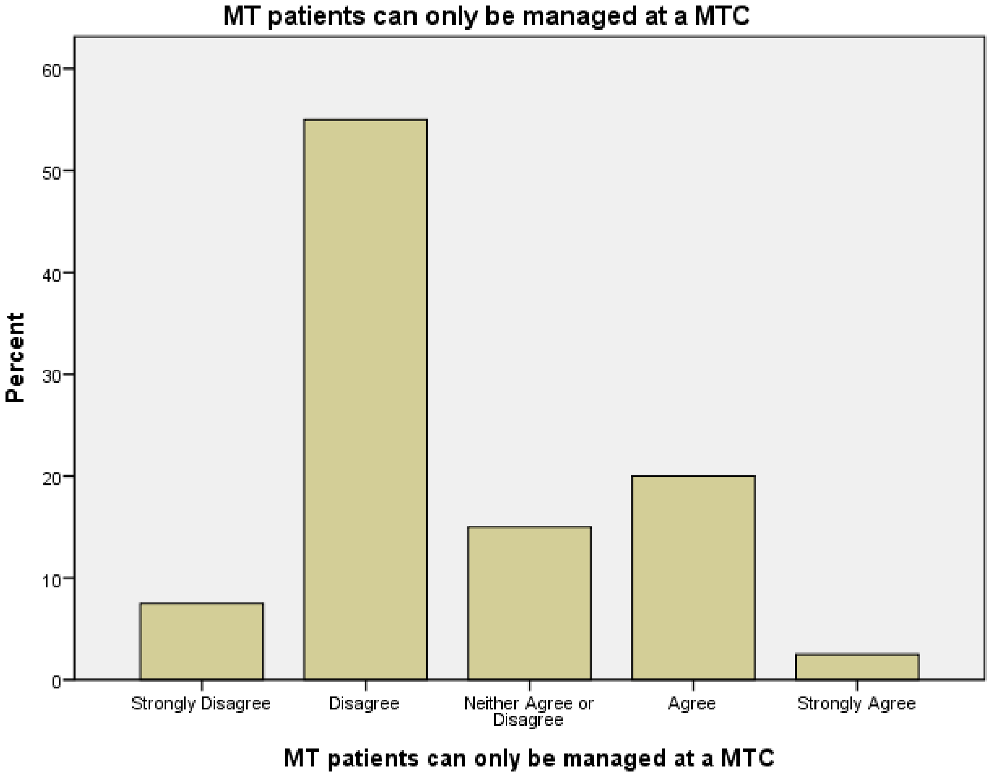

Pecrcieved need for ongoing surgical intervention can be a key factor in identifying MT
Percent
0
10
20
30
40
50
60
Strongly Disagree
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Pecrcieved need for ongoing surgical intervention can be a key factor in identifying MT



Pecrcieved need for ITU can be a key factor in identifying MT
Percent
0
20
40
60
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Pecrcieved need for ITU can be a key factor in identifying MT



Bypass protocols identify patients who would benefit from MTC
Percent
0
10
20
30
40
50
60
Strongly Disagree
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
Bypass protocols identify patients who would benefit from MTC


MT patients can only be managed at a MTC
Percent
60
50
40
30
20
10
0
Strongly Disagree
Disagree
Neither Agree or Disagree
Agree
Strongly Agree
MT patients can only be managed at a MTC

<u>Supplimentary material 2:</u> Personal definitions of Major Trauma

<u>Participant 1:</u> *Injuries sustained in a traumatic way (external forces acting on the body). Major trauma would include significant injuries especially to trunk of body (rather than isolated limb) and injuries resulting in significant physiological changes. Significant trauma usually results in need for blood transfusion, surgical management, involves multiple body systems/areas.*

<u>Participant 2:</u> *These are very much just thoughts, but - Major trauma signifies altered physiology and disruption/injuries likely to disrupt one of the 'significant' body systems - i.e., respiratory/circulatory/neurological. However, there are then subtleties with special patient populations - i.e., the elderly, and specific injury patterns e.g., burns. It would be useful to have specific triage tools for these populations. I don't think mechanism alone should be considered.*

<u>Participant 3:</u> *Patient physiology on scene and throughout the patient journey. Not to consider M.O.I.*

<u>Participant 4:</u> *Major trauma, to me, is significant traumatic injury which is potentially life threatening or life changing and which will require a prolonged hospital treatment, recovery and physiotherapy. Important factors include rapidly identifying life threatening injuries and fixing what can be fixed with rapid transport. Less important factors at the acute prehospital stage include; pre-existing medical conditions and some observations like BM and tympanic temperature.*

<u>Participant 5:</u> N/A

<u>Participant 6:</u> N/A

<u>Participant 7:</u> *A [patient] that has suffered multiple injuries.*

<u>Participant 9:</u> *Major Trauma is a collective term for high velocity mechanism. High injury severity scores are a retrospective marker which can be achieved from low velocity mechanisms especially in older patients. Despite the fact that older patients may suffer significant injury from low velocity mechanisms, that does not mean transfer to MTC from scene (or at all) is necessary - AGGRESSIVE CONSERVATIVE MANAGEMENT i.e., recognise injuries early, treat pain properly, keep hydrated, attempt early mobilisation, monitor nutrition and bowel, look after kidney function - this is what most frail trauma patients need and this can be delivered in TU and MTC.*

<u>Participant 10:</u> *A patient who presents with severe injuries that require medical or surgical intervention to treat them. This can include patients with a high energy mechanism or pattern of injury that raises concerns as well as those with co-morbidities that raise the likelihood of injury.*

<u>Participant 11:</u> *Multi-system injury with deranged physiology.*

Participant 12: *More than one injury to limbs or organs in the body from external forces that will significantly disrupt auto regulation/ ability to complete basic motor function without considerable assistance or intervention from specialities. Significant enough harm that the individuals normal functioning is severely affected regardless of age. Requires care in a hospital setting for longer than 3 days.*

Participant 13: *Injuries which pose an immediate risk to life, cause long term disability or those that prevent a patient returning to their baseline level of function.*

Participant 14: *An injury pattern that has the potential to result in death or significant morbidity for the affected patient.*

Participant 15: *Deranged physiological following a traumatic insult where identified or suspected injuries require or have the potential to require critical life-saving interventions. If it is not life or limb threatening it is not major trauma. In the absence of the above it is simply 'trauma' and should therefore be managed as such.*

Participant 16: *Major Trauma are injuries which are life threatening where a delay in the patient getting to a hospital that can safely treat the patient with a co-ordinated response would be detrimental to the patient.*

Participant 17: *Life threatening injuries with high likelihood of prolonged disability.*

Participant 18: *High impact RTC fall from height fall from standing in height in >65.*

Participant 19: *life threatening, multiple limb injury, abdominal / chest wounds, major haemorrhage, extensive burns*

Participant 20: *Major trauma is a traumatic injury sufficient to cause a significant physiological insult; the exact types of injury will vary across age groups and frailty but major trauma in all cases is associated with worse outcomes and increased mortality.*

Participant 21: *I would identify major trauma as a mechanism that results in multiple or life-threatening injuries. This can be mechanisms of high or low energy.*

Participant 22: *Life threatening or life changing trauma. Defined by injuries that are found or strongly suspected, and deranged physiology that fit those findings / suspicions. Poorly predicted and defined by mechanism.*

Participant 23: *That requiring specialist input*

Participant 24: *Any significant multi system illness with a traumatic cause*

Participant 25: *A condition where the patients injury burden is more than their physiological reserves and may require multiple system support.*

Participant 26: *Significant injury from a traumatic event that requires specialist or multi-disciplinary intervention (including professions allied to medicine input e.g., specialist physiotherapy)*

Participant 27: *MT is an injury sustained by a significant MOI causing traumatic injuries that will impact on patient and cause a high ISS.*

Participant 28: N/A

Participant 29: *Prehospital major trauma should be about which patients will benefit from the added value a major trauma centre brings.*

Participant 30: N/A

Participant 31: *Major trauma should be split into suspected MT, current assessment of MT and Definition of MT. MT = Significant injury that requires definitive clinical care at a specialist centre, following any mechanism that puts the patient's life or multi-limb at risk. Remote assessment for dispatch should be an experienced clinician's personal feelings following the gathering of subjective and objective information from scene. Assessment should reflect the objective information being presented to you at scene. Treatments should reflect assessment and the definition of Major Trauma should then and only then be stated following clinician assessment.*

Participant 32: *An injury of sufficient severity to require urgent specialist interventions. To consider - patients age, resp rate, gcs, area/type of injury, bp (radial pulse?). Not to consider - mechanism, feel there should be no mention to this at all.*

Participant 33: *Any patient with significant polytrauma involving one or more systems that may need specialist intervention.*

Participant 34: *Definition of Major Trauma is an accumulation or constellation of injuries which are potentially life threatening or changing. This would be classically called polytrauma. major Trauma could include isolated injuries high enough in severity to meet the criteria above such as severe head injuries I don't believe mechanism is helpful due to changes in demographics the relevance of severe poly/major trauma from low energy transfer has increased and requires specialist care.*

Participant 35: *Anatomical injuries that, if not managed in a timely fashion, will inevitably result in deranged physiology and lead to significant morbidity/mortality.*

Participant 36: N/A

Participant 37: *Significant injuries resulting in death or disability if not appropriately managed.*

Participant 38: *How you define it will be based on where in the patient journey that patient is. End dx after 3 weeks in hospital with access to complex imaging and specialist input is different to how it will be at the ED front door on in the pre-hospital setting.*

<u>Participant 39:</u> *The physiological impact of trauma and the requirement for physiological support e.g., ventilation, blood products and surgical intervention represent trauma that has caused greatest injury and deviation from normal physiological status. This would incorporate the physiological effect of extremes age and premorbid condition.*

<u>Participant 40:</u> *A complex, multisystem pathological state arising as a result of injury (rather than illness) which left untreated will progress to multi organ failure and death.*

<u>Participant 41:</u> *For me it's about the need for urgent critical care interventions PHEA/ blood transfusion/ pleural drainage or early access to DCS (Damage control surgery)*

<u>Participant 42:</u> *Potential life limiting injuries caused by non-natural events (RTC, assault, falls), causing major injuries/disability to the patient.*

<u>Participant 43:</u> *Patient with multiple, complex, or significant injuries that has the potential to cause prolonged recovery, disability or death. Sustained from a blunt or penetrating mechanism.*

Supplimentary material 3: Work base definitions of Major Trauma

Major trauma bypass protocol (x 9 respondents) +
No specific definition although the Bypass protocol is used with some clinician experience if bypass is not met, but still suspect MTC required.
We have a major trauma tool which identifies patients for bypass to an MTC, this does not necessarily mean they are all major trauma.

ISS >15 (x 8 respondents) +
It reflects the current guidance of ISS. Agree that this retrospective scoring makes life difficult particularly in the acute phase to highlight those requiring specialist trauma care. Need to consider potential major trauma due to high prevalence of "stealth trauma" injuries.

It utilises a significant mechanism of injury (with some examples, but non-exhaustive list), plus altered physiology or significant anatomical injury or high degree of clinical concern.

We do have a major trauma bypass tool which is used to determine if a patient is eligible for a MTC or normal A&E department. No definitive practice to determine a yes or no answer to 'is this major trauma' just clinical judgement and experience alongside the bypass tool.

In truth I am not entirely sure. I do however know that my area of practice interacts with more than one NHS ambulance service. Anecdotally I have observed that the term ‘major trauma’ is used more frequently, and at a much lower threshold in one service, than in another.

Trauma resulting in multiple injuries and need for admission.

MOI, physiology and special circumstances.

Major trauma is any injury that has the potential to cause prolonged disability or death.

Significant mechanism Anatomical and physiological changes Injuries including head, chest, abdomen, pelvis and multiple limb injuries.

APPENDIX 10. DELPHI STUDY RESULTS ROUND 2

Q 1. From the options below rate the items importance with regards to its role in defining major trauma.

	This factor should not be considered n (%)	Low importance n (%)	Medium importance n (%)	High importance n (%)	This is the only factor to consider n (%)
Mechanism of injury	0	6 (18.18)	18 (54.55)	8 (24.24)	1 (3.03)
Actual injuries sustained	0	0	1 (2.94)	32 (94.12)	1 (2.94)
Physiology (e.g. Glasgow Coma Score, Respiration Rate, Systolic Blood Pressure)	0	0	6 (17.65)	28 (83.35)	0
Age (Paediatric)	0	3 (8.82)	21 (61.76)	10 (29.41)	0
Age (>65 years)	0	3 (8.82)	11 (32.35)	20 (58.82)	0
Previous medical history	2 (5.88)	17 (50.00)	11 (32.35)	4 (11.76)	0
Outcome measures such as Injury Severity Scores (ISS)	3 (9.09)	7 (21.21)	11 (33.33)	11 (33.33)	1 (3.03)
Need for surgical intervention	2 (6.06)	2 (6.06)	9 (27.27)	20 (60.61)	0
Need for ventilatory support	2 (5.88)	1 (2.94)	5 (17.65)	25 (73.53)	0
Need for blood products	1 (2.94)	1 (2.94)	5 (14.71)	27 (79.41)	0
Need for Tranexamic Acid (TXA)	2 (5.88)	5 (14.71)	15 (44.12)	12 (35.29)	0
Need for spinal immobilisation (e.g. Collar, Blocks, Scoop)	5 (14.71)	15 (44.12)	12 (35.29)	2 (5.88)	0
Need for pelvic binding/splinting	2 (5.88)	6 (17.65)	17 (50.00)	9 (26.47)	0
Other: please specify below	5 (55.56)	2 (22.22)	2 (22.22)	0	0

Other:	

Q2. Major trauma should be identified by a clinical assessment and actual/perceived injury pattern regardless of the Mechanism of Injury (e.g., High energy v Low energy).

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
1 (2.94)	3 (8.82)	0	21 (61.76)	9 (26.47)

Q3. The older trauma patient (aged 65 years +) should be assessed/triaged/managed differently compared to younger adult trauma patients.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
0	2 (5.88)	2 (5.28)	22 (64.71)	8 (23.53)

Q4. Paediatric trauma patients (aged less than 12 years) should be assessed/triaged/managed differently to adult trauma patients.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
0	3 (8.82)	1 (2.94)	23 (67.65)	7 (20.59)

Q5. Age has no relevance in trauma triage.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
10 (29.41)	20 (58.82)	3 (8.82)	0	1 (2.94)

Q6. Burns (in the non-polytrauma patient).

	Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
Burns should be included within the major trauma triage	0	10 (31.25)	4 (12.50)	16 (50.00)	3 (9.38)
Burns should have a separate protocol/triage from Major Trauma	0	4 (11.76)	4 (11.76)	21 (61.76)	5 (14.71)

Q7. Pre-existing frailty should be considered when identifying major trauma.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
1 (3.03)	4 (12.12)	7 (21.21)	17 (51.52)	4 (12.12)

Q8. Pre-existing medical conditions (co-morbidities) should be considered when identifying major trauma.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
1 (2.94)	11 (32.35)	9 (26.47)	11 (32.35)	2 (5.88)

Q9. Major trauma can only be defined retrospectively using Injury Severity Scores.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
5 (15.63)	21 (65.63)	4 (12.50)	2 (6.25)	0

Q10. Scoring systems are the only way to identify major trauma.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
5 (15.63)	23 (71.23)	4 (12.50)	0	0

Q11. Experienced clinicians are able to identify major trauma patients.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
0	1 (3.03)	4 (12.12)	21 (63.64)	6 (21.21)

Q12. Only high energy mechanisms of injury should be considered in identifying major trauma.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
7 (20.59)	25 (73.53)	1 (2.94)	1 (2.94)	0

Q13. Major trauma triage tools always identify major trauma patients.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
4 (11.76)	22 (64.71)	3 (8.82)	5 (14.71)	0

Q14. Low energy mechanisms of injury (such as a fall from standing) should be considered within major trauma if injury pattern suggests significant injury.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
1 (2.94)	1 (2.94)	0	27 (79.41)	5 (14.71)

Q15. Intoxicated patients make triage of major trauma difficult.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
0	0	3 (8.82)	23 (67.65)	7 (23.53)

Q16. A clinician with a high index of suspicion can confidently identify major trauma without specialist imaging.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
0	3 (8.82)	7 (20.59)	22 (64.71)	3 (5.88)

Q17. A perceived need for ongoing surgical intervention can be a key factor in identifying major trauma.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
0	4 (11.76)	6 (17.65)	23 (67.65)	1 (2.94)

Q18. A perceived need for Intensive Care Unit (ITU) admission can be a key factor in identifying major trauma.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
0	4 (11.76)	6 (17.65)	23 (67.65)	1 (2.94)

Q 19. Major Trauma Bypass Protocols identify patients who would benefit from definitive care at a Major Trauma Centre and not just patients with high Injury Severity Scores.

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
0	3 (9.09)	4 (12.12)	21 (63.64)	4 (15.15)

Q20. Major Trauma patients can only be managed at a Major Trauma Centre (excluding Traumatic Cardiac Arrest, compromised airway, transport time greater than 60 minutes).

Strongly Disagree n (%)	Disagree n (%)	Neither Agree or Disagree n (%)	Agree n (%)	Strongly Agree n (%)
2 (5.88)	14 (41.18)	7 (20.59)	8 (23.53)	3 (8.82)

Table 1. Consensus levels and changes between rounds 1 and 2 (questions 1 to 20).

Variable	Consensus ($\geq$70%)	Round 1 %	Round 2 %	Wilcoxon Signed Rank test
Actual injuries*	Yes	100 (>med)	100 (>med)	0.083
Only high energy mechanisms should be considered	Yes	97.5 (>disagree)	94.12 (>disagree)	0.132
Physiology*	Yes	97.44 (>med)	100 (>med)	1.000
Need for blood products*	Yes	92.3 (>med)	94.12 (>med)	1.000
Age (>65 years) special consideration*	Yes	89.75 (>med)	91.17 (>med)	0.462
Experienced clinicians are able to identify major trauma patients	Yes	89.74 (>agree)	84.85 (>agree)	0.527
Need for ventilatory support*	Yes	89.47 (>med)	91.18 (>med)	1.000
Intoxication makes triage difficult	Yes	87.5 (>agree)	91.18 (>agree)	1.000
Age (paediatric)*	Yes	87.18 (>med)	91.17 (>med)	0.805
Age has no relevance	Yes	85 (>disagree)	88.23 (>disagree)	
Low energy mechanisms should be considered	Yes	85 (>agree)	94.12 (>agree)	0.796
Elderly require different assessment/management	Yes	85 (>agree)	88.24 (>agree)	
Need for surgical intervention*	Yes	84.61 (>med)	87.88 (>med)	0.134
Triage tools always identify major trauma	Yes	82.5 (>disagree)	76.47 (>disagree)	0.057
Mechanism of injury (MOI)*	Yes	82.5 (>med)	81.82 (>med)	0.971
Scoring systems are the only way to identify major trauma	Yes	76.92 (>disagree)	86.86 (>disagree)	0.796
Paediatrics require different assessment/management	Yes	77.5 (>agree)	88.24 (>agree)	
Identified by clinical assessment (as opposed to mechanism of injury)	Yes	77.5 (>agree)	88.23 (>agree)	
Can only be defined by retrospective scores	Yes	75 (>disagree)	81.26 (>disagree)	0.971
Perceived need for Intensive Care Unit admission	Yes	75 (>agree)	70.59 (>agree)	0.808
Triage tools can identify patients who would benefit from MTC care	Yes	75 (>agree)	78.79 (agree)	0.541
Outcome measures (e.g., injury severity scores) *	Yes	71.8 (>med)	69.69 (>med)	0.921
Pre-existing frailty should be considered	Yes/No	70 (>agree)	63.64 (>agree) 21.21 (neutral) 15.15 (>disagree)	0.142
Need for tranexamic acid (TXA)*	No/Yes	69.22 (>med) 30.77 (Low)	79.41 (>med)	0.124
Need for pelvic binding*	No/Yes	64.1 (>med) 35.9 (low)	76.47 (>med)	0.432
Perceived need for surgical intervention*	No/Yes	62.5 (>agree) 22.5 (neutral) 15 (Disagree)	70.59 (>agree)	0.218
Major trauma can only be managed at an MTC	No	62.5 (>disagree) 15 (neutral) 22.5 (agree)	47.06 (>disagree) 20.59 (neutral) 32.35 (>disagree)	0.041
Need for spinal immobilisation	No	61.54 (low) 38.47 (>med)	58.83 ($\leq$low) 41.17 (>med)	0.499
Clinicians high index of suspicion can identify major trauma without imaging	No/Yes	60 (>agree) 15 (neutral) 25 (disagree)	70.59 (>agree)	0.084
Burns should have a separate protocol	No/Yes	57.9 (>agree) 26.32 (neutral) 15.79 (disagree)	76.47 (>agree)	0.325
Previous medical history	No	56.41 (low) 43.59 (med)	55.88 ($\leq$low) 44.11 (>med)	0.830
Burns should be included in major trauma triage	No	55.27 (>agree) 7.89 (Neutral) 36.85 (disagree)	59.38 (>agree) 12.5 (neutral) 31.25 (disagree)	0.533
Pre-existing co-morbidity should be considered	No	51.28 (>agree) 25.64 (neutral) 23.08 (disagree)	38.23 (>agree) 26.47 (neutral) 35.29 (>disagree)	0.148

*Refers to multi-variable choice within question 1.

Table 2. Changes in consensus between rounds 1 and 2 (questions 1-20)

Variable	Consensus (≥70%)	Round 1 %	Round 2 %
Pre-existing frailty should be considered	Changed to No	70 (>agree)	63.64 (>agree) 21.21 (neutral) 15.15 (>disagree)
Need for tranexamic acid (TXA)*	Changed to Yes	69.22 (>med) 30.77 (Low)	79.41 (>med)
Need for pelvic binding*	Changed to Yes	64.1 (>med) 35.9 (low)	76.47 (>med)
Perceived need for surgical intervention*	Changed to Yes	62.5 (>agree) 22.5 (neutral) 15 (Disagree)	70.59 (>agree)
Clinicians high index of suspicion can identify major trauma without imaging	Changed to Yes	60 (>agree) 15 (neutral) 25 (disagree)	70.59 (>agree)
Burns should have a separate protocol	Changed to Yes	57.9 (>agree) 26.32 (neutral) 15.79 (disagree)	76.47 (>agree)

Q21. How would you personally define 'Major Trauma' in your own words? Please include factors you think should be considered and those you think should not be considered.

Major trauma is any injury that has the potential to cause life changing or life-threatening injuries.

Each case on its own value, usually done by examination and identification of suspected injury, the use of trauma triage tools can be misleading if not applied correctly.

The increased potential of prolonged disability or death.

An injury pattern that presents with abnormal physiology or level of consciousness and is consistent with a high energy or dangerous mechanism.

A patient who has sustained significant injuries that may be life or limb threatening and benefit from extended levels of care both in the prehospital environment and within hospital.

Injury or injuries that pose a risk to life, cause long term disability, or prevent the patient returning to their baseline level of function. Mechanism of injury, physiology, pre-morbid function, and comorbidities should be considered alongside suspected and identified injuries when considering the likely impact on the patient.

A patient who has sustained significant injuries or who may have experience significant forces with a high degree of clinical concern to their age.

Severe or life-threatening injuries.

I think of Major trauma as a mechanism-based descriptor. Injury severity scores denote Injury severity and severe injuries can come from low velocity (non-Major trauma) mechanisms. To my mind the term Major trauma describes a high velocity mechanism with a high risk of severe multisystem injury with or without haemodynamic instability and which will benefit from being met by a trauma team in hospital who see these patients more frequently.

Major Trauma is traumatic injury significant enough to pose a threat to life either from isolated severe injury or constellation of injuries (polytrauma).

Life threatening or life changing injuries to that particular patient.

Multisystem or complex single system injuries, causing physiological derangement, and requiring specialist medical input.

Multiple injuries - polytrauma MOI consistent with high suspicion of injury Requirement of multi -specialist team approach to patient care Elderly falls from standing - not major trauma but can have significant traumatic injuries.

Trauma which significantly effects the normal functioning of the body and which requires specialist treatment and rehabilitation.

Where the actual injuries suspected or confirmed, alongside an indicative physiological response are such that there is a severe, imminent or immediate threat to life, regardless of the causative mechanism.

An injury or group of injuries sustained from external factors that threaten the integrity of the body’s main systems and their ability to function normally and sustain life or motion. Consideration should be given to influences that may affect, including type of insult, frailty of patient, capacity to self-identify significant injuries and capacity to communicate.

Significant injury to an individual that will have a major impact on their current physical/mental way of living.

Major trauma is when the type and severity of injury is life threatening and potentially life limiting.

Traumatic injuries that are potentially life-threatening or life-changing and result in altered physiology.

Traumatic injuries sufficient enough to threaten life or limb. Injuries which may be life changing and involve a long recovery period.

Major trauma is a pattern of injuries disrupting essential body functions. The injuries compromise either airway, breathing, circulation or neurological function. Mechanism of injury plays a part in defining it but is not the sole factor. There should definitely be amendments for elderly, with a lower threshold for suspecting significant injuries.

A traumatic insult to the patient resulting in multiple injuries which are life or limb threatening in the short term or have a significant impact on patient's lifestyle (in terms of morbidity and disability) in the longer term.

Trauma that results in physiological compromise and which needs immediate treatment to optimize physiology.

Significant systemic injury as a result of a traumatic episode e.g., fall from standing in an elderly frail patient or potentially latent injuries in a child.

Major trauma is an injury that can cause a patient a potential prolonged disability or death.

Major traumatic injuries.

Injuries with an immediate threat to life or risking long term morbidity.

Major trauma is an umbrella term for conditions that would benefit from MTC input or where the patient would suffer for lack of MTC input. These are normally severe injuries to one system or injuries to multiple systems from an acute non-disease-based process.

Much along the lines of Major Incident - An injury pattern requiring physiological support and expert intervention out-with standard practice.

Table 3. Frequency of free text coding

Variable	Round 2 n
Significant injury/Polytrauma	12
Life threatening/changing/disability	27
Mechanism of Injury (MOI)	9
Specialist input	5
Physiological changes	8
Prolonged treatment/Rehab	3
Age	4
Previous medical conditions	2
Bespoke/patient specific care	6
ISS	1
Total number of variables	77

Table 4. Frequency of free text coding between rounds 1 and 2

Variable	Round 1 n	Round 2 n
Significant injury/Polytrauma	24	12
Life threatening/changing/disability	18	27
Mechanism of Injury (MOI)	14	9
Specialist input	12	5
Physiological changes	10	8
Prolonged treatment/Rehab	8	3
Age	6	4
Previous medical conditions	3	2
Bespoke/patient specific care	2	6
ISS	1	1
Total number of variables	96	77

Q22. Does your area of practice have a definition for Major Trauma and if so, how do they define Major Trauma?

High mechanism of injury and ISS greater than 15.

Yes, the increased potential of prolonged disability or death.

Yes, they use the regional trauma triage tool.

Initially defined using major trauma bypass criteria. Retrospectively defined using ISS >15.

Unsure.

Nothing agreed.

mechanism of injury and primary survey as basis of care form trauma patients.

As per the NTN guidelines.

Not exactly. There is no 'written' definition. There is a nod to the local MTC bypass criteria however this is not referred to often. It is largely based on clinical presentation and the clinician's suspicion of injury pattern alongside the pts likely ongoing speciality requirements. We have discussed a retrospective audit on our specificity when compared to the local MTC bypass protocol in order to validate (or otherwise) our current practice.

Yes, although the definitions used aren't comparable as they don't account for the differential locations of MTC to PT. Objectively biased to ensure over triage.

Follow local trauma bypass and focus on high mechanism of injury.

We have a major trauma bypass protocol which can be used to guide the clinician.

A significant mechanism of injury, plus any of abnormal physiological, anatomical assessment or special circumstances.

As defined in the Major Trauma Bypass Protocol.

They do not.

Same as NTN one.

Defined by patients that meet the major trauma bypass tool.

Q23. Please tick the variables you would use to define Major Trauma.

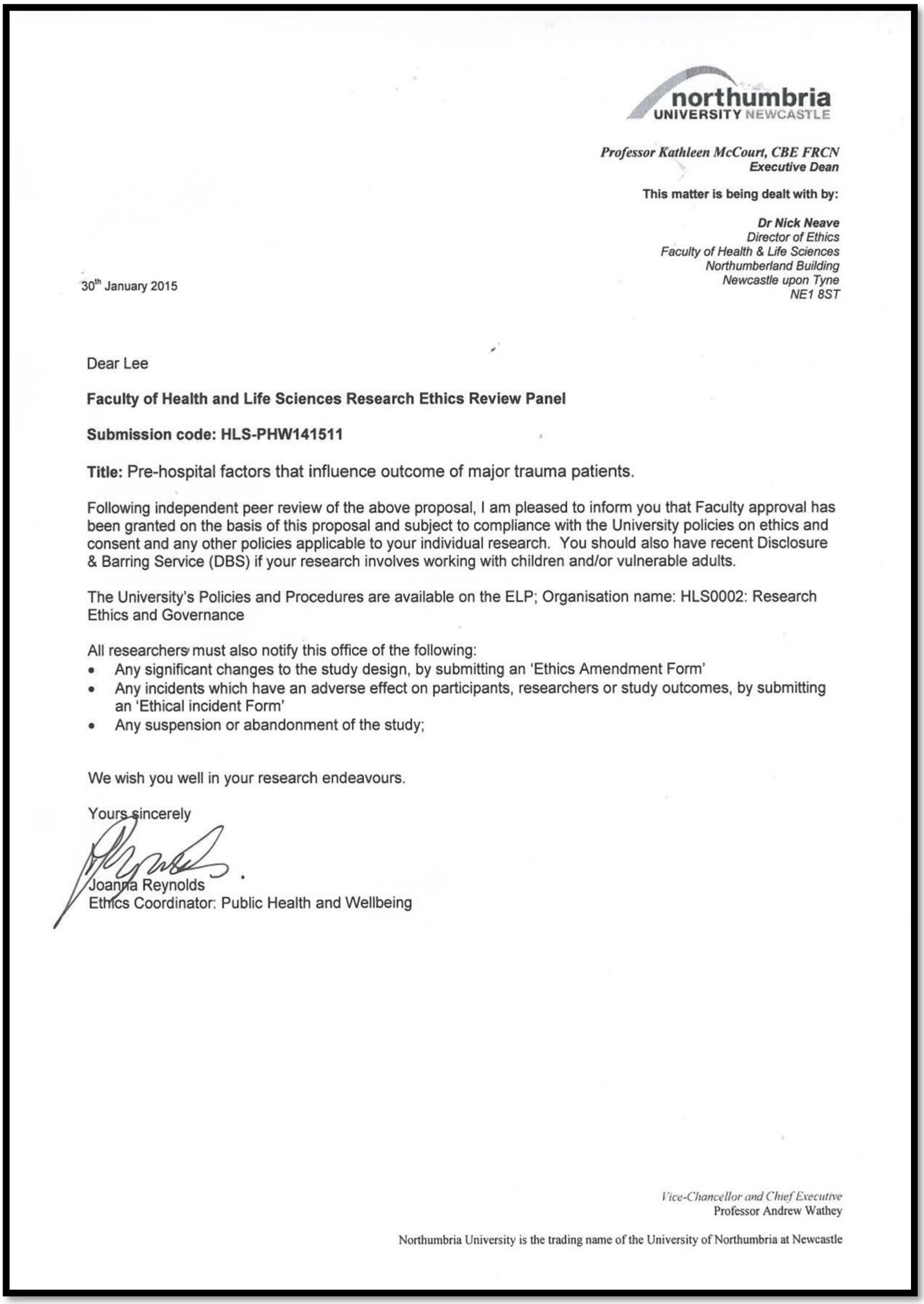
Table 3. Individual variable consensus.

ANSWER CHOICES	RESPONSES n (%)
Life threatening injuries	31 (91.18)
Limb threatening injuries	30 (88.24)
Any injury that requires specialist intervention	14 (41.18)
Major blood loss	31 (91.18)
Injury to more than one limb	7 (20.59)
Burns greater than 15% (10% Child)	18 (52.94)
Injury causing reduced consciousness	22 (64.71)
High energy mechanism (for example but not limited to: roll over RTC, fall from >2m, Gunshot wound)	16 (47.06)
Major Trauma is dependent on multiple factors that are unique to the individual patient at a given time	21 (61.76)
Injury Severity Score (>15)	11 (32.35)
Injury causing new neurology	19 (55.88)
Suspected spinal injury requiring immobilisation	7 (20.59)
Suspected abdominal injury causing haemodynamic instability	26 (76.47)
Suspected pelvic injury requiring splinting	14 (41.18)
Other: See below	1 (2.94)
Penetrating trauma, Chest injuries with hypoxia - suspected flail.	
Frailty/age @ a location. E.g. Nursing home v mountain summit	

Table 4. Differences in consensus of individual variables between rounds 1 and 2.

Variable identified	Consensus (≥70%)	Round 1 %	Round 2 %
Life threatening injuries	Yes	95	91
Limb threatening	Yes	92.5	88
Major blood loss	Yes	87.5	91
Suspected abdominal injury with haemodynamic instability	Yes	80	76
Injury causing reduced consciousness	Yes	72.5	65

APPENDIX 11. ETHICS APPROVAL FOR IDENTIFYING PREHOSPITAL FACTORS ASSOCIATED WITH OUTCOME FOR MAJOR TRAUMA PATIENTS IN A REGIONAL TRAUMA NETWORK: AN EXPLORATORY STUDY.



northumbria
UNIVERSITY NEWCASTLE

Professor Kathleen McCourt, CBE FRCN
Executive Dean

This matter is being dealt with by:

Dr Nick Neave
Director of Ethics
Faculty of Health & Life Sciences
Northumberland Building
Newcastle upon Tyne
NE1 8ST

30th January 2015

Dear Lee

Faculty of Health and Life Sciences Research Ethics Review Panel

Submission code: HLS-PHW141511

Title: Pre-hospital factors that influence outcome of major trauma patients.

Following independent peer review of the above proposal, I am pleased to inform you that Faculty approval has been granted on the basis of this proposal and subject to compliance with the University policies on ethics and consent and any other policies applicable to your individual research. You should also have recent Disclosure & Barring Service (DBS) if your research involves working with children and/or vulnerable adults.

The University's Policies and Procedures are available on the ELP; Organisation name: HLS0002: Research Ethics and Governance

All researchers must also notify this office of the following:

- Any significant changes to the study design, by submitting an 'Ethics Amendment Form'
- Any incidents which have an adverse effect on participants, researchers or study outcomes, by submitting an 'Ethical incident Form'
- Any suspension or abandonment of the study;

We wish you well in your research endeavours.

Yours sincerely

Joanna Reynolds
Ethics Coordinator: Public Health and Wellbeing

Vice-Chancellor and Chief Executive
Professor Andrew Wathey

Northumbria University is the trading name of the University of Northumbria at Newcastle

"It is said that your life flashes before your eyes just before you die. That is true, it's called Life."

— Terry Pratchett (1998), '*The Last Continent*'