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Environmental conditions and bodily decomposition: Implications for long term management of war fatalities and the identification of the dead during the ongoing Ukrainian conflict

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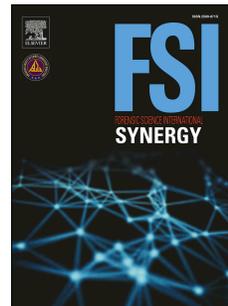
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Title Page: Environmental conditions and bodily decomposition: Implications for long term management of war fatalities in Ukraine following the 2022 invasion

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Environmental conditions and bodily decomposition: Implications for long term management of war fatalities and the identification of the dead during the ongoing Ukrainian conflict

Introduction

On 24 February 2022, Russia invaded Ukraine in what they referred to as a ‘special military operation’. Since then, both Russia and Ukraine have incurred heavy losses, though there remains great discrepancy between the deaths reported by both nations. In recent joint international interventions following mass casualty incidents, the majority of operations have been situated within countries in the global south; particularly within nations which do not have the appropriate medico-legal surviving infrastructures to provide the relief required in an emergency situation where high levels of deaths have been incurred. Two examples of this are the Asian Tsunami of 2004 and Haitian earthquake of 2010. The Asian Tsunami of 2004 had an epicentre 200 km west of Sumatra, with the resulting Tsunami impacting on coastal areas of Sri Lanka, Maldives, Indonesia, Malaysia, Thailand and India. It is estimated 227,000 deaths. The Haitian Earthquake 2010 of 7.0 magnitude resulted in death toll of 220,000, while the larger magnitude (7.2) earthquake of 2021 resulted in fewer fatalities of 2,000. Both mass fatalities of 2004 and 2010 had considerable, multinational responses, which were challenged by scale, extent, and conditions, and resulted in operational protocols being reviewed [1][2][3][4][5][6]. In Ukraine, there are robust forensic infrastructures at local and national levels, with well educated, trained and experienced staff. These infrastructures are connected to international structures such as the International Committee of the Red Cross (ICRC) and International Commission on Missing Persons (ICMP). Despite strong facilities and established procedures in Ukraine at the outset of the conflict, the intensity and nature of the fighting within densely populated areas has resulted in considerable civilian and military fatalities, inevitably this has led to temporary burials conducted during or during a lull in fighting. In areas retaken by Ukraine forces there has been considerable local effort to exhume bodies from temporary graves and to identify the remains using primarily DNA [7]. However, the scale of this activity is disproportionate to the scale of the casualties.

In this paper, the authors provide an overview of the deaths incurred during the early weeks of the war and will attempt to illustrate the range of variables which will inform the practical response to recover and identify those killed, before they receive their final burial. It will introduce some of the organisations which have provided forensic support and will also identify emerging ethical considerations which should be monitored for the remainder of the conflict.

During an active conflict there is not the opportunity to document in detail the precise range of depositional environments and timeframes, this work might be possible in the future but currently there are much more pressing priorities. As such this paper should be seen as a discussion document written at a specific time during an evolving conflict. However, the response, both within Ukraine and

from the international community needs to recognise Ukrainian autonomy, and lead. It also needs to adapt procedures to these specific circumstances of on-going conflict, resources, but importantly not simply importing standard procedures without adaption to local needs. The ongoing war in Ukraine provides an unfortunate reminder of the value of forensic infrastructures during, and in support of a military emergency.

For clarity, within this paper the authors will use standard military definitions of ‘fatalities’ to describe those killed as a result of military action and ‘casualties’ to describe those injured as a result of military action ‘As the war in Ukraine has not yet concluded, this paper will reflect upon the period 24 February-23 May 2022 only.

Casualties in Ukraine

The invasion of Ukraine started on the morning of 24 February 2022, instantly global media was flooded with reports of airstrikes and missiles used to target military bases, airfields, border posts and cities across Ukraine; resulting in the first casualties of the war, incurred by both civilians and military personnel. Targets for advancing infantry and mechanised units included Lutsk, Ivano-Frankivsk, Kyiv, Odesa, Mariupol, Kharkiv and Kramatorsk. At least 18 dead were reported from Odesa during these first bombardments [8]. On 25th February the UN High Commissioner expressed grave concern over the report of civilian casualties [9]. At the same time, media reports described the Russian deployment of mobile crematoria to the front line, raising concerns about the dignity of the dead, and the potential to hide evidence of war crimes. It remains unclear if the crematoria were used at this point, and whether they were repurposed industrial crematoria, or specifically created for the disposal of human remains.

In the first days of March the ground offensive had started to stall, with reports of a large military convoy making little progress towards Kyiv [10]. However, by 5 March Russian forces had advanced to capture Bucha, Hostomel and Vorzel. A Ukrainian counter offensive started on 16 March, retaking Markiv by 25 March, and reoccupying Bucha by 1 April. At this stage, allegations of war crimes by the occupying Russian army started to emerge, including the deliberate killing/execution of civilians and systematic rape [11].

As these allegations continued to mount, accumulating thousands of reports within weeks, the Ukrainian government asked the International Criminal Court (ICC) to investigate events in Bucha as part of its ongoing investigation into war crimes or crimes against humanity [12]. These allegations are denied by the Kremlin [13], though trials against individuals accused of war crimes across Ukraine had begun at the point of writing with the first trial resulting in a guilty verdict for captured

Russian soldier Sgt Vadim Shishimarin for the murder of Oleksandr Shelipov in Chupakhiva on 28 February [14]. As Russian units have continued to move East, claims of targeted civilian deaths and the intentional destruction of civilian infrastructure have continued to be raised, amongst other allegations; but with such levels of destruction and an unsafe environment for emergency responders, concerns over access to evidence have continued to mount.

The ability to isolate a crime scene to record and collect potential evidence as per standard forensic practice has not been possible in almost all cases, which has placed greater emphasis upon digital forms of evidence, such as civilian photography or video footage and particularly satellite imagery. For example, there is timestamped satellite imagery which seems to show civilian bodies lying in streets during the period of the Russian army occupation in keeping with civilian reports [15], while 67 bodies were recovered from a mass grave constructed during the period of Russian occupation, which was located using satellite imagery [16][17]. According to the Mayor of Bucha, Anatoliy Fedoruk, speaking in April, 412 bodies had been found since the expulsion of the Russian army [18]. Inevitably the numbers of the dead have increased during active investigation into both their identity and circumstances of death. Despite the huge losses, there have been huge efforts within Ukraine to recover the dead, transporting them to facilities where they can be prepared for burial within a legal grave until a permanent resting spot is determined, but search and recovery remains difficult and labour intensive.

The response to the recovery of the dead will vary depending on the nature of active combat in any given location (relative safety/opportunity considering current fighting) and critically, who holds the ground. The nature of deaths caused by military power within densely populated civilian areas means that search and recovery plans must draw upon the forensic expertise of civilian practitioners, whilst being informed by a growing body of knowledge about the nature of deaths caused by military action, particularly where mines or explosives have been used [e.g, 19] [20]. With a conflict such as the war in Ukraine, deaths can be divided into several categories:

- 1) Military combat casualties (troops in uniform directly killed by enemy action or friendly fire)
- 2) Civilian casualties (collateral deaths caused by direct military combat)
- 3) Deliberately targeted Civilian casualties e.g., long-distance shelling/rocket attacks on dwellings, hospitals or places of civilian shelter
- 4) Targeting of individual civilians killed directly by troops such as the alleged individual execution/ war crimes committed in Bucha prior to Russian withdrawal

Given the huge volumes of casualties and the security risks presented within active conflict zones, it is likely that deaths will be processed by whichever structure has the capacity to provide an immediate response, whether civilian, military or humanitarian, working with the existing structures in Ukraine to facilitate the smooth transfer of information. While areas to the north west of Kyiv were occupied

by Russian ground troops before withdrawal, the city was targeted by missiles causing destruction to high rise buildings [21]. Similar patterns of destruction have been seen across areas under attack, along with reports of the shelling of civilian infrastructure. On 20 March it is alleged that Art School No.12 in Eastern Mariupol was bombed while about 400 women, children and elderly persons were sheltering [22]. The continued fighting and bombardment had led to considerable destruction of the city, and limited success in evacuating civilians [23]. On 13 April Russian attack was focussing on the abandoned Azovstal iron and steel works, which in addition to providing a defensive strong point for Ukrainian forces, was also a place of shelter for large numbers of civilians. Some heavily bombed structures may not be accessible either to official or civilian teams, civilians may also be forbidden to enter bombed structures in order to search for deceased neighbours or family members due to safety risks. In Ukraine today, the reality is often dealing with multi-floor structures, including underground structures as shelters, many of which were then subject to intensive bombing/missile attacks. There are not enough underground structures or shelters in Ukraine for people to access quickly, and current building legislation and codes of engineering do not reflect the requirements of a wartime shelter and have not withstood shelling [24]. Consequently, many 'shelters' have not proved a reliable source of protection for the civil population. Access to collapsed structures will be extremely difficult and almost impossible during active hostilities, as seen in Kyiv, Odessa and Mariupol.

Another issue for forensic practitioners is the matter of burials performed outside of legal frameworks. Both Civilians and combatants have allegedly been killed by occupying forces and buried in mass graves or left out where they laid. Civilians may have been able to provide temporary burial for individuals, but these bodies under Ukrainian law require documentation prior to an official interment, and therefore must be exhumed for documentation before being reinterred into what is likely a temporary burial until the conclusion of the war. Mass graves have also been used by Russian soldiers to bury Ukrainian soldiers and civilians. On 8 April, Bucha's deputy mayor, Taras Shapravskiy, stated "more than 360 civilians were killed and around 260-280 were buried by other residents in the mass grave". He added "that there were two parallel trenches dug at the mass grave site, with bodies piled on top of each other in layers" [25]. The mayor of Mariupol has claimed that Russian forces established a mass grave site in Manhush. The site in a field, next to an established cemetery, is visible on U.S. satellite images [26]. The presence of the dead is visible both within war zones and within populated civilian areas. The number of civilian casualties is now thought to exceed the number of military casualties [27].

Whilst the Geneva Convention does require the victor of the battlefield to protect the dignity of the dead, and to perform a burial or cremation where possible, the use of mass graves to provide a rapid burial following large losses is deeply rooted in international military culture. Though the majority of medium and large armed forces share very similar burial practices, not all have the same experiences of mass loss. At times, mass loss necessitates mass burials, particularly during military conflicts, but

also during civilian emergencies, e.g., covid. Mass burials are typically performed where there is no time to perform individual burials, where there are limitation on the land due to features or sanitary requirements for the living, or in cultures where the custom is viewed as an act of camaraderie, e.g. German military culture between 1866-1918 [28].

However, since the development of the Imperial (now Commonwealth) War Graves Commission cemeteries during the First World War, there has been an increased desire to provide combatants with a single marked grave wherever possible, regardless of social class or military rank. This is in contrast to the treatment of the majority of war dead in earlier periods. Despite the long history of mass graves as an international military burial culture, the use of mass graves in a military context remains striking to civilian populations. Mass graves can represent a pragmatic response to mass casualties. However, the nature of mass graves can vary considerably from dignified burial with bodies laid out but in a single large hole to a more ad hoc means of disposal.

Many examples of different interments relevant to contemporary conflict can be found within the discipline of Conflict Archaeology. Archaeologists working on the former Western Front of the First World War continue to locate the remains of those who died, (usually unintentionally). Circumstances range from bodies which were never recovered, temporary isolated or grouped field graves which were lost or obscured by subsequent fighting or poor record keeping, accidental burial (e.g., burial as a result of a shell explosion) and organised temporary battlefield burial grounds. Examples can be found of individual graves [e.g., 29], and also of mass graves. In 2002, Yves Defossés (DRAC), Gilles Prilaux (Institut National de Recherches Archéologiques Préventives (INRAP) and Alain Jacques (Municipal Archaeological Service of Arras) recovered a mass grave at Le Point Jour, France, which contained the skeletal remains of twenty British soldiers from the 10th Battalion, Lincolnshire Regiment, known as the Grimbsy Chums [30]. The burial is believed to have been performed by their own comrades, who laid them out to appear as if they were arm in arm, showing that a mass burial could still be a caring act [31].

In accordance with the Geneva Convention, some mass graves from the First World War were performed by the enemy, but again, there are examples which demonstrate respect shown to those interred. Between 2007-8, excavations at Fromelles, Belgium, revealed at least 8 mass graves dug by German soldiers, containing approximately 400 British and Australian dead [32]. The graves had been filled with varying levels of care, with some soldiers laid out carefully, wrapped in groundsheet and placed head to toe with one another, whereas others appeared to have been deposited in a less careful manner. The more organised graves hint at the historical German culture of the Comrades burial [33]. At the time, casualty returns had been forwarded to the Red Cross in Geneva by the German Army, but unfortunately the location of the graves had become lost.

An example of an unintentional burial would be the recovery of eight soldiers from the 11th Battalion of the Northumberland Fusiliers, along with one further unknown soldier in De Reutel, Belgium in 2018. In this case, a shell had struck a trench containing a group of two officers and their men. The impact of the shell resulted damage to the human remains and associated artefacts, which were dispersed within the area of the trench [34]. Personal effects allowed for the identification of Lt Col Albett, who was reburied with his men in a Commonwealth War Graves cemetery in 2021 [35]. Each of these burial types may be encountered during the ongoing forensic response in Ukraine, though of course there may also be examples which demonstrate less respectful conditions shown towards the deceased, as was observed during recoveries at Batajnica and in Iraq [36][37]. These archaeological examples from a historical industrial war may complement more recent forensic investigations of mass graves from different types of conflicts and atrocities [38][39][40][41][42] to offer an insight into the potential situations that forensic practitioners in Ukraine may face in their context of industrial war. Methods of geophysical survey and imaging will assist with the location of potential graves and data acquisition where and when it is safe to conduct this work [43][44]. Geophysical imaging is typically used to identify features within the land, rather than to identify any deposits within a feature, however recent research has shown the potential for geophysical techniques and geoelectrical methods for use within the forensic sphere to detect ‘anomalies associated with disturbed ground and human decay’ depending upon the geology of the site [45][46].

The use of mass or unmarked unmarked graves to bury non-combatants can be problematic particularly from a civilian perspective, and such imagery has caused shock around the world. In many contemporary cultures, the concept of mass graves is commonly associated with atrocities, war crimes and gang violence, and civilians are often unaware of the use of mass graves within a military context or within our recent domestic histories. For instance, in Nineteenth Century England, mass graves were used to facilitate pauper burials for those who did not have the means to pay for their funeral. In this tradition, individuals were provided a ‘free’ place within a mass grave which often remained ‘open’ until it was filled with bodies and could be backfilled [47]. However, mass graves were also commonly used by the paying working classes. Those who chose to purchase a ‘guinea grave’ rather than an individual burial plot, received a place within the mass grave determined by the fee paid [48] [49], This burial type often featured a grave marker, but not exclusively. . This gap in our lay knowledge can make it difficult for some to navigate what is a complex set of issues in Ukraine: a combination of alleged atrocities, a perceived indifference to civilian casualties, plus the lack of, or inability to provide, a respectful burial in some cases. It is likely that we will observe the use of mass graves for a range of purposes, including (but not limited to) the need to provide a rapid field burial to maintain the sanitation of the field for the living, a lack of time to safely perform culturally appropriate burials, security risks for those performing burials, a lack of resources to provide more substantial burials and attempts to hide evidence of war crimes.

Observing nations should consider the implications of this within their own civil-military resilience plans and ensure that any military mortuary affairs provision has the capacity to react and expand in response to mass casualties. This will serve not only to protect the dignity of the dead but will also assist with the ability to respond to information campaigns which manipulate the dead and their families, including the sharing of personal information and exaggerating or minimising casualty figures by combatant nations.

Responsibility for the exhumation and recovery of bodies in the territory retaken by Ukraine is under the auspices of the Prosecutors Office. Ukrainian Deputy Prosecutor Stanislav Kozynchuk (Deputy Head of the Kyiv Region Prosecutor's Office) has stated that "all bodies not buried according to law needed to be exhumed, subject to autopsy and examined by a forensic doctor". There have been many cases where civilians have retrieved a body and performed their own burial, often within the grounds of a family home, having informed the authorities after the burial is complete [50]. In these cases, the process is to recover bodies (including those previously buried) and to transport remains to the closest mortuary or morgue with capacity. Mortuaries in locations close to intensive fighting have often been overwhelmed, quickly reaching capacity and unable to accept all bodies which are brought to them. It is likely that this backlog will also affect the ability to process and bury civilian deaths which do not relate to the war, if this is not already happening.

Work to locate or exhume a burial is conducted by the police, assisted by Ukrainian civilian volunteers and workers from international humanitarian structures where support has been sought. The police document the process of exhumation, as observed during the exhumation of men allegedly executed at former Russian Military checkpoint Borodyanka, 40 miles north west of Kyiv [51]. Fatalities as a result of Russian occupation or bombardment are difficult to verify independently, leaving many researchers dependent on social media reporting, photos and videos as sources of information.

For the first time, we are able to observe a war almost in real time from our positions of safety. However, it is important to remember that all social media posts will have been shared with a specific intention, and may give us some insight into a situation, but this does not mean that we possess the full facts of any scenario, that the picture or footage is definitively from the incident it claims to document (or from a historic event), or that we understand the motives of the poster (which may be an individual, an armed force or a national government department as but three examples). Despite the issues with digital media, it can provide vital evidence to determine the circumstances of death, particularly when used to support evidence from the scene. Evidence is collected not only to determine the cause of death, or the motives which resulted in the death, but also to assist with efforts to identify or confirm the identity of the dead.

Identifying the dead – Forensic Human Identification

Forensic human identification (FHI) is a multi-disciplinary endeavour which brings together a variety of forensic and related disciplines, with the primary aim of medico-legal identification of the dead. FHI brings together multiple forensic specialist areas including identification from the hard (anthropology and odontology) and soft tissues (latent prints, pathology, and surgical intervention), biomolecular methods (DNA and stable isotope fingerprinting), and facial recognition and reconstruction [52]. In early-stage cases where human identification is on relatively complete (non-disrupted) or partially decomposed bodies, the primary biological and personal identifiers are most useful. These are usually addressed by individually sensitive biological markers such as DNA, fingerprints, odontology (teeth), or facial morphology. To make a positive or possible match such markers require an ante-mortem comparator, as well as the biological data from the deceased. The collection of ante-mortem data can come from official primary sources such as DNA databases, dental and medical records, and biometric records (including fingerprints from immigration authorities or law enforcement), from secondary sources of DNA (from hairbrushes or toothbrushes) from a likely decedent, or from tertiary sources such as familial DNA from parents and siblings of a possible decedent [53]. The protocols and procedures for collection and comparison of such data are well established by international organisations such as INTERPOL, the ICRC, and the ICMP [54][55], as well as national identification agencies. In many reported cases from Ukraine [56], forensic professionals are also undertaking identification (both positive and presumptive) through facial and body recognition (particularly to identify Russian soldiers, if not exclusively), a process which may be highly psychologically scarring and stressful, as well as identification based on personal effects and clothing. It is worth noting whilst these can be used to advance an identification, that identity should still be confirmed based on primary biological criteria (DNA, fingerprints, odontology etc) unless ante-mortem comparative data is unavailable.

The requirement to establish the identity of the dead generally falls into three main areas: (i) criminal investigations resulting from homicide, unexplained natural deaths, or suicide; (ii) non-criminal events resulting in single or multiple deaths; and (iii) war crimes investigations and genocide. The latter category is covered under auspices of the 1949 Geneva Conventions governing the protection and amelioration of the wounded and sick involved in armed conflicts, prisoners of war, and civilians in times of war. Other international legal protections or conventions relating to civilians are found in the UN Declarations on Human Rights and Conventions on Genocide, supplemented by non-binding guidance provided by INTERPOL (Resolution on Disaster Victim Identification, or DVI) and other organisations [57].

In the context of the Ukrainian conflict, the role of FHI is critical if the remains of combatants (from both Ukrainian and Russian forces) and civilians are to be treated with dignity and with ultimate

resolution of identity. The nature of the conflict thus far, with widespread attacks on civilians, as well as growing evidence of gross human rights violations and mass atrocities, creates a situation in which FHI is by necessity driven by DVI protocols. In simple terms DVI relates to any situation where the number of fatalities overwhelm or strain local capacity to recover and identify the dead. DVI protocols may be applied equally in criminal or humanitarian contexts (in the latter case overlapping with the developing field of humanitarian forensics), with any activities supported by internationally recognised protocols and documentation. The aim of any DVI operation is to ultimately establish the identity of every victim by comparing and matching accurate ante-mortem (AM) and post-mortem (PM) data. It has been recognized that the inability to identify human remains has important economic, personal, and societal consequences for the families of the deceased and ultimately for the state. This is in no way compromised by the necessity to collect forensic trace evidence, or other biological or anthropological evidence related to abuse, torture, or mechanism or cause of death. As such, with specific reference to how the conflict and impacts on civilian populations continues to unfold, it is perhaps wise to consider FHI in terms of differing forensic, and particularly decompositional or taphonomic timescales.

Decomposition and its effect on the identification process

As described, the intensity and location of fighting has resulted in high levels of fatalities within civilian spaces. At the time of writing, there are numerous videos and images online showing deceased victims left in the streets [58][59], recovered from houses and gardens [60][61], and buried in single graves (often by family) [62][63] or mass graves [64][65]. Much of this content has been shared through social media platforms, e.g., Twitter and Telegram, and later reshared through media reporting. Many of these images are graphic in their nature, and feature scenes of rushed or unfinished burials, occasionally depicting the injuries which are likely to have caused the deaths of those pictured. The positioning of these bodies, along with the environmental conditions at the time of death, will impact the process of decomposition, which will in turn effect the ability of specialists to positively identify decedents.

Considering environmental conditions, when Russia first invaded Ukraine on 24 February 2022, temperatures in Kyiv and Bucha ranged from sub-zero to just above zero °C. As the war progressed into March, temperatures reached slightly above zero before increasing into the low single digits and teens (3-13 °C) in April. Temperatures in the coastal region of Mariupol were a few degrees higher for each month. Overnight lows were below or near zero degrees Celsius for all areas. Snow was visible in some videos [66] during the months of March and April, although it was not accumulating on the ground.

As a result of these temperatures, decomposition appeared minimal to date in those bodies that were exposed on the surface. Usually, insect activity is a key driver of soft tissue decomposition but at low temperatures, insects are either inactive or have limited activity [67]. Hence, flies that would typically be attracted to decaying remains and lay eggs in the orifices of bodies to hatch and feed on soft tissue, did not appear to be present in online images [68]. For this reason, microbial degradation was likely the primary driver of decomposition and while it will not be inhibited at these temperatures, it will be considerably slowed [69][70]. For those bodies left where they had fallen, many were clothed in winter garments that may retain body heat initially, albeit to a small degree, but will rapidly cool to ambient temperatures [71]. Winter jackets and outer layers will be predominantly made of synthetic materials which will not degrade and will aid in holding the body intact, even as decomposition progresses. These materials may also contribute as a secondary or tertiary marker of identification. Footwear could assist in preservation of soft tissue through adipocere formation which may aid DNA identification [72]. Other clothing on the bodies such as gloves or winter hats are more likely to be made of natural textiles such as wool and will degrade with time if the bodies are left in their place of deposition, although the absorbance of decomposition fluid from the body will aid to slow the loss of natural or blended textiles [73][74][75][76]. However, with the exception of footwear, neither synthetic nor natural textiles are likely to preserve soft tissue on the body indefinitely.

The images reported in the media have typically shown human remains on the surface that are still evidently in the fresh stage due to the reduced temperatures and biological activity [77].

Decomposition will accelerate as temperatures continue to rise. Bodies recovered from houses or other buildings may have been subjected to slightly higher temperatures during the colder months, although it is difficult to know if these buildings were heated. If a body is trapped beneath rubble in a collapsed building, there is the potential for heat to be trapped close to the body, particularly as ambient temperatures increase [78]. In these cases, microbial degradation may have commenced to a greater degree, although insect activity would still be minimal at the time of writing. Bodies that had been burnt, impacted by explosion, or buried in single or mass graves will undergo decomposition differently. Bodies buried in graves will experience delayed decomposition compared to the surface, even as temperatures increase [79][80]. Some bodies have been buried in the grounds of the family home based on media images. They are typically shallow graves whereby the conditions in the grave will more closely follow ambient conditions, although differential decomposition is still possible [81][82].

Other burials have occurred in local cemeteries, potentially at greater depths, which will experience reduced temperatures and oxygen compared to the ambient conditions [83][84]. Notably, bodies buried in mass graves may experience differential decomposition with some bodies decomposing and others preserving, or both occurring simultaneously across different parts of the same body [85].

Given the images of wet and clay-like soils, adipocere formation may also occur in buried bodies as a

result of waterlogging within the graves, depending on the timeframe of burial [86][87]. The requirement to excavate all bodies for autopsy, place them in body bags in temporary refrigeration, and re-bury them according to law will also alter the process of decomposition. While body bags may enhance decomposition through the retention of moisture and heat, refrigeration will slow decomposition. Thus, it is anticipated that bodies will undergo a variable decomposition process as they transition from one environment to another.

However, as temperatures increase during the spring and summer months, the rate of decomposition of these bodies will accelerate due to the heat absorbed and an increase in insect activity which will likely commence in the exposed facial orifices but may also occur in other regions of the body (e.g., genitals if exposed, open wounds from weapons, shrapnel, explosions, etc.) [88]. Already there are news reports of bloated bodies being recovered [89] suggesting that decomposition has been initiated with the warmer temperatures. During the early stages of decomposition, the build-up of gases in the body will lead to the distension of the torso and face [90], causing most remains to be visually unidentifiable. As decomposition proceeds with increasing temperatures, the remains will undergo liquefaction and disintegration [91], due to insect and microbial degradation of soft tissue. These changes will increase the likelihood of soft tissue and biochemical evidence being lost, particularly primary identifiers such as fingerprints and DNA, as well as evidence of trauma relating to cause of death (e.g. gunshot wounds) or sexual assault (e.g. semen). Any wounds present on the body as a result of weapon trauma may also provide additional sites for insect oviposition, increasing soft tissue loss in those areas [92]. Some bodies will show signs of partial or complete charring as a result of fire or explosives. Thermobaric/exothermic weapons, also known as aerosol or vacuum bombs, produce 'more heat and overpressure than conventional explosives by exploding vapour into the blast zone' [93]. The use of thermobaric rocket launchers attached to Russian TOS-1 vehicles against Ukrainians was reported on 1 March [94], with many more reports published since, notably during the strike on the Azovstal Steel Plant in May [95]. The plasma cloud created can reach temperatures of between 2,500-3000 °C temperatures which significantly exceed the temperatures required for a cremation in a conventional funerary context. Consequently, only small quantities of the thermally disrupted tissues of those caught within range of thermobaric weapons may remain as evidence, though it is likely that many remains will not be discovered. This can include both soft tissue and hard tissue, reducing the likelihood of other primary identifiers, such as teeth, being recovered for human identification.

At the time of writing, bodies were recovered and transported by local volunteers to whichever mortuary has space in the local vicinity, though it appears that many have long reached their capacity. Improvised humanitarian aid centres were also assisting with body recovery and in some instances, refrigerated trucks were being used to store remains. Since it is inevitable that temperatures will increase throughout the spring and summer months, it is imperative that appropriate refrigeration facilities and/or temporary mortuaries are available to slow the process of decomposition in all

recovered remains. This is necessary to slow the degradation of primary soft tissue identifiers such as DNA and fingerprints.

Preservation of such identifiers will be essential to processes which aim to determine the identity of those recovered, efforts which may be undermined by any issues with the storage of human remains and associated evidence. DNA-based identification can remain effective where the body is 'significantly decomposed or partially incinerated' [96] although this is context and environment dependent. In advanced decomposition which leads to cases of skeletonization (or in situations where bodies are disrupted through burning or explosive trauma) the initial use of primary biological identification markers may not be easily applied, and instead forensic osteological or anthropological markers are generally applied. This is a specialised multi-stage process in which the on-site assistance of a forensic anthropologist will generally be useful in order to: (1) assist in the recognition of any encountered remains, however badly fragmented, if possible to classify them as human or animal, and determine how many individuals may be present; (2) provide an *in situ* assessment of skeletal parameters of identity which may not survive the retrieval process and subsequent transportation to the laboratory; and (3) understand effects of trauma on the body, such as blunt force, gunshot wounds, or burning [97].

The impedance of decomposition is also necessary to preserve evidence of cause of death, and additional evidence that may be used in the prosecution of war crimes. This can include lacerations and penetration into the skin, as well as the ability to differentiate shrapnel damage from gunshot wounds which becomes more difficult as soft tissue is lost. Evidence left on hard tissue may be able to assist with cause of death determination, including sharp force trauma and mutilation resulting from airstrikes, explosions, firearms or other weapons [98][99][100][101][102][103]. Many bodies that have already been buried must be exhumed for identification and cause of death determination prior to re-burial at an appropriate site. Where a grave does not meet legal requirements, e.g., is not cut to the minimum depth required, or has not been recorded by authorities, as in the case of many civilian burials within the yards and gardens of residential houses, the grave must still be exhumed for formal identification and reinternment. Such scenarios are likely to be distressing for the families of the loved ones and may be contrary to religious or funerary customs. Consequently, transparency is required to maintain the dignity of both the dead and the living. Such measures will also prevent scavengers from gaining access to those buried.

While vertebrate scavengers are likely minimal at the time of writing due to low temperatures and the population density in urban environments, over time their presence may increase, particularly as decomposition odour is produced, attracting them into urban and peri-urban environments. Scavengers naturally present in urban and peri-urban environments can include birds (e.g., vultures, corvids and eagles), rodents, domestic or stray pets such as dogs and cats, and other small mammals

including fox, raccoons, polecats and martens. Although there are numerous large mammals in the forests of Ukraine, species such as bear, wolves and lynx are much rarer and unlikely to be active where the majority of bodies are recovered [104]. Many such species are predators rather than scavengers or are not reported to be important scavengers of human remains. However, since there are no reported scavenging studies in Ukraine, these inferences are based on scavenging studies in comparable northern hemisphere environments [105][106][107][108].

Identifying Objects and Marks

A vital part of the identification process is the validation of any identifying objects or documents found with the deceased, before forwarding back to the nation of origin via military or humanitarian structures for return to the family. The Geneva Conventions do not require armed forces to equip personnel with an identity disc or tag. The Ukrainian Army introduced an identity tag in 2014, though the system still has some administrative challenges. It is possible that not all who joined the Ukrainian forces, whether as domestic fighters or international volunteers, has received identity tags as of yet. Whilst military papers, and individual objects marked with an identifying number (e.g., belts, boots, spoons, rifles) can sometimes confirm the identity of the deceased, they do not guarantee an identity. As in previous wars, sometimes soldiers will swap goods between one another, or receive goods which are still registered in the name of another. The location of goods upon the body should always be considered to establish if any possessions are likely to belong to the deceased, or if they were potentially being transported by or had been appropriated by the deceased.

Tattoos can also be an important source of information, acting as another form of 'identifying mark'. Not all armed forces take record of identifying marks upon the body, e.g., tattoos, moles, birthmarks, scars or surgical implants. Though the appearance of tattoos can be affected by decomposition or laser removal, various technologies are available to assist with visualization in a forensic context, e.g., infrared photography, radiography and microscopy [109][110][111]. Though tattoos alone can rarely be used to identify a body, they can help to narrow down a search or to confirm a suspected identity, supported by other forms of evidence.

If future operations or conflicts have the potential to yield high intensity losses, such information should be recorded by armed forces before deployment. In Ukraine, tattoos have been used to identify the deceased, but also to identify the perpetrators of crimes such as looting, occasionally making use of facial recognition software to search for matches of tattoos, as well as faces. As digital surveillance and recognition technologies improve, it is likely that they will play an increasing role in forensic processes, particularly within a DVI context. The ethical implications of this will be considered later within this paper.

The Practical Response

The situation in Ukraine differs from many regions and nations that have suffered mass fatalities in the last 30 years. Before the conflict, it had a well-established investigative infrastructure. Provided that the police, medico-legal and judicial structures remain intact including both personnel and physical facilities such as mortuaries, then the essential structures are in place. However, this does not mean that the sheer volume of the deceased/casework will not be potentially overwhelming if the number of casualties continue to rise. In this case, additional external assistance may be requested from international agencies, though at present, the forensic infrastructures are functioning to the best of their ability.

The National Police of Ukraine was established in 2015 after post-Euromaidan reforms and replaced Ukrainian's previous national police service, the Militsiya [112]. The police are responsible to the Ministry of Internal Affairs while prosecution comes into the purview of the Office of Prosecutor General of Ukraine, Iryna Venediktova (also Procurator General of Ukraine), who is supported by deputies. Currently there is a Memorandum of Agreement between the Prosecutor General's Office (Ukraine) and UK Attorney General's Office [113][114]. Legal support for Ukraine has come from the Chief Prosecutor of the ICC, who announced on 28 February that the ICC would open an investigation into potential war crimes stemming from the conflict. The Ukrainian government has made clear it wishes to take primacy in the investigation of deaths of their own citizens, with Venediktova echoing that "we want to prosecute these war criminals in our Ukrainian courts while acknowledging the role of the International Court" [115]. In April, Venediktova stated that her office was investigating 5,800 cases of alleged Russian war crimes [116], a number which has continued to grow.

Currently, there is some external support for the recovery and documentation of the dead. Humanitarian aid/welfare and evacuation efforts headed by organisations such as United Nations are outside the scope of this paper [117]. From current press reports coming out of Ukraine it is clear that the majority of current body recovery/exhumations in areas under Ukrainian control are led by or supervised by the local Police, supported by external agencies where necessary. One case which describes the typical process for recovery is that of Inna Leschenko [118], who had been sheltering in the basement of her apartment block in Bucha in March. On 19 March she had to go out to find water and was killed by shrapnel. Her family had to wait until there was a lull in the bombardment to recover her body, before burying it within a makeshift grave in a small grass island by the roadside. Once Russian troops had retreated from the area, police exhumed her body for transfer to a mortuary. She was formally identified by family members and was officially buried about a month after death [119]. Where eyewitness accounts do not exist, a body is unidentifiable, or mortuary facilities are overwhelmed, processes become lengthier and more complex.

Prior to the war, Ukraine had a well-established system of medico-legal training and mortuary infrastructure. However, it is not surprising that during the conflict this infrastructure has been challenged by loss of power supplies, and the sheer number of dead leading to temporary measures such as the use of refrigerated trucks [120]. Ukraine had a well-established training program in forensic science from the national universities including undergraduate degrees in forensic science (4 year) and master's degrees in forensic science (2 years). Although it should be noted that much of the investigation of mass graves in Ukrainian territory up until recent work had been concentrated on historic conflicts, such as the Second World War; for instance, the work undertaken by an Australian team lead by Richard Wright between 1990-1991 [121]. However, it is worth noting that the speedy introduction of a prosecutorial component to the recovery of the dead and associated forensic evidence is perhaps unique in the history of conflict victim recovery and identification. Unlike the much-delayed medico-legal international response to the Balkans conflict, in Ukraine this response comes only weeks after the first satellite and on-the-ground evidence for mass fatalities, including graves of civilians, gross human rights violations, and attempts to conceal identity through burning and other means.

External Agencies

Recent research by Topolia explains the role of evidence produced by external agencies within Ukrainian frameworks of administrative law, explaining that the 'purpose and tasks to provide sufficient quantity and quality of legally significant specific information' is 'necessary for a fair and lawful resolution of individual legal cases' [122]. This assessment stands true in an emergency, military context such as the current war. Ukraine has recent experience of responding to casualties, following the 2014 Russian invasion, and already has a strong network of international support who have been able to assist during the ongoing war. Georgia, which also sits on the Russian border, also has experience of the practical and legislative issues associated with the recovery and identification of the dead following war with Russia in recent years [123]. Whilst it is true to assert that the international community 'must ensure the supply of humanitarian aid' into Ukraine, it must also respect Ukraine's existing and chosen structures of support, particularly given the legal implications of the ongoing crisis [124].

At the time of writing, three months after the period of study, both Ukraine and Russia had made allegations of war crimes. As the numbers of allegations continue to rise, it seems reasonable to assume that evidence provided from sources beyond official policing and military structures will play an increasingly prominent role in developing legal cases for trial. This section identifies some of the prominent national and international agencies which are supporting Ukraine's official forensic response and explains the support that they offer. It is not an exhaustive list.

International Committee of the Red Cross (ICRC)

The International Committee of the Red Cross has its origins in mass conflict casualties. Jean Henry Dunant (1828-1910), a Swiss national, witnessed the aftermath of the Battle of Solferino (1859) prompting him to publish a book which called for improved care for wounded soldiers in wartime [125][126][127]. In 1863, Dunant and four other men met in Geneva and formed what was to become the ICRC. The committee persuaded governments to adopt the first Geneva Convention in 1864, obliging armies to care for wounded soldiers. The initial role of the ICRC was one to coordinate, though it gradually became more involved in field operations, acting as a neutral intermediary between belligerents. Their works continued to expand as the articles adopted under the 1907 Geneva Convention introduced a requirement for the victor of the battlefield to protect the dignity of the dead, to forward any identifying marks or papers, and to bury or cremate the dead [128].

By the 21st century the remit has become much broader, as the ICRC has continued to encourage the strengthening of international humanitarian law; has responded to the humanitarian consequences of conflicts; encouraged the 1949 revision of the existing Geneva Conventions; and assisted with the adoption of two additional Protocols to the Conventions in 1977. The Geneva Conventions and ICRC ethos of dignity and care for the wounded and war dead extends beyond the battlefield.

Article 34 of the 1949 Geneva Conventions describes an obligation to facilitate access to the dead for their relatives, which requires that the dead are protected and are either repatriated or provided with a permanent burial. ICRC works are intended to strengthen local forensic services and judicial authorities to ensure the proper management of the dead. Works are planned to ensure that the dead are treated with dignity, and that their families are given the information and respect that they deserve. The ICRC deliver training on management of Dead in Mass Disasters and Armed Conflict as part of their capacity building works, and have published guidance to promote best practise, e.g., *The Management of Dead Bodies after Disasters: A Field Manual for First Responders* [129]. The ICRC has been working in Ukraine since the Russian invasion of 2014. In Ukraine, the bulk of ICRC response has been focused on humanitarian assistance through guidance, the provision of materials and accommodations to ensure that civilians, soldiers and war dead are treated in the best way through dignified management of the recovery, identification and repatriation process [130]. With regards to the dead, this includes guidance on the best way to ensure the traceability of human remains with the aim of providing families with answers as to what happened to their loved one, and the opportunity to have their body or remains returned to them [131].

Black Tulip

Within Ukraine, there is a civilian volunteer group known as Black Tulip. From the early 2000's, Black Tulip volunteers worked to search, recover and identify fallen soldiers from the Second World War. When fighting started in 2014, they were the only Ukrainian group allowed to be present on and cross the front line to collect the bodies of Ukrainian soldiers from territory held by pro-Russian

separatists. Between 2014-18, their work resulted in the recovery of the bodies of over 800 Ukrainian servicemen who had been killed in the Donetsk and Luhansk regions, with a significant number of identities confirmed.

As Black Tulip have been conducting this work for a substantial period of time, they have had the ability to refine their processes and practices to provide a streamlined service. They are well known to ordinary civilians because of their community work, and people often choose to contact them with information about fatalities and burials. One volunteer explained: “Often people contact us even when territory they live on is still under the enemy’s control. They inform us about what they or their relatives have seen, about corpses or burial places they have seen and know. We have built a whole database of such places and people already” [132].

Today, Black Tulip volunteers typically come to begin exhumations following a clearance of the land by Sappers of the Ukrainian Army. Typically, they work together with local police forces, but occasionally they will lead on works where the police are overwhelmed. All volunteers are certified by the ICRC having completed internationally certified training to allow them to exhume and inspect the deceased, write protocols, conduct scene photography and to transfer all relevant evidence, documents and ultimately, the body to the legal forensic examination teams within the mortuary and/or police stations as appropriate.

International Commission on Missing Persons (ICMP)

The ICMP was created in 1996 following the end of conflict in former Yugoslavia which took place between 1991-1995 [133]. The break-up of Yugoslavia resulted in approximately 400,000 missing persons, although conflict patterns differ significantly from the current war in Ukraine. While military actions in Bosnia involved siege warfare (e.g., Sarajevo) and the mass killing of non-combatants (often related to ethnic cleansing and resulting in mass graves), the conflict generally lacked the heavy air bombardment and use of missiles against urban multi-storey buildings such as has occurred in Ukrainian regions like Mariupol [134]. The organisation’s initial work was based out of Sarajevo and focused on the recovery and identification of remains from the western Balkans. Two principal areas of expertise were established: the archaeological/anthropological recovery of remains, and the identification of victims by DNA. The DNA led identification project, linked to archaeological recovery of human remains, remains the largest use of DNA in response to a conflict, internationally [135].

That the ICMP has critical skill sets and experience relevant to the recovery, documentation and identification of human remains is well established. Since the 1990’s the ICMP activity and remit has grown to include DVI operations after natural disasters, for example, the Indian Ocean earthquake and tsunami (2004), Hurricane Katrina (2005); as well as post-conflict investigations in Iraq, 2011, Libya 2013, and also Bosnia and Serbia [136]. The Archaeology and Anthropology division (AAD of

ICMP) has established best practice protocols using combined expertise of forensic pathologists, forensic archaeologists, forensic anthropologists and crime scene managers. The organisation has experience in training and capacity building in the integration of search, recovery and identification of human remains [137].

On 8 April, it was announced that authorities in Kyiv had reached out to the ICMP and a team consisting of a forensic archaeologist, a forensic pathologist and a DNA specialist travelled to Ukraine to begin their work [138]. Other international teams include a French forensic team from the Gendarmerie National despatched to Bucha. The team included ballistics, explosives, and rapid DNA testing specialists [139]. Given the variety of destructive weapons employed by Russia against Ukraine, it seems likely that there will be many cases which require unique, expert analysis, which may result in further deployments of international practitioners, specialists and researchers to support Ukrainian investigations.

New Ethical Concerns for Search, Recovery and Identification Processes

Emergency situations can often result in innovation, as creative thinkers work to find rapid solutions for problems. However, this can also mean that sometimes processes and technologies can be utilised before ethical standards can be reviewed or dictated. This can result in situations where we are forced to retrospectively assess the ethical implications of practice or technology after they have already been utilised. Though the war in Ukraine has not yet concluded, it has been possible to identify some areas of ethical concern. Such intensive fighting in populated civilian areas has not been observed in EURASIA since the world wars, and so there is an increasing need for forensic and military professionals to come together to reflect upon the risks presented. Ukraine is 'going through high-quality reform and legislative innovations' which take 'into account the best world practices'.

However, best practice has not yet been determined for some uses of technology within the context of war, presenting different ethical risks to those assumed in peace time. There is also a need to recognise different cultures of working. The expectations for civilian forensic practitioners with regards to physical and mental health can be vastly different from those held by armed forces professionals tasked with responding to scenes of forensic interest, though both sets of professionals share similar mental and physical risks. Further work is required to interrogate the ethical concerns raised below in light of Ukraine and should inform both the support offered in the immediate term and the force design for any future response to a high intensity conflict in both civilian and military contexts.

Use of Satellite Data

The use of satellite imagery to document activity such as digging mass graves is a well-established technique in the investigation of war-crimes, having been used in the Balkans and Iraq [140][141][142]. In Ukraine, satellite data is being used to document individual bodies lying out in the open both during and after Russian occupation [143], as well as the construction of mass graves, e.g., in Bucha [144] and at Manhush near Mariupol [145]. Satellite imagery is also used for purposes such as to gain critical insight into enemy activity, amongst other uses. However, there are regulatory issues which can prevent commercial organisations from providing their services to assist an overseas nation, along with ethical concerns over the risks presented by private companies entering a conflict and concerns as to the ownership of data collected and who can access it for what purposes [146]. Countries may choose not to share their data, as North Korea have chosen not to share their satellite data with Ukraine [147]. Allied armed forces and international humanitarian organisations may wish to consider arrangements for data sharing to ensure that there are no ‘blind spots’ in future high intensity conflicts.

Use of Facial Recognition Software for Identification of Human Remains

In March 2022, it was confirmed that Ukraine’s Ministry of Defence was using Clearview AI facial recognition software for a range of identification purposes, including identifying the dead [148]. Clearview AI is an American company, which scrapes photos from internet sources, including social media to create a searchable database of faces. This paper will discuss the use of facial recognition software for the identification of the dead only, though the reader should be aware that there are widely applied anatomical and computerised methods that may be used for post-mortem depiction (as an aid to identification) of the dead [149][150][151], as well as unvalidated methods using DNA phenotyping [152].

The suitability of the Clearview software for identification purposes is debatable. Though Clearview’s chief executive Hoan Ton-That has stated that the software ‘can help Ukrainian officials identify dead soldiers more efficiently than fingerprints, and works even if a soldier’s face is damaged’ [153]; it is not clear how the software would be able to assess any visible signs of decomposition, particularly bloat, and to mitigate for the impact of these processes upon the face when attempting to confirm any potential face matches. Facial recognition technology has been deployed in response to large scale disasters previously, e.g., the 2004 Thai tsunami, however error rates were high, meaning they cannot be reliably used in such a scenario at present [154][155]. There is no available data on the accuracy of facial recognition software when used to assess the identity of a body which is in the advanced stages of decomposition.

Though Clearview state that their software should not be used as the sole source of identification, and that it should not be used in violation of the Geneva Conventions, its use remains questionable. Once these systems are deployed, it is not possible to control how they are used, particularly within a

warzone. For this reason, we must discuss the purpose of sharing images of the dead for identification purposes. Though official campaigns, and many grass roots or individual efforts to contact Russian families to share news and images which confirm the death of their son are undertaken with the intention of maintaining the dignity of the deceased and their family, such efforts can also be considered “classic psychological warfare” [156]. This is particularly true of individual efforts that are not driven by humanitarian principals. Not all actors are neutral, nor do all possess positive intentions, and the receipt of such sensitive information is likely to be distressing for the recipient, particularly where state narratives do not respond to the information received, as is likely to be the case for some Russian families.

Beyond ethics, the use of the software can be legally controversial, depending upon the country within which it is licensed for use – a factor which disaster relief planners should consider if debating the use of similar technologies in future deployments. In May 2022, the UK Information Commissioner’s Office fined Clearview in excess of £7.5million for their collection of images of UK citizens from the internet without their consent, ordering them to delete all images and personal data and to stop obtaining further data [157]

Mental and Physical Wellbeing of Humanitarian and Forensic Workers

It is well recognised for the need to look after the mental and physical wellbeing of humanitarian, forensic and medico-legal staff in post-conflict missions [158][159]. However, as highlighted, the war in Ukraine, and the Ukrainian forensic infrastructure do not exactly replicate the conditions of previous wars in recent memory, with losses which exceed recent wars. Thus, there is a need to consider the wellbeing of those who are not only deployed but deployed for extended periods of time in an ongoing war. Over time, the mental strain on workers in Ukraine may result in the need for international support to ease the burden of Ukrainian workers who may be experiencing their own trauma or may require psychological or medical treatment as a result of their experience in service. There is a long history of military co-operation with civilian humanitarian agencies to provide on the ground support. However, these relationships are often complicated, particularly where there are different approaches to the psychological or physical impact upon the worker, or where guidelines and drivers are not aligned across responding organisations [160].

In the field, risks include deliberate targeting by hostile forces, recommencement of military action (including long range bombardment/missile/drone strikes), and unexploded munitions (including deliberate booby-trapping bodies). Direct contact with such acts of violence, or prolonged exposure to the sights, sounds and consequences of war and death increase the risks of Post-Traumatic Stress Disorder (PTSD) [161][162][163][164]. There are well established protocols for rotating ground teams in DVI, e.g., Kenyon International Emergency Services system of team members deployed on rotation, each of whom receive psychological support after any deployment. Such support is not

always possible under conditions of active combat. It should be remembered that the world community has a mental health duty not just to ex-combatants, but also frontline medical staff, forensic practitioners and volunteers working with casualty evacuation and exhumation/body recovery.

Conclusion

At the point of submission, the war in Ukraine is still ongoing, and Russian forces continue to push to occupy parts of the internationally recognised sovereign territory of Ukraine. It is already clear that this conflict has resulted in a large number of fatalities, and will continue to do so, resulting in both combatant and civilian deaths [165]. The range of variables which will affect the practical response required is extensive and requires a multi-skilled response from a combination of partners that may not typically come together during peace time. The impact of these variables will change over time, as will the response.

Ukrainian forensic and medico-legal structures continue to function, even if at an altered capacity, and are well supported by their chosen international partners. The work to recover, identify and bury the dead is likely to continue for years after the conclusion of the war given the volume of casualties and the potential for criminal investigations to investigate war crimes at scale. Ukrainian services are able to provide a skilled, expert response, and can, and will communicate to external partners when assistance is required. Their experiences and the lessons that they learn should inform the design for responses to future conflicts, as opposed to other recent conflicts such as the wars in Iraq and Afghanistan which did not result in mass casualties.

The driving force for the forensic response in Ukraine is the desire and duty to maintain the dignity of the dead and their families. Every person killed, whether soldier or civilian, Ukrainian or Russian is an individual that matters to someone, and we have a humanitarian responsibility to ensure that every effort is made to establish the identity of those recovered, to allow their loved ones access to the available information about their death, along with access to their body. Forensic professionals and willing volunteers are providing an honourable service for their people, which undoubtedly comes at great personal cost. The international community must be ready to support Ukraine on its own terms as and when requested.

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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