Understanding shock in Children

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Abstract

Children present with shock in many health care settings and so the ability to recognise shock in children is an essential skill for nurses caring for children. A lack of understanding the different forms of shock and the similarities in their presentation can lead children to rapidly deteriorate. The physiological nature of children mean deterioration is rapid and can be fatal if not recognised and appropriate interventions given.

Physiology

Shock is an unstable physiological state that occurs from acute failure of the circulation, this results in inadequate tissue perfusion and oxygenation and removal of harmful metabolic waste products. Shock, leads to a decrease in intravascular volume, a disruption to circulating intravascular volume, or impaired cardiovascular function (Waltzman 2015). Recognising shock can be difficult as the signs and symptoms of shock are not those of the underlying disease/process, but the body's attempts to maintain homeostasis by preserving an effective circulation (Cameron et al 2019). If shock is not recognised anaerobic metabolism and tissue acidosis will result, if these changes are not reversed, end organ failure will follow (Crisp and Rainbow 2007).

Key words: Shock, circulation, blood pressure, hypovolaemia, inotropes.

Types of shock

In this article, children will refer to any child or young person up to 16 years of age. However, despite recognising infection as the leading cause of mortality and morbidity in the Newborn (Bedford Russell 2015), early-onset neonatal infection will not be discussed. Shock is classified in many ways to describe the physiological response to the underlying cause. While Waltzman (2015) identifies the three classifications for shock as hypovolaemic, distributive and cardiogenic, Cameron et al (2019) add obstructive and dissociative to total five classifications. While these classifications support an understanding of the underlying cause of shock, an alternative approach is to consider how the child's circulation is compromised. For an effective circulation the child requires three essential components, fluid to transport oxygen and remove metabolic waste (blood), a pump to circulate the fluid (the heart) and vessels (arteries/veins) to contain the fluid.

The common classifications of shock in children, and therefore the focus of this article is hypovolaemic and distributive shock (Cockett and Day 2010). Uncommon causes include cardiogenic shock, leading to an acute state of circulatory failure due to impairment of myocardial contractility and diminished cardiac output (Fuhrman and Zimmerman 2006, Brissaud et al 2016). Obstructive shock, caused by an inability to produce adequate cardiac output despite normal myocardial function and circulating volume, such as in tamponade (Badheka et al 2018), and dissociative shock effecting the oxygen carrying capacity of the blood, for example carbon monoxide poisoning or profound anaemia (Cameron et al 2019), are uncommon in children.

It is important to remember that children can present with more than one classification. For example, a child in a road traffic accident with a head injury may lose the ability to control how vessels constrict and relax; this is distributive shock, while blood loss from an open wound would add hypovolaemic shock.

Sepsis

Sepsis is the systemic inflammatory response to infection, and usually presents with the common classifications of hypovolaemic and distributive shock. The inflammatory response leads to increased permeability in capillary beds, allowing fluid to escape from the circulating volume into the interstitial spaces (Bersten and Soni 2003). While Bentley et al (2016) recognise efforts to improve the management of sepsis in children within one hour of diagnosis; will lead to a reduction in mortality and morbidity. Plunkett and Tong (2015) remind us the problem remains that the initial clinical presentation of sepsis in younger age groups may be non-specific, leading to a potential delay in diagnosis

Table 1 summarise the five classifications of shock and aligns each with its effect on the child's circulation.

Classification	**Problem**	**cause**	**Fluid, pump and vessel**
Hypovolaemic	A loss of circulating volume.	Gastroenteritis, bleeding, vomiting.	Lack of fluid, leading to an empty pump and vessels.
Distributive	Abnormal dilation or constriction of vessels. Dilation is more common	Sepsis, head injury, anaphylaxis.	Blood volume and pump are normal, abnormal vessels prevent blood from reaching the peripheries
Cardiogenic	Reduction in cardiac contractility	Congenital heart disease, pneumothorax, cardiac tamponade	Blood volume and vessels are normal, heart cannot effectively pump blood

			through the vessels.
Obstructive	Abnormal blood flow	Obstructed vessels, tension pneumothorax or cardiac tamponade	Blood volume is normal but cannot reach tissues due to an obstruction in vessels or pump
Dissociative	Oxygen carrying capacity of the blood is too low	Profound anaemia, carbon monoxide poisoning	Fluid (blood) does not work effectively

Stages of shock

Shock follows three distinct phases, it is imperative the nurse caring for a child recognises the presenting features of each stage. Timely and targeted interventions will reduce the likelihood a child will reach the final stage where interventions become ineffective and the condition is fatal. The stages are comparable regardless of the classification.

Compensated

In the first stage a series of physiological changes occur to ensure oxygenated blood supply is prioritised towards the core essential organs of the brain, heart and lungs. Peripheral vessels constrict to minimise blood flow to the extremities and the heart increases the rate of blood flow. At this stage, the child can initially compensate for an inadequate circulation (Jevon 2012) and maintain end organ perfusion (Crisp and Rainbow 2007).

The nurse can observe these changes as the child's heart rate and respirations will increase, peripheral capillary time will be delayed and the child's hands and feet will feel cooler to touch, resulting in a clear warm/cool demarcation line. Importantly, at this stage blood pressure may be unchanged.

Uncompensated

When peripheral vasoconstriction and increased cardiac effort fail to compensate for a reduced circulation, this leads to uncompensated shock and inadequate tissue perfusion occurs. Healthy tissues rely on aerobic metabolism to create energy through the combustion of carbohydrate, fats and protein in the presence of oxygen. Tissues deprived of oxygen rely on anaerobic metabolism and can only burn carbohydrates; lactic acid is a by-product of anaerobic respiration and leads to metabolic acidosis and is used as a marker of hypo-perfusion (Friedman and Bone 2014). The combination of anaerobic metabolism and acidosis disrupts the healthy environment required for normal cell function (Cockett and Day 2010).

The nurse can observe these changes as a reduction in compensation leads to reduced blood flow and impaired organ function, a reduction in blood flow presents as:

- Renal- reduced urine output (<2ml/kg in under 1 and <1ml/kg over age 1)
- Cerebral – reduced conscious level and the child becomes drowsy
- Respiratory-increased respiratory failure as respiratory muscles tire.
- Circulation- hypotension is a late sign of shock, and is the last physiological change to occur, as a result, a reduction in blood pressure is not required to diagnose shock (Friedman and Bone 2014)

Irreversible

Irreversible shock is the final stage where despite correcting the underlying cause and restoring an effective circulation, tissue recovery is not possible and tissues continue to die, despite continued resuscitation and restoration of circulation this stage is often irreversible and fatal.

Physiological response to shock

Compensation increases systemic vascular resistance (SVR), this restricts blood flow to the extremities and improves venous return to the heart, increasing the volume of blood ejected in each contraction. Reduced peripheral blood flow leaves the child feeling cold to touch with cool extremities and demarcation lines (Friedman and Bone 2014). Vasoconstriction and poor perfusion lead to prolonged capillary refill time (CRT). CRT is measured by applying pressure to the child's nail bed leaving a pale area of poor perfusion, and measuring the length of time it takes for blood flow and perfusion to appear. A peripheral CRT of less than 2 seconds is considered normal, with more than 4 seconds abnormal. Mottling is often considered a sign of poor perfusion, however it is not a valid observation as infants can mottle due to an immaturity of controlling blood vessels, a condition known as cutis marmoratum (Cameron et al 2019).

Cool extremities are more common in children as shock is the result of fluid loss, this may also be referred to as cold shock. However, presentation of distributive shock involving anaphylaxis, neurogenic and some forms of sepsis causes peripheral vasodilation and an increase in blood flow to the extremities. In these children, they feel warm to touch and Crisp and Rainbow (2007) refer to this as warm shock.

Children maintain an adequate blood pressure through compensation and it is not true to say a child with a normal blood pressure is not shocked, as compensatory responses maintain homeostasis and an effective blood pressure (Jevon 2012). While children can maintain normal blood pressures through compensation, this is limited in warm shock where vasodilation is seen.

Heart rate increases as a compensatory measure and is more reliable than blood pressure. Nurses must also palpate the child's pulse as this gives a subjective indication of circulating volume, it also allows an assessment of peripheral vasodilation when comparing peripheral and central pulses.

The compensatory measures of cool peripheries, warm/cool demarcation line and prolonged CRT alongside a potentially normal blood pressure, are central to the UK resuscitation councils systematic approach to recognise the early signs of shock in the deteriorating child (Resuscitation council 2015). As children maintain homeostasis and compensate for inadequate circulatory function (Cameron et al 2019) it is important therefore that nurses recognise the clinical signs of a child compensating for shock.

Treatment

Fluid

Hypovolaemic and distributive shock are most common in children, fluid replacement is essential to limit further deterioration. Limited evidence supports the optimal type, rate and volume of fluid to be administered (Dellinger et al 2008). However, the preferred fluid for resuscitation despite limited evidence is isotonic saline (0.9% sodium chloride). Alternatively, despite no associations with improved outcomes compared to 0.9% sodium chloride. Weiss et al (2017) consider balanced crystalloid solutions that closely resemble serum electrolyte concentrations, containing electrolytes such as potassium chloride and magnesium chloride alongside sodium chloride, may be considered an alternative intravenous fluid.

Colloids, such as Human albumin 5% may appear to be ideal as the larger molecules may remain in the intravascular space longer. However, despite no large scale studies in children comparing isotonic 0.9% saline to colloid, no significant differences in mortality were found in the SAFE or CRISTAL trials in adults (Finfer et al 2004 and Annane et al 2013). However, the UK Resuscitation council continue to advocate an initial fluid bolus of 20mls/kg should be given as soon as possible, Friedman and Bone (2014) support this view, suggesting active fluid resuscitation in the first hour reduces mortality. A decrease in heart rate following fluid is a valuable indicator the child is responding (Waltzman 2015)

Unlike hypovolaemic and distributive shock, the definitive treatment for obstructive shock is removal of the obstruction, for example in cardiac tamponade, where cardiac function is compromised from an accumulation of fluid or gas around the heart (Fuhrman and Zimmerman 2006)

Inotropes

Fluid replacement is essential for children presenting with hypovolaemia, however for other classifications inotropes may be useful for children who have received fluid replacement up to 40mls/kg but do not respond (McVea and Turner 2019). Waltzman (2015) cautions that if given without adequate fluid, inotropes can accelerate tissue death, and so fluid remains the first line of treatment. If inotropic support is required the choice of inotropes depends on the child's clinical presentation (vasoconstriction, vasodilation, increased heart rate or stronger contraction). Although fluid replacement is essential in managing cardiogenic shock, pharmacology, including inotropes is essential to restore myocardial contractility and cardiac output to restore and maintain blood flow (Fuhrman and Zimmerman 2006)

Table 2 summarises the common inotropes used and their effect.

Inotrope	Effect	Impact
Dopamine	Low doses stimulate the heart to improve its function Higher doses result in peripheral vasoconstriction and decrease blood flow to the extremities.	Improves cardiac output
Adrenaline	Stimulates the heart to improve function in children that do not respond to dopamine	Improves cardiac output
Noradrenaline	stimulates the heart but also causes peripheral vasoconstriction	Improves cardiac output and blood pressure
Dobutamine	Increases heart contractility and rate. Causes peripheral vasodilation and increases blood flow to the extremities.	Improves cardiac output and blood pressure

Summary

Understanding the five classifications of shock and their effect on the child's circulation supports nurses in playing a vital role in identifying the child in shock. Accurate assessment and physiological monitoring allows the nurse to recognise the underlying cause and initiate an appropriate intervention.

Declaration of interest: none

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