Paediatric Shock

Dr Andrew Pittaway
Department of Anaesthesia
Bristol Royal Hospital for Children
Bristol, UK

Self-assessment:
1. What is the definition of shock?
2. List the different pathophysiological processes leading to shock.
3. What are the commonest causes in children?
4. What is the important aim of early treatment?
5. What are the main differences between shock and dehydration?
6. Does the clinical diagnosis of 'shock' always result from fluid loss?
7. Hypotension is a normal feature of mild shock in children – true or false?
8. In Phase 2 (uncompensated) shock, urine output is maintained – true or false?
9. What is a normal capillary refill time? How do you test for it?
10. In shock an initial fluid bolus of 10ml/kg is appropriate – true or false?
11. What are the approximate circulating blood volumes of a neonate, a one year old child and a ten year old?
12. What are the two most important treatments in shock?

Case history
Imagine you are asked to see a 2 year old child who has a 12 hour history of severe diarrhoea and vomiting. He is pale and lethargic with a HR 160/min, BP 80 mmHg systolic and capillary refill time of 5 seconds.
- What type of shock are they likely to be in and what pathological processes are occuring?
- How would you manage this child?

Definition
Shock is a clinical diagnosis in which the circulation is insufficient to meet the demands of the organs and tissues dependent upon it. Several different pathophysiological processes can all result in a similar clinical presentation of shock e.g acute haemorrhage, sepsis, loss of vascular tone (e.g. anaphylaxis) and acute left ventricular failure. Whatever the cause, if shock remains untreated eventually the affected tissues, starved of vital oxygen and nutrients, will deteriorate and show signs of organ dysfunction. If allowed to

continue, affected organs will fail and die. It is therefore vital that the presence of shock is recognised promptly and effective treatment begun immediately to restore organ perfusion.

Probably the commonest cause of shock in children is overwhelming severe infection (sepsis), followed by acute reduction in the circulating plasma volume – so-called hypovolaemic shock. Although sudden blood loss e.g following surgery or trauma is the commonest cause of hypovolaemic shock, it may also be due to rapid fluid loss from elsewhere e.g the gastrointestinal tract in acute diarrhoea. Regardless of the particular cause of shock, the initial treatment is the same - to rapidly replace fluid losses in an effort to restore the circulation and improve organ perfusion.

Physiology
By the age of 3 years, total body water has fallen from 80% at birth to its adult value of 60% body weight. Of this, about two thirds is intracellular and the rest - about 20% body weight normally – extracellular. Extracellular water is further divided into interstitial and intravascular (or plasma) compartments. Plasma volume is typically one third of extracellular water and is therefore the smallest of all these compartments. Surprisingly little needs to be lost before physiological compensatory processes aimed at restoring the circulation begin. These consist of various neuroendocrine reflexes involving sympathetic activation and renal conservation of salt and water. These increase cardiac output primarily by vasoconstriction, tachycardia and reduced renal losses. Increasing stroke volume in an effort to increase cardiac output only becomes possible with increasing age. (see TOTW: Paediatric anatomy and physiology and the basics of paediatric anaesthesia).

Shock versus Dehydration
How does the fluid loss in shock differ from that in dehydration? Actually, it differs from simple dehydration in several respects. Firstly and most importantly the diagnosis of hypovolaemic shock implies an acute reduction in circulating plasma volume. This means that the acute fluid deficit comes primarily from the intravascular compartment. Eventually however other compartments will also become depleted, as they are normally in physiological equilibrium with each other. A diagnosis of dehydration, by comparison, usually implies a more gradual, prolonged loss of fluid which comes from all fluid compartments. It is frequently associated with electrolyte disturbance, which is unusual in the early stages of shock – at least, until renal dysfunction begins. If dehydration is prolonged or severe, then it is possible for a clinical picture of shock to take over as the primary abnormality.

Infants have much higher fluid requirements than adults – about 100ml/kg/day, compared with 35ml/kg/day. This is a consequence of their increased metabolic rate, larger surface area to volume ratio and reduced renal concentrating ability.

Circulating blood volume is dependent on age and weight, falling from 90 ml/Kg at birth to 85 ml/Kg at 1 year of age and 80 ml/Kg thereafter.

Types of shock

Delivery of adequate amounts of oxygen and essential nutrients to the tissues is a complicated pathway dependent upon a number of different processes. Failure of any of these processes at any stage along this pathway can result in shock. The pathway can be thought of as follows: A pump (heart) delivers nutrients dissolved in fluid (blood) through a distribution network (blood vessels) to the tissues.

Different types of shock can be defined according to where in this pathway the failure occurs. For example, failure of the pump (heart) results in cardiogenic shock. Loss of fluid (blood) causes hypovolaemic shock. Loss of normal vascular tone and integrity (blood vessels) may result from anaphylaxis, or other toxic causes e.g envenomation or other poisons. Infection causes so-called septic shock by interfering with all 3 mechanisms.

Pathophysiology

Shock is described in 3 phases during which different pathophysiological processes occur. The chances of successful outcome of treatment begun during each of these phases becomes progressively worse, reflecting the increasing degree of physiological derangement.

Compensated. Blood flow to vital organs i.e. heart and brain is spared at the expense of non-essential organs. Sympathetic-mediated reflexes preserve cardiac output. A child in this phase is typically mildly agitated or confused, tachycardic and has cool, pale skin with decreased capillary return. If untreated, compensated shock will progress to:

Uncompensated. Compensatory mechanisms begin to fail, and the circulatory inadequacy to worsen. Oxygen-starved tissues produce lactic acid as a by-product of anaerobic metabolism, and energy-dependent cellular processes slow. Inflammatory mediators are released and further depress the circulation. Plasma is lost from the intravascular compartment as capillaries become 'leaky'. Haemostasis is deranged, leading to microvascular thrombosis. Clinically the child has features of phase 1 shock plus: Falling blood pressure, rapid, shallow breathing, reduced conscious level and absent urine output. If untreated, uncompensated shock progresses to:

Irreversible. Sadly, a post-mortem diagnosis. Organ damage is by now too severe for recovery, even if appropriate resuscitation of the circulation is begun. **This final phase underlies the need to recognise and treat early to save lives.**

Presenting features

Shock presents differently in children compared with adults. Although the underlying defect – circulatory inadequacy – is the same, the superimposed physiological differences and responses result in differing clinical pictures. Variables such as pulse and respiratory rate and blood pressure which are the mainstay of monitoring in adults with suspected shock are less useful indicators in children. **Hypotension is a late feature in children and its presence is a sign that the child is on the brink of decompensation and collapse.**

Assessment

Always proceeds according to the '**ABC**' approach. The shocked child typically appears pale with cool, mottled peripheries and is agitated or listless. Examination reveals tachycardia with rapid, shallow respirations and oliguria. A rash or fever is suggestive of sepsis. In some instances the underlying cause is obvious (e.g. trauma) in others relevant history may assist with the diagnosis e.g preceding severe diarrhoea and vomiting.

Airway and Breathing should be assessed and managed appropriately.

Assessment of **Circulation** should include:
- Heart rate and rhythm
- Pulse volume – comparing peripheral with central pulses
- Blood pressure – should be 80 + (age in years x 2)
- Capillary refill time
- Urine output – catheterise; should be at least 2ml/kg/hour in infants, 1 ml/kg/hour in older children.

Capillary refill time (CRT) is one of the most informative and important signs. It is easy to assess – press on the child's sternum or finger for 5 seconds, remove the pressure and then time how long it takes for the 'blanch' mark to fade away. In normal children it should take less than 3 seconds. Longer than this implies that the child is hypovolaemic, and requires immediate volume resuscitation.

Treatment

Again, always follow **ABC:**

- **High flow oxygen** should be given immediately via a suitably-sized facemask.
- **Summon help.**
- **Obtain intravenous access** – ideally 2 short wide-bore cannulae in either antecubital fossa. Remember to take blood samples for full blood count, glucose/electrolytes and cross-matching at this stage; blood cultures also if sepsis is suspected. Femoral vein/long saphenous vein cut-down are alternatives requiring a degree of skill and operator experience. Intraosseous needles are easy to place, globally under-utilised and potentially life-saving. Bone marrow so obtained can be cross-matched and tested for FBC/U+E's but NOT glucose.
- **Give a fluid bolus 20ml/kg** of (preferably warmed) isotonic crystalloid e.g. 0.9% normal saline (**NOT** dextrose-containing solutions) and reassess. If CRT remains>3 seconds, give a further bolus of 20ml/kg. Reassess, and if further fluid boluses are required they should be blood – either O Rhesus negative, type-specific or cross-matched if time allows. In this situation, a surgically-correctable source of ongoing exsanguination should be urgently sought.

  The ongoing debate about crystalloid versus colloid is probably less important in the early stages of resuscitation than the way in which the chosen fluid is given. Three times as much crystalloid is required for the same effect as a given volume of colloid. Some recommend using human albumin solution 4.5% early in septic shock, as well

as empirical antibiotics e.g cefotaxime 80mg/kg after cultures have been taken. In suspected cardiogenic shock, fluids must be given more cautiously to avoid volume overloading an already failing heart. Elective ventilation and Inotropes shouldbe considered early on in treatment, and the child managed in a high dependency or intensive care area.

Summary

Shock is a clinical diagnosis due to circulatory inadequacy caused by several different mechanisms. The commonest causes in children are sepsis and hypovolaemia from any cause.
Shock manifests differently in children compared with adults. The aim of treatment is to quickly restore circulating volume, for which crystalloids or colloids may be used. Continual reassessment is the key to successful resuscitation. Delays in diagnosis or treatment can be fatal.

Answers to questions
1. See Definition
2. Acute haemorrhage, sepsis, loss of vascular tone, left ventricular failure
3. Sepsis and hypovolaemia from any cause
4. Restoration of circulating volume
5. See Shock versus Dehydration
6. No – cardiogenic
7. False. It is a late, and grave feature
8. False. Urine output is negligible or absent
9. See section on assessment.
10. False. The initial fluid bolus is usually 20ml/kg, unless cardiogenic shock is suspected
11. 90, 85 and 80 ml/kg
12. Oxygen and fluids.

Case history
Imagine you are asked to see a 2 year old child who has a 12 hour history of severe diarrhoea and vomiting. He is pale and lethargic with a HR 160/min, BP 80 mmHg systolic and capillary refill time of 5 seconds.

What type of shock are they likely to be in and what pathological processes are occuring?
- **Uncompensated shock** due to hypovolaemia from fluid loss, and possibly also cardiogenic shock and loss of vascular tone due to sepsis.

How would you manage this child?
- **ABC**. Ensure that he has a good airway and is breathing adequately. Give oxygen and ventilate if necessary.
- Establish intravenous or intraosseous access and give fluids, 20 ml/kg initially then assess response and give more if needed.
- Bloods should be taken for FBC, U+E's, glucose (small children may become hypoglycaemic) and cross match. Antibiotics should be given to combat sepsis.

- If the circulation does not improve rapidly with fluid then inotropes should be used early on in treatment.
- The child should be managed in a high dependency area.

Further reading
1. Advanced Paediatric Life Support. The Practical Approach, 4th Ed. ALSG 2005
2. Al-Khafaji A, Webb A. Fluid resuscitation. BJA CEPD Review 2004; Vol.4:4
3. Cunliffe M. Fluid and electrolyte management in children. BJA CEPD Review 2003; Vol.3:1
4. Moss P, Smith G. Hypovolaemic shock. BJA CEPD Review 2002; Vol.3:8
5. Rodney G. Fluid and electrolyte balance for children. BJA CEPD Review 2002; Vol.3:12