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# Evaluation and management of haemorrhagic shock in polytrauma: Clinical practice guidelines

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A B S T R A C T

Haemorrhagic shock is the most common preventable cause of early mortality in polytrauma patients. Road traffic injuries are the most common cause for polytrauma and most commonly include orthopaedic injuries. Hence, orthopaedic trainees and junior orthopaedic surgeons need to be well aware of evaluation and management of haemorrhagic shock in the multiple injured patient. The present narrative review discusses evaluation and current principles in management of haemorrhagic shock in a polytrauma patient. A classification system for haemorrhagic shock based on ATLS guidelines has been described along with novel use of colour coding to facilitate better and effective use of the classification. A treatment algorithm has also been presented for quick reference. The emphasis is to avoid overloading with crystalloid fluids, replacing with blood and blood products (Balanced resuscitation), permissive hypotension, prevent and acutely treat lethal conditions such as hypothermia, acidosis and coagulopathy. The management of haemorrhagic shock in polytrauma patient is quite challenging and require a detailed knowledge of its management. An arbitrary and haphazard management of these patients may lead to severe complications. We have mentioned the broad principles of management of hypovolemic shock in a polytrauma patient.



## 1. Introduction

A patient is defined to have polytrauma or be multiply injured if the Injury Severity Score is more than or equal to 16.[1] A patient with polytrauma would have injury affecting more than one body region along with derangement of physiological parameters such as blood pressure, level of consciousness, coagulation and base excess.[1] It is well known that acidosis and coagulopathy are two risk factors that are associated with the lethal triad of shock. Advanced age has been suggested to be an additional risk factor. As the number of risk factors increases, the mortality rate also increases proportionately. Haemorrhagic shock is present when the systolic blood pressure is less than or equal to 90 mm Hg in a patient with blood loss due to trauma.[2]

Traumatic brain injury is the most common non-preventable cause of early mortality after trauma whereas haemorrhagic shock is the most common preventable cause of early mortality after trauma.[3,4] Wen et al.[5] reported uncontrolled hypovolemic shock as the most commonly observed etiology for mortality in polytrauma patients. It is estimated that approximately 25% of trauma deaths can be prevented by implementation of timely and appropriate intervention to arrest haemorrhage and exsanguinations.[6] It has been estimated that majority of the deaths due to haemorrhagic shock occur within 6 h.[7]

A recent study[8] has reported road traffic injuries to be the most common cause for polytrauma and the polytrauma was most commonly associated with orthopaedic injuries to the pelvis, spine and the extremities. The most common cause for mortality in pelvic fractures was retroperitoneal bleeding and consequent hypovolemic shock.

A retrospective large sample study from urban India reported 601 deaths in the first 24 h after hospital admission due to trauma and majority of these patients (44%) had moderate injury as per the Injury Severity Score.[4] The study concluded that more than 50% of

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the mortality could have been prevented and opinion from an expert panel remarked that inadequate airway management, inadequate management of hypovolemic shock as factors that could have prevented early mortality. Another study from India has reported that the incidence of polytrauma amongst adult trauma victims was 13% and the mortality rate in polytrauma was 8%.[9] Upper and lower extremity injuries are most commonly observed in trauma patients and the orthopaedics department is most commonly referred patients for further treatment by the Accident and Emergency department.[9]

## 2. Methods

An electronic search was performed of Pubmed, Embase (Ovid) and Proquest databases using the keywords “Hypovolemic shock AND polytrauma”, “Haemorrhagic shock AND polytrauma”. Original research articles (retrospective and prospective studies), systematic reviews, meta-analysis and narrative reviews on the relevant topic published in English language till October 15, 2020 were included in the narrative review. Articles published in non-English language were excluded.

## 3. Etiology

Patients with pelvic fracture and acetabular fracture have a high incidence of blood loss and are likely to present with hypovolemic shock. Patients having APC (Antero-Posterior Compression) III and LC III (Lateral Compression) type pelvic injuries are most likely to need blood transfusion due to hypovolemic shock and patients with APC III injuries are likely to require the highest number of units of blood transfusion.[10] Patients having Anterior column posterior hemitransverse type of acetabular fracture are most likely to require blood transfusion due to haemorrhagic shock and patients with Transverse type of acetabular fracture are likely to need the highest number of units of blood transfusion.[10]

A large sample study from a trauma registry from Germany[2] reported that patients with open grade femoral shaft fractures are more likely to present to the casualty department with haemorrhagic shock and require significantly higher volumes of intravenous fluids and blood products for resuscitation. As the severity of open grade fracture increases from grade I to III, a significant stage-wise proportionate increase in the incidence of hypovolemic shock, mortality and increase in the requirements for intravenous fluids and blood products was reported.

## 4. Clinical features on primary assessment

Hypothermia, coagulopathy and acidosis constitute the lethal triad of haemorrhagic shock and development of all three factors is associated with high mortality.[11]

### 4.1. Level of consciousness

Altered consciousness can be a manifestation of haemorrhagic shock or traumatic brain injury. Patient might be confused or demonstrate rowdy, unruly behaviour which could be either due to haemorrhagic shock, traumatic brain injury, hypoxia or due to severe pain as a result of extremity injuries. A drowsy patient who responds only to painful stimuli or non-responding to painful stimuli is likely to be in advanced stage of haemorrhagic shock or have severe traumatic brain injury.

### 4.2. Peripheral vasoconstriction

The skin might feel cold and clammy due to intense peripheral vasoconstriction as part of the sympathetic response to the blood loss. Capillary refill time will be prolonged and more than 2 s. This hypothermia should be treated rapidly in order to avoid precipitating the lethal triad of shock. As severity of the shock increases, the urine output gradually reduces and there is a risk of developing acute renal failure if patient continues to stay in severe shock for prolonged time.

### 4.3. Vital signs

The core body temperature must be above 35.5° Celsius.[12] Core body temperature lower than 35.5° Celsius is an indicator of hypothermia and should be urgently treated.

Tachycardia (heart rate > 100 bpm, tachycardia might be absent in sportsmen, patients on beta-blocker medication and patients with pacemaker), hypotension (SBP < 90 mm Hg; SBP of 100 or 110 mm Hg might be indicator of early stage shock in geriatric patients with hypertension), tachypnea (respiratory rate > 20 per minute) are vital parameters measured on presentation to the Emergency department. In the early stages of shock, the systolic blood pressure might remain normal but reduction in pulse pressure (defined as systolic BP minus diastolic BP) might be noticed due to increase in the diastolic blood pressure due to sympathetic vasoconstriction. As severity of shock increases, the pulse becomes rapid and thread. Peripheral pulses might not be palpable and one could palpate central pulsations of femoral artery or the common carotid artery. It is crucial to palpate for peripheral pulses in both extremities since symmetrical absence or weakness of peripheral pulses is likely to be due to haemorrhagic shock. Absence of peripheral distal pulsations and cold extremity might delay the diagnosis of associated vascular injury in the limb.

### 4.4. Pitfalls

Geriatric trauma patients with hypertension are likely to be under-diagnosed with shock if the clinician were to rely only on the blood pressure estimation. Hence it is crucial to look for other clinical signs of shock in order to avoid false negative diagnosis. Patients on beta-blocker anti-hypertensive medication would not demonstrate tachycardia as a physiological response to blood loss and this might also be a trap for the unwary junior doctor. These patients are more likely to deteriorate rapidly if timely interventional steps are not taken.

### 4.5. Clinical diagnosis and investigations

In the setting of polytrauma, the aphorism “*one on the floor and four more*” is important to focus not only on the obvious extremity injury but also about concealed, silent, life-threatening bleeding that can occur in the body cavities such as pleural space, retroperitoneal space and intra-abdominal space. It is crucial to know the source of bleeding but patient with haemodynamic instability cannot be shifted to the imaging suite for additional imaging investigations unless there is facility available for simultaneous interventional radiological procedure to control the haemorrhage. Portable Ultrasound machines can be used to be perform eFAST (extended Focused Abdominal Sonography for Trauma) examination in the ER to diagnose haemothorax, cardiac tamponade and free fluid in the abdomen. But since the interpretation of ultrasound images is observer dependant, it is preferred that this imaging investigation in the ER is done by trained radiologists or trained ER specialists in addition to trainee radiologist or trainee ER specialist. If patient remains haemodynamically unstable then whole body CT scan is done as part of trauma series at tertiary level trauma centres. If unstable patient is shifted for CT scan then a team consisting of anaesthetist, trauma surgeon and emergency medicine physician should be accompanying the patient to the imaging suite.

Arterial blood gas estimation on presentation to the ED gives information about the oxygenation and acidosis. The normal pH is 7.4. Acidosis can be diagnosed using arterial blood gas estimation if the base excess is less than −6 mmol/L.[1] Higher mortality and morbidity was observed if the base deficit exceeded −6 mmol/L.[13] Serum Lactate >4 mmol/L is an additional indicator of acidosis.[14] Coagulopathy is diagnosed if partial thromboplastin time exceeds 40 s or if the INR is greater than or equal to 1.4.[1]

## 5. Staging of shock

About 91% of trauma patients could not be correctly classified as per the ATLS classification of hypovolemic shock published in the 8th edition of the course manual thereby questioning the utility of the classification.[15] The ATLS classification has also been criticized for mismatch of various physiological parameters to stages of shock.[16,17] The ATLS classification of shock is difficult to remember though it can be printed in the observation chart of the patient. Despite this, a survey on trainers and course directors of ATLS course revealed that only 11% of the faculty members found the classification reliable for managing resuscitation of patient using fluids and blood products.[18]

The classification based on parameters from eight,[19] ninth[20] and tenth[21] editions of the ATLS course with slight modification is given below (Table 1). The eight [19]edition of ATLS course manual had overlapping of physiological parameters such as pulse rate of 120/minute could be stratified either into Class II or Class III shock and similarly a respiratory rate of 30/minute could be stratified either into Class II or Class III shock. Similarly in the tenth[21] edition of ATLS course manual a base deficit of −10 mEq/L could be stratified either as Class III or Class IV shock. Hence, we modified the existing classification to reduce this ambiguity for various parameters in order to increase the objectivity and reduce the subjectivity.

The ATLS classification was well conceived and we feel that colour coding of various parameters could improve the utility of the classification. This could be useful till a better classification is available. We have sub-grouped stage 3 and stage 4 shock as Red cohort, stage 2 shock as Amber cohort and stage 1 shock as Green cohort. The rationale for designing this traffic light colour coding is to make sense of various observations and to alert the treating doctor. Table 2 highlights various colour schemes to alert the physician regarding progress of the patient. Our proposed classification system using traffic light system would need validation in a multi-centric study. The time frame given is a rough approximation and further consensus needs to evolve regarding standard frequency of re-evaluation of patient in shock. Patient in Class III/IV shock would need more frequent reassessment as compared to patient in Class I shock. One needs to be aware that haemorrhagic shock in a polytrauma case is a dynamic condition and treatment of each case needs to be individualized based on the age, co-morbidities, associated injuries to various body parts, severity of injury etc.

## 6. Resuscitation approaches

Presently, emphasis has been laid on damage control resuscitation (balanced resuscitation) and the main components of this form of resuscitation includes minimal administration of isotonic crystalloids, giving packed RBCs, platelets and fresh frozen plasma in the ratio of 1:1:1 and permissive hypotension.[22,23] Recent high level evidence[24–26] has reported significant benefits of permissive hypotension resuscitation in terms of reduction of mortality due to exsanguination after traumatic haemorrhage.

## 7. Urgent interventions (Table 3)

Our preferred treatment algorithm is given in Fig. 1.

Rapid responders show quick response to the interventions mentioned in Table 3 and sustain haemodynamic stability without need for escalation of any therapeutic measures. Temporary responders show improvement in haemodynamic stability but are unable to sustain the improvement and demonstrate deterioration in haemodynamic stability thereby needing escalation of therapeutic measures including surgical intervention to arrest the bleeding. Non-responders do not show any improvement in vital parameters to the interventions mentioned in Table 3 and warrant escalation of therapeutic measures and definite surgical intervention to control the bleeding.

The above treatment algorithm differs from the ATLS protocol by undertaking of measures in addition to fluid challenge during the initial resuscitation of the patient with haemorrhagic shock. The above measures should be performed along with fluid challenge so that crucial time is not lost in taking timely and appropriate steps.

### 7.1. External haemorrhage control

Urgent measure such as application of compression bandage or pressure bandage is needed to control bleeding from wounds or amputated extremities. Active bleeding from arterial bleeders is best managed initially by pressure dressing. Tourniquet can be inflated (300 mm Hg in lower limbs and 250 mm Hg in upper limbs) to control torrential bleeding from wounds. It is important to note the time of inflation of the tourniquet since maximum allowed limit of inflation is 90 min and leaving the tourniquet on for longer time can lead to permanent ischemia. In handover to the vascular surgery team or the general surgical team, it is crucial to mention the time of tourniquet inflation. Sometimes first aid is provided at the road side and it has been observed that patients with bleeding wounds come with handkerchiefs tied proximal to bleeding wound as tourniquet. It is important to note the remove these tourniquets once the patient reaches the ER. And if that fails then atraumatic bull dog clamps can be applied over the arterial bleeder. Temptation to use artery forceps should be avoided since it leads to irreversible damage to the tunica intima and tunica media layers of the artery.

## 8. General interventions

### 8.1. Oxygen

100% $O_2$ (15 L/min) needs to be given in all patients presenting to ER because in haemorrhagic shock there is wide discrepancy between demand and supply of oxygen. It is better to administer $O_2$ using a non-rebreathing mask in order to improve the efficacy of oxygen delivery. This should be the first step in all trauma patients presenting with haemorrhagic shock.

### 8.2. Wide bore intravenous cannula

Since the rate of administration of intravenous fluids is directly proportional to the diameter of the veins, it is preferred to insert wide bore (16G) intravenous cannula in the antecubital fossa of both the elbows. Blood samples are drawn from IV cannula of one side for haemogram, blood gas including base deficit, blood group and cross matching. If peripheral veins are difficult to cannulate due to vasoconstriction, then central vein such as femoral vein or jugular vein might need cannulation. Anaesthetist or intensivists are

**Table 1**
Shows the proposed classification of haemorrhagic shock combining parameters of eight,[19] ninth[20] and tenth[21] editions of ATLS course book along with minor modifications.

| Parameter | Class I Stage of compensation | Class II Stage of decompensation | Class III Stage of deterioration | Class IV Stage of impending mortality |
|---|---|---|---|---|
| Blood loss (ml) Based on 70 kg adult male | < 750 | 750-1499 | 1500-2000 | > 2000 |
| Heart rate (bpm) | < 100 | 100-120 | 121-140 | >140 |
| BP | Normal | Reduced | Reduced | Reduced |
| Pulse pressure | Normal or ↑ | ↓ | ↓↓ | ↓↓↓ |
| Respiratory rate (breaths/min) | 14-20 | 21-29 | 30-35 | > 35 |
| Urine output (ml/hr) | Normal >30 | Oliguria 20-30 | Oliguria 5 - 19 | Anuria Negligible |
| Neurological status (GCS = Glasgow Coma Scale) | Normal | Agitated | Confused Reduced GCS | Lethargic Reduced GCS |
| Base deficit (mmol/L) | ≤ 2.0 | 2.1 to 6.0 | 6.1 to 10.0 | > 10.0 |
| Type of IV fluid | Crystalloid | Crystalloid | Crystalloid<br>Blood (Type specific) | Crystalloid<br>Blood (O –ve)<br>massive transfusion protocol activation |

skilled in central vein cannulation and this usually obviates the need for peripheral venous cut-down or venesection.

### 8.3. Crystalloids

Crystalloids need to be used judiciously until blood products become available. Excessive use of intravenous crystalloid fluids is detrimental due to risk of worsening coagulopathy, hypothermia and acidosis.[22]

Warmed crystalloid isotonic solutions such as 0.9% Normal Saline or Ringer's Lactate are given rapidly using both the intravenous cannula. Devices are available to compress the intravenous fluid bags for rapid fluid replenishment. 1 to 1.5 L of intravenous fluids are administered and response to the fluid challenge is noted. It is preferable not to exceed 2 L of crystalloid solution. Liberal and injudicious use of 0.9% Normal Saline and Ringer's lactate can lead to hyperchloremic metabolic and respiratory acidosis respectively.[22]

Colloids such as Hydroxyethyl Starch (Voluven), Polygeline (Haemaccel), Gelatine polysuccinate (Gelofusine) etc were given in addition to crystalloids but are not recommended presently. Starch based colloids can precipitate coagulopathy, anaphylaxis type

**Table 2**
Schematic shown for a patient (Immediate responder) presenting in advanced stage of shock and showing response to treatment. Serial improvement in all parameters is observed as indicated by the traffic signal colour coding.

| | On presentation and admission to Emergency department (ED) | 15 minutes after admission | 30 minutes after admission | 45 minutes after admission | 60 minutes after admission |
|---|---|---|---|---|---|
| 1. Heart rate (bpm) | 130 | 120 | 110 | 100 | 94 |
| 2. BP (mm Hg) | 90/60 | 100/60 | 110/70 | 120/80 | 120/80 |
| 3. Pulse pressure (mm Hg) | 30 | 40 | 40 | 40 | 40 |
| 4.Respiratory rate (breaths/min) | 32 | 28 | 24 | 19 | 18 |
| 5.Urine output (ml/hr) | 12 | | | | 24 |
| 6.Neurological status (GCS = Glasgow Coma Scale) | 13 | 13 | 15 | 15 | 15 |
| 7. Base deficit | 8 | | | | 5 |

reaction and renal failure.[22]

*8.4. Intravenous tranexamic acid*

Tranexamic acid works by preventing disruption of the fibrin clots that are formed as the body's response to prevent blood loss. Tranexamic acid works best when given within 3 h from the time of trauma. It is given intravenously as a 1 gm loading dose over 10 min followed by 1 gm maintenance dose over 8 h as an intravenous infusion.[27]

*8.5. Vasopressors*

No human studies exist to support the routine use of vasopressors in the trauma setting in order to avoid further tissue hypoperfusion and hypoxia due to vasoconstriction as part of the physiological response to haemorrhagic shock. If more than 1.5 L of intravenous fluids are given and patient continues to be haemodynamically unstable and blood products are awaited then vasopressors can be given to buy time till blood products become available.

*8.6. Blood and blood products*

Blood is the best replacement for haemorrhagic blood loss. If more than 2 L of fluids are given intravenously and patients does not show satisfactory response then blood products need to be given. The total amount of bleeding from various injuries as part of polytrauma needs to be estimated and the total volume of fluids including crystalloids, blood and blood products to be given should be at least thrice the estimated amount.

For example if a patient has closed shaft femur fracture and pelvic fracture then it is estimated that the patient would have approximately 3 L of blood loss and hence the total volume of fluids and blood products needed to replenish would be 1.5 L of crystalloid to replace 500 ml blood loss and the remaining 2.5 L to be replaced by blood (the number of units to depend upon till haemodynamic stability achieved with systolic BP of 90 mm Hg).

Replacement of only packed red blood cells is likely to affect blood coagulation. Hence massive transfusion protocol has been developed to give packed red blood cells: fresh frozen plasma: platelets in the ratio of 1:1:1.[28] Administration of platelets early during the course of treatment in haemorrhagic shock has shown to significantly reduce mortality in critically injured patients.[29]

Each institute needs to have its protocol for massive transfusion. Most accepted indications for activation of massive transfusion are presence of haemodynamic instability despite transfusion of 4 units of packed red blood cells, replacement of >1 blood volume in 24 h or replacement of >50% of blood volume in 4 h.

*8.7. Prevention of hypothermia*

It is important to prevent hypothermia from setting in due to higher risk of associated mortality. Blankets, warming blanket (Bair huggers), use of room warmers and administration of warmed crystalloid solutions can be helpful in prevention and management of hypothermia.

*8.7.1. Strategies in specific injury patterns in polytrauma*

1. Head injury – In order to maintain cerebral perfusion, the goal is to maintain a systolic blood pressure of around 110 mm Hg.

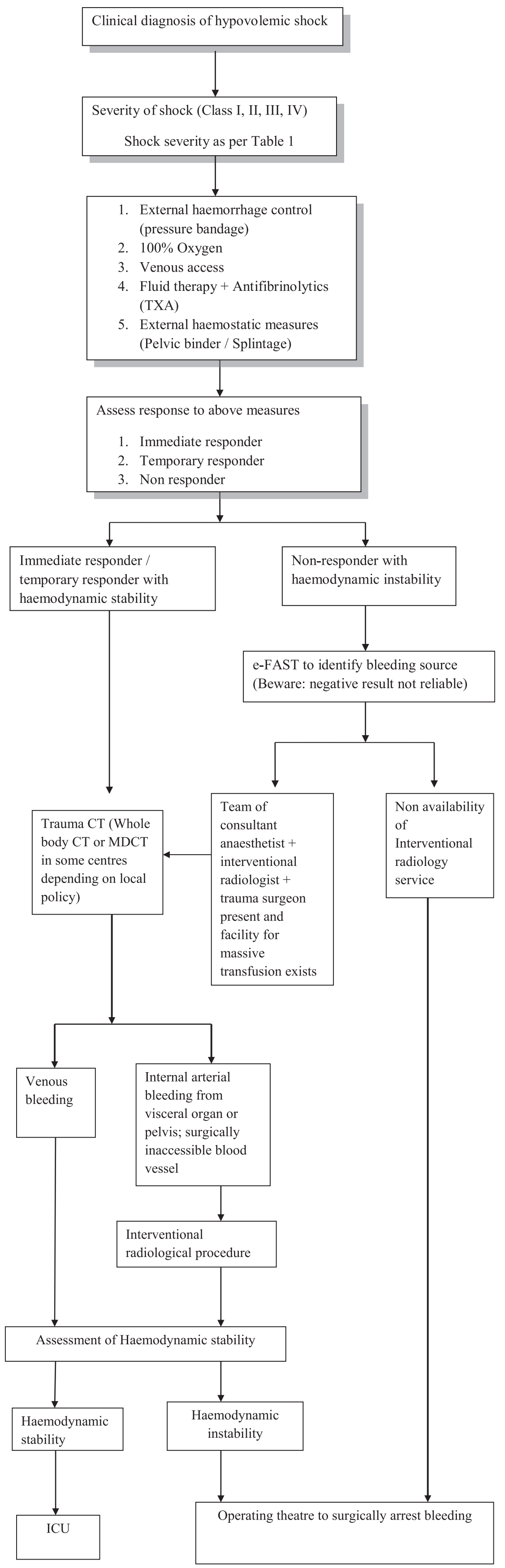


**Fig. 1.** Shows the approach to evaluation and management of haemorrhagic shock.

Permissive hypotension is not practised here due to the danger of reducing mean arterial pressure and consequently leading to cerebral hypoperfusion.[12] Proponents for maintaining permissive hypotension argue that normalizing the systolic blood pressure in polytrauma patients runs the potential theoretical risk of dislodging the blood clot that forms at the site of internal/external bleeding as part of the physiological response to bleeding and this is termed as 'pop the clot' phenomenon. However; one should also remember that there is scarcity of evidence regarding the optimal duration to maintain permissive hypotension and this hence this remains a contentious issue. Another issue is that traumatic brain injury cannot be reliably ruled out on clinical examination solely in a patient present to the casualty department with altered sensorium in stage III hypovolemic shock and allowing permissive hypotension in such patients will only worsen cerebral perfusion pressure which further can aggravate the brain injury (if it exists).[30]

2. Penetrating trauma to torso – permissive hypotension can be safely practised with the intention to reduce blood loss. The systolic blood pressure is maintained around 70 mm Hg using judicious use of crystalloids and blood products till the patient undergoes urgent surgical intervention.[12]
3. Blunt trauma to torso – permissive hypotension can be safely practised and the target systolic blood pressure is around 90 mm Hg.[12] If surgical intervention is needed then permissive hypotension is maintained till patient goes to the operating theatre. If patient is treated conservatively then it is unclear as to whether permissive hypotension is to be maintained or normotension is to be maintained. The duration of permissive hypotension in conservatively treated blunt torso trauma is also unclear.

## 9. Orthopaedic specific interventions

### 9.1. Pelvic fracture

High energy trauma with bruising and swelling around the iliac fossa, hypogastrium or perineum, scrotal odema, labial odema, bleeding from the external urinary meatus, bleeding per vaginum and bleeding per rectum makes the presence of pelvic fracture very likely. Limb length discrepancy with no obvious swelling and deformity in the thigh and history of fall from height of more than six feet should lead to strong suspicion of pelvic fracture. Pelvic compression and pelvic distraction test should not be repeated multiple times and it is preferred to be done only once by the third year resident or senior resident on call. The timely application of a pelvic binder can be lifesaving in an open book type pelvic fracture with diastasis of the pubic symphysis. The hospital bed sheet can be used and applied at the level of greater trochanters (not at the level of the iliac crests) as a pelvic binder [Fig. 2]. If bedside radiograph facility is available then plain radiograph can confirm the presence of pelvic fracture. If bedside radiograph facility is not available in the ER then the haemodynamically unstable patient can be assumed to have pelvic fracture and prophylactic pelvic binder needs to be applied.

### 9.2. Femur shaft fracture

In the presence of haemorrhagic shock and femoral shaft fracture, prompt application of Thomas splint and skin traction is recommended. The choice of the size of the Thomas splint depends on the proximal groin girth and also the limb length. These measurements can be taken using a measure tape on the unaffected limb. In order to accommodate the swelling due to the femoral shaft fracture, the diameter of the ring of the Thomas splint should

**Table 3**
Urgent life saving measures to be undertaken by the healthcare professional during initial assessment of the polytrauma patient with haemorrhagic shock.

| Management rationale | Steps |
|---|---|
| External Haemorrhage control | Pressure bandage (over bleeding wound) Tourniquet (if pressure bandage ineffective) Bull dog clamp if major vessel bleeding |
| Oxygen | 100% $O_2$ (15L/min) – Non-rebreathing mask |
| Venous access | 16G IV cannula in both antecubital fossa/Central venous access [ femoral vein/jugular vein] if peripherally shut down/Venesection if no facility for central venous access<br>Draw blood samples from one side |
| Fluid Management & bleeding arresters | Start IV fluid for resuscitation from another side<br>Isotonic crystalloid (NS/RL)<br>• 1–1.5 L of bolus initially and assess response<br>Tranexamic Acid (Antifibrinolytic)<br>• Should be given within 3 h of trauma<br>• Initial loading IV dose of 1 gm over 10 min<br>• Followed by maintenance of 1 gm over 8 h as IV infusion |
| External haemostatic measures | Pelvic binder (Bed sheet)<br>Limb splint (Thomas splint + skin traction for femoral shaft fracture)<br>In polytrauma (correct deformity + slab application)<br>• Slab for upper limb #<br>• Slab for tibia fibula # |
| Blood products & balanced resuscitation | Packed RBCs<br>Massive transfusion protocol activation (sos)<br>• Indications for activation<br>❖ Haemodynamic instability despite transfusion of 4 PCVs<br>❖ Replacement of >1 blood volume (5L) in 24 h<br>❖ Replacement of >50% blood volume (2.5L) in 4 h<br>❖ Penetrating injury to torso<br>❖ Positive FAST scan<br>• Packed red blood cells: FFP: Platelets = 1:1:1 or 2:1:1 |

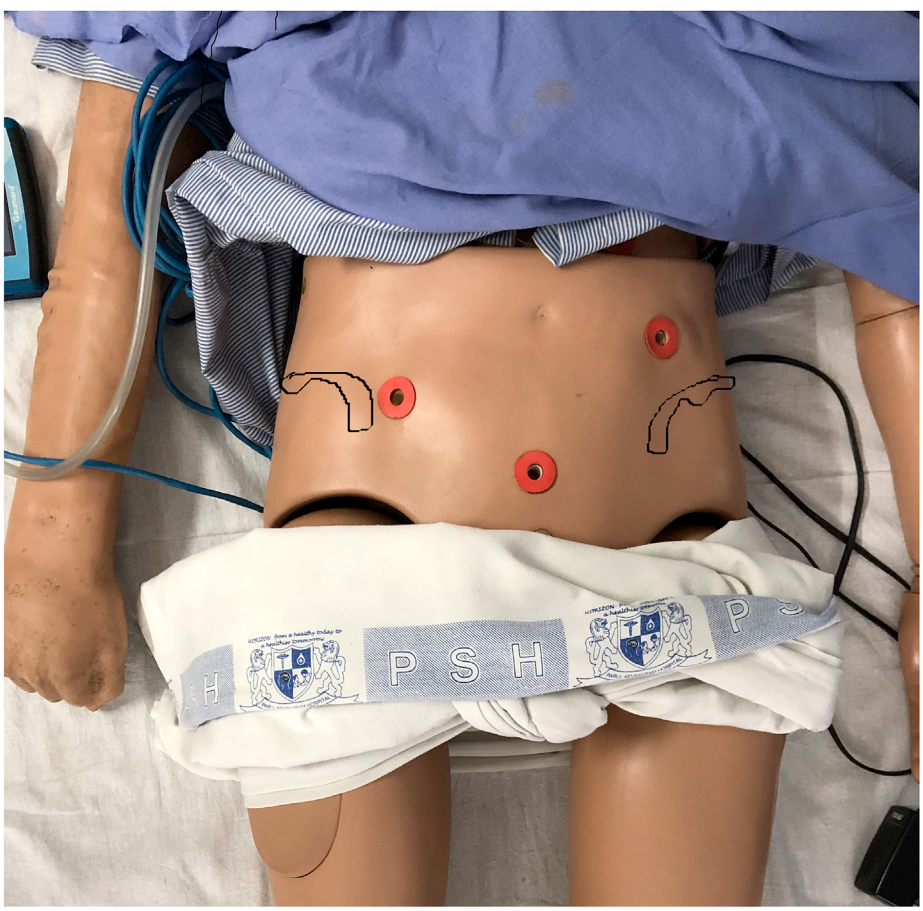


**Fig. 2.** Showing correct level of application of pelvic binder made from bed sheet of the hospital.

be atleast 3 inches more than the groin diameter. The length of the Thomas splint is measured from the ASIS to the lateral malleolus on the unaffected side and the length of the splint should be 6 inches more than the measured limb length. Proper padding needs to be ensured on the proximal ring in order to avoid pressure sores over the groin, ischial tuberosity and the ASIS. Below knee skin traction is applied using sticking plaster and bandage. Gauze pieces are applied in bundles around the malleoli to prevent development of pressure sores. Skin hair would need removal prior to application of the sticking plaster on the leg for skin traction. Plain bandage or crepe bandage can be applied in criss cross pattern over the skin. Non-elastic rope or bandage can be passed through holes made at the end of the sticking plaster. The Thomas splint should pass comfortably over the injured extremity. It is important to feel for distal dorsalis pedis and posterior tibial pulsations prior to application of skin traction. The skin traction is applied and the ends of the rope are tied over the distal end of the Thomas splint. The distal limb pulsations should be palpable after the application of skin traction. Should the distal pulsation disappear, it implies that excessive traction has been applied and the traction should be loosened till the distal pulsation reappears.

### *9.3. Other long bone fractures*

Above knee back slabs are given for tibial shaft fractures, U slabs are given for humeral shaft fractures for temporary stabilization.

## 10. Advances in diagnosis and management OF SHOCK

### *10.1. Whole body computed tomograph (WBCT) scan*

Whole body CT scan has become an integral part of assessment of polytrauma patients presenting with haemorrhagic shock because it allows accurate evaluation of severity of injury to the visceral organs of the torso, valid estimation of the Injury severity score, is rapidly performed and if need be can be subsequently managed with interventional radiology procedures in the imaging suite. The CT scan is mainly focussed for confirmation or ruling out injuries to the head, spine and the torso. Presently the entire body can be scanned in less than a minute using multislice CT.[31] Whole body CT is used by major trauma centres as a modality of initial investigation of polytrauma patients.[32,33] Whole body CT has been shown to reduce early trauma related mortality.[34] In some centres multi-detector computed tomography (MDCT) is available and this involves rapid screening of trauma patients for life threatening injuries including vascular injuries.

### *10.2. B. interventional radiology*

Interventional radiology has emerged as a life saving speciality by arresting ongoing blood loss from visceral organs of the torso (liver, spleen, kidney) and pelvic fracture. Transcatheter arterial embolization (TAE) is an effective modality to treat arterial bleeding and in experienced hands is a rapid procedure without the morbidity of a surgical intervention and hence can be useful in polytrauma patients with comorbidities and whose general medical condition precludes operative intervention. The efficacy of interventional radiological procedures has been proven in a retrospective study on critically injured polytrauma patients with exsanguinations due to ongoing internal bleeding.[35] The study reported significant improvement in vital signs and blood markers of resuscitation such as serum lactate and base excess.[35]

### *10.3. Viscoelastic assay*

Viscoelasticity of blood clot formation (coagulation) followed by subsequent lysis of the clot (fibrinolysis) is evaluated using thromboelastography (TEG) and rotational thromboelastometry (ROTEM). This investigation is performed rapidly and gives a real time picture of coagulopathy seen during haemorrhagic shock. This guides the clinicians in specific administration of suitable blood products such as FFP, platelets or tranexamic acid depending on various parameters such as reaction time, angle of clot formation, maximum amplitude of the clot and percentage of clot lysis at 30 min.[36] The role and validation of various parameters of TEG are being investigated presently.[37] Evidence from the Cochrane group concluded that TEG and ROTEM were found to have negligible clinical role and recommended that investigations such as TEG and ROTEM are to be used only for research purpose.[38] However; recent study has demonstrated that viscoelastic assays help to give targeted blood products and reduce mortality in polytrauma patients.[39]

### *10.4. Ultrasound assessment of the inferior vena cava (IVC)*

Ultrasound assessment of inferior vena cava is helpful to assess the efficacy of fluid resuscitation. Parameters such as inferior vena cava diameter, inferior vena cava collapsibility and inferior vena cava distensibility and variation in diameter also help to distinguish between fluid responder and fluid non-responder. In fluid non responder, the inferior vena cava diameter is wider and variation in the diameter with respiration is smaller. In fluid responder, the inferior vena cava diameter is smaller and the variation in diameter is larger. The ultrasound assement of IVC is a rapid, non-invasive procedure, can be easily taught and yields reproducible results. Discussion about the details of various parameters related to the ultrasound assessment such as distensibility index, collapsibility index are beyond the scope of the present review.

## 11. Monitoring during resuscitation

The following clinical parameters are monitored during resuscitation: Heart rate, Blood pressure, pulse pressure, respiratory rate, urine output and neurological status.

Base deficit as measured by Arterial blood gas estimation[40] has been shown to be very useful to stratify patients with haemorrhagic shock and has been included in the 10th edition of the ATLS course handbook.[21]

## 12. End point of resuscitation

Serum lactate (can be measured from arterial blood gas evaluation) is an indicator of adequacy of resuscitation. The normal serum lactate level is $\leq$ 2.0 mmol/L.[41] However some authors have used serum lactate level <4 mmol/L as indicator for early definitive management in polytrauma patient[42] whereas some authors have suggested a lower threshold of $\leq$ 2 mmol/L as indicator for definitive management instead of damage control surgical intervention.[43] In addition the patient's vital signs must be within normal limits. Though arterial samples are recommended to measure serum lactate, it can be quiet challenging to obtain arterial blood samples and Privette and Dicker[44] have suggested that venous blood samples are also acceptable in order to measure serum lactate.

## 13. Role of the anaesthetist and the intensivist

One of the key determinants of a successful outcome of managing haemorrhagic shock in a multiple injured patient is effective team work and inter-departmental communication. The role of the anaesthetist and the intensivist deserves special mention as the anaesthetist would be involved in primary assessment and management of the patient in the trauma department and later when the patient is shifted to the imaging suite. Intensivists have a crucial role not only in managing non-operatively treated polytrauma patients that are awaiting definitive intervention but also managing postoperative polytrauma patients that have undergone emergency trauma surgical intervention.

## 14. Conclusion

The management of a polytrauma patient is quite challenging and require a detailed knowledge of its management. An arbitrary and haphazard management of these patients may lead to severe complications. We have mentioned the broad principles of management of hypovolemic shock in a polytrauma patient. Treatment of each patient would depend on availability of various products and support infrastructure. If a centre is not optimally equipped to deal with these cases then it is appropriate that timely referral occurs to the nearest appropriate centre.


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## CRediT authorship contribution statement

**Karthik Vishwanathan:** Conceptualization, Methodology, Literature Search, Validation, Writing – original draft, Editing, Drafting. **Sunil Chhajwani:** Methodology, Literature search, Validation, Writing – review and editing. **Amit Gupta:** Conceptualization, Validation, Writing – review and editing. **Raju Vaishya:** Conceptualization, Validation, Writing – review and editing.

## Declaration of competing interest

The authors have no conflict of interest to declare.

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