# Current Practice and New Developments in Trauma

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# PREFACE

Trauma was a neglected disease in the healthcare system of Hong Kong until the 90s, despite the inadequacy in trauma care and the fact that a significant proportion of preventable trauma deaths had already been recognized in the USA in the 60s.[1] The greatest benefit in the development of trauma care in a society is having a system in place. It has been proven that a regional trauma system is associated with improved outcomes.[2] A trauma center is only one part of this system. Nevertheless, healthcare workers, who practice in trauma receiving facilities, witness the aggregated outcomes of trauma patients according to the performance of the trauma care management in their society. Therefore, they are usually the strongest advocates for the development of the trauma system. Naturally, the establishment of a trauma system and further development usually starts from trauma receiving facilities. Some of these facilities eventually become regional trauma centers.

Gilberto KK Leung has described the development of the trauma system in Hong Kong in detail.[3] Most of the essential components of a mature trauma system have been established since the 1990s. The integration of a well-established efficient pre-hospital ambulance service, the designation of trauma centers with organized hospital-based trauma teams, an inclusive trauma network with a well-established inter-facility transfer criteria, a governance structure within the public healthcare system, continuing improvement through structured and regular audit activities, and the promulgation of trauma education within the healthcare structure and public domain are all now in place, although they are subjected to further refinement and updates.

Trauma is a multi-system disease, which can cut across the boundaries of contemporary medical disciplines and even the boundaries within a discipline. Frontline physicians and nurses are frequently confronted by trauma victims from various age groups. They need to manage the following: pre-morbid state, stages of pregnancy, degree of intoxication, exposure to temperature extremes, and multi-specialties/sub-specialties injuries with different priorities, etc. They also must choose what type of radiology to use, as well as which surgical and non-surgical approaches to follow etc. Clinical practice guidelines primarily based on evidence for the management of specific clinical circumstances have been developed but local considerations are also needed, such as resources and good judgement. This book is written from the perspective of the local burdens, beliefs, bargains, and barriers (the 4 Killer Bs)[4] of trauma care in Hong Kong.

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# CHAPTER 0

# EMERGENCY ROOM RESUSCITATION

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The Emergency Room is the first place to receive a trauma patient. The trauma team will use a common language—Advanced Trauma Life Support (ATLS)—to perform a comprehensive patient assessment, resuscitate and stabilize the patient, arrange and prioritize investigations and adjuncts, and finally transfer the patient to the definitive area for further management. Good communication and precise decision making are important during trauma resuscitation. This chapter is going to summarize some areas that we may overlook during trauma resuscitation.

Your team is about to receive a trauma patient. Information retrieved from the ambulance control is that the patient is a thirteen-year-old boy, who has had a suspected fall from a height and sustained multiple injuries. On arrival to the emergency department, the patient is unconscious, and the physical examination finds a crepitus over the bilateral chest wall and an unstable pelvis. The first BP is 66/40, pulse rate is 139, and SpO2 is 100% with a 100% oxygen mask.

- What further information is important to obtain from the paramedic?
- What are your resuscitation priorities?
- What interventions are important to the patient in the emergency room?
- Is the resuscitation of a child different to an adult?

## Clinical handover

Paramedics are well trained in both scene and trauma patient assessment. And, with advanced paramedic skills and development, many interventions and treatments will be provided at a pre-hospital setting. The clinical handover from the paramedics to the emergency department staff is important. By transferring clear and concise information, the receiving parties can increase situational awareness and influence the decision-making process. Active listening, closed-loop communication, and clarifying questions are also important to ensure that all information is correctly received without loss. A repeated or fragmented handover should be avoided.[1, 2]

A verbal handover with a standardized format proved can reduce preventable adverse events, avoid the missing diagnoses, and improve patient safety and outcomes. There are many mnemonics used to standardize the handover;

MIST is one of most common use of mnemonics in both military and civilian trauma settings.

| | |
|---|---|
| **M**echanism of injury | ● Provide clues to anticipated injuries<br>● Enhance an understanding of the patient's physiological state<br>● Can reduce over and under triage through trauma team activation |
| **I**njuries | ● Injuries identified at the primary and secondary surveys |
| **S**igns | ● Vital signs include pulse rate and quality, blood pressure, respiratory rate, SpO2, GCS, temperature, and +/- H'stix |
| **T**reatment | ● Easily recognized: Spinal immobilization including neck collar, pelvis binder, and airway intervention<br>● Maybe hidden: Needle decompression, chest seal, tourniquet, and wound packing<br>● What amount of fluids have been given?<br>● Has any medication been given? How much tranexamic acid has been given? Have any analgesics been given? |

## Lifesaving Procedures

Several procedures are lifesaving in the emergency room. The trauma team should be well trained for the procedures. Precise decision making and avoid pitfalls are also important.

### *A. Tube thoracotomy/chest drain*

Tube thoracotomy/placement of the chest drain is performed to drain the pleural cavity for air or blood, e.g., for treating a pneumothorax, a hemothorax, or a hemopneumothorax. The procedure is done with an aseptic technique and with local anesthesia. In a trauma setting, it could be a lifesaving procedure to relieve the tension of a pneumothorax or a massive hemothorax.[3] Traditional teaching says that a chest X-ray of a tension pneumothorax should not exist; however, it is often not easy to identify a tension pneumothorax in a busy resuscitation room. All resuscitation rooms in Hong Kong are equipped with X-ray machines and there is good evidence that many tension pneumothoraxes will not deteriorate within minutes. As such, we could afford to take a chest X-ray (as part of the trauma series) to diagnose pneumothorax before performing a tube thoracotomy.

Indications:

- Tension pneumothorax.
- Massive hemothorax.
- Traumatic pneumothorax/hemothorax/hemopneumothorax.
- Pulseless electrical activity (PEA) with evidence or mechanism suggestive of a chest injury.
- Following needle thoracotomy.
- Prophylactic chest drain for a patient with suspected chest injury and who also requires positive pressure ventilation or air transport.

Pitfalls (the complication rate may vary from 6% to 37%):

- The complication rate is higher with the trocar technique.
- Bleeding (related to intercostal vein or artery injury).
- Subcutaneous placement: “false tract”.
- Lung parenchymal trauma (a malposition might be related to an intrafissural or an intraparenchymal position).
- Diaphragm laceration with intra-abdominal organ injuries or misplacement into the abdominal cavity.
- Dislodgment, a kink, or a malposition during patient transfer.

### *B. Pelvis binder application*

The pelvic bone is a bowl-shaped structure with a fixed internal volume. In a blunt trauma patient with a pelvic fracture, the bowl structure is disrupted, allowing the internal volume to increase. The pelvis can hold 4 to 6 L of blood before a tamponade effect occurs. The application of a pelvic binder is to limit the pelvic volume and help to tamponade further bleeding. Also, a pelvic binder aids in the apposition of bone fragments which could reduce a bony hemorrhage. The stabilization of bone fragments promotes clot formation and reduces clot disruption.[4] A T-POD and an SAM Pelvic Sling are the two most commonly used commercial products in Hong Kong. Misplacement of pelvic binders can significantly decrease the ability of the binder to reduce pelvic fractures. It should be placed directly at the level of trochanters and the goal is to achieve a normal anatomic position of the pelvis, so the lower legs should be symmetric after stabilization.

**Indications:**

Any blunt trauma/blast injury patients having the following:

- Signs or symptoms of pelvic injury
- Hemodynamic instability
- Altered level of consciousness/being unconscious
- Major limb amputation or near amputation

**Pitfalls:**

- Incorrect positioning of a pelvic binder over the iliac crest may exacerbate fractures and obstruct access to the abdomen for a laparotomy.
- Open pelvic fractures, perineal lacerations, intra-abdominal injuries requiring surgery, morbid obesity, burns, and severe associated pelvic soft tissue injuries are relative contraindications. These may necessitate the external fixation of the pelvis instead of a pelvic binder. However, a pelvic binder may still be placed until the definitive external fixator is applied.
- A pelvic fracture, especially an open book pattern, may realign after the application of a pelvic binder and subtle fracture could be more difficult to identify by X-ray.
- Pressure ulceration in prolonged use (ensure the date and time of application is documented).

### *C. Tourniquet*

The majority of external limb hemorrhages can be controlled by direct pressure; however, occasionally there are situations where direct pressure may fail. Also known as a Hemostatic Arterial Tourniquet (HAT), or simply a

tourniquet, it is an effective mean of arresting a life-threatening hemorrhage from a limb injury. It should be applied as distally as possible with an approximate 5cm margin proximal to the injury. It should not be applied over joints as much as possible and be applied directly onto exposed skin. Its effectiveness is determined by the cessation of bleeding. The second tourniquet can be applied proximal to the first one if the bleeding persists. Slight oozing at the wound site may occur due to some blood flow from the exposed medullary bone.[5] When the hypotensive patient is resuscitated to a higher systolic blood pressure, the bleeding may restart despite the continued use of a tourniquet. This can be avoided by adhering to the principles of hypotensive resuscitation for a non-compressible hemorrhage and by tightening the tourniquet until bleeding is re-controlled. The time of the application must be recorded and handed over to the trauma team members properly. An application of less than 2 hours is safe in general and there is no need for periodical loosening.

Indications:

- Limb hemorrhage not controlled by simple methods (e.g., direct pressure, a dressing, or a bandage).
- Life-threatening limb hemorrhage.
- Limb amputation or near amputation.
- Mangled limb with multiple bleeding points.

Pitfalls:[5, 6]

- An incorrectly applied tourniquet will increase bleeding and the risk of a distal soft tissue injury including compartment syndrome (by not making it tight enough and if there is occlusion of the lower pressure venous outflow as well as an inadequate occlusion of the arterial blood flow).
- Local tissue damage, including a permanent nerve injury, muscle injury, vascular injury, and skin necrosis.
- Complication of limb ischemia and a need for amputation.
- Look for a reperfusion injury.
- Applying a tourniquet is a painful procedure and requires pain relief.

### *D. Blood transfusion and massive blood transfusion activation*

In trauma patients with acute blood loss and hemodynamic instability, intravascular volume loss is restored initially by crystalloid infusion. The transfusion of packed red blood cells (PRBC) primarily serves increases the oxygen carrying capacity thus maintaining tissue oxygenation. Because the drop in hemoglobin concentration (Hb) lags behind the effect of acute blood loss, the clinician should not solely depend on it as transfusion threshold. Both the estimated blood loss and individual clinical scenario should be taken into account when considering an emergency PRBC transfusion:

- Inadequate response to IV crystalloid resuscitation (2L in adult or 40ml/kg in a child).[7]
- Anticipation of ongoing bleeding or the source of bleeding cannot be quickly and adequately controlled in the Emergency Department.
- The hemoglobin concentration is less than 7 g/dL; patients with co-morbidities, such as cardiovascular or cerebrovascular disease, may benefit from a higher hemoglobin concentration.

Massive transfusion was historically defined as a patient requiring at least 10 units of red cells transfusion in 24 hours. Such a transfusion carries some hemostatic and metabolic complications in addition to those from a massive and uncontrolled hemorrhage. The massive transfusion protocol (MTP) is implemented to allow for the timely identification of trauma patients in the Emergency Department who likely require a massive transfusion, to coordinate trauma team members and the blood bank, and initiate a balanced blood product resuscitation. There are various scoring systems to predicate the need for a massive transfusion, and different physiological, radiological, and biochemical parameters are utilized for this prediction.[8] Trauma centers in Hong Kong use the Prince of Wales Hospital (PWH) score, which is simple to apply and has satisfactory accuracy.[9]

| Score variables | Score |
|---|---|
| Hb =< 7 g/dL | 10 |
| Hb 7.1 to 10 g/dL | 1 |
| SBP =< 90 mmHg | 3 |
| Heart rate > 120 bpm | 1 |
| GCS =< 8 | 1 |
| Displaced pelvic fracture | 1 |
| Hemoperitoneum on CT/FAST positive | 2 |
| Base excess < -5 | 1 |
| Total score | |

If the total score is >= 6, activate the Massive Transfusion Protocol (for age > 12 yr)

Pitfalls:

- A patient with chronic anemia can result in over-activation.
- A displaced pelvis fracture is hard to differentiate from a non-displaced one via a plane pelvic X-ray, especially when the patient has a pelvic binder.
- The clinician should reevaluate the score throughout trauma resuscitation. An initial non-MTP activated case may progress to MTP activated during their stay in the emergency department.
- The clinician should consider an unmatched blood transfusion for class 3 to 4 hypovolemia shock although the score is not high enough for the activation of a massive transfusion protocol.

### *E. Focused Assessment with Sonography for Trauma (FAST)/E-FAST scan*

A FAST scan is an essential component of the primary survey for circulation in a trauma patient, and it is used to primarily detect intraperitoneal free fluid and pericardial fluid.[10] Despite the fact the FAST scan has variable sensitivity for different intraabdominal injuries,[11] it remains a triage tool for expeditious definitive care. Moreover, with its bedside availability, relatively low cost, noninvasiveness, and lack of radiation hazard, clinicians can perform serial FAST scans for patient reassessment.

Pitfalls when performing the scan:

- Subcostal view
  - False positive: epicardial fat pads.
  - A hemopericardium may not occur in a penetrating injury with concurrent hemothoraces or mediastinal hemorrhage.[12–13]

- Right/left flank view
  - False positive: perinephric fat pad.
  - Incomprehensive study: scans the hepatorenal and perisplenic space but omits the pleural, subphrenic, and inferior pole of the kidneys.[14]
- Suprapubic view
  - False negative: scan while the bladder is empty.
  - False positive: seminal vesicles in young males and physiological free fluid in women of reproductive age.
  - Cannot distinguish between urine from an intraperitoneal bladder rupture and blood.

Pitfalls: (Utilizing the scan)

- Areas of low sensitivity
  - A patient with stable hemodynamics.
  - Solid organ injuries.[15]
  - Penetrating injuries.
  - Minimal amount of intraperitoneal free fluid required for a positive scan.
    - Varies among operators and injured organs.
    - Time taken for fluid to accumulate after sustaining an injury.
- Inability to appreciate a diaphragmatic injury, a perforated hollow viscus, or a mesenteric trauma.
- Limited use for retroperitoneal structures.[16]
- Relying on a single study for subsequent patient care, especially if the initial study is negative.

**Extended Focused Assessment with Sonography for Trauma (E-FAST)**

A lung ultrasound is incorporated in an E-FAST, mainly to detect a pneumothorax. When compared with a supine chest X-ray in a trauma patient, a lung ultrasound has a similar specificity and greater sensitivity for pneumothorax detection.[17–20] In a hemodynamically unstable patient who requires a resuscitative operation without a CT scan or in a patient with a definitive airway, a lung ultrasound can provide additional screening for an occult pneumothorax and indicate whether there is a need to perform a tube thoracostomy.

### *F. Resuscitative Thoracotomy*

A resuscitative thoracotomy is performed in an emergency room for a traumatic patient who develops an impending cardiac arrest due to a severe thoracic or abdominal injury causing hemorrhagic or obstructive shock. It can be performed by the left anterolateral or the clamshell approach.

The objectives of a resuscitative thoracotomy are as follows:[21]

- Controlling a hemorrhage from the heart, lung, or vessel.
- Relief from a cardiac tamponade.
- Repairing cardiac injuries.
- Allowing an open cardiac massage and internal defibrillation to restore cardiac output.
- Cross clamping of the descending aorta to control an abdominal hemorrhage and improve cerebral and coronary blood flow.

Indications:[22, 23, 24]

- Witnessing a cardiac arrest in a trauma patient with no response to 2 mins conventional cardiopulmonary resuscitation and bilateral chest decompression, with either a blunt or a penetrating injury.
- Penetrating thoracis or extra-thoracic injury presenting pulseless to the Emergency department with or without signs of life (conditional).
- Sustaining exsanguinating abdominal vascular injuries as an adjunct to definitive repair of an abdominal-vascular injury.

Pitfalls:

- Delayed decision making for resuscitative thoracotomy.
- The team has a lack of training in the procedure.
- Insufficient equipment or unfamiliar with the equipment.
- Proceed with nontraumatic arrest.
- Proceed with a patient presenting pulseless without a sign of life after a blunt injury.[2]
- Insufficient volume resuscitation for effective internal cardiac massage.[1]
- The patient suffered from severe head injury or a multisystem injury, or pre-existing co-morbidities mean that successful resuscitation is highly unlikely.

### *G. Perimortem Caesarian Section*

A gravid uterus can cause aortocaval compression and diminish thoracic compliance, especially when the patient is placed supine during resuscitation.[25] Such a mechanical disadvantage can hinder CPR and restore spontaneous circulation even with an appropriate leftward uterine displacement. After the delivery of the baby and emptying the uterus, the cardiac output increases significantly and contributes to successful CPR.[26, 27] The "four-minute rule" and "five-minute rule" of perimortem caesarian section stress that the procedure should be initiated within four minutes and the delivery of the baby within five minutes from maternal arrest to achieve the best neonatal survival and neurological outcome.[28] A perimortem caesarian section is still recommended if the time from maternal arrest exceeds five minutes, or in a patient with presumed viable gestation age fetus sue to its resuscitative benefit to the mother.[29, 30] Moreover, there are case reports of neonates with good neurological function delivered from five to thirty minutes after maternal arrest.[31]

Indications:

- Estimated fetal gestation beyond 24 weeks.
- Uterus palpable above the umbilicus.
- No return of spontaneous circulation (ROSC) after 2 cycles of CPR.

Pitfalls:

- Avoid the procedure due to the absence of fetal pulsation.
- Counterintuitive to perform an operation on an unstable patient.
- Chest compression interruption during the procedure.

## Special population consideration

Some populations have special considerations for their evaluation and treatment during trauma resuscitation.

### *A. Pregnant patients*

The evaluation and management of a pregnant patient with major trauma are challenging because the presence of a fetus means two patients are potentially at risk. The different gestational ages of the fetus have specific concerns and hence may affect the decision on management.[32–37] The initial management of the pregnant patient should follow the structured ATLS approach with specific modifications for pregnancy.

Special considerations for pregnancy survey:

| Primary survey | Special considerations | Remarks |
|---|---|---|
| Airway + C-spine | Increased risk of failed airway management due to the following:<br>● Upper airway mucosal edema<br>● Reduced respiratory system compliance<br>● Reduced functional residual capacity<br>● Increased oxygen requirement | Potential difficult airway; consider the following:<br>● Early intubation by an expert if the condition may lead to a compromised airway (e.g., burn or head injury)<br>● Use of a short handled direct laryngoscope<br>● Prepare a smaller endotracheal tube (0.5 or 1 size smaller)<br>● Prepare a plan B (e.g., the use of a laryngeal mask airway) |
| Breathing and ventilation | ● Increased risk of rapid desaturation<br>● Increased risk of aspiration due to delayed gastric emptying<br>● If a chest drain is indicated, insert 1–2 intercostal spaces higher than usual due to the raised diaphragm from the gravid uterus | ● Provide supplementary oxygen to maintain adequate maternal oxygen saturation above 95% |
| Circulation and hemorrhage control | ● Provide manual left lateral uterine displacement to relieve aorto-caval compression especially when the fundus of the uterus is above the umbilicus<br>● Changes in vital signs may not occur until 15–20% of total blood volume has been lost due to the physiological hypervolemic status of pregnancy | ● Left lateral uterine displacement is critical to maximizing cardiac output<br>● In major trauma and maternal shock, an early blood transfusion is preferable to a massive crystalloid infusion |
| Disability | As for non-pregnant patient | |
| Exposure | As for non-pregnant patient | |

In the resuscitation of pregnant trauma patients, a CT scan of head and neck and X-rays of extremities can be performed without a significant radiation risk. In general, do not defer to radiographic imaging for maternal evaluation including thoracic and abdominal CT due to concerns regarding fetal exposure to radiation. An iodinated contrast can cross the placenta and may be taken up by the fetal thyroid; however, there is no reported case of fetal goitre or abnormal neonatal thyroid function associated with in-utero contrast exposure.

After the primary survey assessment and resuscitation of the pregnant woman, we should assess the fetus before proceeding to a secondary survey.

| Priority | Remarks | Pitfalls |
|---|---|---|
| Estimation of gestational age | Rough estimation by fundal height of uterus (Fig 1)<br>Ultrasound estimation<br>● Biparietal diameter (BPD) of 60mm approximately corresponds to 24 weeks<br>● Femur length (FL) of 40 mm is approximately 22 to 24 weeks | ● Fundal height estimation may subject to the discrepancy<br>● Ultrasound scan is operator-dependent |
| Fetal heart rate (FHR) monitoring | ● Normal baseline FHR for a full-term fetus is 110–160 bpm<br>● FHR is a sensitive indicator of fetal well being<br>● A cardiotocography (CTG) can monitor FHR and uterine contractions for a pregnancy over 23 weeks | ● Difficult to monitor FHR in trauma room<br>● Time consuming to apply a CTG and interpretation requires trained personnel |
| Obstetric history | ● Current antenatal care and rhesus status<br>● Current pregnancy complications | ● Difficult to obtain if the patient is unconscious or has no prior antenatal care |

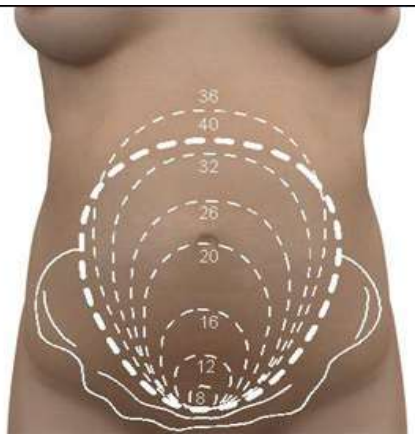


Figure 1

Some severe obstetric complications, such as placental abruption, uterine rupture, feto-maternal hemorrhage or preterm labor may be associated with trauma. Early consultation with an obstetrician is recommended.

| Obstetric complications | Special considerations | Remarks |
|---|---|---|
| Placental abruption | ● Caused by rapid deceleration or blunt abdominal trauma<br>● Needs a high index of suspicion as clinical presentation and signs can be non-specific, and ultrasounds have a low sensitivity | ● An ultrasound is not a reliable diagnostic tool for placental abruption |
| Feto-maternal hemorrhage | ● Consider a Kleihauer test for major or abdominal trauma<br>● Recommend a Kleihauer test for RhD negative women greater than 13 weeks, to help determine the dose of anti-D immunoglobulin | |
| Preterm labor | ● Monitor for signs of labor such as uterine contractions, cervical dilatation, and vaginal bleeding | ● Consider tocolytic therapy (to reduce uterine contractions) and corticosteroids (to reduce neonatal morbidity due to prematurity) |
| Uterine rupture | ● Usually lead to fetal demise<br>● Diagnosis may be made on ultrasound (e.g., fetal parts outside the uterus and intra-abdominal free fluid) | ● Need for an urgent laparotomy and surgical repair |
| Amniotic fluid embolism | ● Unpredictable, rare, and often fatal<br>● Management is primarily supportive | |

Tetanus toxoid should be administered as part of wound management when indicated as it is not contraindicated in pregnancy.

### *B. Pediatric patients*

Pediatric trauma is a common presentation in A&E. Most seriously injured children have multiple injuries, and the majority are caused by a blunt trauma. A non-accidental injury has to be considered as one of the underlying causes.

The structured approach in ATLS is still adopted for the initial management of pediatric trauma. The following table summarizes the major concerns in the pediatric group of patients.[38–40]

| Primary survey | Special considerations | Remarks |
|---|---|---|
| Airway | ● A Relatively larger tongue and smaller airways make upper airway obstruction more common<br>● Possibility of cervical spinal injury (remember C-spine protection) | ● Difficult airway |
| Breathing | ● Hypoxia has a faster onset: children have higher basal metabolic rate<br>● Pulmonary contusion: an immature ribcage is largely cartilaginous, and force is transmitted to the lungs causing a more severe pulmonary contusion | |
| Circulation | ● Beware of shock: more blood may be lost before the clinical manifestations of shock are seen | ● Signs of shock may be a late feature |
| Disability | ● Greater risk of a raised ICP<br>● A C-spine injury is possible without radiological evidence | |
| Exposure | ● Hypothermia is more likely due to the higher body surface area to body mass ratio | |

The index of suspicion should be higher for a blunt abdominal trauma:

- Abdominal viscera are less protected by the transverse lower ribs leading to a higher risk of a liver or spleen injury.
- Aerophagia leads to gastric distension and a higher risk of aspiration.
- Kidneys are less protected by fat and muscle; they are also more mobile and thus more susceptible to a deceleration injury.

The patterns of burn injuries are typically different from adults:

- Head and facial burns are common.
- Scalding injuries from grabbing hot objects are common.

There are several characteristic features of non-accidental injury and the trauma team should be looking for any suspicious cases:

- Delayed presentation
- Injuries inconsistent with the history
- Injuries inconsistent with developmental stage
- Suspicious pattern of injury
  - Bruises in shape of belt buckles or handprints
  - Multiple bruises of different ages
  - Multiple burns of different ages

- Retinal hemorrhages
- Bite marks
- Specific fracture patterns, such as spiral humeral fracture

Specific issues to be considered at a Pediatric Intensive Care Unit include the following:

- A relative vasopressin deficiency may develop in the course of post-trauma SIRS.
- Dramatic hyperglycemia may be triggered by the severe stress response during major trauma and will then be followed by rapid glucose exhaustion. Children recovering from a multi-trauma will rapidly burn through their glycogen stores. They may develop an acute nutritional catastrophe that is unresponsive to nutritional intervention. It is characterized by catabolism and structural protein loss.
- Lactic acidosis may easily develop in children suffering from a major trauma as hyperglycemia offers an abundant substrate to the synthesis of excess lactate.
- Hypothermia is more likely in children due to their higher surface area to body mass ratio. This is a negative prognostic indicator.

Remember to consider family and social issues:

- Counselling for the carer will be required.
- There will be guilt, fear, blame, and accusations even when the injury is accidental.
- Family breakdown is a common consequence of the death of a child and timely social support is important.

### *C. Geriatric patients*

Population ageing is a global phenomenon. Hong Kong has one of the top longevities in the world, with a life expectancy of male of 82.3 years old and female of 87.7 years old respectively.[41] It is estimated that by 2030 one third of the population will be >65 years old. Naturally, increasing numbers of elderly people will attend the emergency department for medical treatment. The physiology of elderly patients will manifest differently in trauma. Hypertension is prevalent in the elderly due to arteriosclerosis, as a result a “normal” blood pressure result may be a subtle sign of hypoperfusion. Similarly, tachycardia, which is a common manifestation in shock, may not be present in an elderly patient. This may be accounted for by a poor cardiac reserve and a decrease in sympathetic drive in old people. Moreover, tachycardia may be masked by medication commonly prescribed for the elderly, such as beta-blockers.

Frailty is a concept that has to be considered when treating elderly trauma patients.[42] It is a state of physiological decline in later life, and the individual will be more vulnerable to an adverse health outcome. In the presence of frailty, even with an identical Injury Severity Score (ISS), geriatric patients tend to have a poor outcome compared to young adults. Nowadays, many screening tools are available to assess frailty. The most commonly employed tools in Hong Kong include the Clinical Frailty Scale (CFS) and the Edmonton Frailty Scale (EFS). However, it takes time to conduct the screening. It may not be desirable to perform it during resuscitation and it can be better to assess it during the rehabilitation phase.

In the evaluation of the elderly trauma patients, other than the traditional primary and secondary surveys stated in the Advanced Trauma Life Support (ATLS), a medication review is particularly important. Medications that are harmful to the elderly have been identified by Beer's criteria.[44] Anticoagulants, antiplatelets, and beta-blockers are may have a detrimental effect in trauma patients. Anticoagulants and antiplatelets increase the risk of intracranial bleeding in patients with head injuries. A reversal agent should be administered promptly during resuscitation. In our center, protocol driven clinical pathways are in place to ensure a quick reversal. Four-factor prothrombin complex concentrate (PCC) can be given for the reversal of warfarin and rivaroxaban, whereas Praxibind is reserved for the reversal of Dabigatran.

Regarding the mechanism of injury, low energy traumas are common in the elderly in contrast to high energy traumas in young adults. Many elderly people have attended the emergency department for a fall from standing (< 2 meters). Though the mechanism may seem trivial on presentation, it may result in a fractured hip, a fractured pelvis, or a severe brain injury which carries significant morbidity and mortality. One study found that in low energy falls there was a decrease in the incidence of hip fracture and an increasing trend of severe head injuries.[45] As the presentation of injuries in the elderly is atypical, a lower threshold of imaging, such as computerized tomography, is advised. This is particularly helpful in old patients suffering from a head injury, as the use of anticoagulants is higher in this age group and the risk of intracranial bleeding is higher.

There is controversy on the under-triage and lack of trauma team activation in elderly trauma patients.[46] It was postulated that insufficient training or resource allocation with regard to the elderly may be underlying causes. Moreover, a local study also suggested that there is low sensitivity and high levels of under-triage when using the current trauma team activation criteria for the elderly.[47] Further research in this field may help to clarify this issue and explore the feasibility of a designated trauma team activation criteria for the elderly.

### *D. Psychiatric patients*

Psychiatric patients are often involved in trauma, either intentional or unintentional. Most have minor self-inflicted injuries, but some of them will have attempted suicide and suffered from high energy mechanism injuries, such as a fall from height or stabbed themselves resulting in a penetrating injury. Studies showed that trauma patients with a comorbid psychiatric illness were observed to have higher complication rates, longer hospital stays, and higher mortality.[48, 49]

The situation is more complicated when a trauma patient present to the emergency room with agitation or violent behaviors. They may have ingested alcohol or psychoactive substances, or be violent due to their psychiatric illness. Agitation and a lack of cooperation will make assessment, monitoring, performing investigations, and providing treatment difficult. Also, they may harm themselves and/or medical staff. When managing a trauma patient with agitation and violence, the critical initial assessment is to rule out hypoxia, hypoventilation, and. Inadequate oxygen and perfusion will alter the patient's mental status with agitation and confusion. Early rapid-sequence intubation, support ventilation, and correct shock status are important for an unstable patient.

After the ABC has stabilized, we need to rule out other organic causes of agitation. Head or traumatic brain injuries are well associated with agitation.[50] It is important to look for signs of a head injury and to document pupil size. Consider performing a CT scan for the head to evaluate whether there is a intracranial lesion. The patient's

temperature and glucose levels need to be checked to rule out heat-related illness, a CNS infection, and hypoglycemia. A toxicology screening can rule out drug intoxication. Pain is disturbing and adequate analgesia can reduce distress. After correcting all the organic causes or if the patient is uncooperative, we can then consider physically and/or chemically restraining the patient.[51, 52]

Physical restraint can help to avoid sedation and allow neurological observation. It usually includes a four-limb restraint and a chest restrain with a safety vest. Beware of causing a limb injury. Also, avoid affecting chest ventilation when using a safety vest. Prolonged physical restraint has complications, including limb circulation obstructions, deep vein thrombosis, rhabdomyolysis, and aspiration. The physical restraint should be removed as soon as possible.

Chemical restraint by sedative medication is another alternative. Benzodiazepines, particularly lorazepam and midazolam, are commonly used. While benzodiazepines are essentially a safe drug, when they are given to a patient with hypovolemia or other significant physiological issues, they may contribute to cardiovascular and respiratory depression. Over-sedation may affect the airway. The patient must be closely monitored.

### *E. Infectious patients*

Apply universal precaution of bloodborne diseases is standard procedure while handling bloody trauma patient. Wearing eye shields, gloves, and gowns can prevent direct contact with blood and body fluids, which can transmit hepatitis B and C, as well as the human immunodeficiency virus. Safe practices and precautions for needlestick and sharps injuries are also important.

The COVID-19 pandemic, an infectious disease transmitted through airborne or direct contact, has raised concerns about handling trauma patients. An infectious trauma patient may present without any COVID-19 symptoms.[53] Medical staff are at risk of being infected and need to be protected. When handling a trauma patient with a confirmed or suspected infectious disease, the evaluation should not be delayed to confirm their infectious status but appropriate precautions must be taken.[54, 55]

- Set up a designated area for providing care.
- Restructure the team to minimize the number of staff.
- Ask for a TOCC history and symptoms, check body temperature, and wear a mask.
- Use standard personal protective equipment and promote staff behaviors that limit the risk of disease transmission.
- Develop policies and procedures for airway management when it requires emergent intubation.
- Establish a dedicated operation theatre with minimal staff and no unnecessary items.
- Maintain situational awareness of the ICU capacity in the hospital.

## Termination of resuscitation and end-of-life care in trauma

Trauma is one of the leading causes of death.[56] With the development of advanced treatment modalities in the previous decades, trauma care has become increasingly resource intensive and technically invasive. The inherent risk to healthcare professionals in heroic resuscitation cannot be underestimated. The resuscitation of patients with a very remote chance of survival has also diverted precious resources from other critically ill clients. Therefore, serious consideration to the termination of resuscitation for selected groups of patients constitutes a part of holistic trauma care.

### *Withholding resuscitation*

Death can safely be declared if an injury is incompatible with life (e.g., exposed brain matter or a hemicorporectomy) or no sign of life was found on the scene with cardiac rhythms showing asystole. Nevertheless, if favorable factors are present, resuscitation should be continued in view of the patient's higher chances of survival.[57–62] On the contrary, resuscitation can be withheld.[57, 58]

Favorable factors:

- Shockable rhythms and pulseless electrical activity (especially sinus tachycardia).
- Sign of life on scene and/or a witnessed arrest.
- Cardiac activity on an echocardiography.
- Isolated penetrating chest injury.
- Hypoxia as an apparent cause of arrest (e.g., electrocution and traumatic asphyxia).
- High quality minimally interrupted chest compressions.

Unfavorable factors:

- Asystole and pulseless electrical activity (especially bradycardia with a HR of <40bpm).
- Cardiac standstill on echocardiography.
- Fixed and dilated pupils.

### *Termination of resuscitation*

As described in the other chapters, the resuscitation of a patient with a traumatic cardiac arrest requires good ACLS as well as addressing life-threatening reversible conditions. Conventional CPR plays a less important role and should not delay lifesaving procedures.[62] Resuscitation can be considered futile and stopped when there is no sign of life after fifteen minutes of appropriate lifesaving procedures together with high-quality ACLS.[57] It is particularly indicative if the end-tidal capnography level is persistently low. The chance of survival for patient with recurrent cardiac arrest episodes is minimal.[62] Further resuscitation is not warranted. A similar approach is also applicable in pediatric traumatic cardiac arrest.[63]

There are special trauma resuscitation scenarios, which can benefit from a longer duration of ACLS. As an example, patients with crush syndrome after prolonged entrapment may suffer from a surge in their serum potassium level, resulting in life-threatening arrhythmia. Intravenous calcium, a dextrose-insulin drip, and sodium bicarbonate should be given to stabilize the myocardium and quickly shift intravascular potassium back to the cells. Commotio cordis is a condition triggered by direct cardiac trauma over the precordium leading to a potentially lethal arrhythmia, such as ventricular fibrillation. Early defibrillation could reverse the condition in this case. Patients suffering from electrical injuries may present as respiratory issues and cardiac arrest on scene. A stunned myocardium can quickly recover, while the respiratory center in the brainstem may lag behind. With prompt resuscitation and mechanical ventilation support, a secondary cardiac arrest due to hypoxia can be avoided. Last but not least, for patients with apparent minor injuries, medical causes should be considered and conventional ACLS should be offered.

## End-of-life care in trauma

The framework for the provision of EoLC in trauma patients does not differ from the one for the management of patients with chronic illnesses. The six clinical domains described by Karyl et al. include decision making, communication, physical care, psychological care, spiritual care, and culturally sensitive social care.[64] Nevertheless, the context is very different in trauma scenarios. The relationship between the caregivers and the patient and their family members will be weak because of the acute encounter. Psycho-spiritual-social preparation will be absent. The acceptance of bad news and bereavement preparation are both challenging. EoLC in terminally ill trauma patients deserves special consideration.

A non-salvageable state is usually determined after extensive evaluation by a multi-disciplinary team with advanced imaging, such as a whole body CT. A typical example is severe brain injury. Occasionally, the patient may suffer from continual exsanguination which is not indicated for or amendable via surgical repair. In these cases, once the joint decision for the termination of futile resuscitation is made, EoLC may be the best option. Depending on the circumstances, the EoLC process may be provided in an appropriate facility in the emergency department (ED) instead of transferring a moribund patient to intensive care. In order to do this, four highly rated obstacles to providing quality EoLC by ED nurses have to be overcome: (i) being too busy, (ii) needing to deal with family members who are angry, (iii) not having appropriate areas for privacy, and (iv) the patient's family not understanding what "lifesaving measures" involve.[73] These obstacles are not unique to trauma scenarios. Emergency physicians and nurses are able to administer EoLC and critical care with symptomatic relief for terminally ill patients.[66–71] Special considerations are required in the management of terminally ill trauma patients.

Paroxysmal sympathetic hyperactivity is a common complication in severe traumatic brain injured patients.[72] They may have recurrent seizure and autonomic dysfunction including hyperthermia, tachycardia, and tachypnea. Medications, such as benzodiazepines and morphine, or non-pharmacological means, such as physical cooling, can help to reduce the discomfort of dying patients and relieve the anxiety of family members. With respect to the withdrawal of treatments such as terminal extubation, the patient may experience respiratory distress, cyanosis, and stridor. With appropriate medications, treatments, and family counselling, the dying process can help to manage the distress of the patient and their family. End-of-Life Care in trauma is not easy and needs very specialized skills. It should be incorporated positively in a mature trauma system rather than viewed as a failure from a resuscitation standpoint. Good communication with the patient's family members is crucial. Implementing EoLC in trauma follows a model called TELOS (Trauma end-of-life optimum support) developed by Bennett et al.[74, 75] This model outlines the best practice for EoLC for trauma patients in pre-hospital, ED, and ICU settings. The development of similar models in Hong Kong will improve the capability of healthcare professionals to provide good care to dying trauma victims and their families.

## The trauma team and leadership

Trauma systems, trauma centers, innovative surgical and non-surgical approaches, new drugs, and targeted rehabilitation schemes have improved trauma care and outcomes. Progress in a mature trauma system slows down when those dimensions are optimized with the available resources. In other industries such as aviation, it was shown that crew resource management, including non-technical skills such as teamwork and leadership, improves safety and

therefore the desired outcomes.[76] The importance of leadership and trauma team management has only been recognized recently.[77] Accelerating progress in trauma care may rest on improving trauma team leadership and teamwork.[78] Furthermore, leadership, and teamwork in trauma care can be taught; in addition, team members' behavior can be modified and performance improved.[79–80]

### *Trauma team*

Reception, initial assessment, and prioritized management of trauma victims at the emergency department by a multi-disciplinary trauma team are the hallmarks of the trauma center. Apart from emergency physicians, the expertise of team members from various specialties should theoretically bring the greatest good to needy patients in a timely fashion. However, this "action team" is formed at short notice in the most stressful circumstances and it is made up of strangers of varying specialties and different training backgrounds, and who are expected to make difficult speedy decisions. Technical proficiency taught in various disciplines does not necessarily guarantee effective and efficient team management. In the setting of trauma resuscitation, the common goal is the successful stabilization of the trauma victim for definitive care. In order to ensure an effective team, the following attributes are required of its members:

1. Clear role delineation
2. Sharing of a common goal
3. Mutual respect and trust for collaboration
4. Performance under stress
5. Flexibility in dealing with issues

The team needs the right people with the right skills to make it effective. There are 4 key areas of non-technical skills[81] which are inter-linked and integrated through communication:

1. Teamwork
2. Task management
3. Situation awareness
4. Decision making

A group of committed, capable, and competent people can only achieve their greatest potential if they work as a team. *Teamwork* requires mutual support, information sharing, clear role delineation, and coordination. A leader or coordinator can enhance communication amongst members, plan ahead, and command the group if needed. Strong leadership and teamwork improve the processes of care in trauma resuscitation, including completion of ATLS standards.[82]

In a patient with multiple injuries, there are many actions or tasks which need to be performed during the process of resuscitation. Management of these tasks requires planning, coordination, and prioritization. Some tasks can only be performed by certain members of the team because they possess the appropriate skills. Leadership is required for *task management* and designation.

The patient's condition and response to treatment can change subtly and rapidly. When team members are concentrating on their own tasks, they are able to observe subtle changes and should report them freely. The leader,

who is not task bound, has the privilege of seeing the bigger picture through information gathering and assimilation. They are, therefore, able to make more accurate predictions of upcoming events. This is collectively known as *situational awareness*. The team leader is the key person who can assess the team's performance, set priorities, and coordinate and direct tasks according.

Although *decision making* on critical issues is the responsibility of the leader, team members should participate through information sharing and alternative proposals. Medical decisions are not straightforward in critical situations. The pros and cons of a decision have to be balanced against the risks and benefits. Communicating decisions to all members is essential in order to confirm understanding and precise implementation. Changes in the patient's conditions, such as vital signs after the implementation of a decision, will help planning for the next stage or decision point. Adjustment may be required if the response does not reach the anticipated target.

The 4 non-technical skills are not standalone but need a clear and good *communication* strategy to integrate for desired outcome. Communication is not just saying something or hearing someone saying it. Effective communication involves a clear understanding of the underlying meaning of what was said and transforms words to actions. One commonly quoted effective communication strategy is called closed loop communication, which has been employed in stressful life and death scenarios, such as battlefields. As an analogy, 2-way radio communication protocol, which uses words such as roger, over, and out, practices one type of closed loop communication. The objective is to ensure there are no misunderstandings. The essential features of closed loop communication are as follows:

1. Address the person(s) you are speaking to.
2. Use common vocabulary.
3. State the facts precisely and repeat if needed.
4. Receiver(s) repeat the message(s).
5. Clarify if needed.

### *Leadership*

The American College of Surgeons' latest edition (10$^{th}$) of their Advanced Trauma Life Support course[76] has an appendix on trauma team resource management which describes, for the first time, the details of configuring a trauma team, the team leader's roles and responsibilities, effective leadership, best communication practices, and conflict management. In the medical literature, there is a lack of high quality evidence on leadership in resuscitation. Nevertheless, from the available evidence, leadership improves the care process in trauma resuscitation as measured by the speed and completion of tasks,[82] as well as a decreased time for computed tomography (CT), endotracheal intubation, and transfer to the operation theatre (OT).[80] The direct effect on patient outcomes is yet to be investigated. The attributes required of an effective trauma team leader include the following:

1. Declare the leadership role at the very beginning, even at the preparatory phase.
2. Stand in a strategic position (e.g., the foot of bed) to observe.
3. Allocate roles to members according to competency and assign helpers if needed.
4. Set goals and priority and announce this to all members (e.g., the time to leave the resuscitation room for the OT).
5. Control, manage, and direct resuscitation.

6. Make decisions for diagnostic adjuncts, interventional procedures, and definitive care.
7. Ensure communication and encourage a “speak up” culture to enhance situational awareness.
8. Ensure staff safety, such as wearing personal protective equipment.
9. Assess the adequacy of resources and summon help if needed.
10. Interview family members to update on the patient’s condition and manage expectations (e.g., advanced directive).
11. Ensure documentation is complete.
12. Team debriefing at a suitable time.

Trauma management requires multi-disciplinary care. The trauma team improves the outcomes of the initial assessment and resuscitation of trauma patients.[83, 84] The presence of a trauma team leader in the team has shown to result in positive outcomes.[83, 85] However, there is inconclusive evidence demonstrating any significant difference in outcome with respect to the background (surgeon or non-surgeon) of the team leader.[86] The leader may not be the most senior doctor in the team but instead possesses a great deal of knowledge and experience in the management of different trauma scenarios. There are 2 optimal styles of leadership,[87, 88] which are affected by the patient’s characteristics and team composition:

1. Directive leadership
   - Authoritative trauma team leader directing the resuscitation.
   - More effective when the patient is critically ill and requires swift decisions.
   - Also applies in a team where all of the members are relatively inexperienced.
2. Empowering leadership
   - Trauma team leader guides and facilitates the resuscitation.
   - Applicable when members of the team are experienced.
   - Deliberate discussion can occur when the patient is less severely injured.

A born leader is rare but there is compelling evidence that leadership skills can be taught and improved.[79, 84] Most commonly used training methods are a combination of didactics and simulation. Some standardized training programs for leadership include the European Trauma Course by the European Resuscitation Council, TeamSTEPPS by the US Agency for Health Care and Quality, and the STARTT program by the UK’s National Health Service.

## Case Scenario Summary

When transferring the patient to the trauma bay, you must obtain further information from the paramedic using the MIST mnemonic. The patient fell from the sixth floor. He had head and chest injuries, and a suspected pelvis fracture. Pre-hospital vital signs were BP 83/50, pulse rate 123, SpO2 100 % with O2, and GCS E1V2M3. Oxygen was given, as well as an IV assess set at the right forearm with 250ml normal saline. A pelvis binder was applied. The patient was put on spinal board with a neck collar and in-line immobilization. The primary survey found that the patient was unconscious with GCS E1V1M1, and their pupils were 5mm fixed and dilated bilaterally. There was crepitus over the bilateral chest wall. The position of the pelvis binder was over iliac crest. The patient had a BP 66/47 and a pulse rate of 127. The FAST scan was negative.

Your team intubated the patient following bilateral chest drains insertion. The position of the pelvic binder was adjusted. 2 packs of unmatched blood were transfused and the MTP protocol was activated. The chest X-ray had a bilateral multiple ribs fracture and pneumothorax; the pelvis X-ray shows a vertical shear fracture. The patient was transferred to the operation room to have a 3-in-1 exsanguination pelvis fracture management.

After the pelvis operation, the patient was transferred for a whole-body CT scan. The CT brain scan showed a fractured temporal bone with a diffuse subarachnoid hemorrhage. There was also a right subdural hematoma with a 1 cm midline shift. A right craniectomy for clot evacuation was performed. Intraoperatively, the brain was swollen and not pulsatile despite the lobectomy, and the neurosurgeon considered that it was unlikely that the brain would be salvageable.

Post-operation, the patient was transferred to pediatric ICU. The pupils remained fixed and dilated. He also had persistent shock and requires high dose inotropic. He developed acute renal failure, rhabdomyolysis, and disseminated intravascular coagulation.

A brainstem function test was performed at day 7 and confirmed a dead brain state. The parents were interviewed and agreed a DNACPR on further deterioration. The patient took a downhill course and succumbed on day 10. Clinical psychologist support was provided to the whole family.

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