CareFlight

Guideline for the Management of Penetrating Trauma

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Table of Contents

Introduction

In comparison with other developed countries such as the UK, Australia has a relatively low incidence of penetrating trauma.[01, 02] Only around 3.7% of major traumas (ISS>12) being admitted to hospital are penetrating.[02] Contrary to popular belief, this figure has remained static over the last 20 years.[03-09]

The incidence of firearm related injury in Australia is also far less than knife injuries, but carries a higher risk of mortality.[05] The degree of injury depends on the physical characteristics of the penetrating object or projectile, and in particular the energy exchange between it, and the tissues. Low-velocity objects such as knives usually produce limited injury localised to their path, whereas high-velocity projectiles such as those from military or hunting-style rifles produce shock waves causing cavitation and tissue damage extending in varying degrees adjacent to their path[10]. The end result of both of these mechanisms is almost universally haemorrhage. It is unsurprising then, that the bulk of penetrating trauma management is centred around rapid haemorrhage control.

Perhaps due to the relative infrequency of penetrating trauma, or the ethics of randomised controlled trials on devices such as tourniquets, there is a paucity of high-quality evidence in the civilian population. Therefore, the majority of research and guidelines arise from expert opinion and the military experience.

General approach

A general approach to penetrating trauma can be followed with a focus on rapid transport, haemostatic control, prevention of coagulopathy, blood replacement and appropriate airway management.

Scene management

Due to the nature of penetrating trauma, scene safety is paramount.

- In the event of an injury involving a weapon, the scene should not be entered unless declared safe by the scene commander.
- Should the CareFlight team be first on scene, they should stand off and not approach the scene until it has been declared safe by either police or the scene commander.

Scene time should be kept shorter than 10 minutes.

- While there is no evidence for a specific scene time, shorter pre-hospital times are associated with improved survival.[11] The provision of medical care does not seem to outweigh the benefits of longer scene times: when compared with civilian transport, transport by (non-physician) EMS teams is associated with significantly higher mortality.[12,13] The presence of physicians and pre-hospital procedures performed is also associated with increased mortality.[14,15]

- Therefore, rapid transport to definitive surgical care is the mainstay of treatment in the unstable penetrating trauma patient. Transport should not be delayed for unnecessary investigations or interventions that can be performed en route or in the hospital.

Haemostatic control

Haemostatic control should be attempted as a priority. Trauma to the limbs and tourniquet is discussed separately below.

- Direct pressure to the wound using a gloved finger(s) is the usual first step until more permanent haemostasis can be achieved.
- In the event of minor bleeding requiring more than a standard dressing, a compression bandage such as the Israeli Bandage or OLEAS modular trauma dressing can be used.
- In more serious bleeding, packing of the wound with Celox Gauze or if a deep, narrow laceration, Celox-A granules can be used. These should be used in combination with direct pressure for at least 3-5 minutes then covered with one of the above dressings.

AAJT in penetrating trauma

The AAJT can be used as a bridging device to keep patients alive when other methods of haemorrhage control have been exhausted until definitive surgical care (and a blood bank) is reached.

The AAJT shows promise compared with standard care. [16,17] Evidence is relatively abundant but mostly low quality. Due to the nature of the injuries being treated and the lack of alternatives, it is highly unlikely that we will see an RCT in humans.

In the exsanguinating patient the AAJT should be applied in two circumstances:

1. Bleeding below the aortic bifurcation (e.g. buttocks, lower limbs) not controlled by normal measures:

- The AAJT is applied across the abdomen and for no longer than 60 minutes.
- The AAJT (and similar devices) have been used successfully in the military for control of exsanguinating trauma below the level of the aortic bifurcation.[18,19] It has been shown in animal studies to be equivalent in both safety and effectiveness to zone III REBOA for 60 minutes of application.[20,21,22] There are obvious pre-hospital advantages to the AAJT vs REBOA in terms of scene time and training. A similar study has shown superiority of the AAJT vs Quick Clot Combat Gauze.[23]
- Recent US military guidelines describe its use in the following manner for any uncontrolled bleeding due to penetrating trauma below the aortic bifurcation: [24]
  - If there is bleeding above the level of the umbilicus, in the upper abdomen or chest, application of the AAJT may increase bleeding.
  - Ideally, ultrasound of the abdomen and chest should be performed to look for bleeding before AAJT application.
  - In the absence of evidence-based protocol, providers may consider:

- After 15–30 minutes of active volume resuscitation and attention to external haemorrhage control, the AAJT should be slowly released.
- If the systolic blood pressure drops below 90mmHg, reinflate the balloon and transfuse an additional unit of blood before releasing the balloon again. Look for other causes of haemodynamic instability.
- Continue to repeat as resources allow, until blood pressure stabilises or arrival at surgical capability.

2. Bleeding in junctional areas (groin, axilla) not controlled by normal measures:

- There are several case reports of it being successfully used in both penetrating axillary and groin trauma.[25, 26, 27]
- The AAJT is applied directly to the groin or axilla – for this use, the manufacturer recommends the AAJT should not be left in place longer than 4 hours.

In both healthy volunteers and case reports, there have been no significant long-term complications reported. [17]

Note this guideline does not cover the use of the AAJT in cardiac arrest, please refer to the corresponding CareFlight guideline (HOTT Drill)

Airway Management

In the penetrating trauma patient with catastrophic haemorrhage, decision to intubate should be based on the overall goals of care – that is, to get the patient to an OT in a manner that is as quick and as safe as possible. The aetiology of decreased GCS in penetrating trauma is fundamentally different from that in blunt trauma – it is usually from lack of cerebral perfusion caused by hypovolemic shock. Therefore, decision to intubate should not be based solely on GCS.

- It should be noted that there are circumstances where rapid sequence induction (RSI) is considered gold standard. These include, but are not limited to, a long flight, agitation, head/neck injury or painful procedures (thoracostomy, tourniquet).
- The Supraglottic Airway Sequence (SAS) is an alternative to RSI in the patient with decreased GCS as a direct result of hypotension alone. It allows airway maintenance without delaying transport (and easily performed enroute) or the deleterious haemodynamic effects of positive pressure ventilation and anaesthetic medications.[28]

Fluid Resuscitation

At least two appropriately sized IV/IO access should be placed.

The goal of blood pressure management in the immediate stages of damage control resuscitation is a balancing act between preventing exsanguination and maintaining central perfusion. Despite the widespread adoption of ‘permissive hypotension’ among pre-hospital services, it is still unclear whether there is robust evidence to support this practice. [30-35]

SBP in the **non-head injured patient** with major haemorrhage should be targeted between 80-100mmHg. In the absence of a reliable SBP, resuscitation can be titrated to radial pulse or other physiological markers of central perfusion.

- Despite a lack of high-quality evidence, the literature does suggest a survival benefit, a reduction in products transfused and a reduction in multiorgan failure when a permissive hypotension strategy is employed.[32, 33, 35] The effect of pre-hospital permissive hypotension strategies has not been specifically studied.
- The literature does not support a specific SBP target, but figures quoted in studies are generally in the region of 70-90mmHg.[33] Consensus guidelines containing specific blood pressure targets are also lacking, but one set of recent guidelines suggest targeting a SBP of 100mmHg.[36]
- Although not well supported by the literature, other surrogate markers may be used as an indication of central/cerebral perfusion when a reliable blood pressure is not immediately available. These include the presence of a radial pulse,[37,38] consciousness, pulse oximetry waveform and ETCO2 trace. They may be used in combination with SBP, especially if blood pressure readings become unreliable (a common scenario in the hypotensive prehospital trauma patient).
- There is no good evidence to suggest a particular maximum time of permissive hypotension, but it should probably be kept to a minimum. Once haemostasis has been achieved (e.g. placement of a tourniquet), normal haemodynamics should be restored.

SBP in the **moderate to severe head injured patient** (GCS<9) with major haemorrhage should be targeted just above 100-110mmHg. Unless catastrophic bleeding is present, the higher end of this range, 110mmHg, should be targeted.

- In patients with traumatic brain injury, cerebral autoregulation is reduced or absent. Even brief periods of hypotension may lead to significant secondary brain injury.[39] When our ultimate goal is to produce neurologically intact survivors, we should aim for normal levels of central perfusion/blood pressure to maintain an estimated cerebral perfusion pressure of 60-70.[40,41]
- The evidence for a specific SBP target is clearer in head injured patients. Mortality is significantly elevated if SBP falls below 90mmHg.[39] Several studies have suggested the optimum SBP to be around 110mmHg (higher in elderly patients) and as a result most major guidelines recommend a minimum SBP of either 100 or 110mmHg in the bleeding TBI patient. [40-45]
- Other physiological markers of central perfusion such as radial pulse are not useful in the head injured patient as they are 'present' far below the above SBP thresholds.[37]
- Additional neuroprotective measures should be instituted to prevent secondary brain injury, including the use of 30° head up, an appropriate ETCO2 (30-35mmHg), O2 saturation (≥ 94%) and hypertonic saline. These are discussed in more detail in the Traumatic Brain Injury Guideline.

In the elderly or chronically hypertensive patients, these limits probably need to be raised. Unfortunately, there is little guidance in the literature in terms of specific blood pressure targets. It is reasonable to aim for a 'high normal' SBP in these patients e.g. 120-140mmHg.

Trauma Induced Coagulopathy

In addition to maintaining tissue perfusion, preventing hypothermia, avoiding crystalloids and administering TXA are associated with reduction in trauma-induced coagulopathy and improved outcomes. [46]

Recent evidence suggests pre-hospital volume replacement should commence with extended life plasma (ELP) followed by packed red cells (PRBC).[47,48,49]

- Crystalloid administration should be avoided. In the event of depletion of blood products and if volume replacement is still necessary, the next choice is hypertonic (7.5%) saline. Although not backed up by large-scale clinical studies, evidence suggests avoiding crystalloids in favour of hypertonic solutions.[50]

For every 2 units of blood products (ELP, PRBC), administer 10mls 10% calcium gluconate.

- Pre-hospital blood product recipients have been found to have significantly higher rates of hypocalcaemia, with severe hypocalcaemia associated with decreased survival and need for massive transfusion.[51]

Prehospital hypothermia is associated with trauma-induced coagulopathy and poor outcomes.[52] Therefore, the patient should be kept normothermic (≥36°C).[53,54]

- All blood products and crystalloid should be passed through the MEQU blood warmer. Attempts should also be made to mitigate the effects of the surrounding environment (e.g. remove patients from a cold road into an ambulance) and utilise passive (space blanket) and/or active (heated blankets) warming techniques.

In accordance with the current PATCH trial in progress, tranexamic acid (TXA) should be administered if a COAST score of ≥3 has been reached and the injury was sustained within the last 3 hours.

- TXA has been shown to significantly reduce mortality in major trauma if given within 3 hours in the in-hospital setting.[55] However, it has been argued that fewer than 2% of the patients in CRASH-2 were treated in countries that routinely provide rapid access to blood products, damage-control surgery and angiography, and advanced critical care.[56] Additionally, the pre-hospital administration of TXA has not yet been well-studied. [57, 58]
- Following the above concerns with the CRASH-2 data, the COAST score has been developed as a predictor of traumatic coagulopathy to identify patients who should receive TXA in Australia. [59] It has been validated in several Western countries and currently forms the inclusion criteria for the PATCH trial which hopes to answer some of the questions that remain unanswered from CRASH-2. [60, 61]

Other general measures

The patient should be fully exposed and careful identification of the exact number and location of wounds needs to occur, including the back and flanks.

Embedded objects should generally be left in-situ as they can have a tamponade-like effect on damaged vascular structures.

- The absolute exception to this rule would be where the object interferes with establishing an airway.
- If the wound is in the neck, axillae or groin and there is ongoing, uncontrollable haemorrhage, the object can be removed so pressure, haemostatic dressings and/or the AAJT can be applied.

In the unstable patient with penetrating wounds to the trunk, a full eFAST exam should be performed before the Code 3 is passed.

- Ultrasound may help guide resuscitation of the patient and is essential for the activation of a pre-hospital Code Crimson or equivalent within the receiving hospital. [62]
- In the unstable or hypoxic patient with chest trauma, an ultrasound of the chest should be performed to rule out pneumothorax **prior** to transport so definitive chest decompression can be performed outside of the vehicle.

Hospital notification should occur as early as possible to enable the required systems to be activated before patient arrival.

- If the appropriate criteria are met, a Code Crimson should be activated as per local guidelines, e.g. NSW Health Code Crimson Pathway. [62]
- In the presence of particular injuries, it is reasonable to request the presence of the appropriate surgical specialty in the emergency department e.g. cardiothoracics.
- On request of the retrieval team, 2 units of packed red cells may be delivered to the helipad.

Titrate analgesia to pain levels.

- This is usually be a combination of fentanyl and ketamine and should be dose-adjusted to the haemodynamic status of the patient.

Penetrating trauma to specific body regions

Penetrating abdominal trauma

A general approach as described above should be followed.

For exsanguinating junctional (inguinal) or pelvic girdle trauma (including buttocks) direct pressure and haemostatic dressings are first line.

- If bleeding is not controlled with the above measures the AAJT should be applied directly to the inguinal region.

Penetrating head and neck trauma

A general approach as described above should be followed. Haemostatic dressings and early intubation are the mainstay of treatment in these patients.

The neck is also considered a junctional area where bleeding can be difficult to compress. Given the vascular nature of the head and face, ongoing massive haemorrhage is not infrequent. From recent experience derived from the military we recommend that a combination of direct pressure and either Celox gauze or granules be used as a first-line in any significant neck haemorrhage. [63]

A cervical collar worsens outcomes and should not be used on these patients.[64]

In the event of a threatened or potentially threatened airway, the airway should be rapidly secured via ETT or surgical airway prior to transport. A general approach should be followed as per the CareFlight Airway Handbook but there are some specific points to be considered in penetrating facial/neck trauma:

- Some patients with severe facial trauma may be managed awake by being seated forward to drain blood away from the airway and self-suction.
- Once the airway is secured, any intraoral/pharyngeal bleeds can be packed in a similar manner to external wounds.
- A surgical airway is recommended if orotracheal intubation is deemed not possible or safe due to bleeding or significant distortion of anatomy.
    - Large lacerations to the neck communicating with the airways may be managed by directly intubating through the laceration.
    - For lacerations distal to the cricoid, the distal trachea should be secured with forceps before inserting an ETT to avoid retraction into the thorax.
    - A semi-awake method using ketamine without paralytics may be appropriate in these circumstances. [65,66]
- In a failed intubation, LMA should not be considered a definitive airway in these patients and it is recommended that progression to surgical airway should be undertaken.

Penetrating head injuries with altered GCS should be treated as per the CareFlight Head Injury Guidelines.

Penetrating trauma to the extremities

A general approach as described above should be followed.

In the event of uncontrolled bleeding, a SOFTT-W tourniquet should be applied a hand's-width above the wound and not over a joint.

- Although there is a lack of high-quality evidence in the civilian population, tourniquet use has been shown to be remarkably effective and simple to use in the military setting. [67-74]
- The tourniquet should be applied in a manner which exposes the least amount of the limb to irreversible ischaemia. Apply as distally as practically possible and tighten until cessation of bleeding and/or distal pulse.
- In the event of an ineffective correctly placed single tourniquet, it is recommended to place a second immediately proximal to this. Skin should not be visible between the two.
- If a second tourniquet is ineffective and they are both placed on the distal (double-boned) portion of the limb, the second (or third, if available) should be moved to the corresponding upper part of the limb (i.e. over the femur or humerus).
- Time of application needs to be clearly documented in the notes and preferably also on the patient.
    - The ADF recommends that a tourniquet should not remain applied for longer than 90 minutes, but it should be noted that complications (nerve injury and limb ischaemia) associated with prolonged tourniquet use are extremely rare. [68, 75, 76] Other sources suggest that tourniquets can be left safely in place for 2 hours and at this time should be released and replaced with a pressure dressing if bleeding has ceased. [24, 77]
    - If a tourniquet has been applied for longer than 2 hours and the decision is made to reduce the tourniquet, the physician should be prepared to manage a reperfusion syndrome, similar to that seen in crush injuries.[24]
    - Despite these time limits, an emphasis should be placed on 'life over limb'.

If the wound is too proximal to fit a tourniquet or is not controlled effectively with a tourniquet(s) and pressure/packing, apply the AAJT.[24]

Tourniquets applied prior to the team's arrival need to be checked for correct, tight placement.

- Often, tourniquets placed by first responders and even paramedics are inappropriately and/or ineffectively placed.[78] In the event of a poorly-placed tourniquet that is not deemed necessary, it is reasonable to attempt simple measures such as pressure/packing rather than reapplying the tourniquet.

Provide sufficient analgesia to patients wearing a tourniquet.

- Do not remove or loosen the tourniquet for pain.
- Patients often require intubation for tourniquet pain management. This should occur after volume replacement (if required).

Avoid covering the tourniquet. The limb needs to be closely observed for any recurrent bleeding and should be kept cool relative to the patient's core in order to increase the likelihood of preserving the ischemic limb's viability. [79]

Penetrating thoracic trauma

A general approach as described above should be followed.

Ultrasound is more accurate than clinical assessment in detection of a pneumothorax.[80, 81]

A simple closed pneumothorax without hypoxia or haemodynamic instability requires no immediate treatment and can be monitored clinically or with ultrasound en route.

In the shocked or hypoxic patient with a pneumothorax, surgical thoracostomy should be performed prior to transport.

- In the patient not requiring RSI, dissociation with ketamine provides excellent conditions to perform this procedure.
- In the patient requiring RSI, needle decompression can be performed prior to intubation. Then, thoracostomy immediately following intubation. In a three-person team these two procedures can occur almost simultaneously following induction of anaesthesia.
- Decision to complete an open thoracostomy with a chest drain and collection bag (e.g. Frontline) depends on several logistical and physiological factors unique to each patient. This is a balance between time on scene, preventing reaccumulation of pneumothorax and avoiding unnecessary, nonsterile instrumentation of the intrathoracic cavity (including 're-fingering' of thoracostomies). For example:
  - A thoracostomy can be left open in patients who are unlikely to re-accumulate such as those with short transport times and thin chest walls.
  - Conversely, a drain should be placed in those with long transport times, thick chest walls or suspected tracheobronchial fistula.
  - A drain must be placed in the spontaneously breathing patient and should be considered in patients with concurrent, large volume haemothorax to monitor output and prevent damage to the vehicle.

Open pneumothorax or 'sucking' chest wounds can be treated by placement of a Russel chest seal over the wound. Larger wounds can be covered with a Halo Seal.

- The performance of a valved/three-sided dressing over a simple occlusive dressing has not been studied.[82]
- If the patient becomes hypoxic or shocked, perform open thoracostomy as described above.

It is rare to encounter a haemothorax in penetrating trauma in the absence of a pneumothorax. Furthermore, it is usually not necessary to place a drain in isolated haemothorax in the pre-hospital environment.

The patient with hypotension and a pericardial effusion demonstrated on ultrasound should be assumed to have cardiac tamponade.

- Initial management consists of balancing intrapericardial pressures with right ventricular pressures, small fluid boluses can be used to augment pre-load.
- In the event of deterioration to an agonal state or cardiac arrest, a pre-hospital thoracotomy should be performed immediately as described in the following section.

Cardiac Arrest in Penetrating Trauma

The HOTTT Drill should be followed as per the HOTTT Drill Guideline.

Indications for thoracotomy in traumatic cardiac arrest (see the CareFlight Thoracotomy Guideline for a full discussion on this topic):

- Thoracotomy should only be performed if there is a penetrating injury in an area consistent with cardiac injury and it is thought that the thoracotomy can be completed within 10 minutes of witnessed signs of life.
- Thoracotomy should be performed in the agonal patient prior to full arrest providing they have had an ultrasound demonstrating a pericardial effusion and usual methods of resuscitation have failed.
- If the injury is from a stab wound, ultrasound should not delay thoracotomy.
- If the injury is a mechanism other than from a stab wound, thoracotomy should not be performed unless cardiac activity and pericardial effusion have been reliably demonstrated on ultrasound.
- If a recent ultrasound has clearly demonstrated no pericardial effusion, a thoracotomy should not be performed.

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Document History

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