# Vascular trauma

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## Abstract

Vascular trauma arises from a variety of causes: penetrating and blast injury in conflict zones; blunt injury from road traffic accidents and falls; and iatrogenic injury from modern invasive medicine. Massive haemorrhage is the pre-eminent cause of preventable death and trauma teams now understand the necessity to control bleeding rapidly, so that effective resuscitation can begin. Vascular surgeons are key members of the trauma team, offering control of bleeding and vascular reconstruction, using aspects of open surgical and endovascular techniques. Unstable trauma patients with haemorrhagic shock require targeted damage-control surgery and goal-directed resuscitation, before the lethal triad of shock, hypothermia and coagulopathy make attempted salvage futile. Once stability has been established, definitive surgical care can restore function and allow successful rehabilitation.

**Keywords** Blunt injury; coagulopathy; damage control surgery; fasciotomy; gun shot wound; penetrating injury; shunting; vascular trauma

## Introduction

Worldwide, approximately 4.8 million people die each year from unintentional injury and violence, and tens of millions are left permanently disabled. Massive haemorrhage is the pre-eminent cause of preventable death after major trauma. Trauma teams now understand the necessity to control bleeding rapidly, so that effective resuscitation can begin. Unstable patients with impending physiological collapse should be identified early by effective triage and fast-tracked for damage control surgery. Goal-directed haemostatic resuscitation then allows definitive surgical care to restore vascular continuity and, ultimately, functional recovery. Vascular surgeons have become key members of the trauma team offering control of bleeding, and vascular reconstruction with combined open surgical and endovascular techniques. Mortality from exsanguination remains high and morbidity due to prolonged ischaemia can result in significant disability.

## Epidemiology

In developed countries unintentional injury is the leading cause of mortality amongst people aged 15–44 years, while in developing countries road injuries are the tenth largest cause of death in all age groups. In developed countries the average age of trauma patients is increasing, with over 25% trauma deaths in United Kingdom affecting patients aged 70 or older. Motor vehicle collisions (MVCs) account for the largest number of traumatic deaths in civilian practice. A strong correlation has been noted between increasing severity of injury and incidence of associated vascular injury.[1] Major skeletal trauma is often associated with specific vascular injuries: thoracic aorta and great vessel injuries, with sternal or first rib fractures; iliac vessel injuries with pelvic fractures; brachial and popliteal artery injuries with elbow and knee dislocations, respectively. In civilian practice low-velocity penetrating injuries, from knives or other weapons, remain common. With exponential increases in performance of interventional procedures, vascular trauma has become a common iatrogenic injury. In military trauma, given the protection afforded by modern body-armour, the majority of penetrating injuries amongst survivors are extremity wounds, mainly caused by improvised explosive devices (IED). Early surgical control of bleeding in vascular trauma and haemorrhagic shock has been shown to improve outcomes in military series.[2] Although many trauma deaths occur at the scene of the injury, in civilian practice over 40% occur after admission to hospital. A third of these result from uncontrolled bleeding and may be preventable. In recent years Western Europe and the United States have seen a spate of terrorist attacks resulting is mass casualties and injuries typically seen only on the battlefield. A recent initiative in the United States aims to transfer the knowledge gained in managing military trauma to civilian practice and surgeons who may infrequently encounter such injuries.[3]

## Mechanisms of injury

Understanding the mechanism of injury can help predict the pathophysiological response. Injury patterns are often complex, but may be considered as blunt or penetrating.

### Blunt injury

Blunt injury commonly results from motor vehicle collisions, falls or assault, with injuries arising from direct transmission impact force and indirect deformation effects of rapid deceleration. In blunt injury, impact force varies due to magnitude (i.e. kinetic energy and area of application), duration, and direction of application. Major skeletal trauma is often associated with specific vascular injury patterns (see above). Deformation of mediastinal structures during rapid deceleration can cause transection or rupture of the descending thoracic aorta at its fixation by the ligamentum arteriosum. High-energy injuries, such as falls from height and road traffic accidents, often involve multiple life-threatening injuries to head, thorax, pelvis and abdomen and have a high-risk of massive blood loss.

### Penetrating injury

The outcome of penetrating injury is ultimately dependent on missile characteristics (mass, shape, velocity, kinetic energy), point of impact and pathway through the body. A stab injury from a knife may be considered low velocity and low energy, but if its path encountered the heart or a major blood vessel then the resulting injury may be fatal. With missile projectiles such

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as bullets, the kinetic energy (KE = 1/2 mass × velocity$^2$) imparted is quadrupled by doubling of missile velocity. High-velocity missiles cause direct injuries along the missile path, and also dissipate indirect energy to surrounding tissues by creating longitudinal shock waves and transverse cavitational shear waves. This cavitation effect can be devastating in relatively inelastic tissues such as brain or solid organs. Missile fragmentation on striking bone can create devastating secondary missile fragments. Iatrogenic penetrating injuries, particularly those arising from arterial cannulation, can cause bleeding, pseudo-aneurysm, arteriovenous fistula, dissection or thrombotic occlusion.

## Pathophysiology of injury

In major vascular trauma, life is threatened in three ways: haemorrhage; regional (arterial occlusion) and global ischaemia (shock); and systemic inflammatory response syndrome (SIRS).

### Bleeding, shock and coagulopathy

In trauma patients with shock, the most common cause is hypovolaemia. Half of all trauma deaths are attributable to haemorrhage within the first 48 hours. Haemorrhagic shock due to loss of more than 30% of blood volume, leads to reduced blood pressure and impaired tissue perfusion. Massive bleeding (haemorrhage) is broadly defined as loss of one blood volume within 24 hours, half-of-one blood volume within 3 hours or blood loss exceeding 150 ml/min.[4] Dangers of massive blood loss may be compounded by the development of a 'lethal triad' of coagulopathy, hypothermia and acidosis. Trauma-associated coagulopathy, initiated by tissue injury, is often exacerbated by dilutional effects of transfusion and compounded by hypothermia and acidosis. Coagulopathy is present in up to one-third of trauma patients who present with bleeding, and all those with massive bleeding. Presence of traumatic coagulopathy significantly increases the occurrence of multiple organ failure and death.[5]

### Systemic inflammatory response

In massive haemorrhage there is potential for local tissue injury to provoke a systemic inflammatory response, which if uncontrolled, may lead to multi-organ dysfunction syndrome (MODS) and death. Local tissue injury and disruption of cellular integrity allows pro-inflammatory mediators to circulate. Interaction of cellular blood components and vascular endothelium initiate an amplification cascade of pro-inflammatory mediator release and immune cell activation, which if uncontrolled, becomes a SIRS, detrimental to the host. Following trauma, increased serum concentrations of cytokines and inflammatory mediators occur.

## Assessment in vascular trauma

Clinical assessment will identify the majority of clinically significant vascular injuries. In the acute phase clinical signs relate to haemorrhage or ischaemia. Clinical signs of vascular injury may be 'soft' or 'hard' signs (Table 1). With extremity injuries, signs may be frank from the outset, but in the cavities of chest or abdomen, signs may be subtle, and must be actively sought.

**Clinical manifestations of vascular injury**

| Hard signs | Soft signs |
|---|---|
| Pulsatile bleeding | Haematoma (small) |
| Expanding haematoma | History of haemorrhage at scene |
| Absent distal pulses | Unexplained hypotension |
| Cold, pale limb | Unexplained tachycardia |
| Palpable thrill | Peripheral nerve deficit |
| Audible bruit | |

The 'hard' and 'soft' signs that may signify major vascular injury.

**Table 1**

### Triage and immediate care

Triage, describes the process of sorting casualties into categories for priority for treatment, with the aim of providing the greatest benefit to the largest number. A systematic approach is essential, using interpretation of established guidance in Advanced Trauma Life Support (ATLS) training. The Definitive Surgical Trauma Care (DSTC) course may also assist the surgeon dealing with poly-trauma in high risk patients.

From ATLS we follow an algorithmic sequence, the ABCDE system-based approach to immediate management. Definitive A-airway control and support of B-breathing remain vitally important, but early identification of C-circulation threatened by ongoing haemorrhage should initiate an abbreviated approach to assessment and rapid progression to definitive surgical control of bleeding.

Damage control surgery (DCS) principles should be considered in unstable patients.[6] Injury patterns may suggest a role for DCS, in patients with multi-system trauma, high-energy impacts (road-traffic accidents, falls from height, blast injuries), and high-velocity missile injuries (particularly those penetrating a body cavity). DCS may also help in those with significant co-morbid disease, or at either end of the age spectrum, where physiological reserve may be limited. These patients typically have evidence of severe physiological derangement, such as: massive haemorrhage (>40% blood volume); profound acidosis (pH $< 7.2$ or base deficit $\geq 8$ Meq/L); and diffuse coagulopathy. Rapid surgical control of bleeding is of paramount importance in facilitating the correction of metabolic instability. Survival rates for patients with multiple traumatic injuries drop precipitously the longer serum lactate remains higher than 2 mmol/l.[7] At triage in penetrating trauma victims, an elevated serum lactate is more sensitive than vital signs at predicting operative intervention.[8]

### Diagnostic imaging

Patients with major vascular trauma are stratified as unstable (requiring immediate surgical control of bleeding with on-table angiography) or stable (may benefit from diagnostic imaging and consideration of endovascular or conservative options) (Figure 1). During initial assessment there is often time for portable chest and pelvic radiographs. In extremity trauma, use of handheld Doppler (HHD) to assess peripheral arterial blood flow is well established, and combined with normal ankle brachial pressure index (ABPI), will exclude most major arterial injuries.




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