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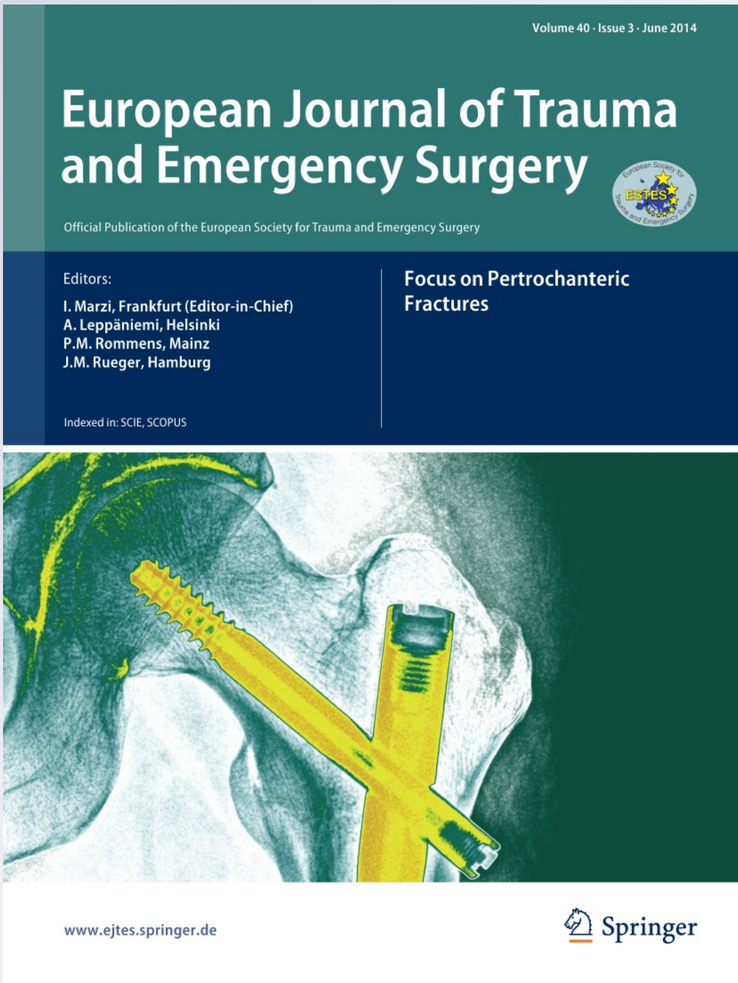

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ORIGINAL ARTICLE

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Abstract

Introduction Motor vehicle collisions account for the majority of blunt vascular trauma. Much of the literature describes the management of these injuries in isolation, and there is little information concerning the incidence and outcome in patients suffering multiple trauma. This study was undertaken to describe the spectrum of blunt vascular injuries in polytrauma patients.

Patients and methods All patients who had sustained blunt vascular trauma over a 6-year period (April 2007–March 2013) were identified from a prospectively gathered database at the Level I Trauma Unit, Inkosi Albert Luthuli Central Hospital, Durban, South Africa. The retrieved data consisted of age, sex, mechanism of injury, referral source, Injury Severity Score (ISS), New Injury Severity Score (NISS), time from injury to admission, surgical intervention and outcome. The initial investigation of choice for patients sustaining multiple injuries was computed tomography (CT) angiography if they were physiologically stable, followed by directed angiography if there was doubt concerning any vascular lesion. If technically feasible, endovascular stenting was the preferred option for both aortic and peripheral vascular injuries.

Results Of 1,033 patients who suffered blunt polytrauma, 61 (5.9 %) sustained a total of 67 blunt vascular injuries. Motor vehicle collisions accounted for 92 % of the injuries. The median ISS was 34 [interquartile range (IQR) 24–43]. The distribution of blunt vascular injuries was extremity (21), thorax (20), abdomen and pelvis (19), and head and neck (7). Endovascular repair was employed in 12 patients (ten blunt aortic injury, one carotid-cavernous sinus fistula, one external iliac artery). Of the extremity injuries, primary amputation was undertaken in 8 (38.1 %) and secondary amputation in 2 (9.5 %). The total amputation rate was 48 %. There were 17 (28.3 %) deaths, of which 11 (64.7 %) were directly attributable to the vascular injury and 6 (35.3 %) of these occurred on the operating table from exsanguination, the majority from injuries to the abdominal vena cava.

Conclusions Blunt vascular injury is uncommon in the patient with multiple trauma but confers substantial morbidity and mortality. In those cases with peripheral injuries, delays in referral to definitive care frequently exceed the ischaemic time, resulting in a high rate of amputations. Central injuries, especially those of the vena cava, account for the majority of directly attributable deaths.

Keywords Polytrauma · Vascular injury

Introduction

Vascular trauma poses a threat to both life and limb. The mechanism of injury, associated injuries and the time from injury to definitive care are all independent predictors of outcome [1]. Although the prevalence of penetrating and blunt vascular trauma varies from country to country, motor vehicle collisions account for the vast majority of blunt vascular injuries, which, due to the high energy transfer, rarely occur in isolation [2]. Although the arrest of ongoing haemorrhage must be undertaken at any primary

D. J. J. Muckart (✉) · T. C. Hardcastle · D. L. Skinner
Level I Trauma Unit and Trauma Intensive Care Unit, Inkosi Albert Luthuli Central Hospital, Durban, Republic of South Africa
e-mail: davidmuc@ialch.co.za

B. Pillay
Department of Vascular Surgery, Inkosi Albert Luthuli Central Hospital, Durban, Republic of South Africa

receiving facility, patients suffering polytrauma need to be managed in centres with access to multiple specialities and intensive care facilities. Transfer to definitive care frequently exceeds warm ischaemic time, resulting in reperfusion syndromes or limb loss. Even with timeous admission, competing interests or physiological derangement may delay or preclude definitive vascular repair.

South Africa suffers from the unfortunate combination of a high rate of motor vehicle collisions [3] and the lack of an adequate number of Level I trauma centres. In 2007. the first Level I trauma unit was commissioned in Durban, KwaZulu-Natal at the Inkosi Albert Luthuli Central Hospital. This is a tertiary facility serving the entire province, which, with an area of 92,000 km^2 and a population of 10 million, is equivalent to the entire country of Portugal. The unit conforms to the requirements of the Committee on Trauma of the American College of Surgeons with in-house registrars in general and orthopaedic surgery and anaesthesia. There are two dedicated theatres, one for orthopaedics and the other for general surgery, and a dedicated trauma intensive care unit (TICU). All complementary surgical subspecialties and necessary allied health care professionals are available in the hospital. Imaging facilities include ultrasound in the unit and an adjacent computed tomography (CT) scanner and angiography suite. The hospital houses the only dedicated neurosurgical and vascular surgery service for the province, although surgery for extremity vascular trauma is undertaken at other selected centres. This audit was undertaken to assess the prevalence and outcome of blunt vascular trauma in patients sustaining multiple injuries admitted to this facility.

Patients and methods

The study spanned a 6-year period from April 2007 to March 2013. Ethics approval was obtained from the Biomedical Research Ethics Committee of the University of KwaZulu-Natal (BE 207/09). All patients who had sustained blunt vascular trauma were identified from a prospectively gathered unit database and the hospital computerised information system. Retrieved data consisted of age, sex, mechanism of injury, referral source, Injury Severity Score (ISS), New Injury Severity Score (NISS), time from injury to admission, surgical intervention and outcome. The initial investigation of choice was CT angiography if patients were physiologically stable, followed by directed angiography if there was doubt concerning any vascular lesion. If technically feasible, endovascular stenting was the preferred option for both aortic and peripheral vascular injuries.

Results

During the study period, a total of 1,383 patients were admitted, of whom 1,033 (74.7 %) had suffered blunt and 350 (25.3 %) suffered penetrating trauma. Of those sustaining blunt trauma, 61 (5.9 %) had sustained a total of 67 vascular injuries. There were 42 (68.9 %) males and 19 (31.1 %) females, with a mean age of 29 years (range 8–67). Fifty-six (91.8 %) patients had been involved in motor vehicle collisions (pedestrian 26, passenger 17, driver 10, motorcyclist 3), and the remaining five had sustained non-vehicular blunt injury as a result of falls from a height in four and a gas explosion in one. Forty-three (70.5 %) patients were referred from other health facilities and 18 (29.5 %) directly from the scene of injury. Of the inter-hospital transfers, 22 (51.2 %) were from within the greater Durban region and 21 (48.8 %) were from elsewhere in the province. With the exception of one patient, all scene referrals were from the Durban region. The median ISS was 34 [interquartile range (IQR) 24–43], median NISS 41 (IQR 29–50), the total number of injuries was 311 and the median number per patient was 5 (IQR 3–6). The median time from injury to admission for the entire cohort was 9.4 h (IQR 2.3–18.4), for referrals from the scene 1.2 h (IQR 1–1.5) and for inter-hospital transfers 12.5 h (IQR = 8.9–22.7). There was no significant difference in transfer times between local and distant hospitals.

The site of the vascular injuries and management are shown in Table 1 and the complications are presented in Table 2.

Head and neck

Two patients suffered vertebral artery occlusions, the injuries being bilateral in one. Both patients sustained neurological sequelae, with the unilateral injury producing ipsilateral cerebellar infarction and the bilateral injury causing severe diffuse brain ischaemia. The unilateral injury was associated with cervical spine fractures at multiple levels, comprising a fracture of the lateral mass of C1, Jefferson fracture of C2 and a fracture dislocation of C4:C5 with quadriplegia. No cervical fracture was evident in the patient with bilateral injuries who, in addition, had suffered unilateral renal artery thrombosis and bilateral lower limb traumatic amputations.

Bilateral carotid-cavernous fistulae occurred in one patient with an extensive basal skull fracture. The initial enhanced CT scan failed to identify any communication but following the development of bilateral proptosis, chemosis and a bilateral temporal bruit cerebral angiography demonstrated bilateral fistulae (Fig. 1), which were successfully occluded with detachable balloons (Fig. 2).

Table 1 Anatomical distribution and management of 67 blunt vascular injuries

Anatomical compartment (*n*)	Management (*n*)
Head and neck (7)	
Vertebral artery thrombosis (3)	Conservative (3)
Carotid-cavernous sinus fistula (2)	Detachable balloon occlusion (2)
Common carotid artery intimal flap (1)	Anticoagulation
Internal jugular vein thrombosis (1)	Conservative
Thorax (20)	
Aortic isthmus (14)	TEVAR (10)
	Conservative (1)
	Repair under by-pass (3)
Ascending aorta (2)	Repair under by-pass (2)
Aortic dissection arch to common iliacus (1)	Conservative due to age and extent
Descending aorta (1)	Died before surgery (combined with RPH)
Intercostal artery haemorrhage (1)	Thoracotomy and ligation
Aorto-pulmonary fistula (1)	Conservative due to MODS
Abdomen and pelvis (19)	
Inferior vena cava (7)	Laparotomy (5)
	Died before reaching operating theatre (1)
	Conservative (1)
Renal artery thrombosis (4)	Conservative (4)
External iliac artery thrombosis (2)	Interposition graft (1)
	Stenting (1)
Hepatic artery aneurysm (1)	Embolisation
Splenic artery aneurysm (1)	Splenectomy
Lumbar artery haemorrhage (1)	Ligation
Infra-renal aorta (1)	Conservative
Common iliac artery thrombosis (1)	Died before intervention
Renal vein thrombosis (1)	Conservative
Extremities (21)	
Popliteal artery occlusion (9)	Primary amputation (4)
	RSVG and fasciotomy (4)
	Primary anastomosis and fasciotomy (1)
Subclavian artery occlusion	Conservative (6)
Thrombosis (5)	
Intimal flap (1)	
Superficial femoral artery occlusion (3)	Primary repair (1)
	Amputation for ischaemia (1)
	Amputation for mangled extremity (1)
Brachial artery occlusion (3)	RSVG (2)
	Conservative (1)

TEVAR thoracic endovascular aortic repair, *RPH* retroperitoneal haematoma, *MODS* multiple organ dysfunction syndrome, *RSVG* reverse saphenous vein graft

Table 2 Complications following blunt vascular injury

Vascular injury (number of injuries)	Complication (number of patients)
Head and neck (7)	
Bilateral vertebral artery occlusion (3)	Diffuse brain ischaemia (1)
	Cerebellar infarct (1)
Thorax (20)	
TEVAR (10)	Left bronchial collapse (1)
	Left subclavian artery occlusion (1)
	Stent erosion into oesophagus: death (1)
Ascending aorta (2)	Acute STEMI (1)
Conservative management of isthmus tear (1)	Rupture into oesophagus day 14: death
Descending aorta (1)	Coagulopathy: exsanguination: death
Intercostal artery (1)	Coagulopathy: exsanguination: death
Abdomen and pelvis (19)	
Inferior vena cava (7)	Coagulopathy: exsanguination: death (5)
Lumbar artery haemorrhage (1)	Delayed diagnosis: coagulopathy: death
Common iliac artery (1)	High above knee amputation: MODS: death
Limbs (21)	
Subclavian artery (6)	Amputation for compartment syndrome (2)
Popliteal artery (9)	Primary amputation (4)
	Secondary amputation (2)
Superficial femoral artery (3)	Primary amputation (2)

STEMI ST segment elevated myocardial infarct

The patient with an intimal tear of the left common carotid artery had also sustained an intimal tear of the left subclavian artery and dissection of the ascending aorta in association with a sternal fracture, bilateral pulmonary contusions and haemothoraces. All intimal tears were minimal and anticoagulation was deemed the treatment of choice.

Thorax

Of the 20 patients with thoracic vascular injuries, 19 involved the aorta, with the isthmus being the predominant site. Only two patients had trauma isolated to the thorax. Ten of the 14 isthmus lesions underwent stenting, eight within 48 h of admission and the remaining two on days 5 and 6. There were two acute and one delayed complications (Table 2). The last mentioned fatal haematemesis arose as a consequence of stent fracture with erosion into the oesophagus 14 days after a successful and uneventful

Fig. 1 Computed tomography (CT) angiogram demonstrating bilateral carotid-cavernous sinus fistulae with arterialisation of the ophthalmic veins

Fig. 2 Successful occlusion of one carotid-cavernous sinus fistula using detachable balloons

deployment. Of the four patients not stented, one was a 12-year-old child whose aortic calibre precluded stent placement, one had combined lesions of both isthmus and arch and was referred for repair under by-pass, in one the landing zone was too short and there was a bovine arch anomaly, and the final patient was deemed unfit for acute intervention due to multiple associated injuries and acute kidney injury. His aorta ruptured into the oesophagus the day prior to planned stenting.

Four patients sustained injury to the ascending aorta, consisting of intimal tears in two, one aortic dissection from the arch to the iliac arteries and one aortic root to pulmonary artery fistula. Those patients with isolated ascending injuries were referred for repair under by-pass; the elderly patient with aortic dissection was asymptomatic and conservative management was considered appropriate and the patient with the fistula died of multiple organ failure as a result of polytrauma before vascular intervention could be considered.

The single non-aortic injury arose in a patient with thoraco-abdominal haemorrhage. Following splenectomy for a Grade V splenic injury, a left thoracotomy was performed for continued bleeding through the intercostal drain. An extensive lung laceration was repaired but haemorrhage persisted from torn posterior intercostal vessels, which, despite rib resection, proved difficult to control. Death occurred from a combination of acidosis, hypothermia and coagulopathy.

Abdomen and pelvis

There were 11 arterial and 8 venous injuries. Of the former, five were managed non-operatively (renal artery thrombosis 4; infra-renal aortic dissection 1). All three iliac artery injuries were associated with pelvic fractures. Both the hepatic and splenic aneurysms arose in 8-year-old children, the former 2 weeks after the initial injury, at which time a Grade III liver injury had been repaired by suture at a regional hospital. The child developed progressive pain and vomiting, and CT angiography demonstrated an aneurysm of the right hepatic artery (Fig. 3), which was embolised successfully (Fig. 4).

The patient with haemorrhage from the lumbar arteries had sustained a Grade III liver injury, Grade V renal injury and bilateral fractured femurs. Following liver packing and nephrectomy, he continued to bleed through the temporary abdominal closure. A review of the pre-operative CT scan identified a blush from the lumbar vessels which had been overlooked. Although the vessel was secured at re-laparotomy, he succumbed to multiple organ dysfunction.

Of the seven injuries involving the inferior vena cava, five underwent surgery, with only one survivor, one died before surgery in combination with an injury to the descending thoracic aorta and one was successfully managed non-operatively following the diagnosis on CT scanning.

Extremities

Four of the eight popliteal artery injuries were associated with knee dislocations, two with fractures of the distal femur, one with a complex Gustilo grade 3C tibial fracture

Fig. 3 Aneurysm of the right hepatic artery following blunt liver trauma

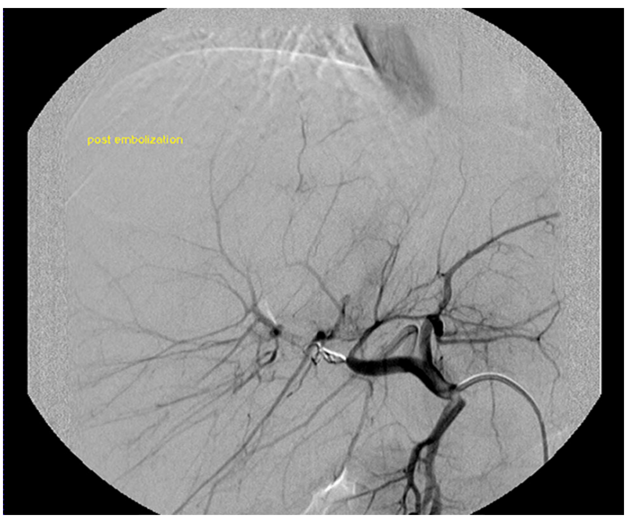

Fig. 4 Aneurysm occlusion following coil embolisation

and one limb was mangled beyond salvage. Six of these injuries required amputation (4 primary, 2 secondary). All three superficial femoral artery injuries were associated with fractures, two of which underwent primary amputation, one for a mangled extremity and the other for irreversible ischaemia. Of the upper limb injuries (5 subclavian; 3 brachial), only two were amputated, one for ischaemia and one for a mangled extremity with a near-complete traumatic amputation.

Overall, primary amputation was performed in 8 (38 %) and secondary amputation in 2 (9 %) patients, giving a total of 10 limb losses (48 %) in 21 extremity injuries. Of the primary amputations, five were undertaken for irreversible ischaemia on presentation, two for non-salvageable mangled limbs and one patient had already suffered a traumatic amputation of the upper limb. The two secondary amputations were performed for sepsis and persistent muscle ischaemia following popliteal artery repairs.

There were 17 (28.3 %) deaths, of which 11 (64.7 %) were directly attributable to the vascular injury (inferior vena cava 4, aorta 2, combined inferior vena cava and aorta 1, intercostal vessels 1, lumbar arteries 1, vertebral arteries 1, common iliac artery 1). Six (35.3 %) deaths occurred on the operating table from exsanguination.

Discussion

Although blunt vascular injury appears uncommon in the context of polytrauma, affecting roughly 1 in 20 patients, this may be an underestimation for a number of reasons. Firstly, clinical studies do not include those who die before reaching hospital, and as many as 90 % of blunt thoracic aortic injuries die at the scene or soon thereafter [4]. These lesions are reported to be the second most common cause of early deaths, surpassed only by traumatic brain injury. Secondly, in the absence of a post-mortem in those who die from haemorrhage, the specific vascular lesion will not be identified. Thirdly, if signs or symptoms of a vascular injury are not evident, imaging may not be undertaken and lesions missed. This is especially true following blunt cranio-cervical and unilateral renal artery trauma, where many injuries are clinically occult [5].

Carotid-cavernous sinus fistulae are classified on the basis of aetiology, high or low flow, and whether direct or indirect based on angiography [6]. The majority arise following trauma in association with basal skull fractures of the middle fossa and are high flow direct communications between the carotid artery and cavernous sinus. Bilateral fistulae are extremely rare. Untreated, these lesions may progress to irreversible neurological sequelae. Using detachable balloons, interventional neuro-radiology allows occlusion of the fistula while maintaining patency of the internal carotid artery with minimal complications [7].

Blunt trauma to the carotid artery occurs in <1 % of cervical injuries but may have devastating neurological consequences, depending on the grade and location of the injury. All investigators agree that symptomatic patients with unexplained neurological signs must undergo cerebral angiography, but whether asymptomatic patients need to be screened is debatable. Although lesions are rare, if untreated, there may be morbid or mortal neurological sequelae, and those with significant risk factors merit investigation [5, 8]. The principal therapeutic aim is to prevent cerebral ischaemia as a result of embolisation or occlusion, and management options include anticoagulation, endovascular stenting or open surgical repair. Grade I and II injuries are best managed with anticoagulation if there are no contraindications. Grade III pseudoaneurysms rarely resolve with heparin alone and should be repaired or stented. In the presence of a Grade IV injury with occlusion, restoration of inflow should be considered in the presence of an accessible lesion, even with an early neurological deficit.

Vertebral artery injuries are more common than those of the carotid, are almost universally associated with fractures of the cervical spine and are usually unilateral [9]. Damage is most likely in fractures involving the transverse foramina, especially of the upper cervical spine and in those with subluxation. Although the majority of patients are asymptomatic, multidetector CT angiography (MDCTA) using a 0.6-mm configuration should be undertaken in all patients with specific risk factors [10]. Neurological sequelae are rare, but cerebellar or brain stem ischaemia may occur if a dominant vessel is injured, collateral flow is inadequate or the lesions are bilateral. Unlike carotid injury, the emphasis is not on restoring flow in the injured vessel but, rather, to stabilise the spine, maintain contralateral flow and minimise thrombus propagation in the affected side using antiplatelet therapy. Alternatively, provided the necessary expertise is available, antegrade or retrograde coil embolisation may be employed [11].

Aortic rupture is the most common blunt thoracic vascular lesion and accounts for almost one-fifth of deaths following motor vehicle collisions [4]. Although head-on impacts were cited as the most common mechanism, this has recently been contested and side impacts may have the highest incidence [12]. Only 10–20 % of patients survive to arrival at hospital and most have suffered multiple extrathoracic injuries. Less than half of these victims present with obvious signs and symptoms of aortic injury [13] and CT angiography, which is the diagnostic modality of choice, should be performed liberally on the basis of the mechanism of injury in patients whose physiology permits imaging. Initial management must concentrate on immediate life-threatening injuries following which, if the aortic injury is contained, medical therapy should be instituted temporarily until definitive repair is undertaken. This consists of avoiding excessive aortic stress by the use of sedation, analgesia, beta-blockade and vasodilatation, as necessary. Although the risk of rupture is ever present, the optimal time for intervention is, as yet, uncertain. The advent of endovascular techniques has revolutionised the management of these lesions and thoracic endovascular stenting is now regarded as the initial treatment of choice. Although there are a number of possible complications, the overall acute morbidity and mortality may be reduced by as much as two-thirds [14] when compared with open repair, and newer graft designs continue to minimise adverse events. Long-term results are, as yet, unknown however; patients are committed to indefinite surveillance using CT angiography and compliance with respect to surveillance remains a challenge in our population.

Although uncommon, blunt vascular injuries within the abdomen are associated with high mortality rates principally from massive haemorrhage [15]. With the exception of mesenteric tears, arterial injuries are exceptionally rare and the vast majority of blunt abdominal vascular trauma involves the major veins, especially those in the retroperitoneum. Injuries to the vena cava are highly lethal, and survival depends on the degree of haemorrhage, the location of the caval injury and whether tamponade has minimised blood loss [16]. Of those with active haemorrhage who require surgical control, very few survive, with death being most commonly due to exsanguination. For vena caval injuries to tamponade, there must be no breach in the surrounding tissue. This contained leak results in a retroperitoneal haematoma, which may be identified by MDCTA imaging [17] and may be managed non-operatively.

The introduction of CT scanning for blunt abdominal trauma has revealed a number of previously occult asymptomatic vascular injuries, especially those involving the renal arteries, where thrombosis and intimal flaps are the most common lesions. The majority involve the left kidney, with bilateral injuries being rare [18]. Irreversible renal damage from ischaemia occurs within 90 min, and this critical period may be even shorter in the presence of hypotension from other injuries. Unless the injury is <6 h old or in the presence of bilateral arterial injury, revascularisation is not recommended. Patients need to be reviewed for the development of hypertension, which occurs in up to half of patients treated conservatively and one-third following revascularisation.

Blunt trauma to the iliac vessels is invariably associated with pelvic fractures, with venous injuries predominating. Arterial injuries are less common, may involve both major and minor vessels, and vary from intimal tears and thrombosis to disruption with active haemorrhage [19]. Independent risk factors for arterial injury include complex pelvic fractures, hypotension on presentation and a high ISS. Death or limb loss is not uncommon. MDCTA is invaluable in identifying the nature of the lesion and indicate the need for interventional angioembolisation or the feasibility of endovascular stenting [20].

Peripheral vascular injuries pose a threat to limb but rarely life. Of limb-threatening injuries, those of the popliteal artery are notorious. Prognostic factors for amputation are blunt mechanism of injury, delay to vascular repair, the presence of associated injuries and pre-existing vascular disease [2, 21]. Although fractures of the distal femur or proximal tibia may result in thrombosis or complete disruption of the vessel, posterior dislocation of the knee without fractures is the most common mechanism of blunt injury. The presence of a palpable distal pulse does not exclude vessel injury and in high-risk patients, imaging should be considered to exclude this lesion [22]. In the absence of vessel occlusion, failure to diagnose an injury may lead to pseudoaneurysm formation with a delayed threat to limb salvage. Amputation rates are generally in the order of 30–40 % in isolated popliteal injury but are considerably higher in those patients with multiple injuries and hypotension [23]. Competing more compelling life-threatening injuries and the presence of hypotension may preclude the possibility of definitive vascular repair, and temporary shunting may be an option [24]. In dire situations of severe physiological instability, although, in isolation, vessel repair is feasible, the threat to life overrules the threat to limb and ligation with fasciotomy or primary amputation may need to be performed [25].

Due to a more generous collateral circulation around the joints, amputation for vascular injuries of the upper limb is less common than for their lower limb counterparts [26]. The majority of subclavian injuries follow penetrating trauma and blunt injury is uncommon [26, 27]. Virtually all blunt injuries are combined with fractures of the upper ribs or clavicle, and almost half have associated injuries to the brachial plexus. Surgical exposure can be challenging and the use of endovascular therapy has increased in the past few years, with excellent results for patency and limb salvage [28]. As with other major vessels, in the presence of a minimal intimal injury, anticoagulation alone may suffice. Vessel calibre and joint proximity preclude endovascular stenting for injuries of the brachial artery. Furthermore, this vessel is easily accessible and lends itself to surgical repair. Elbow dislocation or distal fractures of the humerus are the most common associated injuries [29].

In the setting of blunt polytrauma, vascular injuries are uncommon in those who survive to arrival at hospital, and, when present, usually occur in isolation. Central injuries of the major veins are highly lethal and arterial trauma, especially of the lower limbs, commonly results in the need for amputation. Blunt injury to the thoracic aorta lends itself to endovascular control with low morbidity and mortality rates.

Conflict of interest None.

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