Penetrating Femoral Artery Injuries:

An urban trauma centre experience

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Dr Shreya Rayamajhi

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ABSTRACT

PENETRATING FEMORAL ARTERY INJURIES: AN URBAN TRAUMA CENTRE EXPERIENCE

INTRODUCTION

The femoral artery (FA) is the most common peripheral vessel injured in trauma. The incidence has been as high as 70%. Most experience with vascular trauma comes from the military where the incidence of FA injury is 67% of all vascular injuries. Up to 88% of these injuries are as a result of penetrating trauma. The Groote Schuur hospital trauma unit is a level one centre. It is a quaternary hospital and a referral center for all surrounding secondary level hospitals. Femoral vessel injuries are the second most common peripheral vascular injury (18.8%) seen after brachial artery injuries (48.2%) at our unit.

AIM

This study aims to review a single centre experience with femoral artery injuries and identify factors associated with limb loss.

METHOD

A 11 year retrospective chart review of patients with femoral artery injuries managed from 1 January 2002 to 31 December 2012 at the trauma unit, GSH.

RESULTS

There were 158 patients with femoral artery injuries, 144 men and 14 women with a mean age of 28. Ninty-five percent had penetrating injuries. The most common artery injured was the superficial femoral artery (87%). The most common type of arterial injury was a laceration (39%) and transection (37%). Eighty-one patients had a primary repair (51%), fifty-three patients had a vein interposition graft (33.5%) and sixteen patients (10%) had a prosthetic graft. There were 78 (51%) concomitant venous injuries, 11 were repaired and 1 vein patch was done (15.4%). The rest were ligated (84.6%). There were 4 (2.5%) primary amputations and 10 (6.5%) secondary amputations. One primary amputation resulted from a delay to theatre with a threatened limb. The other three presented with a non-viable limb. Nine of the ten secondary amputations presented with a threatened limb. One viable limb was lost due to bleeding from a false aneurysm secondary to sepsis. One secondary amputation was the result of a delayed fasciotomy for compartment syndrome post revascularisation of a threatened limb. The rest were due to prolonged ischemic time despite attempted revascularization. There were no deaths in this study. Univariate analysis showed that statistically significant risk factors for secondary amputation were: presentation with signs of a threatened (ischemic) limb ($p<0.0001$), the temporary vascular shunt group ($p<0.001$) and the lack of a palpable distal pulse post repair ($p<0.01$). Statistically insignificant factors were: concomitant femur fracture, compartment syndrome, fasciotomy, unstable hemodynamics on presentation, venous ligation and ‘In hospital ischemia time’.

CONCLUSION

The outcome of threatened limbs due to femoral vessel injury is good provided there is no delay to surgery. This study has a primary amputation rate of 2.5%

and secondary amputation rate of 6.5%, 91% of the limbs were salvaged.***(Word count 441).***

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CHAPTER 1

LITERATURE REVIEW

1. BACKGROUND

1.1 Early developments

Vascular surgery today is an amalgamation of innovation, perseverance and experimentation of many surgeons dating as far back as 1600 B.C. For centuries man has used compressive bandages for haemostasis. In terms of directed treatment there were some primitive haemostatic agents. The Egyptians and Chinese used styptics (vegetable matter with various combinations of metals) to control haemorrhage as far back as 1600 B.C. In the middle ages bleeding was cauterised (hot oil, iron, charcoal) (1) .

In the western world, the first documentation of using ligatures to control vascular injuries was by *Hieronymus Brunschwig* in 1497 (2). Galen, a Greek physician living in the Roman empire was known to use ligatures and devised differential management for arterial and venous bleeding as far back as the 2nd century (2). *Ambroise Pare* in 1552 published his progress with ligation and took it one step further to limb amputation in order to control haemorrhage (3)(4). *Hallowell* in 1759 sutured the brachial artery. It was a lateral injury from a common blood-letting practice of the day. He used a steel pin and ligature to make a figure of eight suture-tie and controlled the bleeding (4). Sutures were found in Egyptian mummies dating back to 3000 B.C. Various different materials were experimented with, including plant and animal products. Around the 10th century, sutures were made of animal material, mostly catgut that was derived from sheep and cattle intestine.

The sterilisation of sutures only started after *Joseph Lister*'s introduction of the antiseptic concept. The giant leap for sutures came after 1900 with the revolution of chemical industries. Various absorbable and non-absorbable synthetic sutures were introduced. *Lister* experimented with suture sterilisation during the 1860s but the first sterile suture was achieved in1906 with iodine. The technique of sterilising sutures with irradiation was founded in 1960 (4). Refinement of the modern vascular needle also spanned a few centuries from the primitive man's bone or stone needle to the swagged atraumatic curved needles of today.The 19th century showed progress with attempted vascular repairs from the first lateral suture of 1882 to the first end to end anastomosis of an artery by *John B. Murphy* in 1896 (3). *Goyannes* of Spain did the first vein interposition graft by using the popliteal vein to repair a popliteal artery aneurysm in 1906 (3). *Alexis Carrel* pioneered suturing techniques for blood vessels and was awarded the Nobel prize for medicine in 1912. The 20th century brought with it the concept of antiseptics, sterilisation and the discovery of antibiotics.

1.2 The catalytic wars

The plight and fight of our forefathers has helped the human race not only with freedom and democracy but also with advancements in the medical field. The volume of cases and need for life and limb salvage acted as a catalyst for inguienity and progress for vascular surgery.

1.2.1 World War 1 (1914 – 1918)

From *Makins*' British vascular registry in World War I, the incidence of vascular trauma was 1.3% (5). He documented cases at two surgical centres only. He included acute and late presentations, including the delayed aneurysms and arterio-venous fistulas. There were 366 (30.4%) patients with femoral artery trauma of the 1202 vascular injuries. The standard treatment for vascular injury was ligation using the “life over limb” concept. An uninjured vein would also be concomitantly ligated with the artery. Lateral suture repair only was attempted for 3.2% of patients. The amputation rate was 18.1% (5). The amputation rate is thought to be low because more patients may have died from exsanguination. The introduction of high explosive artillery resulted in mass casualty with less injured evacuation. There was usually a 12 hour or longer delay to transfer injured patients to adequate care facilities. Infectious complications were a norm due to absence of antibiotics. The majority of patients lost limbs or life due to these factors. *Makins* believed in ligating the non-injured vein with the injured artery to decrease the likelihood of gangrene. Many other surgeons of the time believed this too (5).

1.2.2 World War 2 (1939 – 1945)

Debakey and Simeone's registry from World War II had 2471 patients with acute vascular injuries (5). There were 517 (20.9%) femoral artery injuries. Only 81 (3.3%) were treated without ligation. Lower limb arterial injuries caused 19.5% of amputations, infections 11.9% and major limb trauma in the majority of cases (68.8%). The delay in transfer to a surgical field hospital resulted in higher amputation rates for vascular injuries. In patients who arrived within 10 hrs of injury, the amputation rate was 36% vs patients who arrived after 20 hrs

where it was 63%. Patients with femur fractures had an incidence of 72.7% amputation while without a fracture, the incidence decreased to 51%. Popliteal artery injury had the highest amputation rate at 72.5% and femoral artery injury amputation rate at 53.2% (5).

1.2.3 Korean War (1950 – 1953)

In contrast to the high amputation rates of WWII, the Korean War had improved vascular outcomes. Repair was attempted and ligation was only used in exceptional cases. The amputation rate decreased from 49% to 13% (1). Surgeons worked in a fairly controlled environment even in the field hospitals. This experience and the good outcomes was welcomed by the surgical community and vascular training became a regular part of surgical residency. Civilian outcomes improved as shown in the case series by *Ferguson et.al.* in Atlanta published in 1961. The attempted repair rate increased from 10% in 1950 to 80% by 1959 (6).

1.2.4 Vietnam War (1969 – 1975)

The Vietnam War brought with it rapid evacuation of the injured with helicopter transfers. This meant that severely injured patients that normally would die in the field made it to hospitals. The Vietnam Vascular Registry was also established and this helped keep track of data, outcomes and allowed long term follow up. The amputation rate was similar to the Korean War at 13% (1).

2. EPIDEMIOLOGY

Penetrating trauma to the femoral artery accounts for 85% of the injuries. Blunt injury is responsible for 12 to 15% of these injuries. The population at risk is

young men, between 20- 40 yrs of age. In civilian trauma femoral vessel injury incidence is as high as 70% of all peripheral vascular injuries (7). The incidence of civilian trauma has increased over the years. This is due to the rise in urban violence, high speed accidents and iatrogenic injuries (8). The incidence of penetrating femoral artery injury at our institution is 18% and is the second most common peripheral vascular injury seen after brachial artery trauma (9).
When considering all vascular trauma, the incidence of femoral artery injuries in *Asensio's* study is 26% (7). Cargile et al looked at all femoral vascular injuries; there were 48% isolated arterial injuries, 15% isolated vein injuries, and 36% had both vessels injured (10).

3. ANATOMY OF FEMORAL VESSELS

The femoral vessels are superficial and therefore at risk of injury even with a small penetrating injury. The common femoral artery (CFA) is a continuation of the external iliac artery. It starts posterior to the inguinal ligament as it exits the pelvis. The first segment is the CFA which lies in the femoral triangle behind the sartorius muscle, it is a short segment about 4 cm enclosed in the femoral sheath with the femoral vein. It gives off a few small side branches. Laterally is the superficial circumflex iliac artery. Medial branches are superficial epigastric artery, superficial and deep pudendal artery. The CFA gives off two branches, firstly the profunda branch posterior-laterally. The CFA then continues as the superficial femoral artery (SFA) into the thigh. The SFA lies in the medial thigh compartment under the sartorius muscle and exits the thigh at the adductor hiatus to continue as the popliteal artery. This hiatus is part of the adductor magnus muscle and situated at the junction of the middle and distal thirds of the

thigh. The SFA has small muscular branches along its length and gives off a genicular branch before becoming the popliteal artery. The profunda femoral artery travels in a posterolateral direction as it branches and supplies the deep posterior thigh muscles (FIG 1) (8)(11) .

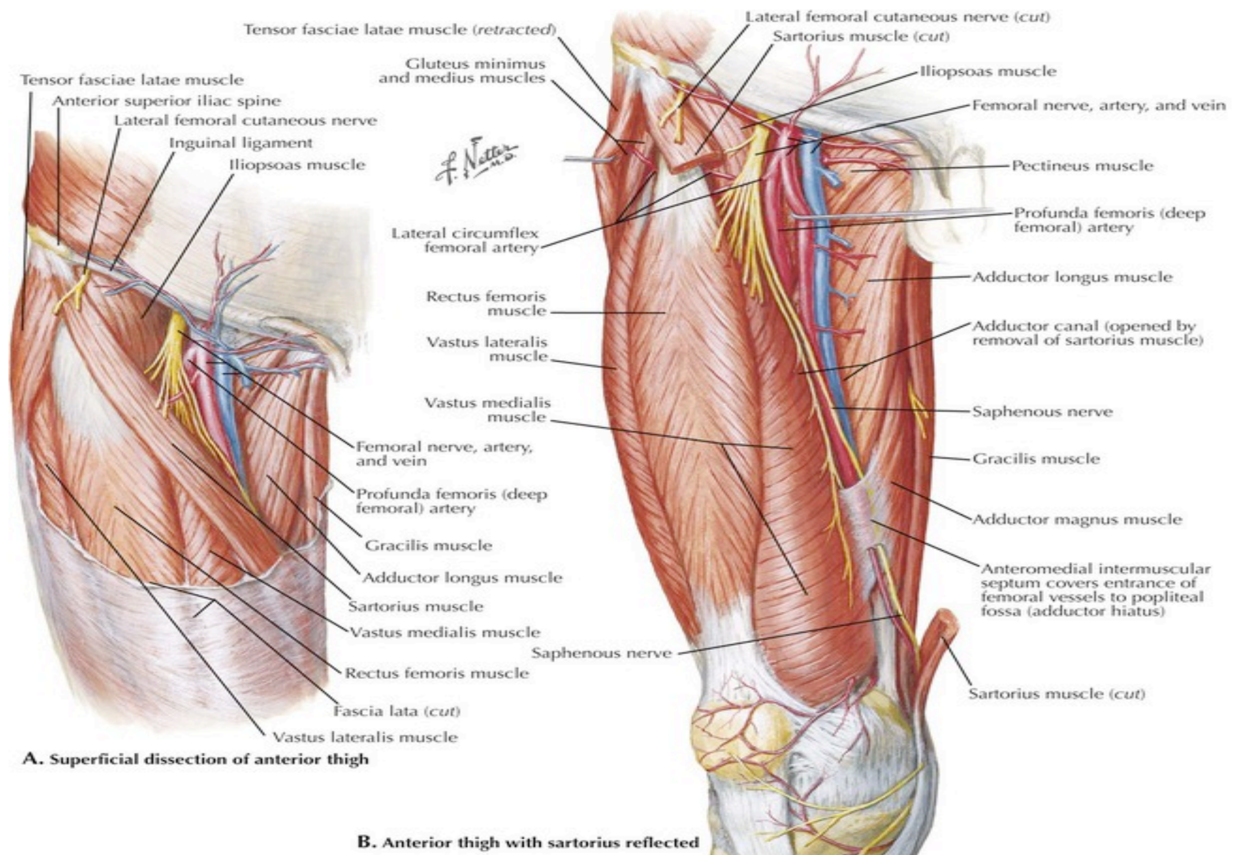

FIGURE 1: Anatomy of the femoral vessels (from Netter's anatomy) (11)

4. PATHOPHYSIOLOGY OF INJURY

4.1 Macrovascular

Penetrating trauma can result in a laceration or transection of a vessel. Transected artery can go into spasm and thrombose, or bleed actively. Stab wounds are more likely to cause lacerations or minor injuries without extensive tissue destruction. Low velocity gunshot wounds cause some tissue destruction

and usually these vessels require a graft interposition. High velocity injury and blast injuries are destructive requiring more extensive debridement, tissue loss with need for flaps and extra-anatomical bypass, and limb loss from extensive tissue injury. Blunt injuries can cause an array of injury as well, from minor intimal contusions, tears and flaps to significant injuries causing thrombosis and occlusion to complete avulsion. Blunt trauma results in sometimes occult injuries and needs a high index of suspicion to diagnose. A review showed that 95% of the blunt extremity vascular injuries were associated with bony fractures. Two thirds of these patients presented with hard signs. Bleeding into a muscle compartment can cause a hematoma, increasing the risk of compartment syndrome. Fractures can also bleed into a compartment. The ischemic limb once perfused is at risk of reperfusion injury and compartment syndrome (8).

4.2 Microvascular

The peripheral nerve cells are most sensitive to hypoxia. The relative ischemic time for muscle is between 3 and 6 hours depending on whether there is a concomitant venous injury, compartment syndrome and extensive injury destroying any collateral circulation. The hemodynamic status of the patient and temperature can also have detrimental effects on collateral circulation. Earliest ischemic changes includes swelling of the endothelial cells, followed by congestion of red blood cells leading to micro-thrombosis and leukocyte infiltration. The ensuing ischemia and hypoxia results in anaerobic metabolism and once this is depleted the cells undergo necrosis, and release inflammatory mediators. The micro-thrombosis can perpetuate and later prevent recirculation and loss of limb despite reperfusion. Another potential cause of the no-flow

phenomenon post repair is thought to be related to the endothelial swelling itself. The high resistance of these vessels to blood flow causes shunting to less resistant vessels with ongoing ischemia.

The secondary injury to ischemic tissue is brought on by reperfusion once and when circulation is re-established. The reperfused tissue produces reactive oxygen species which leads to further cell death and aggravates the limb edema worsening the compartment pressures. Prolonged limb ischemia, once reperfused, ideally should undergo a prophylactic fasciotomy in the absence of compartment syndrome. The circulation of these reactive oxygen species, inflammatory mediators and potassium from cell death enters the systemic circulation and can cause a systemic inflammatory response syndrome with shock, acute lung injury and cardiac arrhythmias. Early repair and reperfusion prevents all these complication (12).

5. COMPARTMENT SYNDROME

Injured extremity is at risk of compartment syndrome as mentioned above. Compartment syndrome is defined as increased myofascial compartment pressures above capillary perfusion pressure hampering tissue perfusion. Absolute compartment pressure of above 30 mmHg or relative pressure of within 30 mmHg of diastolic pressure is regarded as compartment syndrome of the myofascial compartments of the lower limb. Where pressure manometer is unavailable, clinical suspicion is used to diagnose and guide treatment.

The risk factors for developing compartment syndrome are:

- Prolonged ischemia (>4 hours)
- Concomitant venous injury
- Concomitant long bone fractures
- Entrapment trauma or crush injury to limb
- Reperfusion injury

The classical signs of compartment syndrome are:

- Pain out of proportion to the injury
- Painful foot and calf which is worse with passive dorsi-flexion of foot
- Tense compartments
- Paresthesia
- Pulselessness is a late sign

The management is a four compartment fasciotomy of the lower limb. It is either performed therapeutically once diagnosed or prophylactically for the at risk limb. The at risk lower limb is regarded as prolonged ischemia of more than 4 to 6 hours with reperfusion, concomitant venous injury obstructing outflow and ligated deep venous injury (12). A retrospective analysis of early vs late fasciotomy has shown a 4 fold increase of amputation risk in the late fasciotomy group (13). This group also had more surgical site infections and longer hospital stays. *Cargile's* review shows that 3 of the 9 (33%) amputations could have been avoided with a timeous fasciotomy (10).
Although rare, the upper leg can also have a compartment syndrome requiring a three compartment fasciotomy.

6. CLINICAL PRESENTATION AND ADJUNCT INVESTIGATIONS

Vascular injuries present with either hard signs or soft signs (8).

The hard signs of a vascular injury are:

- Active pulsatile bleeding
- Hypovolemic shock in the presence of active pulsatile bleeding
- Expanding hematoma
- Bruit and/or thrill
- Ischemia: pulselessness with sensory and/or motor deficits

The patients with hard signs do not need any further investigation and should have a surgical exploration. 38% patients in *Cargile's* review presented with hard signs and proceeded to exploration (10). All of them had a vascular injury present.

The soft signs of a vascular injury are:

- History of bleeding
- Non-expanding hematoma
- Proximity nerve injury
- Decreased pulse distally
- Proximity injuries (debatable)

These patients will need imaging to delineate the injury if present. Previously all suspected injuries were explored surgically with a high rate of negative explorations. Imaging selected patients can help identify injuries and prevent unnecessary surgery.

Acute limb ischemia can be clinically stratified according to the Rutherford classification which aids management decision making (14).

The following table shows the clinical classification:

Category	Description / Prognosis	Findings: Sensory loss	Findings: Motor loss	Doppler: Arterial	Doppler: Venous
I. Viable	Not immediately threatened	None	None	Audible	Audible
IIa. Marginally threatened	Salvageable if promptly treated	Minimal (toes) or none	None	Inaudible	Audible
IIb. Immediately threatened	Salvageable with immediate revascularisation	More than toes associated with rest pain	Mild, moderate	Inaudible	Audible
III. Irreversible	Major tissue loss or permanent nerve damage inevitables	Profound anesthetic	Profound, paralysis (rigor)	Inaudible	Inaudible

The ideal imaging modality for any suspected vascular injury in the modern era is computed tomography angiography (CTA). Duplex ultrasound (DUS) is highly operator dependent. It has appeal as it is non-invasive and can be done at the bedside. However, in trauma the associated injured soft tissue might obscure optimal view of the underlying vessels. Review of literature published after 2000 shows that CTA has higher specificities and sensitivities than duplex ultrasound (8). CTA also has the advantage of being non-invasive with no large bore needle arterial puncture site complications as with formal peripheral percutaneous angiography. The gold standard of diagnosing a vascular injury is a formal angiogram, but it is time consuming, associated with puncture site complications and higher rates of contrast nephropathy. The CTA has the additional advantage to looking at surrounding tissue, venous injury and bony fractures. The conventional multi slice (>64) CT scanners with ability to do 3D reconstruction has been accepted as a good screening tool for vascular injuries (15).

Investigating patients with proximity injury with a normal clinical examination is debatable. Previously, when an investigation meant an invasive angiogram, the risk of complication compared to the benefit of finding minor intimal injuries was not justified. When reviewing arteriograms done for proximity injuries, only 3.7% to 4.4% of patients had underlying injury (10). Despite mentioning that the policy has changed to no angiograms for proximity injuries based on the numbers above from various studies (16). *Cargile* goes on to mention that in his current review 15% of patients were imaged for proximity (10). Out of these 55% had underlying injury, either intimal flap or pseudoaneurysm (15).

An emergency room angiogram is done with prograde injection of contrast of the specific limb if a part of a proximal artery could be accessed safely. A cut off or contrast extravasation indicates an injury. Ideally this is helpful to confirm or localise an injury in unstable patients with multiple injuries. A single injury to the lower limb with hypovolemic shock is an indication for exploration for vascular injury. *Feliciano's* review from 1981 to 1985 shows that 95% of the angiograms were done by surgical residents in the emergency room. Only 4% of these were misinterpreted leading to delay in surgery for 3 patients without limb loss (10).

7. SURGERY

Femoral artery penetrating injury requires open surgery. An exploration with identification and control of proximal and distal ends is done, and the injury assessed. Simple lacerations and transections without loss of arterial wall can be repaired primarily. Injuries requiring resection with loss of length of artery might require an interposition graft. An autologous vein graft is ideal but where not possible, a prosthetic graft can be used. Review of the larger series of femoral arterial injuries shows that only 0.5% of patients required a prosthetic PTFE graft before 1992, while a study done after 1992 showed an increased use to 10%(7)(10). The concerns of prosthetic graft is that it has an increased risk of sepsis and graft failure. This is an unique problem in trauma. In peripheral vascular disease above knee femoral to popliteal bypass, prosthetic grafts have shown a good patency rate at 10 yrs. However this is elective surgery with less sepsis risks and usually adequate soft tissue coverage. During the Vietnam war all patients who had prosthetic grafts complicated. Another more recent military registry also showed that 4 out of 5 prosthetic grafts used

for extremity vascular trauma complicated with sepsis (17). *Asensio's* review risk stratified patients for sepsis. Coagulopathy, hypothermia, hypotension and associated bony fractures were found to have increased risk for surgical site infection (7).

Endovascular management for traumatic extremity vascular injury is still experimental, with only a few case reports. Stent grafts have been used for blunt intimal injuries of the femoral artery and in cases with delayed presentation of an AVF or pseudoaneurysm.

Regarding the concomitant venous injury the decision to repair or ligate remains controversial. *Cargile's* study from 1974 to 1991 in the USA, had a high proportion of attempts at venous repair. Primary repair was done on 53% of venous injuries. The rest (47%) had complex repairs either consisting of PTFE grafts (2%) or autologous vein grafts. Fourteen percent of these venous repairs thrombosed and occluded, 34% had DVT, 2.5% had pulmonary embolus (10). *Degiannis* had a venous ligation of 19%. Only two of these patients developed limb odema which had spontaneously settled by six months. There was no long term follow up and he doesn't mention the outcome of the venous repairs in 81% of patients (18).

8. TEMPORARY VASCULAR SHUNTS

The current indications for temporary vascular shunts (TVS) for peripheral limb vessel injury are:

1) Damage control for an exsanguinated shocked patient who needs a quick procedure to restore blood flow and then ongoing resuscitation in an intensive care unit. Once fully resuscitated the patient is taken back to theater for a definitive repair or graft (19).

2) Damage control in a polytrauma patient with multiple injuries needing surgical attention (19).

3) In cases with severe fracture where the shunt is placed to perfuse the periphery while bony injuries are fixed. The vessel is repaired after this during the same operation. This is for stable patients who will tolerate the prolonged procedure (19).

4) Resource limitations, either lack of surgical skills or equipment or theatre shortages. The shunt is placed to perfuse the periphery while patient is transferred to another facility with adequate resources. This is mostly used in the military. Our centre also has experience with this as our referring peripheral hospitals either do not have the surgical expertise or vascular tools required to perform a vascular repair (20)(19)(21).

5) To perfuse a traumatic amputated limb while preparing for reimplant (20).

The American military experience from *Iraq* and *Afghanistan* shows that patients with TVS had a similar amputation rate as the non-TVS group. All amputations in the non-TVS group was early and due to graft failure. The TVS group had early amputations due to extensive tissue destruction and 2 late

amputations due to graft failure. The shunts were placed at the discretion of the forward surgical teams and not necessarily as a damage control procedure. There was no data on the duration of shunt in situ, shunt thrombosis and fasciotomy from this study (20). There is compelling evidence from the *Balad* vascular registry for the use of TVS (22). The largest civilian series in the US employing TVS (23), shows that damage control shunts have a higher amputation rate than shunts placed for other reasons (23% vs 11%, p= 0.003). The limb salvage rate was 74%, 80% had a prophylactic fasciotomy and 5% delayed fasciotomy. The indwelling shunt time was 23.5 hrs (SD 15.7). There were no shunt thromboses in proximal limb vessels even without systemic anticoagulation. Fourteen percent had secondary amputation due to graft failure, thrombosis, extensive tissue loss and infection. *Asensio's* review has 10% use of PTFE grafts and this was an independent risk factor for mortality (p=0.005). Their reasoning is that PTFE was used because of its immediate availability in patients with higher injury severity scores, patients who have bled out and required major blood transfusions (7). Perhaps this was a missed opportunity for TVS rather than a PTFE graft.

9. COMPLICATIONS

9.1 Mortality :

Proximal vascular injury especially after penetrating trauma has the potential for exanguination and death. *Kauvar et al* showed a mortality rate of 10% for lower extremity trauma with common femoral artery penetrating trauma causing the majority of deaths (24). These patients either arrived with a systolic blood pressure of less than 60 mm Hg or had no measurable blood pressure (40%) on

arrival. It is likely that many proximal lower limb vessel injury patients die and mortality is under reported in the literature. *Asensio's* review had 21% of patients presenting with shock, 1% in cardiopulmonary arrest and 7 more arrested in the emergency unit (7). These seven had an emergency room thoracotomy and aortic cross clamping and 3 (27%) survived. This study identified significant risk factors for
mortality. These were:

- GCS <8 (p=<0.001)
- Injury severity score >25 (p=<0.001)
- Emergency room intubation (p=<0.001)
- Emergency room thoracotomy (p=0.001)
- Abdominal injury (p=<0.001)
- Hypothermia (p=<0.005)
- Coagulopathy (p=<0.001)
- Hypotension during surgery (p=<0.001)

Degiannis's review of penetrating femoral arterial injuries had 4 emergency room cardiac arrests with a 50% mortality (18). The two that died required emergency room thoracotomy and had abdominal injuries too.

9.2 Amputation :

The rate of limb loss after femoral vessel injury is much less than after popliteal artery injury. Primary amputations for unsalvageable injury is 3.6% in the *Degiannis* study (18). This is comparable to other studies like Hafez et al at 4.9% and *Asensio* at 3% (25)(7). The reason for amputation can be either that it is an ischemic limb on presentation, it is a mangled limb with poor

reconstructive potential, or it is a shocked patient with uncontrollable bleeding and ligation is done in an attempt to salvage life over limb.

9.3 Other:

The most common complication after extremity vascular trauma is surgical site infection. *Asensio* and *Cargile* had a 15% and 23% surgical site infection rate, respectively (7)(10). In the latter series, two of the amputations were as a result of ongoing local sepsis progressing to graft sepsis and vascular repair rupture. Nine patients with systemic sepsis were as a result of ongoing myonecrosis following delayed or inadequate debridement. The risk factors associated with surgical site infection in *Asensio's* study were (7):

- Hypothermia (p=<0.001)
- Coagulopathy (p=<0.001)
- Hypotension in OR (p=<0.004)
- Fractures (p=<0.002)

PTFE graft sepsis was the reason for late amputation in two of the four patients in *Feliciano's* study (19). Another late amputation was secondary to chronic osteomyelitis. Five PTFE grafts were exposed due to extensive tissue loss; three of these occluded and one had ruptured due to sepsis.

Neurological deficit is another complication after extremity vascular trauma. The etiology is multifactorial. Prolonged ischemia with irreversible nerve damage, direct injury to a nerve from the primary trauma, iatrogenic injury to the nerve during surgery are the possible causes. *Feliciano et al* had a neurological deficit in 6.9% of their patients, whereas *Cargile et al* had a 13% neurological deficit in their discharged patients (19)(10).

10. CONCLUSION

Femoral vessels are commonly injured. Its superficial location perhaps adds to its risk of being injured during penetrating trauma. The diagnosis can be easily made, based on the presence of hard vascular signs. In the case of soft vascular signs further imaging maybe indicated. In the current era a CT angiogram is adequate for screening the presence of femoral artery injuries. Surgical exploration and repair is the gold standard of management. The injury can be repaired primarily with lateral repair or resection with end-to-end anastomosis, or with an interposition graft when there is loss of length. This can be either a native vein graft or a prosthetic PTFE graft. Concomittant deep venous injuries are repaired or ligated depending on the physiological state of the patient, type of injury and expertise of the surgeon. Temporary vascular shunts are placed in certain circumstances, a damage control situation is the most common scenario for this. The risk of amputation is higher in this group of patients. Fasciotomy of the lower limb is performed for established compartment syndrome or for patients with prolonged ischemia and concomitant venous and arterial injuries. Delay to fasciotomy increases the risk of limb loss.

The length of ischemic time is the most important determinant of limb outcome. Ideally the repair should occur within 4 to 6 hours of injury. Other factors contributing to limb loss is compartment syndrome and damage control procedure requiring temporary vascular shunting. It is not clear from the literature whether concomittant venous injuries and femur fractures are a risk factor for limb loss.

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CHAPTER 2

PUBLICATION READY MANUSCRIPT

PENETRATING FEMORAL ARTERY INJURIES: AN URBAN TRAUMA CENTRE EXPERIENCE

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ABSTRACT

Aim

This study aims to review a single center experience with femoral artery injuries and identify factors associated with limb loss.

Patients and Methods

The data of all patients with femoral artery injuries admitted to the Trauma Centre at Groote Schuur Hospital from January 2002 to December 2012 was reviewed. These were analysed for demographics, injury mechanism, perioperative and surgical management. Outcome was grossly categorised by limb salvage.

Results

There were 158 patients with femoral artery injuries, 144 men and 14 women with a mean age of 28. Ninety-five percent had penetrating injuries. The most common artery injured was the SFA (87%). The most common type of arterial injury was a laceration (39%) and transection (37%). Eighty-one patients had a primary repair (51%), fifty-three patients had a vein interposition graft (33%) and sixteen patients (10%) had a prosthetic graft. There were 78 (51%) concomitant venous injuries, 11 were repaired and 1 vein patch was done (15.4%). The rest were ligated (84.6%). There were 4 (2.5%) primary amputations and 10 (6.5%) secondary amputations. One primary amputation resulted from a delay to theatre with a threatened limb. The other three presented with established ischemia. Nine of the ten secondary amputations presented with a threatened limb. One viable limb was lost due to bleeding from a false aneurysm secondary to sepsis. One secondary amputation was the

result of a delayed fasciotomy for compartment syndrome post revascularisation. The rest were due to prolonged ischemic time despite attempted revascularization. There were no deaths in this study. Univariate analysis showed that statistically significant risk factors for secondary amputation were: presentation with signs of a threatened limb ($p<0.0001$) , presence of neurological deficit due to ischemia ($p<0.001$), the temporary vascular shunt group ($p<0.001$) and the lack of a palpable distal pulse post repair ($p<0.01$). Statistically insignificant factors were: concomitant femur fracture, compartment syndrome, fasciotomy, unstable hemodynamics on presentation, venous ligation and ‘In hospital ischemia time’.

Conclusion

The outcome of threatened limbs due to femoral vessel injury is good provided there is no delay to surgery. This study has a primary amputation rate of 2.5% and secondary amputation rate of 6.5%, 91% of the limbs were salvaged.

ARTICLE TEXT

Civilian vascular injuries form a significant workload in urban trauma centers. Following brachial artery injuries, femoral vessel injuries are the second most common peripheral vascular injury seen in our center. The purpose of this study was to review our experience with femoral artery injuries in a busy urban trauma center with a high incidence of penetrating trauma and to identify factors associated with limb loss.

Material and Methods

The medical records of all patients admitted to the trauma centre at Groote Schuur Hospital who underwent surgery for a femoral vessel injury during the eleven-year period, January 2002 to December 2012, was retrospectively reviewed. These were analysed for demographics, injury mechanism, perioperative management, intraoperative findings, type of repair, need for fasciotomy and complications. Patients were initially assessed and resuscitated along Advanced Trauma Life Support (ATLS®) guidelines. Hard vascular signs were defined as pulsatile bleeding, expanding / pulsatile haematoma, bruit or thrill, absent distal pulses or signs of distal ischemia. Soft signs were defined as stable haematoma, transient hypotension, proximity injury, peripheral nerve deficits, history of spontaneously arrested bleeding and diminished distal pulses. The presenting limb status was categorised into viable (Rutherford I), acute ischaemia ("threatened", Rutherford IIa and IIb) or non-viable (Rutherford III) limbs. Injury severity was categorised using the revised trauma (RTS) and injury severity scores (ISS). Patients presenting with shock, either from femoral vessel injury or other concomitant injuries were taken for emergency exploration. Hemodynamic stable patients, and those who stabilised after

simple resuscitation underwent further evaluation. Stable patients with distal ischaemia were either explored immediately or underwent emergency room one-shot Lodox Statscan® arteriography followed by immediate exploration. Angiography was performed in cases of suspected femoral artery injury in hemodynamically stable patients with a viable limb, and a pulse discrepancy or large hematoma or bruit / thrill. Exposure of the femoral artery was approached with a medial incision in the line of the sartorius muscle. Extra-peritoneal proximal control of the external iliac vessels was performed for very proximal CFA injuries. The repair of the artery was either by direct tension-free primary repair, the use of interposition saphenous vein or synthetic polytetrafluoroethylene (PTFE) grafts. Temporary shunting was performed as a damage control procedure in multiple trauma patients with other life-threatening priorities. All patients with pre-operative neurological deficit and those found to have a nerve injury intra-operatively were referred to the orthopaedic surgery department for further evaluation and treatment. All patients were administered a prophylactic dose of a first-generation cephalosporin antibiotic in the perioperative period and continued for a further 24 hours post operatively. All wounds were routinely copiously lavaged with saline. Associated injuries, particularly those to the femoral veins, nerves and femurs were documented. Indications for fasciotomy were clinical evident or impending compartment syndrome; ischemic time > 6 hours, prolonged hypotension, and combination of bony, arterial and or venous injury and gross swelling of the lower limb. Fasciotomy consisted of the standard double incision for four-compartment calf fasciotomy, and double incision for three-compartment thigh fasciotomy.

The study was approved by the local Human Research Ethics Committee (HREC) of the University of Cape Town. (HREC no: 177/2010)

A retrospective folder review was done and a data collection proforma completed. This data was transferred to an Excel spreadsheet on the principal investigator's computer which is password protected. Patients are identified with a folder number and no personal information was captured.

The data collected included:

- Demographics - age, gender
- Mechanism of injury: penetrating/blunt, gunshot, stab, road traffic accident, falls
- Vital signs on admission: blood pressure, heart rate, respiratory rate, Glasgow coma score
- Haemoglobin
- Associated injuries
- Lactate, pH
- Clinical signs – pulse status, bruit, thrill, pulsating or non-pulsating hematoma, neurological fallout, bleeding
- Limb status: viable/ threatened/ non-viable
- Presence of compartment syndrome
- Special investigations: emergency room angiogram, digital subtraction angiogram, CT angiogram
- Time to surgery from admission
- Type of repair- primary or graft, vein or prosthesis
- Temporary vascular shunt

- Concomitant venous injury: ligation or repair
- Fasciotomy
- Amputation: primary or secondary
- Morbidity
- Mortality

RESULTS

One hundred and fifty-eight patients (158) with injuries to the femoral artery were included in this study. There were 144 men and 14 women, with a mean age of 28 years (range 15 – 71, SD 9.3). One-hundred and fifty patients (95%) had penetrating trauma and eight (5%) had blunt trauma. Of the 150 patients with penetrating trauma, there were 112(72%) gunshot injuries and 38 (24%) stab injuries. (**Table 1**)

The mean systolic blood pressure was 120 mmHg (range 40-185, SD 25.2). The mean heart rate was 100 beats per minute (range: 53 – 150, SD 21). Thirty-three patients (21%) were hypotensive (systolic blood pressure < 90 mmHg) on arrival. The mean finger prick hemoglobin estimation on admission was 9.5 G/dL (range 3.5 – 16, SD 2.4). The mean respiratory rate was 18 breaths per minute (range 12-35, SD 4). Sixty-three (40%) patients had a pH recording, with a mean of 7.3 (range 7.27 - 7.63, SD 0.12). Lactate levels were available in 56 patients (35%), with a mean of 4.3 mmol/L (range 0.5 - 13, SD 3). The mean Injury Severity Score (ISS) was 18 (range 16 - 41, SD 5.2). The mean revised trauma score (RTS) was 7.656 (range 4.502 - 7.841). Associated injuries are listed in **Table 2**.

Distal pulses (d*orsalis pedis* and / or p*osterior tibial*), on admission were absent in eighty-eight patients (56%), while forty-nine patients (31%) had a diminished distal pulse and twenty-one (13%) had normal distal pulses.

One-hundred-and-twenty (76%) patients presented with hard signs of a vascular injury. On neurological evaluation, twenty-two (14%) patients had a global motor deficit of the lower limb suggesting advanced severity of muscle ischemia (Rutherford IIb). The soft vascular signs included 31 (19%) non-

pulsatile hematomas, and a diminished pulse in 49 (31%) cases. The limbs were classified as *non-viable* 3 (2%), *threatened* 70 (44%) or *viable* 85 (54%). (**Table 3**) Thirty-four patients (22%) had a compartment syndrome on presentation.

Imaging of the femoral vessels was performed in 101 (64%) patients. Emergency room angiography (LODOX™) was done in 25 (16%) cases. A formal or a computed tomographic angiography was performed in seventy-six (48%) cases. Abrupt cut-off of the affected vessel was the most common finding. **Table 4** shows the breakdown of the various investigations and findings.

Emergency exploration was performed in 115 patients (73%), including 12 temporary vascular shunts and 3 primary amputations (+1 threatened limb on admission with a delay to surgery - see later).

At surgery, the most commonly injured vessel was the superficial femoral artery in 137 (87%) cases. The profunda femoral artery was injured in 5 (3%) patients and the common femoral artery was injured in 16 (10%) patients. Two patients with profunda artery false aneurysms were managed by endovascular coil placement. The most common injury found was a complete transection of the vessel (39%), followed by a partial laceration (37%). The femoral artery was repaired primarily in eighty-one (51%) patients. Fifty-three (36.8%) with a reverse saphenous vein grafts (RSVG) and sixteen (11%) prosthetic grafts were used. (**Table 5**)

There were seventy-eight (51%) femoral vein injuries; sixty-six (85%) of these were ligated. Eleven had simple repairs and one patient had a vein patch.

Twelve patients required a damage control procedure with a temporary vascular

shunt. Of these twelve, four had secondary amputations and eight were salvaged.

Fourteen (8.8%) patients had an amputation; four (2.5%) patients required a primary amputation. Three of these were delayed presentations with irreversible ischemia on admission and one patient with a threatened limb on admission and delay to surgery lost his limb. Ten patients (6.3%) required secondary amputation. Nine had a threatened limb on admission. One patient with a viable limb and successful primary repair of a SFA injury complicated with sepsis and anastomotic suture line rupture, resulting in amputation. There were four delayed fasciotomies for untreated compartment syndrome and one of these resulted in an amputation. The fourteen amputations are summarized in **table 6**.

The in-hospital ischemic time for the threatened limbs was five-and-half hours in the amputation group and six-and-half hours in the salvage group.

The viable limbs were operated on the next-day semi-urgent list.

The average length of stay was 12 days, the earliest discharge being on day 2. The longest stay was 134 days, but was related to multiple long bone fractures, requiring several orthopedic operative interventions and rehabilitation.

Univariate analysis with two tailed *p*-value for risk of secondary amputation was done for the following variables: venous ligation, hemodynamic instability, threatened limb, fasciotomy, compartment syndrome, temporary vascular shunt, femur fracture, absent post operative pulse distally and in hospital ischemia time. (**Table 7**)

The statistically significant risk factors for amputation following femoral artery injury are: threatened limb on admission, the use of a temporary vascular shunt and absent post-operative distal pulses.

The mortality rate was 0% for surgically managed patients. The complications are tabulated in **Table 8.** All graft occlusions proceeded to an amputation. There were two early anastomotic false aneurysms that presented with bleeding. They both had a primary anastomosis during their index procedure. One patient however lost his limb. Patients with groin sepsis were managed conservatively with antibiotics, removal of sutures and drainage. There was a single patient with a PTFE graft sepsis. The peri-graft purulent collection was drained and he was treated with prolonged antibiotics according to cultures. The sepsis resolved and the graft was salvaged.

Fifteen patients (9.5%) had postoperative neurological deficit of varying degrees. Six had preoperative evidence of a peripheral nerve injury. The remaining patients had a threatened limb on presentation, which required a fasciotomy. It is not clear from the folder notes whether the neurology was secondary to ischemia or due to nerve injury (either from the trauma or iatrogenic during fasciotomy). Four patients had a seroma. These cases were managed expectantly and resolved without intervention. One patient had a pulmonary embolism at six months from index procedure. This patient suffered a GSW with SFA and femoral vein injury, and a femur fracture. The vein was ligated and the artery was repaired with a vein graft (RSVG). A compression ultrasound showed a femoral vein DVT proximal to ligation. One patient with an

anastomotic stenosis presented with claudication and was further managed by the Vascular Surgery unit.

DISCUSSION

Penetrating and blunt trauma to the femoral artery accounts for 85% and 15% of injuries, respectively (1). In civilian trauma, the incidence of femoral vessel injury is as high as 70% of all peripheral vascular injuries (1). The incidence of penetrating femoral artery injury at our institution is 18% and is the second most common peripheral vascular injury seen, following brachial artery trauma (2). When considering all vascular trauma, the incidence of femoral artery injuries is 26% (1). Cargile et al looked at all femoral vascular injuries; there were 48% isolated arterial injuries, 15% isolated vein injuries, and 36% had both vessels injured (3).

The rate of limb loss after femoral vessel injury is much less than after popliteal artery injury. Primary amputations for unsalvageable injury is 3.6% in the *Degiannis* study (4). They noted that the four amputees in their group had an ischemic time of more than five hours. This amputation rate is comparable to other studies like Hafez et al at 4.9% and *Asensio* at 3% (5)(1). The reasons for amputations are: an ischemic limb on presentation; a mangled limb with poor reconstructive potential; or a shocked patient with uncontrollable bleeding and ligation is done in an attempt to salvage life over limb.

The total amputation rate in this study was 8.8%. The primary amputation rate was 2.5% and secondary amputation rate was 6.3%. This is higher than in all the published studies of civilian femoral artery injuries post World War I (1)(3)(4)(5). *Cargile et al,* had an amputation rate of 4.7% (3). However, their total incidence of a permanent non-functional limb (including the amputations)

was 9%. This comprised of limbs with severe nerve, soft tissue, bone injuries, amputation and venous edema.

The statistically significant risk factors in our study for amputations were: presence of ischemia on admission, the use of temporary vascular shunts and lack of post –operative distal pulses. Even though there was no statistically significant difference between the in hospital ischemic time in the amputation and salvage groups in our study, the mean waiting times in both groups was longer than five hours. This does not include the out-of hospital ischemic time. This may have contributed to the higher rate of secondary amputations. Surgery in patients with threatened limbs should be expedited. The mean waiting time of five-and-a-half hours is too long. Vascular injuries with threatened limbs should be prioritized to undergo surgery immediately. This will need a multifaceted approach. Awareness among paramedics, ER staff, theater staff, anesthetists, and surgeons should be raised and protocols should advocate for a shorter time interval to theater.

In this study, the deployment of temporary vascular shunts (TVS) was only for damage control. Twelve patients had a TVS and four (33%) of these proceeded to an amputation. This amputation rate is higher than published civilian data for damage control shunts (23%) (6). The American military data from the *Balad registry* had an amputation rate of 13% in the TVS group. The indication for shunt use in the *Balad registry* was, however, varied and not inclusive of damage control procedures (7). The current recommendations for TVS in peripheral vascular injury are:

1) Damage control for an exsanguinated shocked patient who have one or more of the following despite ongoing resuscitation: PH <7.2, base

excess >10.5 and Temperature of <35 degrees Celcius. This is extrapolated from damage control surgery principles for abdominal trauma.

2) Damage control in a polytrauma patient with multiple injuries or multiple cavity injuries needing surgical attention.

3) In cases with severe fracture where the shunt is placed to perfuse the periphery while bony injuries are fixed. The vessel is repaired after this during the same operation. This is for stable patients who will tolerate the prolonged procedure.

4) Resource limitations, either lack of surgical skills or equipment or theatre shortages. The shunt is placed to perfuse the periphery while patient is transferred to another facility with adequate resources. This is mostly used in the military. Our centre also has experience with this as our referring peripheral hospitals either do not have the surgical expertise or vascular tools required to perform a vascular repair.

5) To perfuse a traumatic amputated limb while preparing for reimplant.

Another risk factor for amputation in this study was a diminished or absent foot pulse, post-repair. These patients did not routinely have completion angiography. It was logistically difficult to do previously; however now, every patient without a palpable distal pulse post vascular repair undergoes a completion angiography with the assistance of the vascular surgeons. The

angiogram can identify any anastomotic or distal thrombo-embolic events; and these can be addressed immediately.

Patients that presented with hemodynamic instability did not have an increased risk for limb loss. Since patients were deemed unstable on a once-off admission vital sign, this perhaps does not represent the shocked patients well. The temporary vascular shunt group probably represents the *unstable* group of patients better. Ongoing shock in this regard definitely increases the risk of limb loss.

About half (51%) of the repairs were done primarily, including one patient in the shunt group. Low velocity GSWs and stab injuries resulted in less destruction of the arterial wall, making primary repair possible. RSVG was done in 33% of patients only, 10% of the patients had a prosthetic graft (PTFE). Risk of graft sepsis, especially with extensive soft tissue destruction, has driven the preferential use of native vein graft. In this study there was one case of graft sepsis and this was salvaged with drainage of peri-graft collection and antibiotics. The long-term graft patency outcomes for young trauma patients are unknown. The median age of injury was 28 years, making it likely that these patients will have to live with a prosthetic graft for longer than the average patient with peripheral vascular disease.

Femoral vein injuries was managed mostly with ligation (85%). Of the 66 ligated venous injuries, four had some residual minor limb edema in the early postoperative period (6%).

Because of the lack of long term follow up, the true incidence of chronic limb edema and venous stasis complications in these patients remain unknown.

None of the minor venous repairs or vein patches had thrombotic or edema-

related complications in the immediate postoperative period. When more heroic venous reconstructions are performed, the thrombotic and embolic complications seem to increase, as shown in Cargile's review (3). They performed 131 venous repairs of which 69 were lateral repairs and 50 complex repairs. Eighteen of these thrombosed (14%). Four patients developed a pulmonary embolism (PE). Thirty-four percent had some venous morbidity described as either DVT or limb edema, severe enough to require treatment. Two-and-a-half percent of patients suffered the development of PE. The venous morbidity in this study was significantly higher and seems related to the complexity of the repairs.

In this study, 70% of the secondary amputations had a concomitant femoral vein injury that was ligated. Statistically, venous injuries were not a significant risk factor for limb loss. However in the secondary amputation group a concomitant venous injury was 2.3 times more likely to occur.

Simple lateral repair or interposition vein graft repair should be attempted when possible, especially after reperfusing a threatened limb.

It is paramount to address established compartment syndrome with an expeditious decompression to salvage the limb (8). In our review four patients had a delayed fasciotomy of which one resulted in limb loss. The surgeon needs to be aware of the risk factors for developing compartment syndrome and perform a prophylactic fasciotomy as necessary. The risk factors of compartment syndrome include prolonged ischemia, concomitant venous injuries, long bone fractures and crush injury (8)(9). In this study, patients who had a fasciotomy had a lower risk of amputation.

This review showed no mortalities. The reasons for this could be multifactorial. We only looked at data of patients that had an operation. This excluded the patients that demised in the emergency unit. Furthermore, there is a significant delay in transporting the patients from the scene to the level I
unit. Hemodynamically unstable patients could have demised *en-route* or at the scene. The retrospective nature of this study with patient selection from operative notes imposed bias, as the pre-operative mortalities would have been missed.

Five percent of patients in Asensio's review had an emergency room thoracotomy, aortic cross clamping, and open cardiopulmonary resuscitation. Three (27%) of the 11 patients survived (1). The paper does not mention the exact vessel involved in these patients or whether they had multiple injuries. Extremity vascular injury can be controlled with direct pressure, compression dressing, foley's catheter tamponade, tourniquets and other techniques. EDT is an extreme measure in an exsanguinating patient, perhaps also when the injured vessel is the proximal common femoral artery with difficulty in controlling bleeding with the above mentioned techniques. The other presumed benefit of cross clamping is the increase in afterload and increase in cardiac output, with better perfusion of the coronaries and brain, while decreasing blood loss via lower limb bleeder.

In summary the risk factors identified for limb loss in this study were:

1. Reversible ischemia – threatened limbs
2. Pulse deficit following repair
3. TVS group

Other potential risk factors for limb loss that were not statistically significant were:

1. Delayed fasciotomy
2. Sepsis with false aneurysm
3. Delay to surgery, prolonged ischemic time
4. Femoral vein ligation (indeterminate risk factor)

To improve our amputation rate, the following is recommended:

1. Expedite surgery, even more so for threatened limbs, especially if motor neurological deficit is present.
2. Compartment syndrome can present before or after repair. For high risk patients (prolonged ischemia, concomitant venous injuries, long bone fractures and crush injury); a prophylactic fasciotomy is justified. A delayed fasciotomy can lead to limb loss.
3. Identify reversible causes of an absent distal pulse after repair with completion on table angiography. Findings of which could guide embolectomy and / or redo of the anastomosis. There is, however, a group of patients that have established distal thrombus who are at very high risk for subsequent limb loss.
4. Damage control TVS can save life and limb. Patient selection is key. However, the amputation rate in these patients is significantly higher.

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Table 1: Mechanism of injury distribution

		(N)	*(%)*
Penetrating		150	*95*
	GSW	112	*72*
	Stab	38	*24*
Blunt		8	*5*
	MVA	6	*4*
	PVA	1	
	Fall	1	
Total		158	*(100)*

GSW: Gun shot wound
MVA: Motor vehicle accident
PVA: Pedestrian vehicle accident

Table 2: Associated injuries

	N	%
Femur fracture	36	*23*
Other fractures	19	*12*
Laparotomy	13	*8*
Hemo or pneumothorax	9	*5.7*
Soft tissue injury	18	*11*
Spinal cord injury	1	*0.6*
Mangled limb	1	*0.6*
Head Injury (no craniotomy needed)	8	*5*

Table 3: Vascular assessment on presentation

	(N)	*(%)*
Hard signs *	120	*76*
Pulse deficit	70	*44*
Active bleeding	28	*17*
Bruit	24	*15*
Pulsatile hematoma	13	*8*
Motor deficit	22	*14*
Sensory deficit	14	*9*
Soft signs	38	*24*
Hematoma	31	*19*
Diminished pulse	49	*31*
Viability of limb		
Threatened limb	70	*44*
Viable limb	85	*54*
Non-Viable limb	3	*2*

*Some patients had more than one sign and therefore total will not add up i.e. absent distal pulse and muscle ischemia, bleeding or bruit proximally

Table 4: Imaging modality and findings

			Cut-off	AVF	FA	Filling defect	Inconclusive
DSA/CTA	76		19	13	27	14	2
ERA	25		14	5	3	2	3
Total	***101***		***33***	***18***	***30***	***16***	***5***

DSA – Digital subtraction angiogram
CTA – Computer tomography angiogram
ERA- Emergency room angiogram (done on LODOX™ machine)
AVF – Arterio-venous fistula
FA – False aneurysm

Table 5: Intra-operative findings and procedure performed

		Transection	Laceration	Intimal injury	False aneurysm	AVF
Intra-operative findings						
Emergency	117	52	44	13	4	4
Semi-elective	41	9	14	5	8	5
Total		***61 (39%)***	***58 (37%)***	***18 (11%)***	***12 (8%)***	***9 (5%)***
Procedure performed						
Primary repair	81(51%)	26	31	9	9	6
RSVG	53 (33%)	20	21	6	3	3
PTFE	16 (10%)	10	5	1		
Shunt	12 (7.6%)	9	2	1		
Primary amputation	4 (2.5%)	2	1	1		

The procedures do not add up to 158 as some patients had more than one procedure, i.e. shunt first then anastamosis and PTFE after failed primary anastamosis.

Table 6: Summary of patients with amputations

No	Mech	Vessel	Vein	Vital	ISS	Limb	Fasc	Shunt	Femur frac	Other trauma	Post op pulse	Neurology	Amp
1	GSW	CFA	L	Un	20	V	+P	-	-	+	+	-	
2	GSW	SFA	L	Un	16	T	+T	-	-	-	+	-	
3	Stab	SFA	-	S	16	T	+T	-	-	-	+	M	
4	GSW	SFA	-	S	16	D	-	-	-	-	-	M/D	P
5	MVA	SFA	-	S	25	D	-	-	-	-	-	M/D	P
6	GSW	CFA	L	Un	25	T	+T	+	-	-	+	M	
7	GSW	CFA	L	Un	16	T	+D	+	+	-	+	-	
8	GSW	SFA	-	S	20	T	+T	-	+	+	+	M	
9	PVA	SFA	-	S	17	T	-	-	-	-	-	S	P
10	GSW	SFA	L	S	20	T	+P	-	+	+	A	-	
11	Stab	SFA	-	Un	16	D	-	-	-	-	-	M/D	P
12	GSW	SFA	L	S	16	T	+T	+	-	-	A	M	
13	GSW	SFA	L	S	16	T	+P	-	-	-	A	-	
14	GSW	SFA	-	S	16	T	+T	+	+	-	A	M	

GSW= Gun shot wound, Stab= stab wound, MVA= Motor vehicle accident, PVA= Pedestrian vehicle accident, CFA= Common femoral artery, SFA= Superficial femoral artery, L= ligation, Un= Unstable hemodynamics, S= Stable hemodynamics, V= Viable, T= Threatened, D= dead, non-viable, fasc= fasciotomy, p= Prophylactic, += yes, -= No, M=Motor deficit, M/D= Motor deficit with a non viable limb, S= sensory deficit, p= Primary amputation

Table 7 : Risk factors for secondary amputation

	***p*-value**
Venous ligation	0.12
Hemodynamic instability	0.27
Threatened limb	<0.0001
Fasciotomy	0.71
Compartment syndrome	0.09
Temporary vascular shunt	<0.001
Femur fracture	0.38
Absent post op foot pulse	<0.01
In hospital ischemia time	0.26

Table 8: Complications

	N	%
Limb complications		
Graft occlusion	5	*3*
Trifurcation embolus	4	*2.5*
False aneurysm- Anastomosis	2	*1*
Anastomotic bleeding	1	*0.6*
Profunda false aneurysm	2	*1*
Bleeding	6	*4*
Surgical site infection	34	*21.5*
Neurological deficit	15	*9.5*
Seroma	4	*2.5*
DVT	1	*0.6*
Limb edema	4	*2.5*
Anastomotic stenosis	1	*0.6*
Systemic complications		
Pneumonia	3	*1.9*
Pulmonary embolism	1	*0.6*

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Please need to sign declaration form FHS013. 2/6/15

HUMAN RESEARCH ETHICS COMMITTEE

- 2 JUN 2015

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

Form FHS007: Amendment - study staff

HREC office use only (FWA00001637, IRB00001938)			
Approved			
This serves as notification that all changes to the study staff and documents have been approved.			
Chairperson of the HREC signature		Date	3/6/2015

Principal Investigator to complete the following:

1. Protocol information

Date (when submitting this form)	02/6/15
HREC REF Number	177/2010
Protocol title	Penetrating femoral artery injuries - an urban trauma centre experience
Protocol number (if applicable)	–
Principal Investigator	Dr S. Rayamajhi
Department / Office	J45 General Surgery
1.1 Does the protocol require US Federal funding?	Yes / **No**

2. Items for approval

Please fill in the page. [illegible]

3. List of documentation (eg: CVs, Declarations & GCP Certificates)

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

4. Staff changes (tick ✓)

Are new personnel being added to the research?	**Yes**	No
Are current personnel being removed from the research?	Yes	**No**
Is the principal investigator for the research being changed?	**Yes**	No
If yes, please attach [illegible]		
Do the research staff changes [illegible]	Yes	**No**
If yes, [illegible]		

5. Signature

My signature [illegible]

Signature of PI	Dr S. Rayamajhi	Date	2/6/15