European Journal of Trauma and Emergency Surgery (2019) 45:909–917
https://doi.org/10.1007/s00068-018-0951-6

ORIGINAL ARTICLE

Penetrating femoral artery injuries: an urban trauma centre experience

Shreya Rayamajhi[1,2,4] · Nivashini Murugan[1,2,4] · Andrew Nicol[1,2,4] · Sorin Edu[1,4] · Juan Klopper[2,4] · Nadraj Naidoo[2,3,4] · Pradeep Navsaria[1,2,4]

Received: 11 January 2018 / Accepted: 30 March 2018 / Published online: 4 April 2018

Abstract

Aim This study reviews a single centre experience with penetrating femoral artery injuries.

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

Results One-hundred and fifty-eight (158) patients with femoral artery injuries were identified. There were 144 (91%) men and 14 women with a mean age of 28 years. Ninety-five percent ($N=150$) sustained penetrating injuries. The superficial femoral artery (87%) was most commonly injured. The most common type of arterial injury was a laceration (39%) and transection (37%). Eighty-one (51%) patients had a primary repair, 53 (33%) patients had a vein interposition graft, and 16 patients (10%) had a prosthetic graft. There were 78 (51%) concomitant venous injuries, 11 were repaired, and 1 vein patch repair was performed (15.4%). There were 4 (2.5%) primary amputations and 10 (6.5%) secondary amputations. There were no deaths. Statistically significant risk factors for secondary amputation derived by univariate analysis were: ischaemia ($p<0.0001$), neurological deficit due to ischemia ($p<0.001$), temporary vascular shunting ($p<0.001$), and the absence of a palpable pulse post-repair ($p<0.01$).

Conclusion This study has a primary and secondary amputation rate of 2.5 and 6.5%, respectively. There was greater than 90% limb salvage rate. The outcome of threatened limbs due to femoral artery injury is good, provided that there is no delay to surgery.

Keywords Femoral artery · Penetrating trauma · Amputation

Background

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. Limb loss with penetrating femoral artery injuries is low. This study is an audit and evaluation study of our experience with penetrating femoral artery injuries. The primary outcome and secondary outcomes are to determine the amputation rates and to identify risk factors associated with limb loss, respectively.

Materials 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 11-year period, January 2002–December 2012, was retrieved and reviewed. A hard copy of all surgical procedures is filed and maintained in the unit. All the operation notes that included a femoral vessel exploration were manually retrieved and the patients' medical

✉ Pradeep Navsaria
pradeep.navsaria@uct.ac.za

1 Trauma Center-C14, Observatory, Groote Schuur Hospital, Cape Town 7925, South Africa

2 Department of Surgery, Groote Schuur Hospital, Cape Town 7925, South Africa

3 Division of Vascular Surgery, Groote Schuur Hospital, Cape Town 7925, South Africa

4 Faculty of Health Sciences, University of Cape Town, Cape Town, South Africa

records were then requested and data manually captured on an Excel spreadsheet. These were analysed for the basic demographics, injury mechanism, perioperative management, intra-operative 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 ischemia. Soft signs were defined as stable haematoma, transient hypotension, proximity injury, peripheral nerve deficits, and history of spontaneously arrested bleeding and diminished distal pulses. The presenting limb status was categorised as viable (Rutherford I), acute ischaemia or "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 in shock, either from femoral vessel injury or from 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 limb ischaemia were either explored immediately or underwent emergency room one-shot Lodox Statscan® arteriography followed by immediate exploration. Emergency room angiography using the Statscan® machine (Lodox Ltd, Industrial Development Corporation, Johannesburg, South Africa) machine was performed in the resuscitation suite exclusively by the emergency unit staff. After being placed on a resuscitation table designed specifically for the Statscan unit, an 18 gauge plastic intravenous cannula was inserted in retrograde fashion into the common femoral artery via direct puncture. An intravenous extension set was then attached to the cannula to aid in positioning the operator's hands away from the visualized area. Thirty millilitres of a non-ionic, water-soluble iodinated contrast material (Ultravist 300, Schering Ltd., Berlin, Germany) was rapidly injected by hand into the artery. The Statscan machine was then activated to image the limb just prior to completion of the contrast bolus. A digital image of the arterial system was available for interpretation within 13 s. Typically, this procedure required less than 10 min to complete in its entirety. If needed, lateral and/or oblique views could be obtained as well (Fig. 1) [1]. Formal angiography, and more recently in the last 5 years, computerised tomographic angiography in the radiology department was performed by the radiology department 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 (Fig. 2a). Temporary shunting was performed as a damage control procedure in multiple trauma patients with other life-threatening priorities (Fig. 2b). All patients with pre-operative neurological deficit and those found to have a nerve injury intra-operatively were referred to the orthopedic 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 h post-operatively. Intra-operative systemic heparin was administered 1-min prior to proximal control of the femoral artery. In addition, local heparin was copiously injected to flush proximal and distal limbs of the injured artery.

Post-operative continuous heparin was administered for 48 h to those who underwent trifurcation exploration and embolectomy. All other patients, including those with femoral vein ligation, received heparin subcutaneously (low-molecular weight heparin in the latter 5 years) as DVT prophylaxis routinely. No long-term anticoagulation was prescribed on discharge. All wounds were routinely copiously lavage 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 h, prolonged hypotension, and combination of bony, arterial, and/or venous injury. Compartment syndrome was clinical diagnosis. 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).

The data collected included: age, gender, mechanism of injury: penetrating/blunt, gunshot, stab, road traffic accident, falls, and vital signs on admission: blood pressure, heart rate, respiratory rate, Glasgow coma score, hemoglobin, 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, and 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 (95%)

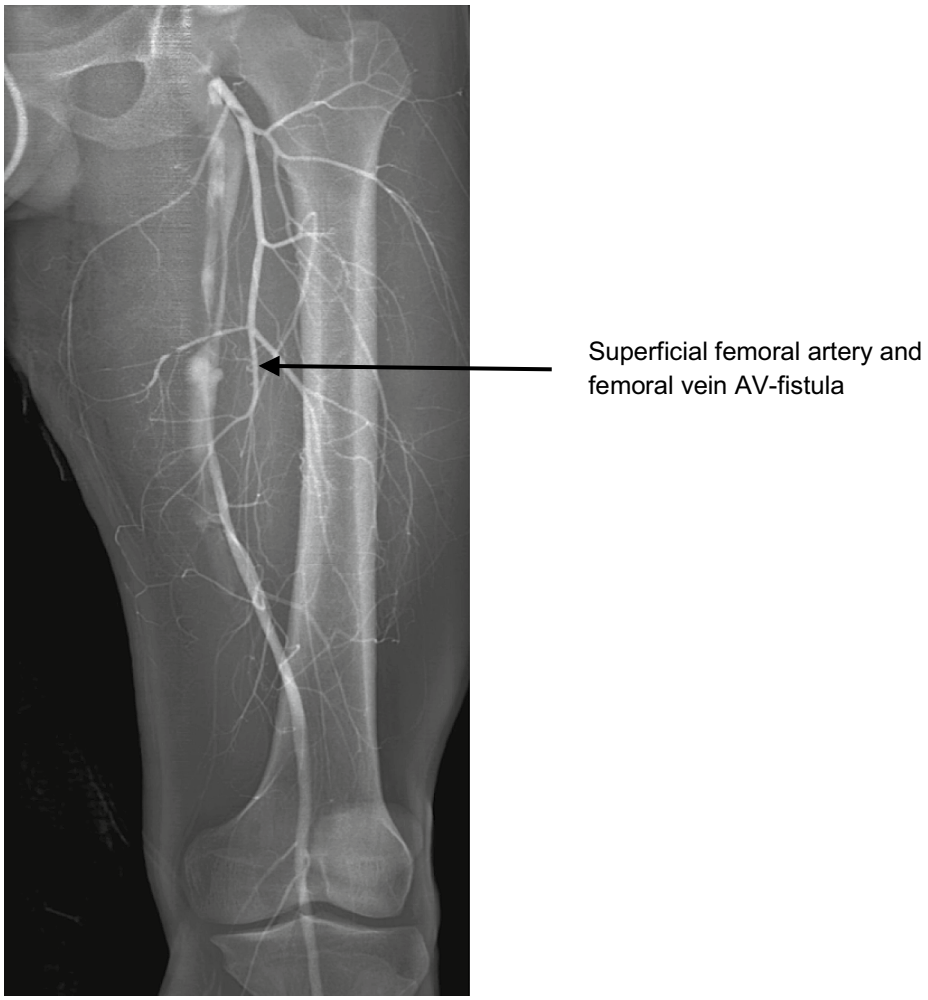

Fig. 1 Statscan® single-shot emergency room angiogram showing arterio-venous fistula

patients sustained 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). One blunt injury had a laceration, and three had established thrombus with presumed intimal injury (two of which lost a limb). Four patients were noted to have an intimal injury at exploration.

Two of the eight blunt injuries lost limbs. The mean systolic blood pressure and heart rate were 120 mmHg (range 40–185, SD 25.2) and 100 beats per minute (range 53–150, SD 21), respectively. 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 (dorsalis pedis and/or posterior tibial), on admission, were absent in 88 patients (56%), while 49 patients (31%) had a diminished distal pulse and 21 (13%) had normal distal pulses. One-hundred and twenty (76%) patients presented with hard signs of a vascular injury. On neurological evaluation, 22 (14%) patients had a global motor deficit of the lower limb suggesting advanced 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/ischemia 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 76 (48%) cases. Abrupt cutoff of the affected vessel was the most common finding. Table 4 depicts the various vascular

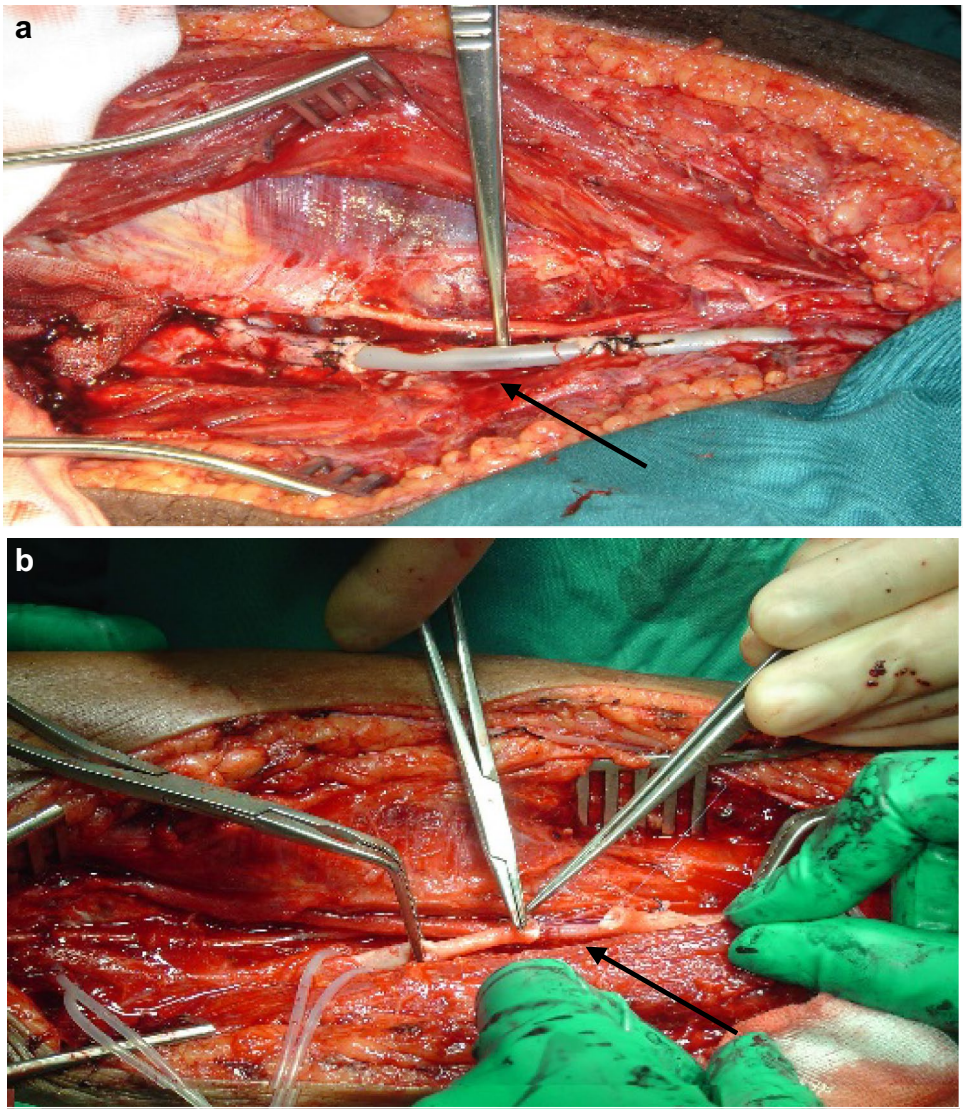

Fig. 2 **a** Shunted femoral artery (bold arrow). **b** Femoral artery undergoing primary repair (bold arrow)

Table 1 Mechanism of injury distribution

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

GSW gunshot wound, *MVA* motor vehicle accident, *PVA* pedestrian vehicle accident

Table 2 Associated injuries

Associated injury	*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

investigations and findings thereof. Emergency exploration was performed in 115 patients (73%), including 12 temporary vascular shunts and 4 primary amputations. At surgery, the most commonly injured vessel was the superficial femoral artery in 137 (87%) patients. 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

Table 3 Vascular assessment on presentation

	(*N*)	(%)
Hard signs[a]	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

[a]Some patients had more than one sign

by endovascular coil placement. The most common type of injury was a complete transection of the vessel (39%), followed by a partial laceration (37%). The femoral artery was repaired primarily in 81 (51%) patients, 53 (36.8%) with a reverse saphenous vein graft (RSVG), and 16 (11%) with prosthetic grafts (Table 5).

There were seventy-eight (51%) femoral vein injuries; 66 (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 12, 4 had secondary amputations.

Fourteen (8.8%) patients had an amputation; 4 (2.5%) patients had a primary amputation. Three of these were delayed presentations with irreversible ischemia on admission and 1 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 an SFA injury complicated with sepsis and anastomotic suture line rupture, resulting in SFA ligation and subsequent amputation. There were four delayed fasciotomies for untreated compartment syndrome and one of these resulted in an amputation. The 14 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.

Table 4 Imaging modality and findings

		Cutoff	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 anastomosis and PTFE after failed primary anastomosis

RSVG reverse saphenous vein graft, *PTFE* polytetrafluoroethylene graft

Table 6 Summary of patients with amputations

No	Mech	Vessel	Vein	Vital	ISS	Limb status	Fasc	Shunt	Femur fracture	Other trauma	Post-op pulse	Neurology	Am
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

Significant values are in bold ($p < 0.05$)

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

DVT deep vein thrombosis

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. The five 5 graft occlusions (PTFE 1, RSVG4) were noted at secondary amputation. Whether this was due to a poor flow state of an already suspected ischaemic limb with progressive thrombosis is not known. The correct assumption would be technical failure! The four trifurcation emboli trashing were detected intra-operatively (1), post-operatively within 24 h (2) and 36 h (1). Trifurcation exploration and embolectomy resulted in limb salvage in all four patients. 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 surgical site 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 post-operative neurological deficit of varying degrees. Six had pre-operative 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 hospital 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 6 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. In civilian trauma, the incidence of femoral vessel injury is as high as 70% of all peripheral vascular injuries [2]. The unit's incidence of femoral artery injuries is 18.8% [3] that of brachial artery injuries 48.2% [4], axillary artery injuries 15.3% [5], popliteal artery injuries 12.8% [6], and subclavian artery injuries 5.9% [7]. When considering all vascular trauma, the incidence of femoral artery injuries is 26% [1]. Cargile et al reporting on femoral vessel injuries indicated that 48% are isolated arterial injuries, 15% isolated vein injuries, and 36% had both vessels injured [8]. The rate of limb loss after femoral artery injury is much less than after popliteal artery injury. Primary amputations for unsalvageable injury is 3.6% in the Degiannis study [9]. They noted that the four amputees in their group had an ischemic time of more than 5 h. This amputation rate is comparable to other studies like Hafez et al at 4.9% [10] and Asensio et al at 3% [2]. 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 amputation rate in this study was 8.8% with a primary amputation rate of 2.5% and secondary amputation rate of 6.3%. This is slightly higher than most published studies of civilian femoral artery injuries [2, 8, 11, 12]. Cargile et al. had an amputation rate of 4.7% [8]. 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 oedema.

The statistically significant risk factors in this study for amputation were: the 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 were longer than 5 h.

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 ischaemic limbs must be prioritized and expedited. The mean waiting time of five-and-a-half hours is too long. This unacceptable long time to surgery can be attributed to the lack of a dedicated trauma theatre after hours in a resource constrained environment. Patients requiring emergency surgery compete for two emergency theatres and are triaged according to urgency [13]. A shocked patient with an abdominal gunshot injury, a cardiac tamponade, an unstable upper GIT bleed, or an intracranial bleed with low GCS will go to the operating room before an acutely ischaemic limb. Especially, over weekends, this waiting time escalates as trauma gets busier. This will need a multifaceted approach to correct. Awareness among paramedics, ER staff, theatre staff, anesthetists, and surgeons should be raised and protocols should advocate for a shorter time interval to theatre, with the development of a 24-h dedicated trauma theatre.

In this study, the deployment of temporary vascular shunts (TVS) was 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%) [11]. The American military data from the Balad registry had an amputation rate of 13% in the TVS group. The indication for shunt was, however, varied and not inclusive of damage control procedures [12].

Another risk factor for amputation in this study was an 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, and 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 were managed mostly with ligation (85%). Of the 66 ligated venous injuries, four had some residual minor limb edema in the early post-operative 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 remains unknown. None of the minor venous repairs or vein patches had thrombotic or edema-related complications in the immediate post-operative period. When more heroic venous reconstructions are performed, the thrombotic and embolic complications seem to increase, as shown in Cargile's review [8]. They performed 131 venous repairs of which 69 were lateral repairs and 50 complex repairs. Eighteen of these vein repairs 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 that 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 should be attempted when possible, especially after reperfusion of a threatened limb.

It is paramount to address established compartment syndrome with an expeditious decompression to salvage the limb [14]. 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 [14, 15]. In this study, patients who had a fasciotomy had a lower risk of amputation.

This review showed no mortalities. 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 department thoracotomy (EDT), aortic cross clamping, and open cardiopulmonary resuscitation. Three (27%) of the 11 patients survived [2]. His 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.

Conclusion

In summary, the risk factors identified for limb loss in this study were: reversible ischemia—threatened limbs, absence of distal pulse following repair, and TVS deployment. Other potential risk factors for limb loss that were not statistically significant were: delayed fasciotomy, sepsis with false aneurysm, delay to surgery, prolonged ischemic time, and femoral vein ligation (indeterminate risk factor). To improve on our current amputation rate, we need to expedite surgery, even more so for threatened limbs, especially if motor neurological deficit is present. 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. We need to 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. Damage control TVS deployment can save both life and limb. However, the amputation rate in these patients is significantly higher.

Funding There is no funding source.

Compliance with ethical standards

Conflict of interest Drs. Pradeep Navsaria, Andrew Nicol, Shreya Rayamajhi, Nivashini Murugan, Juan Kloppers, Sorin Edu, and Sharfuddin Chowdhury declare that they have no conflict of interest.

Ethical approval The study has been approved by the institutional ethics committee and has been performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards: University of Cape Town Human Research Ethics Committee approved study: 177/2010.

Informed consent This was a retrospective chart/database review; therefore, no consent was taken. The patients were managed according to the standard Unit protocols. All data were collected by the first and second authors on a password protected computer and Excel sheet. None of the patients could be identified in the database as they were numbered consecutively from 1 to 158. The privacy and confidentiality interests of participants were preserved. No information can identify an individual.

References

1. Ball CG, Nicol AJ, Beningfield SJ, Navsaria PH. Emergency room arteriography: an updated digital technology. Scand J Surg. 2007;96(1):67–71.
2. Asensio JA, Kuncir EJ, García-Núñez LM, Petrone P. Femoral vessel injuries: analysis of factors predictive of outcomes. J Am Coll Surg. 2006;203(4):512–20.
3. Zellweger R, Hess F, Nicol A, Omoshoro-Jones J, Kahn D, Navsaria P. An analysis of 124 surgically managed brachial artery injuries. Am J Surg. 2004;188(3):240–5.
4. Murugan N, Navsaria PH, Edu S, Nicol AJ. Femoral vessel injury: an audit of 64 patients. S Afr J Surg. 2008;46(4):120.
5. Gill H, Jenkins W, Edu S, Bekker W, Nicol AJ, Navsaria PH. Civilian penetrating axillary artery injuries. World J Surg. 2011; 35:962–6.
6. Banderker MA, Navsaria PH, Edu S, Bekker W, Nicol AJ, Naidoo N. Civilian popliteal artery injuries. S Afr J Surg. 2012; 50(4):119–23. https://doi.org/10.7196/sajs.1257.
7. Sobnach S, Nicol AJ, Nathire H, Edu S, Kahn D, Navsaria PH. An analysis of 50 surgically managed penetrating subclavian artery injuries. Eur J Vasc Endovasc Surg. 2010;39(2):155–9. https://doi.org/10.1016/j.ejvs.2009.10.013.
8. Cargile JS, Hunt JL, Purdue GF. Acute trauma of the femoral artery and vein. J Trauma. 1992;32(3):361–4.
9. Degiannis E. Penetrating injuries to the femoral artery. Br J Surg. 1995;82(4):492–5.
10. Hafez HM, Woolgar J, Robbs JV. Lower extremity arterial injury: results of 550 cases and review of risk factors associated with limb loss. J Vasc Surg. 2001;33(6):1212–9.
11. Subramanian A, Vercruysse G, Dente C, Wyrzykowski A, King E, Feliciano DV. A decade's experience with temporary intravascular shunts at a civilian level I trauma center. J Trauma. 2008;65(2):316-324-326.
12. Baylor Woodward ME, Colonel Darrin Clouse LW, Jonathan Eliason ML, Michael Peck MA, Colonel Andrew Bowser LN, Mitchell Cox MW, et al. Penetrating femoropopliteal injury during modern warfare: experience of the Balad Vascular Registry. J Vasc Surg. 2008;47(6):1259–65.
13. Chowdhury S, Nicol AJ, Moydien MR, Navsaria PH, Montoya-Pelaez LF. Is case triaging a useful tool for emergency surgeries? A review of 106 trauma surgery cases at a level 1 trauma center in South Africa. World J Emerg Surg. 2018;13(4):4. https://doi.org/10.1186/s13017-018-0166-5. (eCollection 2018).
14. Farber A, Tan T-W, Hamburg NM, Kalish JA, Joglar F, Onigman T, et al. Early fasciotomy in patients with extremity vascular injury is associated with decreased risk of adverse limb outcomes: a review of the National Trauma Data Bank. Injury. 2012;43:1486–91.
15. Percival TJ, White JM, Ricci MA. Compartment syndrome in the setting of vascular injury. Perspect Vasc Surg Endovasc Ther [Internet]. 2011; 23(2):119–24.