Research Article

Interventional Cardiology

Penetrating popliteal vascular injury: Surgical management and early outcome during current war in Taiz-Yemen

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Received date: March 01, 2021
Accepted date: March 15, 2021
Published date: March 22, 2021

Abstract:

Background: Popliteal vascular injury remains a challenging entity, and carries the greatest risk of limb loss among the lower extremity vascular injuries. Operative management of traumatic popliteal vascular injuries continues to evolve. We aim to review our experience with complex penetrating popliteal vascular injuries, thereby focusing on initial presentation, therapeutic challenges, and early outcomes.

Methods: From September 2015 to December 2019, we managed total of 728 penetrating vascular injuries with 157 popliteal vascular injury presented to the Authority of Althawra hospital in Taiz-Yemen. Of 125 patients, 103 patients were fulfilling the inclusion criteria. Traumatic limb amputations were excluded from this study. Variables were retrospectively collected included patient demographics, mechanism and type of injury, limb ischemia time, clinical status at presentation, type of vascular reconstruction, associated complications, limb salvage, and mortality.

Results: 157 vascular reconstructions were performed for 103 patients with penetrating popliteal vascular injuries, 94 (91.3%) were males and 9 (8.7%) were female. The mean age was 27.3 ± 12.3 years. There were 84 (18.6%) penetrating gunshot high-velocity injuries, and 19 (18.4%) blast injuries. Popliteal vascular injuries were the second most common accounting for 35% of lower extremity vascular injuries and 22.4% of the total vascular injuries. Nearly half 54 (52.4%) of the patients sustained complex popliteal vascular injuries (arterial and venous injuries), 85 (82.2%) isolated arterial injuries, and 72 (69.9%) isolated venous injuries. Management of vascular injury was repaired by saphenous venous interposition graft in 68 (66%), end-to-end anastomosis in 15 (14.5%), ligation in 1 (1%), and venous patch in 1(1%). Venous injury was repaired in 53 (51.4%) and ligated in 18 (17.5%). Less than 6 hours from injury to completed revascularization was achieved in 58 (56.3%) patients. The overall fasciotomy was 28 (27.2%) which significantly increased the length of hospital stays (17 days vs. 7 days, P=0.0003). The overall limb-salvage rate in our study was 94.2%. During the study period, the most common complication was 14 (13.6%) wound infection, 14 (13.6%) graft thrombosis, 6 (5.8%) bleeding, 4 (3.9%) graft infection. Early limb loss occurred in 6 (5.8%). In our study, the mortality rate was 2 (1.9%).

Conclusions: Wartime penetrating popliteal vascular injury is a real challenge. However, team approach and promptly vascular repair found to associate with a remarkable limb salvage rate of 94.2%. We advocate repair of arterial injury with vein graft as the treatment of choice whenever possible.

Keywords: Popliteal vascular injury • Penetrating injury • Amputation • Fasciotomy

Introduction

The popliteal artery is the second most commonly injured vessel in the lower extremity in which its injury remains a challenging entity and is frequently associated with high levels of morbidity and poor rates of limb salvage compared with other vascular injuries [1,2]. There is a wide variation in the incidence, cause, and mechanism of vascular trauma depending on the local conditions.

In the current warfare conditions, vascular trauma represents 7%-10% of total battle injuries [3-5]. Popliteal artery injuries account for about 5%-19% of extremity arterial injuries in civilians [6,7] while in the military setting, the reported incidence of vascular injuries has changed significantly since World War I (WWI) until now. The rate in WWI was reported to be 0.4% to 1.3% and in World War II 0.96%. The rate increased slightly during the Vietnam and Korean wars to a rate of 2% to 3%. However, the rate increased to 12% during the recent tours in Afghanistan and Iraq. Of these injuries, 66% occurring in the lower extremities of which popliteal artery injuries constitute 50% to 60% of all extremity arterial injuries and had an increased rate of secondary amputation, probably as a result of the associated soft-tissue injuries that accompany Improvised Explosive Device (IED) injury patterns [8-12].

However, popliteal artery injury has the highest rates of amputations amongst all lower extremity vascular injuries. Despite technical advancements and the lessons learned during the war era [13-15] the associated amputation rates are high (10%-16%) [13,14,16-18] although in the military population remain at approximately 30%, whereas range between 14.5%-25% in the literature for civilians [9,19]. The practice of early vascular repair over simple ligation has greatly improved limb salvage rates [19-22].

Since the first moment of Yemeni revolution in February 2011, an exponential rise in the number of vascular injuries in Taiz city in Yemen, in which Yemen international hospital received 63 cases of vascular injuries with 10 (16%) patients of popliteal vessels injury that present critical challenges in resource-limited settings of developing countries.3 Ideally, war injuries should be treated by surgeons having military surgery experience. In fact, civilian surgeons may find themselves trapped in wars practicing military surgery without prior training or experience in this field [15]. The purpose of this study was to review our recent experience with penetrating popliteal vascular injuries in Taiz-Yemen, thereby focusing on initial presentation, surgical management, and early outcomes and to highlight lessons learned from that period.

Material and Methods

Data collection

From September 2015 to December 2019, we managed 125 patients with Popliteal Vascular Injuries (PVI) at the Authority of Althawra Hospital in Taiz-Yemen. 103 patients were fulfilling the inclusion criteria. Data were retrospectively collected from hospital records included age, gender, mechanism of injury, clinical presentation, and associated trauma. Surgical data included type of popliteal vessel injury, type of repair, early complications related to vascular reconstruction (such as bleeding, graft infection, pseudoaneurysm formation, graft thrombosis, or amputation), and development of compartment syndrome. Early outcomes variables included limb salvage, mortality, and length of ICU and hospital stay.

Any of the following was considered criteria for exclusion: presented with late complications of PVI (pseudoaneurysms and arteriovenous fistulas), primary traumatic amputation of lower limb associated with PVI, blunt PVI, iatrogenic PVI, and incomplete or missed file data during the study period.

All patients were resuscitated in emergency room according to Advanced Trauma Life Support protocols in the hospital field. The diagnosis of PVI was based on clinical examination and hand-held Doppler. Hard signs findings of vascular injury like (distal ischemia, pulsatile bleeding, expanding hematoma, palpable thrill, or bruit) were indications for immediate surgical exploration and repair. For soft signs of vascular injury and no immediate threat to life or limb, patients were admitted for close observation and frequent vascular examination, as we were unable to send patients for computed tomography angiography because of limited sources in the city related to war. Routine x rays of the lower extremity were performed on arrival to assess for bony fractures or dislocation. All patients were diagnosed and operated on within 24 hours. Time of limb ischemia was defined as the time from injury to revascularization. Limb salvage was defined as the presence of a viable limb at 1 month after injury, regardless of functional outcome.

Our approach was to perform surgical revascularization as soon as the vascular injury was recognized. Operative exploration of injured vessels was performed via standard incisions, distal and proximal control. Flow and backflow were assessed, and we routinely passed an embolectomy catheter to proximal and distal segments to perform thrombectomy followed by the flushing of the distal segment with heparinized saline. This was followed by definitive repair. Direct end-to-end anastomosis was performed if approximation of debrided arterial ends were free of tension. When this was not possible, interposition vein grafting, using autologous reversed long saphenous vein from the contralateral limb, was done. The prosthetic graft was not used in our study.

Deep venous injuries were repaired rather than ligated if patients were hemodynamically stable and when judged necessary. The venous return was restored after arterial repair. Vascular reconstruction was performed before orthopedic stabilization whenever possible. We did not use Temporary Intravascular Shunting (TIVS). We routinely performed calf fasciotomy (4 compartment via 2 incisions), when compartment syndrome was anticipated. Compartment syndrome was based primarily on the clinical finding of tense calf swelling. Postoperatively, frequent monitoring and vascular checks (eg, pulse presence, quality, and capillary refill) continue for the first 24-48 hours. The injured lower limb was kept elevated and wrapped with a compressed bandage. Early ambulation (within the first 24-48 hours) was encouraged. All patients received prophylactic antibiotics, which were continued postoperatively for 3-5 days unless prolonged use was dictated by the presence of obvious contamination or infection. Low Molecular Weight Heparin (LMWH) was administered throughout hospital confinement. Patients with arterial injuries received antiplatelet therapy with 100 mg acetylsalicylic acid routine 90 days postoperatively. Complications and outcomes were reviewed through OPD appointment and telephone survey.

Data and statistical analysis

This study is a retrospective review. The major endpoints are overall limb-salvage and mortality rates. Subgroup analysis was performed for secondary endpoints including fasciotomy and vascular complications. Numerical values were expressed as mean ± standard deviation. Continuous data were compared with unpaired Student's t-tests. All statistical analyzes were performed using SPSS Statistics 24.0. Variables were compared by using analysis of Chi-square analysis or Fisher exact test. P values ≤ 0.05 were considered statistically significant.

Results

From September 2015 to December 2019, we managed a total of 728 penetrating vascular injuries presented to our hospital. During that period, 125 patients presented with popliteal vascular injuries. Twenty-tow patients were excluded from the study, as they were not candidate for the inclusion criteria. Among them: blunt injury (patient), iatrogenic injury (one patient), late presentations; including the delayed aneurysms (3 patients), and arteriovenous fistulas (one patient), branches injury (5 patients), and incomplete file data (2 patients). Mean age was 27.3 ± 12.3 years and the majority of patients were males 94 (91.3%). There were 84 (81.6%) patients who sustained a penetrating injury due to high-velocity gunshot and 19 (18.4%) were blast injuries. Popliteal vascular injuries were the second most common accounting for 35% of lower extremity vascular injuries and 22.4% of the total vascular injuries. Demographic data are summarized in Table 1.

Table 1: Patient demographics data.

Patient demographics	Number	%
Age (years)	27.27 ± 12.3	
Gender		
Male	91.3	94
Female	8.7	9
Mechanism		
Gunshot injury	18.4	19
Blast injuries	81.6	84
ICU stay (days)	1.1 ± 1.4	
Hospital stay (days)	9.96 ± 9.6	

All patients presenting with hard signs on arrival were immediately transported to the operating room for vascular repair. Upon ED arrival, 85 (82.5%) patients were presented with absent peripheral pulse, 53 (51.5%) patients were presented with active bleeding, the mean Systolic Blood Pressure (SBP) was 97.3 ± 18.4 mmHg, and mean blood hemoglobin (Hb) was 10.4 ± 1.99 gm\dl (Table 2).

Table 2: Physical findings in popliteal vessels injury, patients, n=103.

Physical findings	Number	%
Peripheral pulse		
Absent\inaudible	82	76.6
Absent\audible	3	2.9
Present	18	17.5
Peripheral nerve deficit	41	39.8
Injury in proximity to major vessels	103	100
SBP at admission (mmgh)	97.33 ± 18.4	
Hb at admission (gm\dl)	10.4 ± 1.99	
SBP: Systolic Blood Pressure; Hb: Blood Hemoglobin.		

Total of 157 popliteal vascular injuries were classified as 85 (82.2%) popliteal arteries injuries and 72 (69.9%) popliteal venous injuries. Fifty-four (52.4%) patients had combined ipsilateral popliteal arterial and venous injuries. Regarding intra-operative findings, type of injury was classified into 57 (55.3%) completely transected, 26 (25.2%) partially transected, and 2 (1.9%) contused with thrombosis and/or intimal injury. Popliteal venous injuries finding were; 43 (41.7%) completely transected, 28 (27.2%) partially transected, and 1 (1%) contusion, which was managed medically with anticoagulation.

All popliteal arterial injuries were managed with debridement and definitive repair. The optimal technical repair was used for each injury: 68 (66%) Reverse Saphenous Interposition Grafting (RSVG), 15 (14.6%) end-to-end anastomosis, 1 (1%) venous patch, and 1 (1%) ligation. Popliteal venous injuries were repaired in 14 (13.6%) saphenous interposition grafting, 37 (35.9%) end-to-end anastomosis, 18 (17.5%) ligation, 2 (1.9%) venorraphy, 1 (1%) observation with anticoagulation (Table 3). Less than 6 hours from injury to completed revascularization was achieved in 58 (56.3%) patients.

Table 3: Methods of arterial and venous repair, patients, n=103.

	Number	%
Type of repair popliteal artery	Ligation	Ligation
Saphenous interposition grafting	68	66
End-to-end anastomosis	15	14.6
Venous patch	1	1
Ligation	1	1

Type of repair popliteal vein	Ligation	Ligation
Saphenous interposition grafting	14	13.6
End-to-end anastomosis	37	35.9
Venoraphy	2	1.9
Ligation	18	17.5
Conservative treatment	1	1
TOTAL	157	

The overall fasciotomy was 28 (27.2%) of which 16 (15.5%) were prophylactically done immediately post vascular reperfusion and 12 (11.7%) were therapeutic done after clinical diagnosis of compartment syndrome. Associated orthopedic injuries in 63 (61.2%) patients; 50 (48.5%) patients required external stabilization, 3 (2.9%) patients were fixed with Open Reduction and Internal Fixation (ORIF), and 10 (9.7%) patients by plaster casts. Adjacent concomitant injuries included nerve injury in 40 (38.8%) patients, significant soft tissue loss requiring skin or muscle flaps in 27 (26.2%) patients, and associated major body injuries in 15 (14.6%) patients (Table 4).

Table 4: Adjacent Associated injuries, patients, n=103.

Associated injury	Number	%
Fracture	63	61.2
Distal femur	48	46.6
Proximal tibia	11	10.7
Proximal tibia and fibula	2	1.9
Proximal fibula	2	1.9
Nerve injury	40	38.8
Sciatic nerve	10	9.7
Tibial nerve	23	22.3
Common peroneal nerve	7	6.8
Significant soft tissue loss	27	26.2
Major body injury	15	14.6
Chest	3	2.9
Abdomen	6	5.8
Contralateral lower limb	6	5.8

The overall limb-salvage rate in this study was 94.2%. Complications in the survival group were: 14 (13.6%) wound infection, 14 (13.6%) graft thrombosis, 6 (5.8%) bleeding and\or hematoma collection, 4 (3.9%) graft infection, 6 (5.8%) Above-Knee Amputations (AKA), and pulmonary embolism developed in one case (Table 5). Six patients had above-knee amputation after revascularization. Among them, 2 patients were associated with massive soft-tissue injuries and preoperative neurologic impairment in the injured limb. In spite of good vascular repair, patients had a recurrent infection and sensory and motor loss, they later developed wounds infection and did not regain motor or sensory function in the reconstructed limb. Two patients had failed revascularization and the last 2 patients had a severe infection and graft thrombosis. Details about patients undergoing amputations are summarized in Table 6.

Table 5: Postoperative complications and 30-day outcome, patients, n=103.

	Number	%
Postoperative complications	1	1
Graft thrombosis	14	13.6
Bleeding and\or hematoma	6	5.8
Wound infection	14	13.6
Graft infection	4	3.9
Secondary amputations(AKA)	6	5.8
Compartment syndrome	12	11.7
Limb gangrene	4	3.9
Ligation of graft	3	2.9
Significant Lower limb edema	8	7.8
Anastomotic Aneurysm	2	1.9
Myocardial infarction	1	1
Acute kidney injury	1	1
pulmonary embolism	1	1
Pneumonia	2	1.9
30-day outcome	1	1
Mortality	2	1.9
Limb salvage	97	94.2

All vascular repairs were patent upon hospital discharge. Seventy-five patients (72.8%) required ICU admission, with a mean length of stay of 1.1 ± 1.4 days. The overall mean length of hospitalization was 9.96 ± 9.6 days. The hospital stay was significantly longer in patients who had fasciotomy and wound infection compared to patients without fasciotomy or infection (7 days vs. 17 days, 8 days vs. 21 days, P=0.0003, P=0.02 respectively).

Table 6: Popliteal vascular injuries requiring amputation.						
Patient	**No 1**	**No 2**	**No 3**	**No 4**	**No 5**	**No 6**
Age (years)	20	25	33	3	60	18
MOI	Gunshot	Gunshot	Gunshot	Blast injury	Gunshot	Blast injury
Fracture location	Proximal tibia & fibula	Distal femur	Proximal tibia	Proximal tibia	Distal femur	-
Popliteal vessels injury	Artery/vein	Artery/vein	Artery/vein	Artery	Artery/vein	Artery/vein
Ischemic time (hours)	8	6	14	5	12	7
Method of repair popliteal artery\vein	RSVG\ Ligation	RSVG\ Ligation	RSVG\ Ligation	RSVG	RSVG\ SVG	RSVG\ SVG
Nerve injury	Tibial nerve	Tibial nerve	Tibial nerve	-	Sciatic nerve	Sciatic nerve
Complication	Graft thrombosis	Wound and Graft infection, Graft thrombosis	Compartment Syndrome	Bleeding, Graft infection, Graft thrombosis	Wound infection, Graft thrombosis, limb edema	Bleeding, Wound & Graft infection, Graft thrombosis, Compartment syndrome, pseudoaneurysm
Re-operation	Embolectomy	Embolectomy 3 times	Fasciotomy	Embolectomy	Embolectomy, Regraft after 36 days, of Graft ligation after 40 days	Embolectomy, Regraft twice after 20 days, Graft ligation after 26 days
Reason for AKA	Failed revascularization	Infection	Failed revascularization	Large tissue defect	Large tissue defect & Infection	Infection and sepsis
Time of amputation (days)	2	37	2	5	40	35
Hospital LOS (days)	20	9	7	10	45	40
Outcome	Alive	Alive	Alive	Alive	Alive	Alive

Abbreviations: MOI: Mechanism of Injury; RSVG: Reversed Saphenous Vein Graft; AKA: Above-Knee Amputation; LOS: Length of Stay

The overall mortality rate for patients who sustained penetrating popliteal vascular injuries was 1.9% (two patients). The first patient had missed popliteal arterial injury and died 7 hours post vascular repair due to hemorrhagic shock, the second patient developed a pulmonary embolism and died 3rd post-operative day.

Discussion

Austere environments, the lack of usual supplies, and exposure to horrific injuries all affirm Debakey's comment that "war is never a cheerful business [13]. Now, as we approach this fifth year of the Austere environments, the lack of usual supplies, and exposure to horrific injuries all affirm Debakey's comment that "war is never a cheerful business [13]. Now, as we approach this fifth year of the In this study, 103 patients with popliteal vascular injuries were recorded and most of them were active young patients (mean age was 27.3 ± 12.3 years with 89.3% being less than 45 years) thus, optimal management to control bleeding and reestablish circulation is crucial. The management of complex injuries involving vascular and skeletal elements of the lower extremity remains challenging and still incurs a high incidence of limb loss and morbidity [23-27]. The management of military vascular trauma has changed considerably as a result of the wars of the 20th century and the significant contributions of Debakey, Hughes, Rich, and others [13,14,28].

Gunshot and blast injuries caused the penetrating popliteal vascular injuries in our study. In which gunshot wounds from high-velocity weapons accounted for the majority (81.6%) of popliteal vascular injuries, producing deep cavity wounds frequently associated with fracture and neurovascular injury. The majority of penetrating popliteal artery injuries can be detected by initial examination, Wagner et al. found 55% of limbs preoperatively had clinical ischemia, and capillary refill was considered an unreliable measurement of distal perfusion [29]. Some signs including motor and sensory dysfunction, pain, and pallor are signs of late distal ischemia and may delay appropriate management. Unmistakable frank hemorrhage and "hard" signs of vascular injury, including a pulsatile expanding hematoma, pulselessness, presence of bruit or thrill, and signs of distal ischemia require immediate surgical intervention.

Repair of popliteal arterial injury by end-to-end anastomosis was used only in 15 (14.6%) patients. Military weapons often produce a deep cavitary injury and segmental arterial loss thus, a tension-free anastomosis cannot be achieved. Mobilization of the arterial ends in a young patient with non-diseased arteries often allows the construction of a tensionless primary arterial repair [30]. Popliteal arterial repair with a reversed saphenous vein graft comprised 68 (66%) most of the arterial repairs in our report, therefore an interposition graft is the most used type of repair, preferably utilizing a contralateral reversed autogenous saphenous vein. Vein graft was covered by healthy tissue or routed around the zone of injury. Similarly, most studies recommended using the interposition vein graft where's autologous vein graft remains the most durable and effective means of vascular repair [31]. Prosthetic grafts are typically avoided because of their lower rates of patency [25,29], we don't use prosthetic graft in our practice mainly due to limited sources in our city.

Our practice with concurrent venous injuries is to repair rather than ligated whenever possible. Of 72 popliteal venous injuries, the majority 53 (51.4%) were repaired, 37 (35.9%) by end-to-end anastomosis, 14(13.6%) by interposition venous graft, 2 (1.9%) venoraphy repair, and one case had contused vein that observed without intervention. The remaining 18 (17.5%) popliteal venous injuries were treated by ligation. Although repair of accompanying venous injury is controversial, venous repair may enhance venous drainage and, therefore decreased compartment pressure and eventual limb loss [25,29,32]. However, others have found no vascular-related complications from venous ligation [27,33]. In our cases, we recommend venous repair in stable patients and ligation as damage control in hemodynamically unstable patients. Venous graft should be maintained as patent in particularly for the first 72 hours. Venous circulation may be provided by collaterals even if it is occluded after this period. Venous repair is required especially for diffuse soft tissue defects that may prevent the development of venous collateral circulation. Restoration of venous circulation in order to enhance the patency of arterial anastomoses and to reduce the risk of late venous stasis may be more important at the popliteal region than any other site [34]. In contrast, there are also reports indicating that venous ligation does not have an important sequel and venous ligation is tolerated well even at the popliteal region and does not have a negative impact on arterial circulation [10,33].

A major concern is that repair of venous injuries will result in vein thrombosis and subsequent pulmonary emboli, although support for this scenario is somewhat anecdotal [35]. In the largest recent study, they have found this to be the contrary; in fact, the risk of pulmonary emboli is low in venous repair compare to venous ligation or equivalent [36]. In our study result, pulmonary embolism was recorded in one (1%) patient, in which venous injury was repaired by venous interposition graft. Regardless of long-term results, venous patency during the initial 2 weeks after the injury perhaps improves patency rates in a new arterial anastomosis before development of collateral venous canals [37,38]. Moore et al. advocate that venous patency for 2 weeks after reconstruction virtually assures long-term patency [39]. Finally, Reagan et al. reported their analysis of a review of more than 100 traumatic military venous injuries [36]. They conclude that management of vein repair versus ligation for traumatic venous injury remains a controversy. In an ideal setting, venous injuries should be repaired when possible and tolerated by the patient especially in a watershed area, as in popliteal venous injury. Repair is especially encouraged to ameliorate the high risk of leg phlegmasia or fascial edema. They found also no significantly different infection rates for venous injuries patients who were treated by ligation or venous repair. In our study, there were no significantly different infection rates for venous injuries patients who were treated by ligation or venous repair (p=0.24).

It is a controversial issue that which one should be repaired first for cases that have both popliteal artery and popliteal vein injuries. Some indicated that first venous and then arterial repair should be done and thus venous circulation should be improved after arterial revascularization [40]. However some authors reported that arterial repair should be done first in order to reduce the duration of ischemia [41]. For our report, first arterial repair was done and thus ischemia duration was kept as short as possible. The shunt was not used because we thought venous circulation was provided partly by collaterals until venous repair was done.

Furthermore, our results confirm that a good limb-salvage rate is achieved without the use of TIVS if revascularization is performed as soon as the arterial injury is recognized. The placement of an intravascular shunt would be an additional step with no real benefits and may potentially cause vessel complications such as dissection or thrombosis [42]. In support of our contention, other large series have found the use of intravascular shunts not helpful [27,29,43]. However, TIVS may be useful as part of a "damage-control" strategy for patients who are too "unstable" to undergo immediate vascular reconstruction because of other life-threatening injuries

[44]. In this setting, limb perfusion can be maintained through the intravascular shunt until the patient's condition ameliorates at which time vascular repair can be performed.

More than half of the vascular injuries (61.2%) were associated with long-bone fractures in our report. The timing of orthopedic fixation in concomitant bone injury is a source of debate. Prior skeletal fixation is strongly advocated in some series [45,46], while more recent reports have highlighted the importance of reducing ischemia time by proceeding with vascular reconstruction first [27,47]. Wolf et al. reduced ischemia time by using TIVS and then performing orthopedic fixation before vascular reconstruction [48]. In our practice, we use vascular repairs firstly in all cases followed by orthopedic fixations on a stable base. Based on this experience and that of others, we advocate that definitive arterial reconstruction should precede orthopedic intervention for combined complex lower-extremity injuries [27,47,49].

Fact, mortality in this series from penetrating popliteal vascular injuries was 1.9% which is similar to previous studies ranging from 1% to 9% [27,50,51]. Popliteal vascular injuries are associated with higher rates of compartment syndrome. Predominant risk factors included prolonged ischemia (>6 h), combined vascular and skeletal injuries, or venous ligation [23]. In our experience, 2-incision fasciotomies were usually performed at the initial operation immediately after restoration of blood perfusion. The technique for a single-incision fasciotomy is a well-described alternative for adequate decompression of the lower extremity however; a more involved surgical dissection is required [52]. Also, the decision to perform fasciotomies was clinical one and its liberal use has been recommended by some groups [19,23,42,53].

The overall fasciotomy rate in this study (27.2%) is superior to previously reported series [27,29,42,54], and National Trauma Data Bank (50%) [19]. The liberal use of fasciotomies appears to be associated with lower rates of amputation but the fasciotomy wounds themselves are a source of morbidity. In fact, the length of stay was significantly longer in patients who had fasciotomy compared with no fasciotomy (17 vs. 7 days).

In our study, we found low amputation rates of only 5.8%, superior to previous studies (11% for penetrating injuries) and other series ranging as high as 71% [19,53]. In a series of 550 patients with lower extremity arterial injury, of which 31% corresponded to popliteal arterial injuries, Hafez et al. showed amputation rates of 16% [27]. Nair et al. reported a series of 117 popliteal artery gunshot wounds with 27% and 50% amputation rates for low and high-velocity injuries, respectively [25]. We acknowledge in this series, the fasciotomy wounds were associated with increased morbidity and longer length of hospital stay.

Although it is generally accepted that skeletal muscles can tolerate ischemia for up to 6 hours, we found that the ischemic time alone could not be used to predict limb viability. Prolonged ischemia is a well-recognized predictor of cell death, but the tolerance period varies between persons, depending on the severity of the ischemia and the presence of collateral flow.

Conclusion

Wartime penetrating popliteal vascular injury is a challenge. However, team approach and promptly vascular repair found to associate with a remarkable limb salvage rate of 94.2%. This study represents the first analysis of popliteal vascular injuries during the contemporary war in Taiz city in Yemen. We advocate repair of arterial injury with vein graft as the treatment of choice whenever possible.

References

1. Hossny A. Blunt popliteal artery injury with complete lower limb ischemia: Is routine use of temporary intraluminal arterial shunt justified ? J Vasc Surg. 40(1): 17-21 (2004).
2. Starnes BW, Bruce JM. Popliteal artery trauma in a forward deployed mobile army surgical hospital: Lessons learned from the war in Kosovo. J Trauma. 48(6): 1144-1147 (2000).
3. Al-ganadi A. Management of vascular injury during current peaceful Yemeni revolution. Ann Vasc Surg. 29(8): 1575-1580 (2015).
4. Jawas A, Abbas AK, Nazzal M, et al. Management of war-related vascular injuries: Experience from the second gulf war. 22: 1-5 (2013).
5. Fox CJ, Gillespie DL, Donnell SDO, et al. Contemporary management of wartime vascular trauma. 41(4): 638-644 (2004).
6. Feliciano DV, Kenneth ML, Joseph MG, et al. Five-year experience with PTFE grafts in vascular wounds. J Trauma. 25: 71-82 (1985).
7. Baker SP. Injury severity score: An update. J Trauma. 16(11): 882-885 (1976).
8. Huber GH, Manna B. Vascular extremity trauma. Stat Pearl. (2021).
9. Dua A, Patel B, Desai SS, et al. Comparison of military and civilian popliteal artery trauma outcomes. J Vasc Surg. 59(6): 1628-1632 (2009).
10. Ekim H, Basel H, Odabasi D. Management of traumatic popliteal vein injuries. Injury. 43(9): 1482-1485 (2012).
11. Dennis JW, Frykberg ER, Crump JM, et al. New perspectives on the management of penetrating trauma in proximity to major limb arteries. 11(1): 84-93 (1989).
12. Sciarretta JD, Macedo FIB, Otero CA, et al. Management of traumatic popliteal vascular injuries in a level I trauma center: A 6-year experience. Int J Surg. 18: 136-141 (2015).
13. Michael DE, Fiorindo AS. Battle injuries of the arteries in World War II: An analysis of 2,471 cases. Ann Surg. 123(4): 534-579 (1946).

14. Rich NM, Baugh JH, Hughes CW. Popliteal Artery Injuries in Vietnam. 118(4): 531-534 (1969).

15. Frcs AB, Frcs JM. War in juries during the Gulf War: Experience of a teaching hospital in Kuwait. 76(6) 127: 407-411 (1994).

16. Hughes CW. Acute vascular trauma in Korean War casualties: An analysis of 180 cases. Surg Gynecol Obs. 99: 91–100 (1954).

17. Dua A, Patel B, Kragh Jr JF HJ. Long-term follow-up and amputation-free survival in 497 casualties with combat-related vascular injuries and damagecontrol resuscitation. J Trauma Acute Care Surg. 73(6): 1517–24 (2012).

18. Dua A, Desai SS, Shah JO, et al. Outcome predictors of limb salvage in traumatic popliteal artery injury. Ann Vasc Surg. 28(1): 108-114 (2014).

19. Mullenix PS, Steele SR, Andersen CA, et al. Limb salvage and outcomes among patients with traumatic popliteal vascular injury: An analysis of the National Trauma Data Bank. J Vasc Surg. 44(1): 94-100 (2006).

20. Perkins ZB, Yet B, Glasgow S, et al. Meta-analysis of prognostic factors for amputation following surgical repair of lower extremity vascular trauma. Br J Surg. 102(5): 436–50 (2015).

21. Parker S, Handa A, Deakin M. Knee dislocation and vascular injury: 4 year experience at a UK major trauma Centre and vascular hub. Injury. 47(3): 752–6 (2016).

22. Kauvar DS, Sarfati MR, Kraiss LW. National trauma databank analysis of mortality and limb loss in isolated lower extremity vascular trauma. J Vasc Surg. 53(6): 1598-603 (2011).

23. Frykberg ER. Popliteal vascular injuries. Surg Clin North Am. 82: 67-83 (2002).

24. Moniz M, Ombrellaro MP, Stevens SL. Concomitant orthopedic and vascular injuries as predictors for limb loss in blunt lower extremity trauma. Am Surg. 41(4): 182-186 (1997).

25. Nair R, Abdool-Carrim ATO, Robbs JV. Gunshot injuries of the popliteal artery. Br J Surg. 87(5): 602-607 (2000).

26. Sagraves SG, Conquest AM, Albrecht RJ, et al. Popliteal artery trauma in a rural level I trauma center. Am Surg. 69(6): 485-9 (2003).

27. Hafez HM, Woolgar J, Robbs JV. Lower extremity arterial injury: Results of 550 cases and review of risk factors associated with limb loss. 33(6): 1212-1219 (2001).

28. Woodward MEB, Darrin CW, Colonel L, et al. Penetrating femoropopliteal injury during modern warfare: Experience of the Balad Vascular Registry. 47(6) 1259-1265 (2007).

29. Wagner WH, Calkins ER, Weaver FA, et al. Blunt popliteal artery trauma: One hundred consecutive injuries. J Vasc Surg. 7(5): 736-748 (1988).

30. Norman RM, Carl HW. The fate of prosthetic material used to repair vascular injuries in contaminated wounds. J Trauma. 12(6): 459e67 (1972).

31. Rich NM, Rhee P. An historical tour of vascular injury management: From its inception to the new millennium. Surg Clin North Am. 81(6): 1199-1215 (2001).

32. Reyes DC. Popliteal artery injuries. Vasc Endovascular Surg. 17: 189-94 (1983).

33. Yelon JA, Scalea TM. Venous injuries of the lower extremities and pelvis: Repair versus ligation. J Trauma. 33(4): 532-536 (1992).

34. Rich NM, Hobson RW, Collins GJ. The effect of acute popliteal venous interruption. Ann Surg. 183(4): 365-368 (1976).

35. Smith LM, Block EF, Buechter KJ, et al. The natural history of extremity venous repair performed for trauma. Am Surg. 65(2): 116-120 (2011).

36. Quan RW, Gillespie DL, Stuart RP, et al. The effect of vein repair on the risk of venous thromboembolic events: A review of more than 100 traumatic military venous injuries. J Vasc Surg. 47(3): 571-577 (2008).

37. Phifer TJ, Gerlock AJ, Rich NM, et al. Long-term patency of venous repairs demonstrated by venography. J Trauma. 25(4): 432-46 (1985).

38. Parry NG, Feliciano DV, Burke RM, et al. Management and short-term patency of lower extremity venous injuries with various repairs. Am J Surg. 186(6): 631-635 (2003).

39. Moore TC. Experimental replacement and bypass of a large veins. Bull Soc Intern Chir. 3: 274-282 (2000).

40. Lim LT, Michuda MS, Flanigan DP. Popliteal artery trauma: 31 consecutive cases without amputation. Arch Surg. 115 (1980).

41. Khalil IM, Livingston DH. Intravascular shunts in complex lower limb trauma. J Vasc Surg. 4(6): 582-587 (1986).

42. Huynh TTT, Pham M, Griffin LW, et al. Management of distal femoral and popliteal arterial injuries: An update. Am J Surg. 192: 773-778 (2006).

43. Adam SJ, John HL, Reinert CMM. Treatment of femur fracture with associated vascular injury. J Trauma Inj Infect Crit Care. 40(1): 17-21 (1996).

44. Granchi T, Schmittling Z, Vasquez J, et al. Prolonged use of intraluminal arterial shunts without systemic anticoagulation. 180(6): 493-497 (2001).

45. Burg A, Nachum G, Salai M, et al. Treating civilian gunshot wounds to the extremities in a Level 1 trauma center: Our Experience and Recommendations. IMAJ. 11: 546-551 (2009).

46. Singh D. Management of peripheral vascular trauma: Our experience. Internet J Surg. 7(1): 1-7 (2004).

47. Mchenry TP, Holcomb JB, Aoki N, et al. Fractures with major vascular injuries from gunshot wounds: Implications of surgical sequence. 53(4):16-19 (2002).

48. Wolf YG, Rivkind A. Vascular trauma in high-velocity gunshot wounds and shrapnel-blast injuries in Israel. Surg Clin North Am. 82(1): 237-244 (2002).

49. Dennis BF. Vascular injury associated with extremity trauma. Clin Orthop Relat Res. 318: 117-124 (1995).

50. Fabian TC, Turkleson ML, Connelly TL, et al. Injury to the popliteal artery. Am J Surg. 143: 225-228 (1982).

51. Kauvar DS, Sarfati MLK. National Trauma Databank analysis of mortality and limb loss in isolated lower extremity vascular trauma. J Vasc Surg. 53(6): 1598-1603 (2011).

52. Bible JE, McClure DJ, Mir HR. Analysis of single-incision versus dual-incision fasciotomy for tibial fractures with acute compartment syndrome. J Orthop Trauma. 27(11): 607-611 (2013).

53. Feliciano DV, Herskowitz K, O'Gorman RB, et al. Management of vascular injuries in the lower extremities. J Trauma. 28(3): 319-328 (1988).

54. Franz RW, Shah KJ, Halaharvi D, et al. A 5-year review of management of lower extremity arterial injuries at an urban level-I trauma center. J Vasc Surg. 53(6): 1604-1610 (2011).