

Case Report

A transtibial amputation following femoral artery injury: application of military trauma protocols in civilian care – a case report

Ahmed Ali Shabbay^{1-3*}, Sjef G. Van Baal⁴, Pim van den Hoven⁵, Zarina Ali Shabbay⁶,
Nancy Wambura⁷, Jay Lodhia^{1,2}, Fabian Massaga⁷

¹Department of General Surgery, Kilimanjaro Christian Medical University College (KCMUCo), P.O. Box 2240 Moshi, Tanzania

²Department of General Surgery, Kilimanjaro Christian Medical Centre (KCMC), P.O. Box 3010 Moshi, Tanzania

³Institute of Infectious Diseases and Research, Lugalo Military College of Medical Sciences (MCMS) and General Military Hospital (GMH), P.O. Box 60000 Dar es Salaam, Tanzania

⁴Medical Advisor STEPP Organization Hengelo, The Netherlands

⁵Leiden University Medical Center, Albinusdreef 2, 2333 ZA Leiden, Department of Surgery, The Netherlands

⁶Muhimbili Orthopedic Institute (MOI), P.O. Box 65474, Dar es Salaam, Tanzania

⁷Department of Surgery, Bugando Medical Center, P.O. Box 1370 Mwanza, Tanzania.

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*Correspondence:

Dr. Ahmed Ali Shabbay,

E-mail: ahmedshabio84@gmail.com

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ABSTRACT

Surgical management of vascular injuries remains a daunting challenge to practicing clinicians. Timely and appropriate management is critical. We present a case of a 20 -year-old man who sustained a penetrating vascular injury that led to a transtibial amputation of his left lower limb due to distal vascular occlusion. Inappropriate and untimely management of vascular injuries can lead to limb and life loss. Military protocols adopted during battlefield care have contributed to the development of new guidelines in civilian settings. Due to increasing violence, crime rates, and contemporary threats such as improvised explosive devices associated with terrorist attacks in urban settings, civilian medical personnel have started to encounter high-energy blast injuries in urban medical centers that mimic war injuries. Timely and appropriate management is critical in preventing limb and life loss. It is the author's opinion that vascular injuries should be managed by trained vascular specialists.

Keywords: Superficial femoral artery, Penetrating vascular injuries, Thrombectomy, CT angiography

INTRODUCTION

Vascular injuries remain a daunting clinical challenge for practicing surgeons.¹ Combat frontline war zones present chaotic, uncontrolled, harsh and unpredictable environments, with a wide spectrum of injuries that vary depending on scope, objective, terrain and nature of military operation². Vascular trauma can result from blunt, penetrating, or iatrogenic injuries.² Traumatic vascular injuries contribute significantly to morbidity and

mortality worldwide³, with femoral vessels being predominantly affected (72%).⁴

Large-caliber arterial injuries are associated with high mortality despite the level of care available.²The pattern of vascular injury varies widely, ranging from intimal contusion and disruption to puncture, arteriovenous fistula, and complete vessel transection.⁵ These injuries occur across all age groups, with a higher prevalence among young males and higher rates reported in military populations (17.6%) than in civilian urban populations

(6%).⁶ Early diagnosis of vascular injuries is essential for timely management, as delays may result in irreversible ischaemic sequelae, leading to impaired function and limb loss.⁷ Haemorrhage control and restoration of perfusion are key components of vascular trauma management and are essential for preserving limb and life.⁸

We report a case of a 20-year-old man who had sustained a penetrating left groin injury from a sharp object during an altercation with armed robbers. The injury involved a laceration of the superficial femoral artery and complete truncated femoral vein. He underwent vascular repair at a district-level hospital using end-to-end anastomosis; however, thrombectomy, resection of the damaged vascular segment, and/or patch repair were not performed. He subsequently developed complete distal vascular occlusion at the level of the popliteal artery, with eventual gangrene of the distal two-thirds of the lower limb. A below-knee amputation was therefore performed. This case points out the importance of early diagnosis and appropriate management of vascular injuries, compliance to vascular trauma protocols, and consideration of the clinical condition of the limb when determining the appropriate level of amputation.

CASE REPORT

A 20-year-old man of African descent was referred from a district hospital approximately 100 km away to our Level IV National Referral Hospital. He presented with a four-day history of an assault involving a penetrating sharp object to the left groin. On arrival, he was hypotensive, distressed, and in severe pain, with a normal blood glucose level. He had completed high school education. The referral note indicated that the assault was from when he had been perpetrated by armed robbers with knives who were attempting to steal his mobile phone. During the altercation, the patient was stabbed with what was later believed to be a knife.

He was rushed to the designated district hospital, where he was diagnosed with a penetrating superficial femoral artery injury. There was a history of severe bleeding at the scene. Intra-operative findings showed a transected left femoral vein and a laceration on the left superficial femoral artery, where a repair was done. No documentation was available regarding the details of the repair, including whether thrombectomy was done on the injured vessels or whether a patch was required in the repair. Telephone consultation with the referring doctor confirmed that the repair involved only an end-to-end anastomosis.

The referral note indicated that postoperative ultrasonographic Doppler examination demonstrated absent colour signals in the dorsalis pedis, anterior tibial, posterior tibial, and peroneal arteries. He was commenced on antibiotics and heparin injections.

Upon arrival at our center, he was ill-looking, distressed, and anaemic. His blood pressure was 99/49 mmHg, pulse rate was 96 beats per minute, respiratory rate of 17 breaths per minute, and oxygen saturation on room air was 98%. Local examination revealed a swollen, tender, and cold left lower limb from the proximal one-third of the tibia, with reduced sensation. The distal two-thirds of the tibia were gangrenous. Pulsation of the dorsalis pedis, anterior tibial, posterior tibial, and peroneal arteries was absent while the femoral artery pulse was palpable. Capillary refill in his toes was absent. The limb was darker and colder to touch than the contralateral right lower limb.

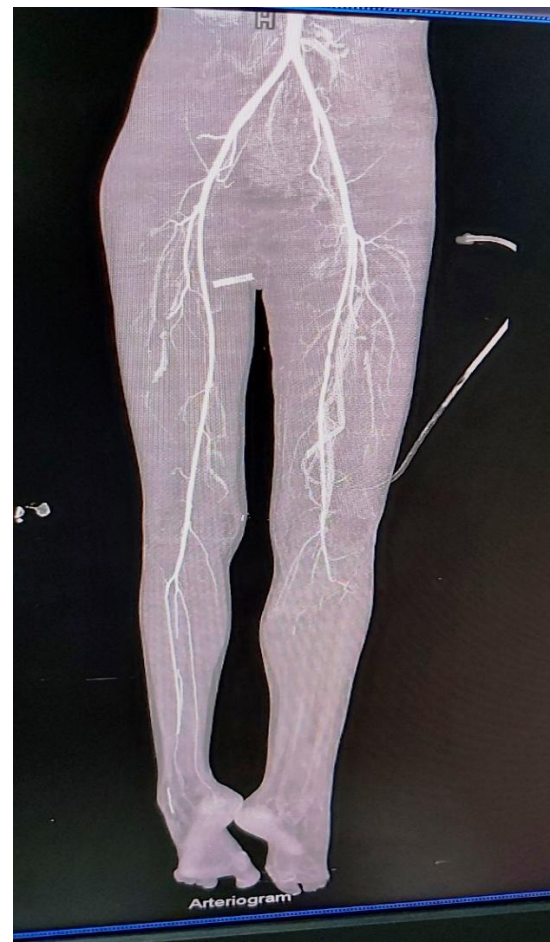


Figure 1: Computed tomography angiography demonstrating absent blood flow from the level of the distal popliteal artery.

He was initially commenced on intravenous ceftriaxone 1g once daily and subcutaneous heparin 5,000 units every 8 hours. Computed tomography angiography (CTA) revealed absent blood flow from the level of the distal popliteal artery (Figure 1). The left lower limb below the proximal one-third of the tibia was non-viable, with gangrene involving the distal two-thirds.

He was scheduled for below-knee amputation after thorough counselling and obtaining informed consent from the patient and his family. Although CTA

demonstrated absent blood flow below the distal popliteal artery, the decision to perform a below-knee amputation was based on the presence of clinically viable, warm, and healthy tissue approximately 12 cm proximal to the knee joint, at the level of the proximal one-third of the tibia. His preoperative haemoglobin level was 4.9 g/dl.

A transtibial amputation was performed, and the stump was closed using the fish-mouth technique. Intra-operatively, adequate tissue perfusion was noted at the stump. He received a total of nine units of blood during his 15-day hospital admission; four units preoperatively and five units postoperatively. The amputation was uneventful, and his postoperative recovery was satisfactory. He was treated with antibiotics and analgesia and was referred to the occupational therapy department for prosthetic fitting. He was discharged on postoperative day 5. Two weeks after surgery, the stump wound had completely healed, with healthy-appearing tissue.

DISCUSSION

Military and civilian vascular injury management settings differ, as combat-zone vascular injuries often involve high-energy blast injuries, with the management and evacuation of injured soldiers taking place in hostile, mountainous, and resource-constrained austere environments.^{2,9}

The pattern and clinical presentation of vascular injuries in war zones differ from those in urban civilian settings because of differences in the mechanisms of injury, epidemiology, pathology, and outcomes. High-energy ballistic and explosive injuries cause extensive tissue destruction compared with the lower-energy injuries commonly associated with civilian assaults.²

Lessons learnt from warfare, from the medieval and Hippocratic eras to modern 20th-century military conflicts involving high-kinetic-energy ballistic vascular injuries, together with surgical techniques introduced by DeBakey, Hughes, Rich, and others, have contributed substantially to the development of contemporary vascular surgical techniques widely practiced in vascular centres.^{10,11,12}

With the increasing occurrence of high-energy explosive injuries in civilian settings, whether due to terrorist attacks, land mines, or increasing combat-related injuries, civilian medical practitioners need to strengthen their skills in managing such injuries. The War Surgery Field Manual by Husum and colleagues can provide civilian surgeons with knowledge of the spectrum and management of wartime trauma including high-energy trauma wounds.¹²

Management protocols for vascular injuries have advanced remarkably over the past century, with each global military conflict contributing to the understanding and management of these injuries in both civilian and

military settings. Recent conflicts, such as those in Iraq and Afghanistan, have significantly improved the understanding of the principles of vascular injury management, thereby improving outcomes and reducing limb morbidity and mortality.¹³ Military and civilian management models have overlapping lessons in terms of techniques, skills, and technological devices. Further studies are needed to determine the best practice models and improve outcomes.¹⁴

Maintaining the same level of surgical skills as military surgeons returning from war zones has proven challenging, as most ultimately work in military centres that primarily treat fit, active-duty personnel and their families.¹⁰ Programs such as the Senior Visiting Surgeon Program at Landstuhl Regional Medical Center in Germany, a facility tasked with providing care for critically injured military personnel from Afghanistan and Iraq, offer a potential solution for civilian medical practitioners who may not otherwise have the opportunity to manage critically ill patients with high-energy blast injuries that are rarely encountered in civilian settings.¹⁰ Ideally, high-energy blast injuries sustained during war should be managed by surgeons or operators with experience in the management of such injuries.¹⁵

Fox et al reviewed combat vascular injuries among American servicemen in Iraq and Afghanistan over two years. Vascular injuries accounted for 7% of direct combat-related injuries.¹¹ This represented an increase of approximately 3-4% compared with similar major conflicts six decades earlier, such as the Vietnam War.² Of these vascular injuries, nearly two-thirds (68%) were caused by explosives, while 25% were caused by gunshot injuries.^{2,11} The majority of injuries involved the upper and lower extremities, accounting for 39% and 51%, respectively, as traditional body armour primarily protects the trunk, leaving the extremities exposed to penetrating injuries.

The limited protection provided by body armour to the extremities was also reflected in the pattern of vascular injuries. The most commonly injured or transected vessels were the brachial artery (23%), superficial femoral artery (21%), popliteal artery (9%), and radial artery (17%).¹¹ The majority of victims were male (95%).² Nearly 80% of military vascular trauma involved the extremities, reflecting the limited protective coverage of the limbs compared with the torso.² Lower extremity injuries were approximately twice as common as upper-extremity injuries, which may be explained by the greater exposure of the major vessels in the lower limbs compared with those in the upper limbs.² Approximately 70-80% of assault-related trauma was attributed to high-energy explosive and ballistic injuries, with the remainder resulting from stab injuries (10-15%) and blunt force trauma (5-10%).² Woodward observed that nearly 50% of lower-extremity vascular injuries were associated with concomitant arterial and venous involvement, with nearly

all cases having associated orthopaedic injuries and approximately 20% having partial-thickness burns.²

However, military organizations place considerable emphasis on protection from penetrating and blast injuries through the use of body armour, as well as the implementation of management protocols involving rapid evacuation systems and structured trauma-care echelons. These measures contribute to improved survival among military vascular trauma casualties compared with their civilian counterparts.¹⁴

Vascular limb injuries are common in polytrauma settings and consequently increase risk of limb loss. The duration of limb ischaemia is directly associated with the risk of amputation.^{3,6} Blunt trauma is associated with poorer outcomes than penetrating injuries, with femoral and popliteal arterial injuries demonstrating higher rates of amputation and mortality.⁶ More than two-thirds of traumatic vascular injuries involve the lower limbs, with particularly high amputation rates reported in injuries involving the popliteal and superficial femoral arteries.⁶

Rapid and appropriate evacuation and hospital-based management are associated with improved outcomes.⁶ Restoration of arterial blood flow and vascular repair within 3 hours of injury have generally been associated with favourable outcomes.^{12,16} Amputation rates of approximately 6% have been reported when vascular repair is performed within 60 minutes, increasing to 11.7% when repair is performed within 1-3 hours and 13.4% when performed within 3-6 hours.¹²

The superficial femoral artery has been associated with the highest rate of complications. In one study, complications occurred 9 of 11 repairs, resulting in graft removal and wound-related complications.¹¹ The femoral artery is the principal arterial supply to the lower limb and is commonly injured during trauma.⁴ Its relative fixation, resulting from tethering by its branches, periadventitial connective tissue, and femoral sheath, contributes to its vulnerability, particularly at the junction between the middle and distal thirds of the thigh.^{17,18} The superficial femoral artery is the most frequently injured vessel, accounting for approximately 33–37% of vascular injuries, followed by popliteal and tibial arteries, each accounting for approximately 25%.² Without prompt management, femoral artery injury may result in complications such as compartment syndrome and may ultimately necessitate amputation.⁴

Management of femoral artery trauma may require preoperative imaging before surgical exploration of the site of injury.¹⁸ Definitive management depends on the pattern and extent of vascular injury, which may include complete transection, partial transection, or a lesion of continuity.¹⁸ The initial objectives of vascular trauma management are haemorrhage control, restoration of circulating volume, optimization of oxygenation, and definitive repair of the injured vessel.⁵

It is well established that computed tomography angiography (CTA) is a reliable, non-invasive imaging modality, with a reported sensitivity of 90-95.1% and specificity of 98.7 -100% for detecting extremity vascular injuries. CTA is generally preferred over conventional angiography because the latter is associated with greater exposure to ionizing radiation, infection, haematoma formation, and iatrogenic vascular injury.^{7,19} Caution is warranted in patients with pre-existing renal insufficiency or a history of allergic reactions to contrast media. Adequate fluid resuscitation and sodium bicarbonate administration may help reduce the risk of adverse outcomes in selected patients.¹²

Proper management of vascular injuries requires careful planning and clearly defined protocols and priorities to prevent limb and life loss.² Historically, when surgical expertise and technology were limited, amputation was often the only available intervention for preserving life.¹² Definitive assessment of the injured vessel is frequently performed intra-operatively, with arterial repair taking precedence over tendon and nerve repair.⁷ The injured arterial segment is exposed after haemorrhage is controlled and proximal and distal vascular control is established.²

In clinical situations where fracture fixation is expected to take more than 30 minutes, arterial repair should take precedence. Venous injuries should be repaired whenever feasible to minimize venous congestion and reduce the risk of compartment syndrome.⁵ Fasciotomy may be required to relieve pressure within the muscle compartments; however, it carries risks including infection and fluid loss and may necessitate a subsequent procedure for wound closure.¹⁶ Following debridement, the wound should be assessed for associated venous, nerve, and surrounding soft-tissue injuries.²

Management protocols for vascular injuries include end-to-end repair or reversed interposition vein grafting for completely transected vessels, lateral suturing or vein patch grafting for partial transections, and resection of the injured segment followed by repair in cases of lesions in continuity associated with intraluminal thrombus resulting from an intimal tear.¹⁸ Primary anastomosis is generally feasible for vascular defects measuring less than 1 cm.¹⁶

The extent of vascular reconstruction ranges from observation of an injured vessel to major repair involving reconstruction of an entire vascular segment.¹⁶ In a study by Junior et al., autologous vein grafting was the most commonly used repair technique for vascular injuries, while end-to-end anastomosis was the second most frequently used in tension-free vascular stumps. Other techniques included venorrhaphy, graft interposition, and venous ligation.⁶ However, arterial reconstruction using an autologous vein graft remains the preferred treatment for vascular injuries in war zones.¹¹ In contaminated wounds, primary repair should be avoided.¹¹

Recent literature suggests that venous ligation does not increase the risk for amputation, whereas repair of injured veins may increase the risk of thromboembolism.⁶ Venous ligation may be necessary in severe blunt injuries associated with extensive tissue and vascular damage. In such circumstances, distal limb perfusion depends on collateral circulation, the presence of pre-existing vascular disease, and the patient's intravascular volume status.¹⁶ However, venous ligation should be performed cautiously, as ligation of certain vessels, particularly the popliteal vein, has been associated with higher amputation rates.^{12,16}

Arterial repair without resection of the injured segment leaves traumatized endothelium *in situ*, thereby increasing the risk of thrombosis.⁶ During arterial reconstruction using a saphenous vein graft, harvesting from the contralateral limb is recommended to avoid venous congestion and the potential development of compartment syndrome associated with deep venous ligation in the ipsilateral limb.^{2,6,7} The Spanish Surgeon J. Goyanes was the first to revolutionize the use of the saphenous vein as an autologous graft in a patient with a popliteal artery aneurysm in 1906.⁷ A reversed autologous saphenous vein graft harvested from the contralateral limb remains the graft of choice because it is readily available, provides a compatible endothelial conduit, requires a relatively short harvesting time (5-10 mins), and is compatible in size with most peripheral arteries, with favourable short and long-term outcomes.⁷

The development of expanded polytetrafluoroethylene (ePTFE), a material demonstrated to have greater resistance to infection and acceptable patency rates when used in above-knee positions, enabled surgeons to routinely use prosthetic conduits as vascular substitutes.^{2,12}

However, these grafts were subsequently superseded by autologous vein grafts. A similar observation was reported approximately five decades ago during the Vietnam War, when the use of polytetrafluoroethylene grafts in war-related vascular injuries was discouraged because of their association with subsequent amputation.¹¹

Each graft modality has limitations. Although autologous vein grafts are resistant to infection and durable, harvesting is time-consuming and may delay reperfusion. Synthetic grafts are readily available but are associated with a higher risk of infection.⁸

Newer technologies, including the development of bioengineered human arterial conduits such as the acellular tissue-engineered vessel (ATEV), offer potential alternatives in advanced centres. ATEV is a vascular conduit developed from human vascular cells that is available off the shelf, can be implanted without eliciting significant immune rejection, and may provide an alternative to conventional grafts.²⁰ Early clinical

evidence suggests that ATEV may provide improved patency and limb-salvage outcomes while reducing operative time associated with graft harvesting. It may also demonstrate greater resilience in contaminated wounds compared with traditional synthetic grafts.^{21,20,8} However, ATEV remains an investigational biological product undergoing late-stage clinical development.²¹

In clinical trials conducted in the United States, Israel, and Ukraine, ATEV demonstrated a 30-day secondary patency rate of 91.5% among patients with extremity injuries, compared with the historically reported rate of 78.9% for synthetic grafts. Amputation rates were 4.5% for patients with extremity injuries compared with 24.3% for those receiving traditional synthetic grafts, while infection rates were 0.9% and 8.4%, respectively. These findings suggest favourable short-term outcomes with ATEV compared with conventional synthetic grafts in both civilian and military trauma patients.²⁰

Clinicians managing vascular injuries should consider the potential distal effect of reperfusion. Systemic anticoagulation with heparin should be administered before reperfusion when clinically appropriate. Clinical manifestations of reperfusion injury include increased compartmental pressure. Agrawal et al reported that 13 patients (52%) in their study developed compartment syndrome requiring prophylactic fasciotomy, with 2 patients (8%) dying despite surgical intervention, and limb loss was reported in the study population.²

The use of anticoagulants as sole therapy for thrombolysis is limited and is generally more appropriate following arterial or venous repair, after carefully weighing the potential benefits against the risks, particularly in patients with concomitant brain or spinal injuries.¹⁶ Vascular injuries that do not result in vaso-occlusive complications may be managed conservatively. However, once an injured limb develops "hard signs" of vascular injury, medical therapy alone is insufficient to prevent adverse outcomes. Observation of an injured limb should therefore be undertaken only in centres with the expertise and equipment required for emergency vascular exploration.^{12,16}

Perioperative anticoagulation has been associated with reduced rates of limb loss. In a retrospective study of 150 patients with lower-extremity vascular injuries, amputation rates were higher among patients who developed compartment syndrome (41% versus 7%) and among those who did not receive preoperative anticoagulation (15% versus 3%).²

Even in cases involving intraluminal thrombus secondary to an intimal tear, thrombectomy using a Fogarty balloon catheter introduced through a proximal femoral arteriotomy may be effective, as reported by Arora et al.¹⁸ The catheter should be inserted gently both proximally and distally across the injured segment, followed by

intraluminal flushing with heparinized saline solution to reduce the risk of thrombosis or thrombus propagation.²

Trained vascular surgeons play a vital role in the management of complex vascular trauma.⁶ Limb prognosis is influenced by the surgeon's level of training and expertise.⁶ Prognosis following axillary, brachial, and femoral vascular injuries has been reported to be favourable when managed by trauma surgeons, whereas popliteal vascular injuries, which are associated with higher amputation rates, may have better outcomes when managed by vascular surgeons.²²

The principal clinical challenge in our case, was the delayed restoration of vascular patency to prevent gangrene of his lower limbs. The patient presented four days after the injury, whereby gangrene had developed in the distal lower limb. The emergency vascular procedure performed at the district-level hospital involved an end-to-end anastomosis without thrombectomy. Consequently, any distal thrombus within the injured vessels would not have been removed. Despite postoperative anticoagulation, distal vascular patency was not restored. By the time of admission to our centre, the limb had developed extensive gangrenous changes, and vascular re-exploration was therefore no longer considered beneficial. We hypothesise that a distal thrombus persisted within the arterial lumen and subsequently became lodged at the level of the distal popliteal artery, resulting in continued vascular obstruction.

In this case, we opine that our patient's limb prognosis was poor because the patient presented 4 days after the injury and had received initial surgical treatment at a lower-level facility without access to a vascular surgeon. Furthermore, the referring facility did not have Computed Tomography Angiography available. The vascular "repair" performed there did not include thrombectomy; consequently, any residual thrombus would have remained within the arterial lumen and continued to compromise distal perfusion.

Despite Computed Tomography Angiography showing absent blood flow below the distal popliteal artery, viable tissue was present approximately 12 cm proximal to the knee joint. This led to the decision to perform a below-knee rather than an above-knee amputation, preserving the knee joint and allowing the potential use of a below-knee prosthesis. This may have been enabled by collateral circulation through the genicular arterial anastomoses. Therefore, in addition to radiological findings, the clinical assessment of tissue viability should be considered when determining the appropriate level of amputation in patients with vascular trauma.

CONCLUSION

Vascular injuries require timely assessment and appropriate intervention by appropriately trained clinicians to minimize the risk of limb loss and mortality.

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