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**CIVILIAN POPLITEAL ARTERY INJURIES:
A TEN YEAR AUDIT IN AN URBAN TRAUMA CENTRE**

by

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Declaration

I, Dr Mohamed Asif Banderker, hereby declare that the work on which this dissertation is based is my original work and that neither the whole work or any part of it has been, is being, or is to be submitted for another degree in this or any other university.

Signature:

Date: 18 March 2011

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ABSTRACT

Background:

Civilian popliteal artery injuries are associated with high amputation rates ranging from 10-70%.

Aim:

The aim of this study is to identify factors associated with limb loss in patients with popliteal artery injuries.

Methods:

Retrospective chart review of a prospectively collected data base of all patients with popliteal artery injuries presenting to the Groote Schuur Hospital Trauma Centre from 01 January 1999 to 31 December 2008. Demographic data, mechanism of injury, hemodynamic status, limb status (viable, non-viable or ischaemic), special investigations, associated injuries, ischaemic time, surgical treatment and amputation rate were analysed. The statistical package EPICALC 2000 (Brixton Health) was used to conduct statistical analysis. Statistically significance was defined as *p less than 0.05*.

Results:

One hundred and thirty six patients with popliteal artery injuries were identified. The mean age was 29.7 (range 13 – 84) years. Penetrating and blunt trauma accounted for 81 (59.5%) (72 gunshot and 9 stab wounds) and 55 (33 motor vehicle accidents and 22 falls) injuries, respectively. The anatomical level of arterial injury was above the knee in 39, at the knee in 47, and below the knee in 34 cases. Associated injuries included fractures in 66 (48.5%), knee dislocation in 29 (21.3%) and popliteal vein injury in 59 (43.4%) patients. Limb viability on admission was assessed as viable in 40 (30.3%), ischaemic in 85 (64.4%), and non-viable in 7 (5.3%). Fifty-seven (41, 9%) patients had full-blown compartment syndrome on admission. Treatment of the arterial injury involved reversed vein grafting in 68, primary anatomises in 33, prosthetic graft insertion in 11, and primary amputation in 7. Thirty-two patients required delayed amputation, resulting in an overall amputation rate of 37.5%. Mechanism of injury ($p = 0.684$), concomitant venous injury ($p =$

0.701), fracture ($p = 0.183$), knee dislocation ($p = 0.784$), anatomical level of arterial injury ($p = 0.393$) and type of repair ($p = 0.086$) were not associated with increased amputation rates. The delay between injury and definitive repair of more than 7 hours in patients with ischaemic limbs ($p = 0.0236$) and the presence of a compartment syndrome ($p = 0.003$) were the only factors significantly associated with an increased amputation rate.

Conclusion:

In the current series, the amputation rate was 37.5%. The most significant factors associated with this finding were an ischaemic time of more than 7 hours, and the presence of a compartment syndrome.

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CHAPTER ONE:

LITERATURE REVIEW

INTRODUCTION

Injury to the popliteal vessels has been recognized as the most limb threatening of peripheral vascular injuries for as long as vascular trauma has been studied. **The popliteal artery is an end artery with a tenuous collateral supply.** In addition, the popliteal vein provides the bulk of lower leg and foot drainage, and explains why injury to these vessels is so devastating. Despite this, limb loss and limb morbidity following trauma to the popliteal vessels have been reduced to the same minimal levels as is reported for all other peripheral vascular injuries in some recent reports.

The diagnostic and therapeutic factors which account for this accomplishment merit review from the perspective of the distinct history, anatomy, and epidemiology of popliteal vascular trauma.

HISTORY

Ligation had remained as standard management of all extremity arterial injuries through World Wars I and II and as the surest means of avoiding death by exsanguination, shock, and secondary infection. Although the techniques for vascular repair had been established by this time^{10, 63}, the lack of timely transportation, unsanitary conditions, and the absence of effective blood banking, antibiotics, and anaesthesia prevented this approach from being used on a large scale.⁶ In fact, delayed treatment of vascular injuries was encouraged through the beginning of the Korean War to promote collaterals so as to optimize limb salvage after ligation.^{41, 50}

In the report of 2471 vascular injuries in World War II by Debakey and Simeone¹³, the standard approach of ligation of injured popliteal arteries resulted in limb amputation in 72.5% of cases, the

highest of any extremity vessel. Even in those limbs salvaged, arterial ligation led to significant problems with functional and neurologic disability.

The first use of a vein graft to repair an arterial injury was performed on a traumatic aneurysm of the popliteal artery in 1906.³¹ The injured artery segment was excised and replaced with the adjacent popliteal vein. Popliteal artery repair was first performed on a large scale in the Korean War, and the limb amputation rate was only 32.4%.³⁸ Similarly, routine repair of these injuries in the Vietnam War resulted in only a 29.5% limb amputation rate,⁷⁸ clearly demonstrating the superiority of repair over ligation. In addition, salvaged limbs had only minimal levels of disability related to the arterial injury. Virtually all cases reported from military conflicts were caused by penetrating trauma, most commonly from bomb and land mine fragments, followed by high-velocity gunshots.⁷⁸ D'Sa et al¹⁸ reported 66 cases of popliteal vascular trauma from the Northern Ireland hostilities in the 1970s, largely resulting from "knee capping" with high-velocity gunshots. Their amputation rate was only 12.5% for arterial injuries. Sfeir et al⁸⁶ reported an amputation rate of only 12% following treatment of 118 popliteal artery combat wounds from the hostilities in Lebanon in the 1980s. These reports show that significant improvement in limb salvage has continued since Vietnam, even in the setting of highly destructive combat injuries. These results were extrapolated quickly to the civilian sector, where further improvements in limb salvage occurred. During the 1950s, repair of arterial injuries rapidly supplanted ligation by civilian surgeons in the United States, with the same improved results in limb salvage and function.²⁵ This was all the more remarkable in light of the fact that civilian vascular trauma includes a substantial portion of blunt injuries, with their poorer overall prognosis. Fabian et al²¹ documented this progress in civilian popliteal vascular trauma in their report of 165 such injuries (125 penetrating, 40 blunt) treated over 30 years. Although the overall amputation rate was 27%, this evolved from 74% in the 1950s, to 28% in the 1960s and only 6% in the 1970s. Daugherty et al¹² reported an overall amputation rate of 33% among 24 civilian popliteal artery injuries, improving from 54% between 1967 and 1972 to only 9% between 1972 and 1977. Thomas et al⁹⁴ reviewed

610 published cases of popliteal artery injuries in 25 series showing a 30% and 15% amputation rate before 1980 and after 1980, respectively.

By 1990, four published series had reported the remarkable accomplishment of a total of 78 civilian cases of both blunt and penetrating popliteal artery injury without a single amputation.^{49, 76, 87, 99}

Strict attention to factors that correlate with improved limb salvage in this setting was responsible for these improved outcomes.

PROGNOSTIC FACTORS

Analysis of the extensive military and civilian experience with popliteal vascular trauma over the past 60 years **has revealed a number of factors which clearly affect limb salvage**: time interval between injury and treatment, mechanism of injury, associated injuries, chronic vascular disease, and clinical presentation. Knowledge of these prognostic factors is necessary for any surgeon treating injury to these vessels if limb salvage is to be optimized.

The *time interval between injury and treatment* must be minimized to ensure salvage of both life and limb. This makes sense in terms of the time-dependent nature of the two major consequences of extremity vascular trauma, haemorrhage and ischemia. The importance of this is magnified when popliteal vessels are involved, in view of their poor collateral supply. Both experimental and clinical evidence has repeatedly confirmed the direct correlation between a delay of treatment of more than 8 hours and limb loss. Most series have documented that the most common cause of limb loss following popliteal vascular injury is delay in diagnosis and treatment.^{3, 12, 21, 33, 73, 74, 94,99}

Even many salvaged limbs following delayed treatment manifest residual disability from muscle and nerve damage.

Mechanism of injury has been shown to be an important risk factor for limb loss in this setting.

As in all trauma, penetrating wounds tend to have better outcomes than those from blunt injury because surrounding tissue damage tends to be less severe. Blunt popliteal vascular injuries are also

more difficult to diagnose because associated organ and tissue injuries can easily obscure a vascular injury. For the same reason, patients with simple, low-velocity gunshot wounds tend to have better outcomes than do patients with high-velocity gunshot wounds.

Associated injuries to surrounding structures or other body systems clearly increase the risk for limb loss following popliteal vascular injury. Injuries to the torso or head certainly pose life-threatening risks and must be managed first. The most common injuries to nearby limb structures are skeletal injuries (with posterior knee dislocation being especially common), popliteal vein, tibial and peroneal nerve, and soft tissue and tendon.^{3, 57, 73, 74}

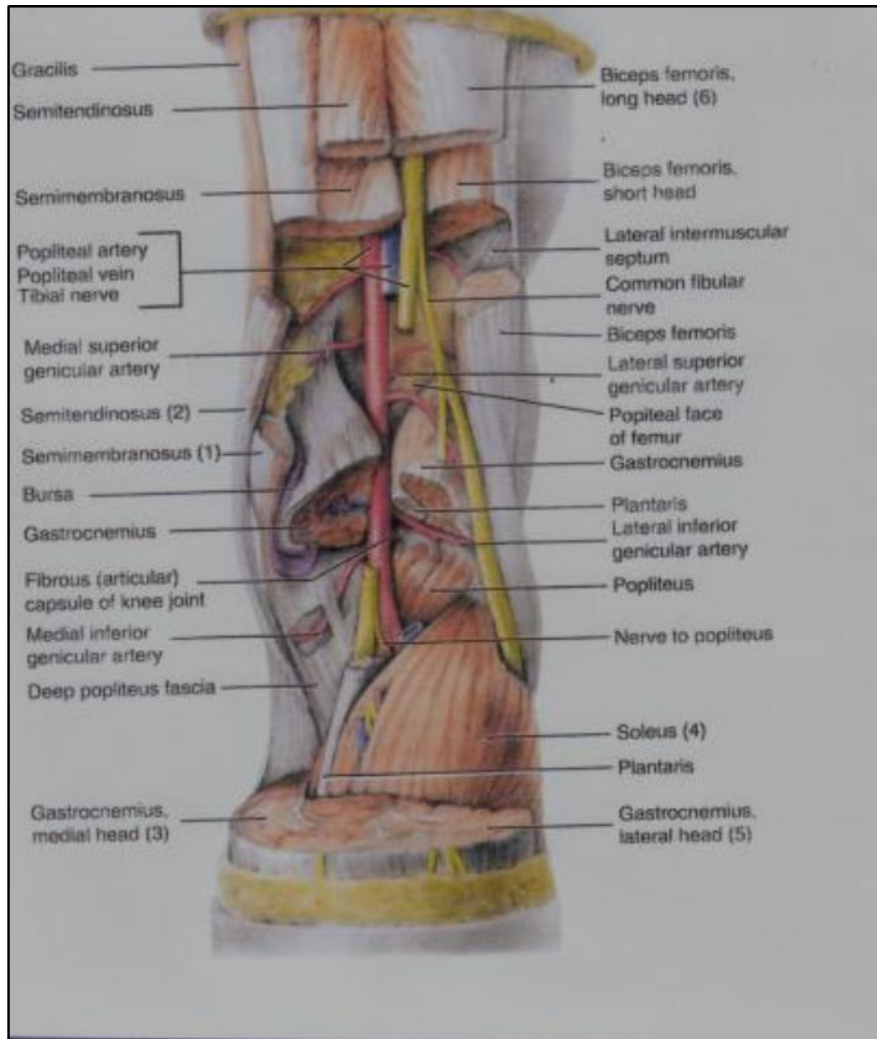
Chronic vascular occlusive disease in elderly victims of popliteal vascular injury adversely affects prognosis because these limbs often have elements of established chronic ischemia and are more sensitive to any ischemic insult. Also, accurate diagnosis of an acute vascular injury may be obscured by the chronic existence of pulse deficit and ischemic changes in these patients.⁴⁵

The **clinical presentation** of popliteal vascular injury is another prognostic factor. Patients with injuries which present with established ischemia, or active haemorrhage and shock, have a poorer prognosis and demand more urgent management than do patients with lesser injuries in which perfusion remains intact.^{3, 57, 74}

ANATOMY OF THE POPLITEAL VESSELS

The popliteal artery begins as the continuation of the superficial femoral artery as it courses through the hiatus of the adductor magnus muscle. Proximally, it is covered by the semimembranosus muscle, but in the popliteal fossa behind the knee joint, it is covered only by subcutaneous tissue lying between the two heads of the gastrocnemius muscle and at the border of the soleus muscle. It is in this area that the popliteal artery is vulnerable to stretch and direct injury by skeletal distortions, such as fractures and knee dislocations, because it is tethered to the distal femoral shaft

Figure 1. Anatomy of the popliteal artery



at the adductor hiatus and to the proximal tibia by the tendinous arch of the soleus muscle. The artery rarely trifurcates. It most often bifurcates as the anterior tibial artery courses laterally through the interosseous septum, and the main tibioperoneal trunk then continues for another 2 to 3 cm before it divides into the peroneal and posterior tibial arteries. The popliteal artery gives off several geniculate, sural, and muscular branches behind the knee, which anastomose in a rich collateral network with the branches of the profunda femoris proximally and tibial arteries distally. Although abundant, this collateral network is frail and subject to obliteration and thrombosis by disruption or soft tissue swelling. These vessels are inadequate to maintain viability of the leg and foot on their own, explaining the high rate of limb loss when the popliteal artery is acutely occluded.^{48,60}

The popliteal vein arises from the confluence of several tibial venous commitantes at the distal portion of the popliteal fossa. It travels proximally in a dense sheath along with the popliteal artery, entwining the latter in several venous tributaries. This proximity explains the frequent coexistence of popliteal venous trauma when the artery is injured. The tibial nerve enters the popliteal fossa between the semi-membranosus and the biceps femoris muscle. It lies on the lateral aspect of the popliteal vessels at the level of the knee joint, then crosses the vessels posteriorly to become the most superficial midline structure during posterior exposure of the popliteal artery.

EPIDEMIOLOGY

Injury to the popliteal artery accounted for 12 % of all arterial injuries among survivors in World War I,⁵¹ 20% of those in World War II,¹³ 26% of those in the Korean War,³⁸ and 21.7% of 1000 arterial injuries in US troops in the Vietnam War.⁷⁸ Over the past 25 years, the civilian sector has provided the bulk of experience with these injuries, in which setting blunt mechanisms account for 20% to 75% of all cases. Popliteal artery injuries account for 19% of all extremity arterial injuries²⁶ and have an incidence of 5.6 per 1000 cases of penetrating trauma and 1.6 per 1000 cases of blunt trauma.⁵⁷

A compilation of 1209 published cases of civilian popliteal artery trauma from 24 series⁷⁵ makes evident the importance of mechanism on outcome, and the improvement in overall outcome during the past few decades, as a result of strict attention to optimizing the known prognostic factors.

Although penetrating wounds accounted for 56% of these injuries, they resulted in only a 10.5% overall amputation rate, ranging as high as 27%. Blunt trauma resulted in amputation in 27.5% of all cases, ranging as high as 71%. A total of 79 cases of penetrating popliteal artery injury were successfully repaired without a single amputation.⁷⁵ The fact that 50 recently published cases of even blunt popliteal artery trauma had no amputations reflects a major improvement over past years.

The highest overall amputation rates tend to be reported in older series, which involve cases from as long ago as the 1950s; however, even some recent series report high rates of limb loss, reminding physicians of how dangerous popliteal artery injuries remain. Iatrogenic injury is an exceedingly rare cause of popliteal vascular trauma as these vessels are not typically cannulated for diagnostic or therapeutic purposes.

DIAGNOSIS

Most cases of popliteal vascular trauma present with obvious clinical manifestations, or “hard” signs of vascular injury, including active haemorrhage, presence of a large, expanding or pulsatile hematoma, presence of a bruit or thrill, absent pulses, and distal ischemia (the 6 Ps: pain; pallor; paralysis; paresthesias, poikilothermy, pulselessness). It is widely agreed that, in the setting of uncomplicated penetrating trauma to the lower extremity, the presence of any one or more hard signs mandates immediate surgery.^{24, 52, 91}

The clinical findings will provide the answers to the two questions necessary to decide whether to operate or not, namely, whether a significant vascular injury exists, and where it is located.²⁸

Any further imaging or diagnostic test is therefore unnecessary, costly, and potentially dangerous considering the adverse impact of delay on outcome. Most limb-threatening complications of delayed diagnosis of popliteal vascular injury are the result of overlooking hard signs, rather than an absence of signs, on initial presentation. Systemic heparinization should be initiated immediately if an injured extremity is clearly ischemic, and if not contraindicated by other injuries.^{12, 21, 91}

In some special circumstances, contrast arteriography may be indicated to confirm or exclude popliteal artery injury, even in the presence of hard signs, when the physical examination is not sufficiently reliable to allow for a therapeutic decision. Blunt trauma and complex trauma to the lower extremity, which cause extensive bone and soft tissue injury, may manifest hard signs that do

not arise from vascular injury at all but rather from soft tissue and bone bleeding, as well as direct nerve damage. A physical examination with hard signs in this setting is falsely positive for the presence of vascular injury in as many as 87% of cases. Arteriography is recommended here to exclude arterial injury and thus prevent a high rate of unnecessary surgical exploration in their already compromised limbs.^{2, 11} Imaging is also of value in shotgun wounds because of multiple possible sites of injury that may be missed on surgical exploration.

Arteriography should be used liberally in elderly patients with chronic vascular insufficiency following extremity trauma, because pulse deficit and ischemia may not be related to an acute vascular injury.⁴⁵ In these circumstances, arteriography should be performed by direct hand-injection of contrast percutaneously into the femoral artery at the groin in the front room or operating room by the surgeon to save time, and with acceptable accuracy.^{17, 39, 47, 65}

Patients with popliteal artery injuries which presents in a delayed fashion of more than 12 to 24 hours after injury, with clinical evidence of gangrene, false aneurysm (pulsatile mass), or arteriovenous fistula (bruit or thrill), should undergo preoperative arteriography.

The time consideration here is no longer important, and imaging is necessary to delineate the morphology, location, and distal runoff to accurately plan the operative repair.

Imaging is generally unnecessary in the absence of hard signs following extremity trauma.

Extremity wounds which place the popliteal vessels at risk and do not manifest hard signs (i.e., have a negative physical examination) have long posed a diagnostic dilemma; many studies have shown that vascular injuries do still occur in this setting in 10% to 24% of these cases. These injuries include penetrating trauma in proximity to the popliteal vessels and any high-risk blunt trauma, such as lower extremity crush, distal femur or proximal tibia fractures, and posterior knee dislocations. In the past, routine surgical exploration or arteriography was recommended in patients with these asymptomatic extremity injuries to avoid any missed popliteal trauma, with its known limb-threatening consequences.^{45, 71}

More recently, several studies have provided compelling evidence that most of the asymptomatic vascular injuries which occur in this setting are non-occlusive, have a benign and self-limited natural history with a high rate of spontaneous resolution, do not require surgical repair, and therefore do not require the considerable expense and resources necessary for detection.^{2, 16, 27} The low reported missed injury rate (<1%) when clinical management of injured extremities is based entirely upon the physical examination is comparable to that of arteriography and surgical exploration but is far less expensive and invasive.^{28, 84}

Non-invasive testing with Doppler pressure measurements and duplex ultrasonography has been applied to injured extremities in recent years to assess for vascular trauma. These tests have the potential advantage over arteriography and surgery of being rapidly available, less costly, less invasive, and equally accurate^{9,43}; however, several disadvantages have prevented these modalities from achieving widespread acceptance for trauma, including the equipment expense, the lack of round-the-clock availability of the necessary skill and expertise in most hospitals, the uncertain accuracy in injured limbs with skeletal deformities, swelling, hematomas and bulky splints and dressings, and the lack of any long-term follow-up validation of their accuracy. They have never been compared with physical examination to demonstrate any added benefit to justify their added expense.¹⁵

TREATMENT

Surgical Repair

Patients with injury to the popliteal vessels require prompt transport to the operating room.

Induction of general anaesthesia, and prepping and draping of the entire leg into the operative field to be able to visualize the foot and palpate distal pulses is required. One uninjured extremity also should be prepped in the event that autogenous vein harvesting is necessary.

The patient should be supine, with a support under the knee in slight flexion and the hip abducted and externally rotated. Although the posterior S-shaped incision across the knee joint has been used in past years to approach these vessels, the standard approach for trauma is a medial longitudinal incision placed 1 cm posterior to the distal femur and proximal tibia. This latter incision provides greater versatility of exposure of the distal vessels and associated structures, easy access to the medial leg compartments for fasciotomy, and easier patient positioning.^{24, 32, 49}

Care must be taken to avoid damage to the saphenous vein and nerves in the superficial tissues. The sartorius and semimembranosus muscles are retracted posteriorly to expose the popliteal artery, and the vein and nerve lie immediately lateral and posterior to this.

Digital pressure can be used to control hemorrhage until enough vessel can be dissected free to obtain proximal and distal control with clamps or vessel loops. More distal exposure of the tibioperoneal trunk can be obtained by division of the medial head of the gastrocnemius muscle and the tendons of the semimembranosus, semitendinosus, and gracilis muscles. Although these structures may later be reattached, an excellent functional result can be obtained even if this is not done.

Damaged portions of artery and vein should be debrided back only to grossly normal-appearing vessel. End-to-end anastomosis is preferred if it can be done without undue tension, but this is generally not possible if more than 2 cm of vessel is lost.⁷⁰

Division of geniculate collaterals to achieve mobility should be avoided because of the detrimental effect that this may have on limb perfusion. It is best to place an interposition graft in this setting, preferably using reversed autogenous saphenous vein from the opposite leg to preserve venous outflow from the injured limb.^{24, 97}

Prosthetic grafts across the knee joint generally have lower patency rates than does vein and are best avoided in this setting.^{30, 44}

Systemic heparinization should be used during the vascular repair, if associated injuries permit, to reduce distal thrombosis and maximize successful revascularization.^{12, 21, 57}

Balloon catheter thrombectomy should be carried out in the proximal and distal vessel segments before repair until good backward and forward bleeding are achieved, and heparinized saline should then be injected into the distal arterial segment to further retard thrombus. Both arterial and venous anastomoses are performed with a running monofilament suture to achieve good intimal coaptation. Approximately 10% to 15% of popliteal artery injuries are amenable to lateral arteriorrhaphy, which requires a clean tangential laceration involving less than 30% of the vessel circumference, mostly from stab wounds¹⁷; however, this technique should be applied cautiously in the relatively small popliteal artery to avoid stenosis and thrombosis, and many surgeons prefer resection and anastomosis. Vein patch angioplasty may be used in this setting to avoid resection and still minimizes the risk for stenosis.

Extra-anatomic bypass has been advocated for popliteal vascular repair when the native vascular bed is infected, has extensive soft tissue loss, or is not easily accessible.¹² An interposition graft is tunneled through a new uncontaminated area laterally. This may be dangerous if injury of the original vessels is left untreated because false aneurysms may enlarge, rupture, impinge on nerves, or embolize. Therefore, proximal and distal ligation of the artery is recommended if bypass is undertaken. Completion arteriography should be performed liberally following vascular repair. Several investigators have reported unsuspected anastomotic problems needing revision in as many as 10% of cases.^{49, 67}

Nonoperative Observation

A unique spectrum of arterial injuries is non-occlusive and manifests no hard signs, and includes vessel narrowing, intimal flaps, and small false aneurysms and arterio-venous fistulas. They comprise approximately 10% of all arterial injuries and may be found following blunt or penetrating trauma. In past years, all such minimal arterial lesions were routinely subjected to surgical exploration and “repair” to minimize the complications of missed vascular injuries; however, as

mentioned earlier, these clinically occult arterial injuries have a largely benign natural history and can be observed safely without surgery and without a need for detection.⁹¹ Approximately 10% of these lesions may deteriorate into false aneurysms, at which time they can be repaired without adverse sequelae. No case of thrombosis has ever been reported, and there has never been a single case of limb loss or limb morbidity resulting from expectant management of these injuries.^{26,28} This evidence supports the policy of not searching for popliteal vascular trauma in injured extremities which do not manifest hard signs. Simple proximity of wounds to popliteal vessels thus no longer justifies arteriography or surgery. The avoidance of unnecessary surgical exploration of the popliteal vessels in traumatized limbs has clear advantages in terms of the substantial cost savings and reduced morbidity and resource utilization.²⁸

SPECIAL CONSIDERATIONS

Popliteal Venous Injuries

As with all extremity vascular traumas, popliteal vein injuries most commonly occur in combination with popliteal artery trauma, with only 5% to 10% of cases occurring in isolation. For this reason, and the absence of any known morbidity of missed asymptomatic venous injuries, preoperative venography is not necessary in extremity trauma. Vein injuries rank only behind skeletal trauma as the most common injuries associated with popliteal artery trauma.

Penetrating mechanisms are the cause of 80% to 95% of cases in the civilian sector.^{19,24}

Hemorrhage and hypotension are the most common presenting manifestations of popliteal vein injury, and shock is more likely to occur, and morbidity is higher, in the presence of concomitant arterial and venous injury than with either in isolation.²⁴

It is widely agreed that popliteal vein injuries should be repaired, if at all possible, to restore venous outflow through this major drainage channel of the lower extremity. The safety and benefits of

lower extremity venous repair were first shown in the early 1960s,²⁹ when ligation was thought to be the safest approach because of a fear of thrombo-embolic problems if veins were recanalized. The severe limb-threatening complications of venous ligation, especially of the popliteal vein, including compartment hypertension, massive disabling edema, and failed arterial repairs, were demonstrated in experimental and clinical studies arising out of the Vietnam War experience.^{35,77,79} The resulting enthusiasm for mandatory routine repair of all venous injuries has been tempered by several subsequent civilian reports that demonstrate remarkably uncomplicated long-term outcomes following ligation of the popliteal and other lower extremity veins.

In fact, equivalent morbidity was shown between ligation and repair of these veins.^{5,62}

Although most venous repairs seem to thrombose in the early postoperative period, long-term follow-up shows restoration of venous outflow through recanalization and no significant morbidity resulting from this.⁶⁴

The current consensus favours repair of popliteal vein injuries unless life-threatening problems exist that preclude further surgery, or more complex repairs than simple lateral suture and end-to-end anastomosis are necessary, in which settings ligation is recommended.

If venous ligation is performed, elastic wrapping, leg elevation, and four-compartment fasciotomy of the lower leg are recommended to effectively reduce morbidity.²⁴ Although long-term anticoagulation and distal arterio-venous shunts have been advocated to improve the patency of vein repairs and follow-up venography has been used, most investigators now agree that these measures are unnecessary because thrombosis is common and resolves on its own and because the clinical status of the injured limb, rather than radiography, should dictate management.⁸⁹

The techniques of venous repair are identical to those used in injured arteries. In combined injuries of both the popliteal artery and vein, many recommend that the vein be repaired first to ensure outflow from the arterial revascularization, which should minimize failure of the arterial repair.²⁴

The dilemma this poses, in terms of prolonging arterial ischemia, is resolved by inserting a temporary intraluminal arterial shunt of plastic or silastic tubing to immediately restore circulation

to the lower leg while venous repair is undertaken. Another approach would be to repair the artery immediately while shunting the vein to ensure limb drainage for the restored inflow. The shunted vessel then can be repaired definitively, with minimal ischemic time imposed on the patient.⁴⁶

Compartment Syndrome

Popliteal vascular injuries always pose a high risk for lower leg compartment syndrome, as does any combined arterial and venous injury, prolonged ischemia (>4–6 hours), complex and multiple extremity fractures, combined vascular and bone or soft tissue injury, arterial or venous ligation or thrombosed repair, and elevated compartment pressure measurements.

Compartment syndrome is characterized by a compromise in tissue perfusion, and ultimately necrosis, of muscle and nerve tissue, caused by increased pressures within the limited space of a fascial compartment. Bleeding, venous hypertension, and ischemia/reperfusion injury are the most common specific causes of increased compartmental pressures from trauma.⁶¹

Ischemic tissue damage gives rise to the classic manifestations of pain out of proportion to injury which is worsened by passive stretch, sensory-motor deficits, and palpable swelling and tenseness of the lower leg. Prompt treatment is necessary when these findings are present. However, tissue loss is usually already established at this point, leading to long-term disability or limb loss. Palpable pulses do not rule out this condition, and absent pulses always should be attributed to vascular injury and not compartment syndrome.

Fasciotomy is the definitive treatment, involving complete incision and decompression of the skin and investing fascia of each of the four lower leg compartments:

- 1- the superficial posterior, containing the gastrocnemius and soleus muscles;
- 2- the lateral, containing the superficial peroneal nerve;
- 3- the anterior, containing the anterior tibial vessels and foot dorsi-flexors; and
- 4- the most important deep posterior compartment, containing the posterior tibial and peroneal vessels and the tibial nerve.

This procedure most commonly is performed through two longitudinal lower leg incisions, laterally and medially, although one lateral incision can be used with or without fibulectomy.

It is generally agreed that prophylactic fasciotomy, which is done before the development of symptoms and tissue loss in asymptomatic patients with the high-risk injuries and findings mentioned earlier, is far preferable to therapeutic fasciotomy done after the development of symptoms and signs of tissue loss. The liberal use of prophylactic fasciotomy substantially improves the historically poor rate of limb salvage and function following popliteal vascular trauma. In fact, this is best done as the initial procedure when operating on popliteal artery and vein injuries, before the vascular repair, to ensure tissue perfusion and optimize successful revascularization. Prophylactic fasciotomy has more acceptable cosmetic results than when the procedure is done therapeutically for established compartment syndrome. This is because there is no bulging, swollen muscle that requires skin grafting. Primary closure is always possible, often at the bedside without the need for another operative procedure.

Careful serial examination of injured extremities at high risk for compartment syndrome is a valid option, but such observation must include serial measurements of compartment pressures due to the insensitivity and unreliability of physical findings. Any pressure measurements of more than 25 mm Hg mandate immediate fasciotomy.²³

Combined Vascular and Skeletal Extremity Trauma

Complex extremity trauma, involving popliteal vascular injuries in association with skeletal injuries of the same limb, poses a substantially higher risk for limb loss and morbidity than either injury alone.^{2, 13, 55, 57} Amputation and limb disability rates in this setting still approach 70% in the most experienced trauma centres presumably because of delayed recognition, disruption of tenuous collaterals, inadequate soft tissue coverage of vascular repairs, and the high incidence of compartment syndrome. Amputation rates can be substantially decreased through prompt diagnosis and revascularization, liberal completion arteriography, aggressive use of prophylactic fasciotomy,

meticulous surgical repair, early skeletal stabilization and fixation, immediate coverage of soft tissue defects with tissue flaps, rapid return to surgery for loss of pulses following repair, close cooperation between orthopaedic and trauma surgeons, and avoidance of surgery for nonocclusive vascular injuries. Prompt diagnosis is achieved by liberal use of immediate on-table hand-injected arteriography in the front room or operating room for any extremity skeletal injury manifesting hard signs.^{17, 94}

Prioritization of management of the vascular and skeletal injuries is crucial to the success of limb salvage. In past years, orthopaedic stabilization and fixation were recommended as the first priority to avoid disruption of an initial vascular repair by subsequent skeletal manipulation. However, it has been clearly demonstrated that revascularization must always be the first priority because limb salvage is significantly improved in this setting compared with delay of revascularization. This makes sense because perfusion, rather than immediate skeletal continuity, is the sine qua non of limb survival, and published studies overwhelmingly show that the most common reason for limb loss in these injuries is delay or failure of revascularization, not of skeletal repair.

Also, initial restoration of extremity perfusion can always be accomplished in a matter of minutes with the use of temporary intraluminal shunts, which then allows for deliberate attention to debridement and skeletal repair without ongoing ischemia and renders moot any concerns of disruption of a formal vascular repair. Shunting is best used in unstable comminuted fractures, major skeletal injuries with bone loss, and dislocations in which skeletal stabilization or repair may be warranted before a definitive vascular repair. On the other hand, initial revascularization can be accomplished by immediate definitive arterial repair when the skeletal injury is stable and minimal manipulation and length discrepancy is anticipated. Thus, immediate restoration of perfusion does not necessarily always have to be accomplished by a definitive vascular repair but must always be the first priority in this setting.

Posterior knee dislocation is associated with a substantial incidence of popliteal artery injury, which in past years led to a recommendation for mandatory arteriography of all cases.^{21, 47} However, it has

been demonstrated for all other forms of extremity injury, that the absence of hard signs on physical examination (which is how 80% of all posterior knee dislocations present) reliably excludes by significant popliteal artery injury. This allows for substantial cost savings by safely avoiding routine arterial imaging of this population.

Asymptomatic nonocclusive arterial injuries do occur in this setting, but once again, their uniformly benign natural history precludes any need for detection. Arteriography or surgery is warranted in that minority of these patients who manifest hard signs following posterior knee dislocation.⁵⁹

AMPUTATION

Immediate or early amputation of severely injured limbs with popliteal vascular trauma is a difficult decision for any surgeon. In certain circumstances, this may be better for the patient than heroic salvage attempts with prolonged and multiple hospitalizations, multiple operative procedures, lost time from work, excessive costs, and complications that threaten life and limb, but that result in amputation anyway. Prognostic factors have been identified that correlate with a high risk for limb loss and that should prompt consideration of immediate or early amputation. These include open comminute tibio-fibular fractures with popliteal artery injury, extensive crush injuries and soft tissue damage, multiple comminuted skeletal fractures with bone loss, life-threatening problems that preclude extremity treatment, multiple failures of revascularization, and sciatic or tibial nerve transection.⁴²

The mangled extremity severity score (MESS) is a scoring system that can be applied to mangled extremities and help one determine which mangled limbs will eventually come to amputation. The MESS is a graduated grading system based on skeletal and soft tissue injury, shock, ischemia, and age. The decision for amputation must remain a matter of surgical judgment in which the patient's best interests are considered in each specific case; this decision should be made only with the consensus of the patient and the entire multidisciplinary team.

CHAPTER TWO

AIM

The aim of the study was to analyse the outcomes of patients presenting to the level one urban trauma centre at Groote Schuur Hospital, Cape Town, South Africa with popliteal artery injuries.

The key objective being to define the amputation rate and the factors contributing to limb loss.

University of Cape Town

CHAPTER THREE

METHODS

All patients presenting to the Trauma Unit at Groote Schuur Hospital with a popliteal artery injury over a ten year period from 01 January 1999 to 31 December 2008, were included in this study.

The charts of patients were retrospectively reviewed.

The Trauma Centre's Surgery Operative Data Base was the basis for identifying patients with popliteal artery injuries.

Approval from the Department of Surgery Research Committee and Faculty of Health Sciences Human Research Ethics Committee was obtained prior to accessing data. (*Appendix 1 & 2*)

Patients' charts were obtained from medical records and numeric codes were assigned in order to maintain privacy.

Standard demographic data, mechanism of injury, degrees of ischemia and vascular investigations were recorded. Operation notes documented the location of the popliteal artery injury, method of repair and local associated injuries. Complications and mortality were noted. Initial management and resuscitation were conducted along standard Advanced Trauma and Life Support (ATLS)® guidelines. Patients presenting in shock with active bleeding, compartment syndrome, or limb ischemia [Rutherford 11(b)] were resuscitated and expediently taken to the operating room (OR) for emergency exploration. Hemodynamically stable patients and those who stabilized after simple resuscitation (less than 2L crystalloids) underwent further evaluation. Indications for emergency room single-shot angiography (ERA) included a hemodynamically stable patient with hard signs of

a vascular injury (pulseless limb, bruit or pulsatile haematoma) and the clinical assessment of a potentially threatened limb. Pulseless limbs were identified with the use of both digital palpation, as well as hand-held portable Doppler ultrasound. Patients with diminished pulses or shotgun injuries, and a viable limb, underwent formal angiography in the vascular radiology suite. Contraindications for ERA encompassed hemodynamic instability, massive bleeding or a rapidly expanding hematoma. ERA using the Lodox Statscan™ 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 seconds. Typically, this procedure required less than 10 minutes to complete in its entirety. If needed, lateral and/or oblique views could be obtained as well. Indications for formal angiography were: ipsilateral distal pulse discrepancy, absent pulse in the presence of a viable limb, moderate to large hematoma, palpable thrill and/or audible bruit and all knee dislocations without any signs of ischemia. The length of time from injury to hospital, length of time from presentation to definitive repair, and the length of time from injury to definitive repair was calculated.

The data was captured on a proforma data base sheet in Microsoft Excel and included the following data points: (*Appendix 3*)

- Demographics

Age and gender

- Mechanism of injury:

Blunt (motor vehicle accident or fall) or penetrating (stab or gunshot wound).

- Limb viability on presentation as defined by Rutherford's classification for limb ischemia
 - I. *Viable: not immediately threatened, no sensory or motor loss*
 - II a). *Marginally threatened: minimal sensory loss, no motor loss*
 - II b). *Immediately threatened: sensory and motor loss*
 - II. ***Unsalvageable: irreversible tissue and nerve damage***
- Presence or absence of compartment syndrome
- Presence or absence and of a fracture
- Presence or absence of a knee dislocation.
- Length of time from injury to hospital.
- Length of time from presentation to definitive repair.
- Length of time from injury to definitive repair.
- Angiography:
 - Not performed, or front room single-shot, or formal angiography, or on table angiography.*
- Operative findings
- Level of injury to artery
 - Above knee, knee level or below knee*
- Type of injury to artery
- Presence or absence of a venous injury
- Type of arterial repair
- Type of venous repair
- On table assessment of viability
- Completion angiography
- Fasciotomy
 - Prophylactic or therapeutic*
- Reoperation procedures
 - Vascular-related, soft tissue or bone*

- Amputations:

Primary: no attempt at revascularisation

Secondary: failed revascularisation attempt

- Length of hospital stay.
- Complications
- Follow up
- Mortality

The above data and variables were collected and analysed on an excel spread sheet.

The statistical analysis was conducted with the use of a biostatistics package: Epicalc 2000 by Brixton Health. The statistic analysis was in collaboration with the School of Public Health at the University of Cape Town. Proportional comparisons between groups were conducted with Fisher's exact test. Normally distributed variables were compared between groups within each category using Students t-test. For non-parametric data or data that were not normally distributed, the Mann-Whitney U-test was used for between group comparisons. Confidence intervals (CI) were calculated to 95%. A *P-value* of 0.05 was defined as the level of significance.

CHAPTER FOUR

RESULTS

One hundred and thirty six patients with popliteal artery injuries were evaluated and managed during the 10 year study period from 01 January 1999 to 31 December 2008. There were 106 (77.9%) men and 30 (22.1%) women with a mean age of 29.7 (range : 13-84) years. Penetrating and blunt mechanisms of injury occurred in 81 (59.5%) and 55 (40.5%) patients, respectively. Gunshot wounds [72, (88.8%)] accounted for most of the injuries in the penetrating group, while stab wounds occurred in 9 (11.2%) patients only. Road traffic accidents accounted for 33 (60.0%) popliteal artery injuries. The remaining were associated with falls [22, (40%)]. More than half of the blunt injuries; [29, (52.7%)], were associated with knee dislocations. (Table 1).

No. of popliteal artery injuries	136
Men	106 (77.94)
Women	30 (22.06)
Mean age (years)	29.7 (R 13 – 84)
Mechanism of injury	
<i>Penetrating</i>	<i>81 (60)</i>
Gunshot	72 (88.8)
Stab	9 (11.2)
<i>Blunt</i>	<i>55 (40)</i>
Motor vehicle accident	33 (60)
Fall	22 (40)
Dislocation	29 (52.7)

Table 1. Basic Demographics of 136 patients with popliteal artery injuries

Eighty five (62.5%) patients presented with an ischemic limb, all of whom proceeded to undergo emergency surgery for revascularization. Prior to surgery, 42 (49.4%) patients had emergency room angiography, 12 (14.1%) patients had on table angiography and 13 (15.2%) had angiography in the radiology suite (marginally threatened limbs). These investigations were pursued as per the grade of ischemia and clinical presentation. Eighteen patients proceeded directly to theatre without any vascular imaging. Forty (29.4%) patients presented with a viable limb. These patients had formal angiography in the radiology suite and all subsequently proceeded to undergo urgent popliteal artery repair. Seven patients presented with **unsalvageable** limbs, all of whom proceeded to undergo the appropriate ablative procedure. Four patients had no recorded limb status on presentation (Fig.1).

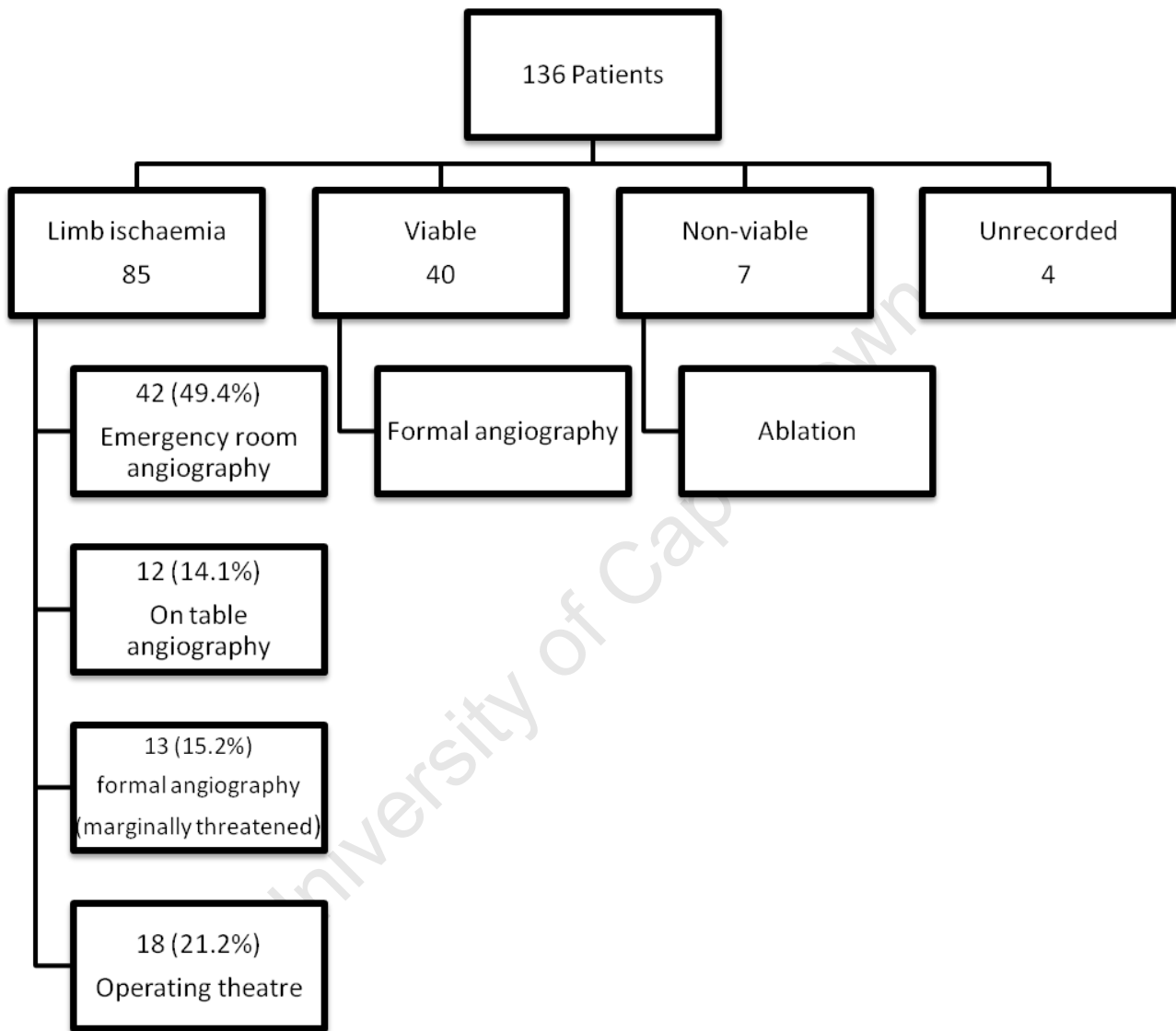
Nineteen (13.9%) patients presented with a history of knee dislocation and a viable limb, and were investigated with formal angiography. Ten (7.4%) patients with knee dislocation presented with ischemic limbs of which 5 had on table angiography, 3 had emergency room angiography and 2 cases proceeded with exploration without any imaging.

OPERATIVE FINDINGS

The operative findings included popliteal artery lacerations, transections, contusions, intimal tears and intimal flaps. These injuries were present at various levels of the popliteal artery. Thirty nine (32.5%) popliteal arterial injuries were above the knee joint, forty seven (39.1%) at the level of the knee joint and thirty four (28.3%) below the level of the knee joint. In 16 (11.7%) cases the level of injury was not recorded.

Of the popliteal artery injuries which were explored with intent to revascularization, the majority were repaired with reverse saphenous vein grafts [N = 68 (53.9%)], thirty three (26.2%) were repaired primarily, eleven (8.7%) were repaired with PTFE, two (1.5%) were temporarily shunted, and twelve cases (9.5%) went on to have a primary amputation. No data was available for three cases.

Figure 2. Clinical presentation and early management of 136 patients with popliteal artery Injuries



After repair, only 12 patients had completion angiography studies. Ninety one fasciotomies were performed. Fifty seven (62.6%) were therapeutic and 34 (37.4%) were prophylactic. Concomitant venous injuries were present in 59 (43.4%) patients. The majority of these were ligated [N = 36(61%)], 19 (32.2%) underwent primary repair, two cases (3.3%) had vein grafts, and PTFE grafts were used in 2 (3.3%) patients. There were 66 cases of popliteal artery injuries associated with a fracture. Twenty five (37.8%) patients underwent open reduction and internal fixation and 41

(62.2%) patients were managed with external fixation.

AMPUTATION

There were 32 (23.5%) patients who required a secondary amputation. Twenty eight (20.6%) of these patients had an ischemic limb on presentation and 4 patients had viable limbs on presentation. Nineteen (13.9%) patients underwent primary amputations. Seven of these patients presented with **unsalvageable** limbs and 12 patients presented with ischemic limbs. The total number of amputations were 51, resulting in an amputation rate of 37.5%.

A number of factors in the literature have been associated with limb loss. Several of these prognostic factors associated with limb loss were analysed to determine their significance in our series. These factors included mechanism of injury, viability status of the limb on presentation, level of injury, type of repair, associated injuries i.e. concomitant venous injuries and fractures, presence of compartment syndrome and the ischemic time.^{2, 3,12,21,24,26,45,55,57,71,74,75,94,99}

Mechanism of injury

In the penetrating group (81) there were 32 amputations, resulting in an amputation rate of 39.5% (CI 29.01-79 – 51.01). Of the 55 blunt cases, there were 19 amputations resulting in an amputation rate of 34.5% (CI 22.59-48.66). $P= 0.684$ (Table 2)

In the penetrating group of injuries (81), there were 72 gunshot wounds and 9 stab wounds. Of the 72 gunshot wounds there were 28 amputations resulting in an amputation rate of 38.8% (CI 25.37- 48.35). Of the 9 stab wounds there were 4 amputations resulting in an amputation rate of 44.4% (CI 15.34-77.35). $P= 0.902$ (Table 2)

Posterior knee dislocations were present and associated with the popliteal artery injury in 29 cases. There were 11 amputations associated with a posterior knee dislocation. The amputation rate in this group was 38 % (CI 21.30 – 57.64). The remaining 26 cases in the blunt injury group that were not associated with posterior knee dislocations were associated with 8 amputations. The resulting amputation rate being 31 % (CI 15.09 – 51.90). $P= 0.784$ (Table 2)

Associated fractures

Fractures were present and associated with the injury in 66 cases. There were 29 fractures associated with a fracture, resulting in an amputation rate of 44% (CI 31.39 – 56.6). In the remaining 70 cases, there were 22 fractures, with an amputation rate of 31.5% (CI 21.15 – 43.76). $P = 0.183$ (Table 2)

Viability status

The viability of the injured limb was assessed as being viable (Rutherford 1), ischemic (Rutherford 2a or 2b) or **unsalvageable** (Rutherford 3). There were 40 patients who presented with viable limbs. Of these, 4 cases resulted in amputations, resulting in an amputation rate of 10%. All these amputations were secondary. The causes for these amputations included: missed compartment syndrome in two patients cases, graft occlusion, and diseased crural vessels with poor run-off. Eighty five patients (62.5%) presented with ischemic limbs. There were 40 amputations in this group, resulting in an amputation rate of 47%. Of these amputations, 12 were primary (30%) and 28 were secondary (70%). Seven patients presented with an **unsalvageable** limb, resulting in 7 primary amputations (100%). There were 4 cases where the viability was not recorded; however these did not result in significant morbidity. (Table 2)

Level of injury

The level of popliteal artery injury was recorded as above the level of the knee, at the level of the knee or below the level of the knee. Sixteen cases were not recorded.

Thirty nine cases had popliteal artery injuries above the knee. There were 14 amputations in this group, resulting in an amputation rate of 36% (CI 21.68 – 52.85) There were 47 cases of popliteal artery injuries at the knee level. In this group there were 15 amputations, with an amputation rate of 32 % (CI 19.52 – 47.25). There were 34 cases of popliteal artery injuries below the level of the knee. There were 13 amputations in this group, resulting in amputation rate of 38 % (CI 22.69 - 56.38). $P = 0.393$

There were 9 amputations in the group the group of patients who did not have their level of injury recorded. (Table3)

The popliteal artery injuries were repaired either primarily, shunted, or with an interposition graft – either using a reverse saphenous vein graft or PTFE.

Thirty three cases were primarily repaired which resulted in 7 amputations, with an amputation rate of 21% (CI 9.63 – 39.40). Sixty eight cases were repaired using an interposition reverse saphenous vein graft. Of these, 19 resulted in amputations, with an amputation rate of 28% (CI 18.06 – 40.34). Eleven cases were repaired with interposition PTFE graft. There were 2 amputations in this group resulting in an amputation rate of 18%. (CI 3.21 – 52.25). A shunt was used in 2 cases. Both cases were subsequently repaired using an interposition vein graft, however resulted in delayed amputations (CI 19.79 – 95.11). In three patients the data was not recorded. $P= 0.0865$ (Table 2)

Concomitant venous injuries

Concomitant venous injuries were present in 59 cases. These cases were associated with 18 amputations resulting in an amputation rate of 30.5% (CI 19.54 – 44.05). Sixty eight cases were not associated with venous injuries. There were 24 amputations in this group, resulting in an amputation rate of 35% (CI 24.36 – 47.90). Nine cases were not explored. All of these resulted in amputations (CI 62.88 – 98.97). $P= 0.701$ (Table 2)

Compartment syndrome

There were 57 cases (42%) where compartment syndrome was diagnosed on presentation. These cases were associated with 30 amputations, resulting in an amputation rate of 53 % (CI 39.09 – 65.82). Seventy nine cases were not associated with compartment syndrome. There were 21 amputations in this group, resulting in an amputation rate of 26.5% (CI 17.56 – 37.91) $P= 0.003538$ (Table 2). A total of 91 fasciotomies were performed, resulting in a fasciotomy rate of 66.9%.

Ischemic time

The ischemic time of a peripheral vascular injury is a significant variable. This data had been captured, in hours, as the length of time from injury to definitive vascular repair. The length of time from making the diagnosis to definitive repair was also captured. The data with regard to the ischemic times was only available in 109 cases. The mean ischemic time in hours i.e. length of time from injury to definitive repair, for the whole group of patients, was 18 hours. The range was 3.5 hours to 164 hours. The ischemic times for patients who had amputations resulting from the popliteal artery injuries were compared with regard to the presenting status of the lower limbs i.e. viable, ischemic and **unsalvageable**. There were 34 patients who presented with viable limbs. There were 3(9%) amputations in this group. The mean length of time from the injury to the definitive repair in this group of amputees was 28.05 hours compared to 39.55 hours in the non-amputee group. The mean length of time from making the diagnosis to the definitive repair was 15.97 hours. (Table 3) Seventy two patients presented with ischemic limbs. There were 33 (46%) amputations in this group. The mean length of time from the injury to the definitive repair in this group of amputees was 15.69 hours compared to 7.66 hours in the non-amputee group. The mean length of time from making the diagnosis to the definitive repair was 3.43 hours. (Table 3) Three patients presented with **unsalvageable** limbs, with a 100 % amputation rate. The mean length of time of the injury to the definitive procedure was 7.97 hours. The mean length of time from making the diagnosis to the definitive procedure was 2.77 hours. (Table 3) There were a total of 39 amputations in the group of 109 patients who had ischemic times recorded. In this group, the mean length of time from the injury to the definitive surgical procedure was 15.46 hours. The mean length of time from making the diagnosis to the definitive procedure was 4.55 hours. (Table 3) Patients who presented with an ischemic limb were analysed as a subgroup. There were a total of 72 (52.9%) patients (as noted above, for which data was available) in the ischemic limb group. The mean length of time from the injury to the definitive repair was 11.51 hours. (Table

4) Of these patients who presented with ischemic limbs, there were 33 amputations (45%). The mean length of time from the injury to the definitive repair was 15.69 hours. (Table 4)

The remaining 39 patients in the ischemic limb group (55%), did not have amputations. The mean length of time from injury to definitive repair for these patients was 7.68 hours. (Table 4)

The amputation rate in the group of patients presenting with ischemic limbs (N = 72) was examined above and below the mean time of 7.68 hours.

When the length of time from the injury to definitive repair was less than 7.68 hours, there were 11 amputations, resulting in an amputation rate of 15.2% (CI 8.23 – 26.12), i.e. 11 amputations in the ischemic limb group of 72 patients. When the length of time from the injury to the definitive repair was more than 7.68 hours, the amputation rate was 30.5% (CI 20.53 – 42.67) i.e. 22 amputations in the ischemic limb group of 72 patients. [$p= 0.0236$] (Tables 2 and 5)

Mortality

The mortality rate was 4.4% i.e. six of the 136 patients died in this series. All of these deaths were related to associate injuries, i.e. not directly related to the popliteal artery injury. Three deaths were caused by associated head injuries, one death was caused by an associated pelvic fracture, one death was caused by an associated penetrating chest injury and one death caused by renal failure and sepsis. Complications and outcome with regard to the limbs that were salvaged were not assessed as the recorded data was insufficient.

Table 2. Prognostic factors that were assessed

<i>Prognostic Factors</i>	<i>Variable</i>	<i>Number</i>	<i>Amputation (%)</i>	<i>P value</i>
Mechanism of Injury	Penetrating	81	32 (39.5)	<i>0.684</i>
	Blunt	55	19 (34.5)	
Penetrating injury	GSW	72	28 (38.8)	<i>0.902</i>
	Stab	9	4 (44.4)	
Blunt injury- Dislocation	present	29	11 (38)	<i>0.784</i>
	not present	26	8 (31)	
Fracture	present	66	29 (44)	<i>0.183</i>
	not present	70	22 (31.5)	
Limb Viability	Viable	40	4 (10)	<i>0.00002</i>
	Ischemic	85	40 (47)	
	Non viable	7	7 (100)	
	Not recorded	4		
Level of Injury	Above knee	39	14 (36)	<i>0.393</i>
	Knee level	47	15 (32)	
	Below knee	34	13 (38)	
	Not recorded	16	9 (56)	
Venous Injury	present	69	18 (30.5)	<i>0.701</i>
	not present	68	24 (35)	
	not explored	9	9 (100)	
Type of repair	Primary	33	7 (21)	<i>0.0865</i>
	RSVG	68	19 (28)	
	PTFE	11	2 (18)	
	Shunt	2	2 (100)	
	Not recorded	3		
Compartment Syndrome	present	57	30 (53)	<i>0.003538</i>
	not present	79	21 (26.5)	
Ischemic Time	< 7.68 hours	33	11 (15)	<i>0.002369</i>
	> 7.68 hours	39	22 (30.5)	

RSVG: reverse saphenous vein graft

PTF: polytetrafluoroethylene

Table 3. Mean ischemic time for all grades of popliteal artery injuries

Length of time from injury to definitive repair	Number recorded	Amputations N (%)	Mean length of time from injury to definitive repair (hours)	Mean length of time from diagnosis to definitive repair (hours)
Viable	34	3 (9%)	28.05	15.97
Threatened	72	33 (46%)	15.69	3.43
Unsalvageable	3	3 (100%)	7.97	2.77
Total	109	39 (36%)	15.46	4.55

Table 4. Mean ischemic time for threatened popliteal artery injuries

Mean length of time from injury to definitive repair for ischemic limbs	Amputations	No. of non-amputatees	Overall
Number	33	39	72
Mean time (hours)	15.69	7.68	11.51

Table 5. Correlation of overall amputation rate and cut-off ischemic time of 7.68 hours

Length of time to definitive repair for threatened limbs	Overall Amputations N (%)	No. of non-amputatees	Total
< 7.68 hours	11 (15.2)	22	33
> 7.68 hours	22 (30.5)	17	39
Total	33 (45.8)	39	72

CHAPTER FIVE

DISCUSSION

Popliteal artery injuries have always been associated with high amputation rates. Improved therapies of shock, antibiotic use, better surgical techniques, and rapid transport have all been suggested as reasons for the decreased amputation rates when compared to wartime experiences. Amputation rates after civilian injuries, although lower than wartime reports, remain fairly high for a number of reasons. Modern day popliteal artery injuries have variable results. The quoted amputation rates vary between 0 % to 71%.^{26, 57, 75} In this series, the overall amputation rate was 37.5%, with the most statistically significant prognostic variables being the ischemic time prior to presentation and the presence of compartment syndrome.

During the study, no patients with confirmed angiographic popliteal artery injuries were managed non operatively as per our institutional protocol. It is possible however to have missed popliteal artery injuries in patients who had viable limbs at presentation and were not investigated, thus probably underestimating the prevalence of popliteal artery injuries in our series.

Mechanism of injury has been shown to be a significant risk factor for limb loss in popliteal artery injuries. Blunt injuries have been shown to have poor outcomes when compared to penetrating injuries.^{3, 57, 73, 74} In this series however, 60% of the popliteal artery injuries were associated with penetrating mechanisms of injuries. The amputation rate in this group was 39.5%. Eighty nine percent of the penetrating injuries were due to gunshot wounds. The rest of the penetrating injuries were due to stab wounds. There was no statistical significant difference in limb loss between gunshot wounds and stab wounds. The blunt injuries were mostly secondary to falls and motor vehicle accidents. The amputation rate for the blunt injuries was 34.5%. When comparing the blunt injuries to the penetrating injuries in this series, there was no statistically significant difference in

the limb loss rate. Posterior knee dislocations are associated with a substantial incidence of popliteal artery injuries.^{21,47}

In this series there were 29 cases of posterior knee dislocations, with an amputation rate of 38% in this group. This was however not statistically significant when compared to the rest of patients in the blunt group of injuries. Popliteal vascular injuries associated with skeletal injuries of the same limb, poses a substantially higher risk for limb loss and morbidity than either injury alone.^{2, 13,55,57}

In our series there were 66 cases of popliteal artery injuries associated with fractures. These injuries were collectively from blunt and penetrating mechanisms. The amputation rate in this group of patients with associated fractures was 44 %. However, this did not carry statistical significance when compared to those patients where fractures were not present. ($p = 0.183$). Concomitant popliteal venous injury ranks as one of the most common associated injuries with popliteal artery trauma, and has been reported as being associated with an increase in morbidity.^{19,24}

We have not been able to show any statistical significance with regards to limb loss when a concomitant venous injury was present. In our series we looked at the level of popliteal artery injury i.e. whether it was above the level of the knee, at the level of the knee or below the knee level. The amputation rate in this series was similar with respect to the level of injury ($p = 0.393$).

We found that the type of repair did not statistically temper with the amputation rate ($p = 0.0865$).

In this series we compared primary repair of the artery, shunts and interposition vein or PTFE grafts. Popliteal vascular injuries always pose a high risk for lower leg compartment syndrome. This is usually associated with a significant increase in morbidity.⁶¹

Forty two percent of the patients (57 cases) in our series presented with full blown compartment syndrome. The amputation rate in this group of patients was 53% which has proven to be statistically significant when compared to patients in whom compartment syndrome was not present ($p = 0.003538$).

Experimental and clinical evidence has repeatedly confirmed the direct correlation between a delay of treatment of more than 8 hours and limb loss. Most series have documented that the most

common cause of limb loss following popliteal vascular injury is delay in diagnosis and treatment.^{3, 12, 21, 33, 73, 74, 94,99} In our series we analysed the patients who presented with ischemic limbs with regard to the ischemic time i.e. length of time from the injury to the definitive repair. We found that patients who had an ischemic time of less than 7.68 hours had a significantly lower amputation rate (15%) when compared to patients with ischemic times more than 7.68 hours (30.5% amputation rate) ($p = 0.02369$).

In the group of patients who presented with ischemic limbs, the mean length of time from the injury to the definitive repair was 15.69 hours. The mean length of time from diagnosis to definitive repair was 3.43 hours.

These numbers reflect significant delay to definitive treatment, more so in the pre-hospital aspect of management, with potential room for improvement of the in-hospital management. The prolonged ischemic time has directly impacted on the overall amputation rate of 37.5%.

Efforts to improve limb salvage should include awareness and early diagnosis of popliteal artery injuries at all levels of care, as well as improved transfer time from injury to definitive care both at the pre-hospital level and in-hospital level.

With regards to angiography, completion arteriography was only done in 12 cases. There is data available suggesting completion arteriography to be done routinely.^{49, 67} A change in practice in support of routine completion arteriography may result in an improved limb salvage rate. This however, will be dependent on available resources.

Pitfalls during the analysis of the patients with popliteal artery injuries, where the limbs were salvaged, included poor documentation of complications i.e. from all disciplines, and also poor follow up data of these patients.

The follow up visits documented were short term, with no record of long term outcomes or morbidity.

CHAPTER 6

CONCLUSION

Popliteal vascular injury remains one of the most difficult diagnostic and therapeutic challenges for trauma surgeons. Only with strict attention to rapid diagnosis; early surgical treatment with meticulous technical skill; and aggressive use of various adjunctive measures, such as completion angiography, anticoagulation, fasciotomy, and proper prioritization of management of multiple injuries, can limb salvage be optimized.

In our series, compartment syndrome on presentation and an ischemic time of more than seven hours, has been shown to be statistically associated with an increase in limb loss.

We strongly recommend implementing measures at variable levels of care to diminish the ischemic time associated with popliteal artery injuries and to recognize and treat compartment syndrome promptly.

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Appendix 1



UNIVERSITY OF CAPE TOWN

Department of Surgery

Departmental Research Committee

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09 March 2009

Dr MA Banderker
Department of Surgery
University of Cape Town
Cape Town

Dear Dr Banderker

RE: PROJECT 2009/086

PROJECT TITLE: Civilian popliteal artery injuries – A ten year audit

The above proposal was reviewed by the Department of Surgery Research Committee and I am pleased to inform you that the committee approved the study.

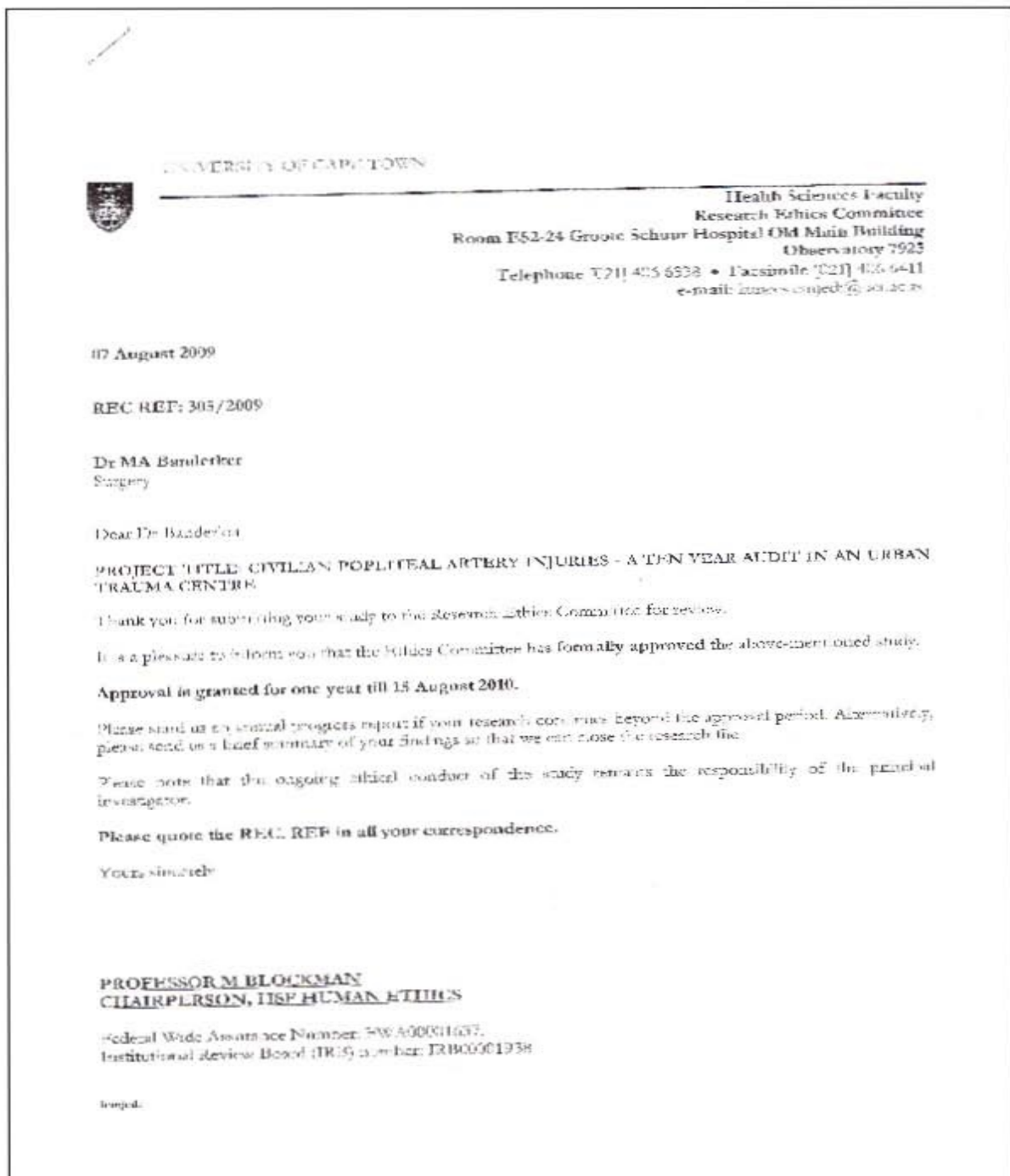
Please use the above project number in all future correspondence.

Yours sincerely
PROF ANWAR S MOLL
CHAIRMAN: RESEARCH COMMITTEE
DEPARTMENT OF SURGERY

**PROFESSOR ANWAR S MOLL
CHAIRMAN: RESEARCH COMMITTEE**

UCT's MISSION is to be an institution teaching and inspiring students to
confront the world and addressing the challenges facing our society.

Appendix 2



Appendix 3



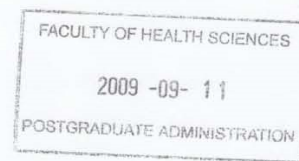
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9 September 2009

Dr Mohammed A Banderker
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Dear Dr Banderker

Candidature approval

Degree	MMed (Surgery)
Title	Civillian popliteal artery injuries – a ten year audit in an urban trauma centre.
Department	Surgery
Supervisor	Associate Professor Pradeep H Navsaria
Co-Supervisors	N/A
Ethics Approval	305/2009

I am pleased to advise that the Chair of the Dissertations Committee has approved your candidature for the above degree on behalf of the Committee. Formal approval was obtained by publication in the Dean's Circular, MED 11/09.

Sincerely

Adri Winckler
Manager: Postgraduate Administration

Appendix 4

DATA SHEET	
AGE	
SEX	
FOLDER NO.	
ADMISSION DATE	
STAY	
MECHANISM	
VIABILITY	
COMPARTMENT SYNDROME	
FRACTURE	
FRACTURE SITE	
KNEE DISLOCATION	
OTHER INJURIES	
ANGIOGRAM	
WHERE WAS ANGIO DONE	
ARTERY FINDINGS	
LEVEL OF ARTERY INJURY	
TYPE OF REPAIR	
VEIN INJURED?	
VEIN REPAIRED?	
ON TABLE VIABILITY	
POST REPAIR ANGIO?	
FASCIOTOMY DONE?	
VASCULAR RELOOKS	
SOFT TISSURE RELOOKS	
BONE RELOOKS	
AMPUTATION Y/N	
WHEN AMPUTATION DONE?	
DIED	
ERROR	
F/U DAYS FROM D/C	
COMMENTS	
REVIEW NEEDED	
COMPLICATIONS	
TIME- INJURY TO DIAGNOSIS	
TIME- DIAGNOSIS TO OR	
TIME- INJURY TO OR	

RESEARCH PROPOSAL

CIVILIAN POPLITEAL ARTERY INJURIES – A TEN YEAR AUDIT IN AN URBAN TRAUMA CENTRE

INVESTIGATOR:

Dr. Mohammed Asif Banderker

SUPERVISOR:

A/Prof. Pradeep H Navsaria

INTRODUCTION:

Injuries to the popliteal artery are generally unforgiving and associated with high amputation rates. Amputations rates for penetrating and blunt popliteal artery injuries have been reported to be as high as 27% and 71%, respectively. This limb loss rate is higher than any other type of peripheral vascular trauma.

LITERATURE REVIEW:

Trauma centres that have published popliteal artery injury series have done so with relatively small patient numbers. Those who have published larger patient numbers have done so by incorporating patients from a number of trauma centres. All series have shown a concern for high rate of limb loss.

Certain negative predictive variables have been identified such as ischemic time, level of injury to popliteal artery, extent of soft tissue damage, efficiency of collateral circulation, compartment syndrome, associated fracture, associated venous injury, and velocity of firearm.

The management of popliteal artery injuries is found to be a complex process, requiring an experienced multidisciplinary approach. The critical factor associated with limb salvage is prompt diagnosis and prompt intervention.

AIMS & OBJECTIVES

The aim of this study is to identify factors associated with limb loss and limb salvage rate in patients with popliteal artery injuries presenting to the Groote Schuur Hospital Trauma Centre.

PATIENTS AND METHODS

Retrospective chart review of a prospectively collected data base of all patients with popliteal artery injuries presenting to the Groote Schuur Hospital Trauma Centre between January 01, 1999 to December 31, 2008.

Demographics, mechanism of injury (blunt vs penetrating – stab / gunshot), haemodynamic status, clinical findings of injured limb: viable, non-viable or ischaemic, diagnosis of injury, associated injuries, surgical treatment, amputation rate, complications and mortality will be determined.

ETHICS

This study has the potential to improve the management of popliteal artery injuries and directly result in an increase in limb salvage rates.

The study adheres to the Declaration of Helsinki 2000.

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