ORIGINAL ARTICLE

Popliteal Artery Injury in Traumatic Knee Dislocation and its Relationship to Body Mass Index

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ABSTRACT

Background: Popliteal artery injury is an uncommon complication of traumatic tibio-femoral dislocation. This study looks at the relationship between vascular injury, body mass index and outcomes of patients with tibio-femoral dislocation. **Methods:** In this series, patients with vascular injury were selected from those who had tibio-femoral dislocations. There were 42 patients, 11 of whom had popliteal artery trauma with 10 requiring arterial reconstruction. **Results:** There were six arterial contusions, three transections and one a complete avulsion with three concomitant venous and five nerve injuries. Most of the patients with arterial injury due to tibio-femoral dislocation were found to have a high body mass index. In addition, those patients who had poor outcomes such as major amputation, unstable knee joints and delayed rehabilitation were either obese or morbidly obese. **Conclusion:** Patients with high Body Mass Indices who are either obese or grossly obese appear to have a greater chance of tibio-femoral dislocation especially after trivial injuries and are more likely have delayed or missed arterial injuries than the non-obese population. They are also more prone to complications than non-obese patients with overall poorer outcomes.

KEY WORDS: Tibio-femoral-dislocation, Popliteal-arterial-injury, Obesity, Morbid obesity, Limb-loss.

Introduction

Tibio-femoral (knee) dislocation is an uncommon injury accounting for only a small percentage of orthopaedic admissions to hospital[1]. Tibio-femoral dislocations can be categorized into high-velocity and low velocity injuries and are usually due to motor vehicular accidents, crush injuries, falls, walking on level ground or descending an incline. The low-velocity injuries have become significant in the increasingly obese patient population, which has seen a rise in the percentage of dislocations per year[2] from 7% in the 1995-2000 period to 53% in the 2007-2012 period[3,4]. Seemingly trivial injuries can lead to knee dislocation and the chances of neurovascular injury increases with increased body weight[5].This study investigates the nature of popliteal artery injuries in traumatic tibio-femoral (knee) dislocations on the Caribbean Islands of Trinidad and Tobago. We herein present 42 cases of tibio-femoral dislocation seen at the orthopaedic department, eleven of whom had vascular injuries, with ten undergoing surgical intervention. In our study, a record was made of the body mass index (BMI) of all patients and this was then compared with the eventual outcome of the patient.

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Plain Language Summary

Traumatic injury to the popliteal artery is not common in knee dislocations. The outcomes of arterial injury are worse in blunt rather than penetrating trauma. In traumatic knee dislocation, only a small percentage of popliteal arteries are injured and of these, not all proceed to surgery

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whether by interventional or open repair. We look at the patients who did proceed to surgery after traumatic dislocation, review the mechanism of injury and the factors thought to produce very good or poor outcomes. There has been a trend worldwide with an increasing number of dislocations especially in obese and morbidly obese patients. We sought the relationship between body mass index (BMI) and popliteal artery injury in knee dislocations and the incidence of morbidity and amputation in a mid-sized population (42 patients). There appears to be a relationship between increased BMIs and poorer outcomes in these patients many after seemingly trivial injury at ground level or walking down an inclined slope.

Patients & Methods

Study Design: The study was intended to capture those patients presenting to a single regional medical facility with arterial injury arising as a result of tibio-femoral (knee) dislocation (TFD). It is aimed at finding the patients who had to undergo surgical exploration for possible popliteal artery injury and those who had arterial reconstruction including the nature of the injury and the postoperative outcomes. Outcomes were divided into short and long-term and endpoint being amputation and or full mobilization. Patients with multiple soft tissue and ligamentous injuries acquired in trauma to and around the knee joint were excluded, as were patients with vascular injuries around or at the knee joint who did not have documented tibio-femoral dislocation (TFD).

Data were collected from patients with popliteal artery injury and repair secondary to traumatic tibio-femoral dislocation (TFD). The data were retrospectively collected for the period 2001-2020 at the San Fernando General & Teaching Hospitals in Trinidad & Tobago, which has a catchment of approximately 600,000 persons. The body mass index (BMI) for all patients admitted was calculated but only data for those undergoing surgery were presented in this study. They were categorized into the classes of normal, overweight, Class I, II and morbid obesity. Approximately forty-two (42) patients presented with TFD during this period. This does not take into consideration patients who had reduction prior to arrival at the emergency department, those that reduced spontaneously or had subluxation of the tibio-femoral joint.

The study also included patients who had multi-ligamentous injuries with dislocation, but our data show that none of these patients had popliteal artery injury nor underwent surgical exploration despite the high probability of popliteal artery injury. Only data from the surgically treated patients are presented in this study. Patients with non-dislocated multi-ligamentous injuries were not included since this study specifically documented popliteal artery injury in TFD. However, none of these patients presented with popliteal artery injury during the study period. The patients who had dislocations, but no vascular injuries were observed for 24-48 hours and discharged with close follow-up. None of this group of patients had any subsequent vascular compromise, required readmission, surgical exploration nor ended with an amputation.

There were eleven (11) recorded popliteal artery injuries, with one patient who had a CT angiogram having an injury to the adventitia of vessel, with no intimal injury, no disruption to flow nor thrombosis. This patient was observed, treated conservatively, and discharged after a repeat CT angiogram showed no progression after 72 hours. Ten (10) patients underwent urgent surgical exploration of the popliteal fossa and repair of the popliteal artery. Primary outcomes were limb salvage and factors leading to early or delayed amputation. Secondary outcomes included the ability to achieve a reasonable level of mobility, return to work or regain normal mobility status.

The protocol of the current study was discussed with the responsible IRB and being classified as a case report/ case series required informed consent by retrospectively included patients, but no formal review nor IRB approval was necessary. Informed consent was obtained from all patients involved in this study and this study followed all the factors enshrined in the Declaration of Helsinki.

Results

Forty-two (42) patients presented with tibial-femoral dislocations (TFDs), eleven of whom had vascular injury consisting of one adventitial injury and ten major popliteal artery injuries requiring surgical intervention. There were 4 males and 6 female patients with an age range of 23-60 years (mean-36 years) with six patients in the 20-39 age-group, three in the 40-59 age group and one in the 60-79-year age groups respectively [Table 1].

The mechanism of injury included two motor vehicular accidents (MVAs), two crush injuries, a fall from height, and five patients who tripped at ground level or slipped whilst walking down an incline. Half of the injuries (5/10) were low energy falls at the same level [Figure 1].

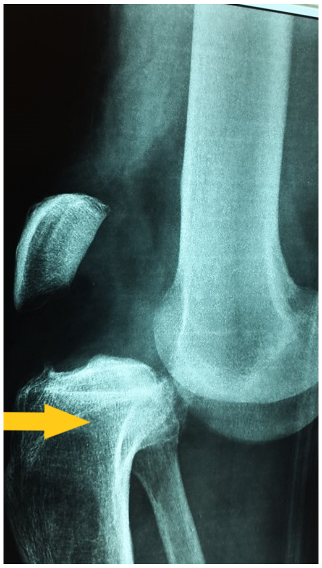

Figure 1: Tibio-femoral Dislocation: The tibia and fibula are displaced anterior to the femur (Yellow arrow) causing neurovascular injury

Eight patients reached hospital within 4 hours, but two patients took eight hours to arrive due to delay in transportation from a secondary health facility [Table 1]. Nine of the ten patients were diagnosed clinically and from use of a Hand-held Doppler confirming no blood flow over the dorsalis pedis and posterior tibial vessels. The absence of palpable pulses complemented by Hand-held Doppler was an absolute indication for surgical exploration in any patient. Only one patient required angiography (patient # 9) after sustaining direct trauma to the posterior aspect of the popliteal fossa [Figure 2].

All 10 patients underwent surgical exploration and popliteal artery injury was observed in each case. The popliteal artery was contused with secondary thrombosis in six patients, completely transected in three cases, and avulsed in one case. Three patients also had concomitant popliteal vein injury and there were five associated nerve injuries- four common peroneal and one tibial nerve [Table 1]. None of the patients with popliteal vein injury ended with amputation but one patient with a fracture-dislocation and common peroneal nerve injury had a delayed secondary amputation. No information was recorded as to the nature of the dislocations, whether

Figure 2: Angiogram showing complete occlusion of left popliteal artery following tibio-femoral dislocation (Blue arrow)

anterior, posterior, or rotational.

Arterial repair consisted of arterial segment excision with an interposition graft of the great saphenous vein (GSV) in three patients and polytetrafluoroethylene (PTFE) in seven patients, using an end-to-end anastomotic technique [Figure 3]. There was no difference in outcome with choice of material used for the interposition graft. Fasciotomies were done in all patients but in two cases, closed fasciotomies were initially done then converted to open fasciotomy over a 24-72 hour period.

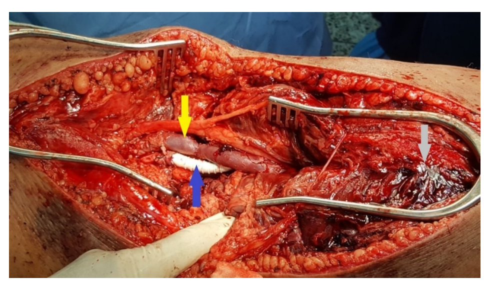

Figure 3: Intraoperative surgical field showing: the repaired popliteal vein (Yellow arrow); the Interposition PTFE graft which replaced the excised segment of popliteal artery (Blue arrow) and extensive muscle contusion (Grey arrow)

One week after surgery all limbs were viable with palpable pedal pulses, but three patients had re-operations and two ended with amputations after

Table 1: Popliteal Artery Injury in Traumatic Knee Dislocation-Age, Gender, Mechanism, Time to hospital; Bone, Nerve, Vein, Arterial injury and Treatment

Case	Age	Gender	Mechanism of Injury	Time	Bone fractured	Nerve injured	Popliteal Vein	Popliteal Artery	Graft	Fasciotomy
1	25	Male	Motor vehicular accident	< 4 hours	Femur	Common peroneal	Contused	Avulsed	GSV	Open
2	28	Female	Slipped walking down hill	< 4 hours	no	none	not injured	Transected	PTFE	Open
3	23	Female	Tripped over power hose	8 hours	no	none	not injured	Contused	PTFE	Closed-Open
4	27	Male	Jumped down 15 feet	< 4 hours	no	none	not injured	Contused	PTFE	Open
5	29	Male	Motor vehicular accident	8 hours	Femur / Tibia	Common peroneal	not injured	Contused	PTFE	Open
6	40	Female	Slipped on floor at home	< 4 hours	no	none	Contused	Contused	PTFE	Closed-Open
7	25	Female	Slipped walking down hill	< 4 hours	no	none	not injured	Contused	GSV	Open
8	45	Female	Slipped on floor at home	< 4 hours	no	none	not injured	Contused	GSV	Open
9	58	Male	Hyperextension injury	< 4 hours	no	Common peroneal	Strictured	Transected	PTFE	Open
10	61	Female	Pinned on wall by vehicle	< 4 hours	no	Common peroneal/tibial	not injured	Transected	PTFE	Closed
11	65	Male	Direct trauma	< 4 hours	no	None	not injured	Contused	Nil	Nil

Legend: GSV, Great Saphenous Vein; PTFE, Poly Tetra Fluoro Ethylene

12 days, even though they had patent grafts at day 7 (one PTFE, one GSV) [Table 2]. One of these (patient #3 who presented after 8 hours) had a re-operation because the graft became thrombosed. This patient had extensive muscle necrosis, but further revascularization and muscle debridement could not prevent amputation at day 12. The second patient (patient #8) who had an amputation after 12 days, had cardiac arrhythmias, severe muscle necrosis and despite a patent graft, she required an amputation.

The BMIs of the ten patients with vascular repair ranged from 19.0 kg/m^2 to 42.5 kg/m.^{2} The other 32 patients had varying BMIs with no predominance of any one weight/ height class, but the majority were either overweight or obese. Table 2 shows that aside from 2 patients who had normal BMIs [18.5-24.9kg/m^2]all the others belonged to either Class II obese [35.0 -39.9kg/m^2] or morbidly obese categories [> 40.0 kg/m^2]. In addition, the patients with unstable knee joints, delayed (or none-) mobilization and amputation were either obese or morbidly obese. The TFD patients with normal BMIs either had a fall from a height or a motor vehicle accident (MVA) with fractures, which are usually high-velocity type injuries [Table 2].

Long Term Outcomes

One patient (patient #5), who had limb salvage after multiple debridements developed an infection after total knee replacement (TKR) one year later, had delayed secondary amputation and was fitted with a prosthetic limb. At 2 years post-surgery, all other patients had limb salvage with 9 patients being mobilized (9/10 mobility) and able to move independently, including two of our amputees. One patient was wheelchair bound (patient #8) due to her frail frame and cardiac status.

Table 2:

A: Popliteal Artery in traumatic Knee Dislocation: Further Surgery, Outcomes, Body Mass Index (BMI) and Adverse factors

Case	Age, Gender	Further Surgeny	Short Term Outcome	Long term Outcome	Patients' Approx. BMIs	Patients' BMI Range	Patients' BMI Class	Adverse factors
1	M-25	Knee replacement	Salvaged	Fully mobilized	19.0 kg/m^2	18.5-24.9 kg/m^2	Normal	Fractures, Avulsed artery
2	F-28	None	Salvaged	Fully mobilized	45.5 kg/m^2	> 40.0 kg/m^2	Morbid obesity	Morbid obesity
3	F-23	Graft thrombectomy	Amputation	Prosthesis	42.5 kg/m^2	> 40.0 kg/m^2	Morbid obesity	Morbid obesity, time delay
4	M-27	None	Salvaged	Fully mobilized	18.0 kg/m^2	18.5-24.9 kg/m^2	Normal	Subluxed joint missed initially
5	M-29	Muscle excision	Salvaged	Knee replacement	36.5 kg/m^2	35.0-39.9 kg/m^2	Class II Obesity	Fractures, Infected joint**
6	F-40	Open Fasciotomy	Salvaged	Unstable Knee Joint	37.0 kg/m^2	35.0-39.9 kg/m^2	Class II Obesity	Closed fasciotomy initially
7	F-25	None	Salvaged	Fully mobilized	45.5 kg/m^2	> 40.0 kg/m^2	Morbid obesity	Morbid obesity
8	F-45	Mutiple debridements	Amputation	Wheel chair	37.0 kg/m^2	35.0-39.9 kg/m^2	Class II Obesity	Cardiac disease, slipped ex-fix
9	M-58	Multiple debridements	Salvaged	Fully mobilized	38.5 kg/m^2	35.0-39.9 kg/m^2	Class II Obesity	Injury noted after 18 hours
10	M-61	None	Salvaged	Fully mobilized	36.5 kg/m^2	35.0-39.9 kg/m^2	Class II Obesity	Crush injury, missed initially
11	M-65	None	Salvaged	Fully mobilized	27.5 kg/m^2	25.0-29.9 kg/m^2	Overweight	Mildy contused, no surgery

Legend: M, Male; F, Female; Approx., Approximate; BMI, Body Mass Index; **Total Knee Replacement became infected with secondary amputation; ex-fix, external fixator.

B: Comparison of patients with no Arterial injury, with arterial injury by BMI and Mechanism

Patients with Arterial Injury		Patients with No Arterial Injury		Mechanism of Injury in those with no Arterial Injury	
Normal BMI	2	Normal BMI	11	Low Energy with no ligamentous injury	0
Overweight	1	Overweight	16	High Energy with no ligamantous Injury	0
Class 1 Obesity	0	Class 1 Obesity	4	Low Energy with Multiligamantous Injury	7
Class II Obesity	5	Class II Obesity	0	High Energy with Multiligamantous Injury	24
Morbid Obesity	3	Morbid Obesity	0	Other	0

Table 3:

A: Comparing Morbid Obesity (1) and Class II Obesity (2) with Outcomes-Success in Gaining Full Mobility			
	Successes	**Total**	**Percentage (%)**
Group 1	2	3	66.67
Group 2	2	5	40
Two Tailed p-value: 0.4945248; One Tailed p-value: 0.2472624.			
There is a 50.548% chance that patients would have good mobility.			
There is a 75.274% chance this group has a good long term outcome.			

B: Long Term and Short Term Outcomes relating to Limb Salvage (Group 1) or Full Mobility (Group 2)		
	Successes	**Total**
Group 1- Short Term Outcome	8 - number limbs salvaged	10
Group 2- Long Term Outcome	6 - number fully mobilized	10
Two Tailed p-value: 0.628483; One Tailed p-value: 0.3142415.		
There is a 37.152% chance of either amputation or poor mobility short term.		
But there is a 68.576% chance of being fully mobilized eventually.		

Statistical Analysis

Using the Two Sample 2T test, since the numbers are small, our p-values are not significant. However, from Table 3 **A**, we note that there is a 50. 5% chance that patients may have good mobility after tibiofemoral dislocation and a 75.2% chance of patients in this group having a good long-term outcome due to popliteal artery repair, good physiotherapy and close follow up.

From Table 3 **B**, we note that in the short term, there is a significant chance (37.1%) of patients having either amputation or poor mobility following tibiofemoral dislocation but a 68.6% chance of being fully mobilized eventually after popliteal arterial repair.

Discussion

Tibio-femoral dislocation (TFD) accounts for only 0.001 to 0.013% of all orthopaedic injuries[1], however if accompanied by vascular or nerve injury,there is a high risk of limb loss[3,6,7]. The overall rate of vascular injury in knee dislocations varies from 23 to 32%[6,7] with high-energy knee dislocations ranging from 7 to 43%[8–15] and low-energy dislocations 5 to 11%[7,16]. Injuries which are high energy usually involve both cruciate ligaments and one collateral ligament[17], and these have a higher frequency of vascular injury[18].

The most common causes of popliteal artery injury are usually falls causing dislocated knees and motor vehicular accidents (MVAs) causing fractures[19]. Dislocations due to motor vehicular accidents and crush injuries are regarded as high-velocity dislocations[20,21] whilst those during athletic activities are low-velocity[22]. The term ultra-low velocity dislocation describes TFD caused by trivial actions such as stepping off a stair, walking down an inclined slope, or falling whilst standing at height[3,5].These falls at ground level[23] occur particularly in the obese and morbidly obese populations[24].

Knee dislocations have also been observed to occur spontaneously in the morbidly obese[25] and have been reportedly increasing in frequency in the obese populations in many series,including those with pooled data[7,26–28]. Vascular injuries were seen especially in the 20-39-year age group[29] as in our series, with patients being in either the Class II or morbidly obese categories. Those who suffered severe complications or had an amputation also belonged to this category.

The overall rate of vascular injury with TFD requiring intervention in the general population is approximately 5.6%, but this rose to 7.2 % in the obese patients and 11.3% in the morbidly obese[4]. The chances of combined neurovascular injury therefore increases with increased body mass index (BMI)[5]. Obesity can be considered an independent risk factor for limb loss and morbid obesity a specific risk factor for spontaneous knee dislocation, vascular injury, and unusual post-operative complications[25].

Generally, surgical delays, musculoskeletal injuries[30] and blunt (v penetrating) trauma[28] cause longer hospitalization, worse functional outcomes, and higher amputation rates after popliteal arterial injuries[28,30,31]. In addition, concomitant tibial nerve, and popliteal vein injuries, but not severe tissue injury are predictors of limb loss[32]. With obese and morbidly obese patients, delays in transfer and lack of prompt revascularisation have an adverse effect on patient outcomes[3,30]. Time to revascularization of more than 6-8 hours' post-dislocation is attended by a very poor outcome and high percentage of limb loss[5,6,33,34]. In our study, two of our patients had delayed arrival at hospital 8 hours after knee dislocation, more than twice the average time (4 hours) taken for the other patients. One belonged to the Class II obese group and the other was morbidly obese, with both having poor outcomes [Table 2].

There were postoperative complications such as extensive muscle necrosis due to reluctance to use an open fasciotomy from the onset instead of the closed version. We also saw latent cardiac issues become major ones [patient 8] due to poor initial bone stabilization requiring repeated surgical intervention. The authors believe a senior orthopaedic surgeon should be present at the application of an external fixator. Patients required regular physiotherapy initially and an extensive long term follow up to avoid prolonged immobilization. Splinting of the foot in cases of peroneal nerve injury was crucial especially in cases of neuropraxia, where there was quicker recovery. Prophylactic anticoagulation was used for the first week (Enoxaparin) with addition of an antiplatelet (Aspirin 81mg daily) drug on day 2, and patients were discharged with dual antiplatelet drugs (two weeks duration).

If patients avoided amputation, there was still a high incidence of poor functional outcomes in the obese patients after popliteal artery injury [Table 3]. In our series, the three patients who did not rehabilitate fully were either Class II or morbidly obese patients [Table 2]. Since these injuries are now more common in the obese populations, admitting physicians need to have a high index of suspicion for knee dislocations and look for non-typical presentation in the obese patients[14],especially after trivial injuries[3,5].

We compared our study with nine other published series involving TFD [Table 4] and noticed that the average number of dislocations ranged between seven[9] and sixty-seven[35] but the overall number of arterial injuries was actually small, numbering one to twelve cases per series. The percentage of arterial injuries in TFD however, ranged from 5% to 59%, with our series being mid-ranged at 26%.

When patients with a high BMI present with TFD, a thorough clinical examination is crucial, and a high index of suspicion must be exercised in order to avoid

Table 4: Comparison of Studies

Authors/Year	Disloca-tions	Arterial Injuries	% Arterial Injury
Frassica et al 1991	17	10	59
Kendall et al 1993	35	6	17
Klineberg et al 2004	55	12	22
Harner et al 2004	47	5	11
Bui et al 2008	20	1	5
Boisrenoult 2009	67	8	12
King et al 2009	7	3	43
Nicandri et al 2010	31	6	19
Levy et al 2010	9	2	22
Azar et al 2011	17	7	41
Harnarayan et al 2021*	42	11	26
Legend-* Unpublished			

a potentially devastating outcome[36]. Inadequate initial assessment or diagnostic delays are known to be associated with a substantial increase (60-80%) in amputation rates in this group[37]. If the vascular examination is equivocal, selective imaging with arteriography is required[38,39],but routine imaging is not needed in the majority of cases[8,13]. Although vascular intervention on patients with high BMIs may be difficult, timely intervention with arterial repair gives good surgical outcomes[40].

Conclusion

This study confirms the relationship between popliteal arterial injury, body mass index and outcomes in traumatic knee dislocation in our region. Although our series was mid-sized (42 dislocations), the percentage arterial injury (26%) was substantial, comparable with many continental studies. It showed that the majority of the patients with popliteal artery injury undergoing vascular repair were obese (5/10) or morbidly obese (3/10) and the injuries were mainly from trivial falls at ground level. In addition, those patients who had poor outcomes such as grossly unstable knee joints, delayed rehabilitation and major amputation belonged to these categories. Popliteal artery injury requiring reconstructive surgery in tibio-femoral dislocation appears to be more likely in those patients with a high or very high BMI.

Conflicts of Interest

There is no conflict of interest amongst the authors in publishing this article.

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Disclosures

The authors have no disclosures to make.

Consent & Ethical approval

Informed consent was obtained from all the patients involved in this series. Institutional Review was sought at the San Fernando General & Teaching Hospitals/South-West Regional Health Authority's Bioethics Committee, but ethical approval was not required for this series. This study was conducted in accordance with The Declaration of Helsinki.

Data Availability Statement

The data in this manuscript will be made available to researchers without limit.

Author Contributions

All authors contributed to data analysis, drafting or revising the article, have agreed on the journal to which the article will be submitted, gave final approval of the version to be published and agree to be accountable for all aspects of the work.

Conceptualization, PH.; Methodology, TS.; Software, PH.; Validation, PH, MJR and SI.; Formal Analysis, PH, SC.; Investigation, TS; Resources, PH, TS.; Data Curation, PH, MJR; Writing – Original Draft Preparation, PH.; Writing – Review & Editing, MJR.; Visualization, PH, SI.; Supervision, SI; Project Administration, SC.

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