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RESEARCH ARTICLE

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Posttraumatic Popliteal Artery Course and Characteristics as Described by CT Angiography

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ABSTRACT

Introduction: Although rare, injuries to the popliteal artery are one of the most morbid complications in orthopedics, with severe sequelae. These injuries occur more frequently in previously injured extremities. We aim to quantify the relationship of the popliteal artery to the distal femur and proximal tibia using CTA in patients with and without a history of lower extremity trauma.

Methods: All patients with CTA of lower extremities over three years at a single institution were reviewed. The patients were split into two groups: a control group with no history of injury and a study group with a history of lower extremity injury about the knee at least one month prior to presentation. Exclusion criteria were history of vascular injury, or femoral shaft, distal femur, proximal tibia, or tibial shaft fractures within one month of presentation. Artery location was measured using a line tangential to the posterior tibial and femoral condyles, and the midline of the joint by a single author.

Results: 99 patients met inclusion: 18 traumatic and 81 atraumatic. In the study group, the average location of the popliteal artery was more posterior than the control group in relation to the femur (6.0mm vs. 1.4mm; p=0.001) and the tibia (4.8mm vs. 3.2mm; p=0.021). There was no difference in the lateral location of the artery when comparing the study group to the control group in relation to the femur (3.7mm vs. 4.1mm; p=0.574) or the tibia (3.5mm vs. 4.5mm; p=0.356).

Conclusion: In a posttraumatic knee, the popliteal artery is displaced posteriorly while the lateral location does not significantly change.

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Introduction

The relationship of the popliteal artery to the posterior knee joint and proximal tibia is of considerable importance to the treating orthopedic surgeon [1]. Injuries to the popliteal artery have been described as one of the most morbid complications in both total knee arthroplasty and fixation of tibial plateau fractures [2-6]. Although such injuries are relatively rare, the sequelae often result in severe complications including amputation or death [7-10]. Previous studies have assessed the relationship of the popliteal artery within the popliteal fossa using ultrasound, anatomic dissection, and magnetic resonance imaging (MRI). These studies have found that the popliteal artery is generally 7-8 mm posterior to the posterior tibial cortex at the level of the tibial joint line [11-16]. While it has frequently been proposed that both post traumatic and post-operative fibrosis results in anterior displacement of the artery due to soft tissue contractures, this has not been assessed via advanced imaging, and studies have shown conflicting results [11,17-19]. Post traumatic osteoarthritis is a common diagnosis leading to total knee arthroplasty (TKA) in the United States [20]. Studies have found that patients undergoing total knee replacement for post-traumatic arthritis are at risk for increased intraoperative complications as well as worse postoperative outcomes [21,22]. Interestingly, a disproportionate percent of popliteal artery injuries associated with TKA are found in the post-traumatic knee [2]. A combination of soft tissue contracture and post-traumatic fibrosis is thought to explain the higher rate of popliteal artery injury in the post-traumatic knee. Improved understanding of the anatomic course of the artery, and how it changes following lower extremity trauma would be an invaluable resource to the treating arthroplasty and trauma surgeon.

While multiple studies have evaluated the variations of popliteal artery anatomy using computed tomography (CT) angiography, studies that assess the relationship of the popliteal artery to its surrounding bony structures utilizing CT angiography are lacking [23,24]. The purpose of this study was to examine and quantify the relationship of the popliteal artery to the distal femur and proximal tibia using CT angiography studies of patients presenting

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to a single level one trauma center with and without a history of lower extremity injuries. Our hypothesis is that contracture of surrounding soft tissues leads to an anteriorly displaced popliteal artery that is consistently closer to the joint line while post-traumatic fibrosis results in a less mobile and more tethered vessel which would both significantly increase the risk for vascular injury.

Materials and Methods

At our institution, patients that present to the emergency department with a mechanism concerning for acute lower extremity trauma frequently undergo bilateral lower extremity angiographies as part of our institution's treatment algorithm. A significant number of these patients are subsequently found to have no acute injuries, and consequently offer excellent data on normal anatomic variations. All patients that underwent CT angiography of the lower extremity between the three-year period of 01/01/2016 and 12/31/2018 at a single level one trauma center were retrospectively reviewed. The patients were split into two groups: a control group without any history of injury to the lower extremity and a study group with a remote history of lower extremity injury about the knee. "Remote" was defined for this study as at least one month prior to presentation. Exclusion criteria were patients less than 18 years of age, patients with vascular injury, or patients with acute femoral shaft, distal femur, proximal tibia, or tibial shaft fractures at the time of presentation, or within one month prior to presentation. 99 scans were suitable for inclusion in our study. 18 out of the 99 scans corresponded to patients with a history of traumatic lower extremity injury and 81 out of 99 scans corresponded to patients without any history of lower extremity injury.

All studies were measured using the synapse picture archiving and communication system (PACS). Demographic data, including patient age and gender at the time of imaging and injury history for the injury group were recorded through the patient's electronic medical record (Cerner Powerchart). Measurements were performed by a single author. The center of the knee joint was first identified on an axial image using coronal and sagittal images to confirm location. The location of the artery was then measured at two areas: an axial image of the femur 1cm proximal from the center of the knee joint and an axial image of the tibia 1cm distal from the center of the knee joint. 1cm proximal and distal to the joint line was chosen as this is generally the level of the bony cuts in joint arthroplasty. A line tangential to the posterior condylar axis of the femur and tibia at a distance of 1cm proximal and distal to the joint line was drawn. Another line perpendicular to the first at the midline of the femur and tibia was drawn in order to establish a standard measurement system. The distance from these lines to the popliteal artery was then measured (Figure 1). Similar to a graph, measurements that were posterior to the X-axis were given a negative value and measurements that were anterior to the X-axis were given a positive value (Figure 2). While the Y-axis value did not differ based on limb laterality, the X-axis value was different based on if the limb was right (negative value) versus left (positive value) since the popliteal artery is a lateral structure. In order to account for this, X-axis values were recorded as the distance lateral to the midline of the joint and measurements were not given a positive or negative value. All patients were in supine position Statistical analysis was performed using the Student t-test with a significance level of 0.05.

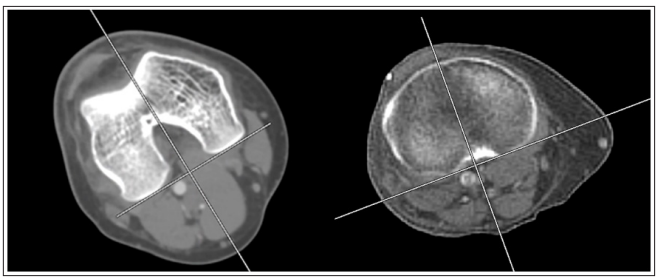

Figure 1: Measurement method: A line tangential to the posterior femoral and tibial condylar axes and a line perpendicular to the first at the midline of the bone was drawn and the distance from the popliteal artery to these axes was then measured

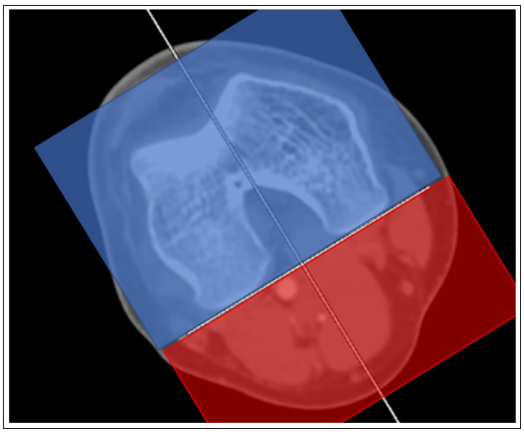

Figure 2: Value measurements for the X axis: values posterior to the X axis (red) were recorded as negative and values anterior to the X axis (blue) were recorded as positive

Results

This study included 80 males and 19 females with an average age of 43. In the study group, there were 16 males and 2 females with an average age of 49.5 years. In the control group, there were 64 males and 17 females with an average age of 41.5. Of the 18 patients in the study group, 6 patients had proximal 1/3rd tibial shaft fractures, 4 patients had tibial plateau fractures, 3 patients had distal femur fractures, 2 patients had segmental tibia and fibula fractures, 2 patients had multi-ligamentous knee injuries, and 1 patient had an isolated soft tissue injury involving the popliteal fossa after an auto versus pedestrian accident. The average time between traumatic injury and CT angiography was 12 months (range, 1 month – 47 months) (Table 1).

Table 1: Demographic information for patients in the study group

	Study	Control
Age (years)	49.5	41.5
Sex Male Female	 16 2	 64 17
Injuries Proximal tibial shaft Tibial Plateau Segmental tib/fib Distal femur Multi-ligamentous knee Soft tissue	 6 4 2 3 2 1	 N/A
Time from injury to CT (months)	49	N/A

In the study group, the average location of the popliteal artery was more posterior than the control group in relation to the femur (6.0mm vs. 1.4mm; p=0.001) and the tibia (4.8mm vs. 3.2mm; p=0.021). There was no difference in the lateral location of the artery when comparing the traumatic injury group to the control group in relation to the femur (3.7mm vs. 4.1mm; p=0.574) or the tibia (3.5mm vs. 4.5mm; p=0.356). (Table 2; Figures 4).

Table 2: The average location of the popliteal artery (mm) posterior to the tangential condylar axis and lateral to midline in relation to the femur and tibia in the study and control groups

	X Femur (mm)	Y Femur (mm)	X Tibia (mm)	Y Tibia (mm)
Study	3.7	6.0 (p=0.001)	3.5	4.8 (p=0.021)
Control	4.1	1.4	4.5	3.2

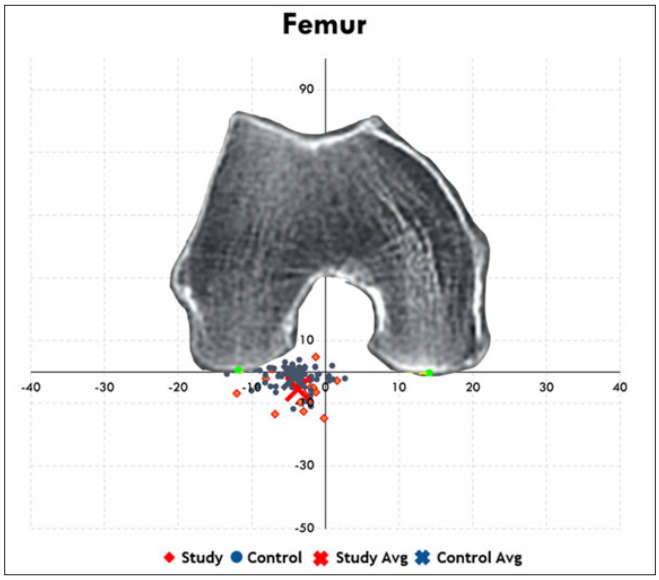

Figure 3: The location of the popliteal artery (mm) in relation to the femur in study and control groups and the average location (mm) of the popliteal artery in study and control groups. Avg = Average

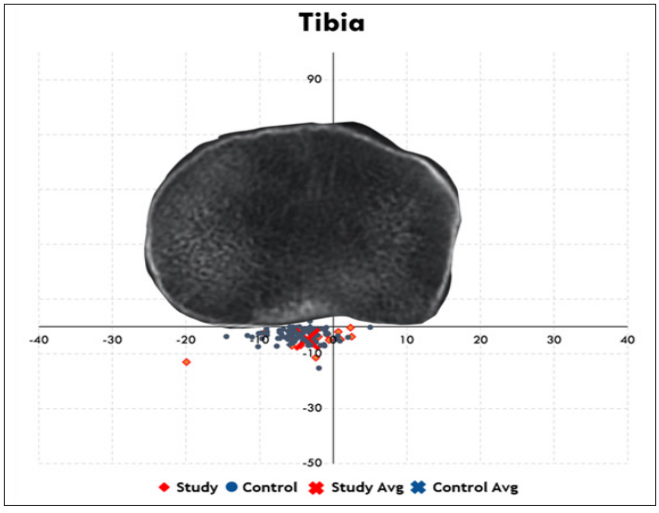

Figure 4: The location of the popliteal artery (mm) in relation to the tibia in study and control groups and the average location (mm) of the popliteal artery in study and control groups. Avg = Average

Discussion

As the demand for TKAs performed in the United States continues to increase, being mindful of the location of and protecting the neurovascular structures of the lower extremity will remain of significant importance [25]. Though a rare complication, with estimated rates between 0.03% - 0.2%, popliteal artery injury is associated with a significant increase in morbidity and mortality [6,10,26-28]. Popliteal artery injury resulted in a $50,000 increase in mean hospital charges, a 7 day increase in mean length of stay, and 20 times increase in mortality [2]. Wilson et al. found that out of 27 total popliteal artery injuries, 71% of patients had a history of surgery in close proximity to the location of artery injury [29]. Previous studies have evaluated risk factors for popliteal artery injury in the setting of arthroplasty [2,30,31]. Ko et al. identified revision surgery, peripheral vascular disease, weight loss, metastatic disease, renal failure, and coagulopathy as significant risk factors for popliteal artery injury during TKA [2]. They note that peripheral vascular disease was the most significant medical comorbidity with a risk ratio of 41.32. Both Ko et al. and Calligaro et al. report that patients undergoing revision surgery were twice as likely to have a popliteal artery injury when compared to patients having a primary total knee replacement [2,28]. Additionally, factors such as release of a flexion contracture or a tethered artery, which can both be commonly encountered in patients with a post-traumatic knee, are noted to be risk factors for popliteal artery injury [30,31].

The findings in our study are in accordance with previous advanced imaging positional studies of the relationship of popliteal artery to the femur and tibia in atraumatic limbs [11,15]. Notably, our results are contrary to our initial hypothesis of a more anterior location for the popliteal artery after trauma and we found that the popliteal artery is actually more posterior and farther away from the knee joint in the post-traumatic knee. What likely happens is that trauma and the resultant swelling leads to posterior displacement of the popliteal artery which then scars into its new position. This new position of the popliteal artery is likely somewhere in-between the initial displacement and original location. This suggests that positionally, the artery should theoretically be at less risk for iatrogenic injury based on its more posterior location. However, it is well documented that a history of previous traumatic injury of prior surgery involving the knee result in higher rates of popliteal artery injury [29]. These higher rates of vascular injury could be due to post-traumatic fibrosis which can result in decreased pliability of surrounding tissue and a less mobile and more tethered artery that is under a higher amount of tension during surgical manipulation and instrumentation. Several studies have shown that the popliteal artery moves posteriorly with knee flexion and that this amount of displacement could be as great as 9mm [19,32]. It could be that although the artery is more posterior in extension in the post-traumatic knee, as the knee is moved into flexion, the artery is actually more anterior due to a lack of normal posterior displacement. We also note that although the artery is more posterior, significant care should always be taken as there were patients with as little as 0.22mm of space between the posterior cortex and popliteal artery.

Interestingly, there was no statistically significant difference in regards to the lateral location of the popliteal artery in a traumatic or non-traumatic knee. This may be a result of the knee joints primarily sagittal based kinematics, and warrants further exploration in future studies.

There were several strengths to our study. Our study had a diverse patient population with a variety of traumatic pathologies. To our knowledge, this is the first study to evaluate the relationship between lower extremity trauma and popliteal artery location. Additionally, most other studies have evaluated popliteal artery location using ultrasound and MRI.

Limitations to our study include the retrospective nature of the study, the lack of testing with intra- or interobserver analysis, and the variability with formatting CT angiography studies. Additionally, all of the CT angiography studies were performed in knee extension. While we were unable to perform dynamic measurements of the popliteal artery, prior studies have shown that the normal posterior displacement of the popliteal artery with increasing degrees of knee flexion are impaired in a revision arthroplasty setting likely as a result of post-surgical fibrosis and scarring and this presumably also applies to a post-traumatic knee [13,19]. The extent to which the normal posterior displacement is affected during hyperflexion, as during Total Knee Arthroplasty procedures, could not be assessed in this study, and warrants further investigation.

Many studies have shown variables such as body mass index (BMI), age, and comorbidities to affect the location of the popliteal artery. Most of these studies were based on MRI and cadaver studies. Future studies examining various demographic factors and the location of the popliteal artery on CT angiography as well as if demographic factors affect location of the popliteal artery in the post-traumatic knee.

Conclusion

This study demonstrates that in a post-traumatic knee, the popliteal artery is displaced posteriorly relative to bony landmarks when compared to an atraumatic knee. Additionally, the lateral location of the artery does not change in the setting of trauma. Although the artery is more posterior, care should always be taken to avoid injury to the popliteal artery and its surrounding neurovascular structures due to the high morbidity and mortality in the setting of injury.

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