The Determination of Safe Zones for Arthroscopic Portal Placement into the Posterior Knee by Mapping the Courses of Neurovascular Structures in Relation to Bony Landmarks

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Abstract

Purpose:

Minimally invasive surgery in the posterior knee is high-risk for iatrogenic injury to popliteal neurovasculature structures. This study aimed to use reliable landmarks to define safe zones for arthroscopic portal placement into the posterior knee.

Methods:

Distances were measured between bony landmarks and neurovascular structures within the popliteal fossa using 45 formalin-embalmed cadavers: small saphenous vein (SSV), medial (MCSN) and lateral (LCSN) cutaneous sural nerves, tibial nerve (TN), common fibular nerve (CFN), popliteal vein (PV) and artery (PA). The structures were measured in relation to medial (MEF) and lateral (LEF) femoral epicondyle, medial (MCT) and lateral (LCT) tibial condyle and the midpoint between the landmarks.

Results:

The mean distance (mm) between MEF and structures were, male and female respectively: SSV 37.6+12.5, 37.9+8.2; MCSN 39.2+14, 38.8+10.1; TN 39.4+10.2, 38.0+8.1; PV 38.4+12.9, 32.8+5.6; PA 38.4+12.1, 34.6+4.9. At midpoint and MCT all structures medialized between 5 and 28%. The mean distance between LEF and structures were, male and female respectively: CFN 13.4+8.2, 8.4+9.1; LCSN 24.9+7.3, 18.4+10.4. At midpoint and LCT the CFN lateralized by 37-42% and the LCSN medialized by 8-9%.

Conclusions:

Results suggest posteromedial portal placement can be safely established < 20 mm from the medial femoral epicondyle, tibial condyle or the midpoint between the two landmarks. Posterolateral portal placement is of higher risk, entry point is 18 mm from the lateral femoral epicondyle, tibial condyle or the midpoint between the two landmarks in males and 12 mm in females. These landmarks will allow safe portal placement in 99% of cases.

Key words:

popliteal fossa; tibial nerve; popliteal artery

Introduction

Access to the posterior knee compartment proves difficult through anterior arthroscopic portals [17, 23, 25]. Anterior and posterior cruciate ligaments and the curvature of the femoral condyles commonly obstruct advancement of the arthroscope or arthroscopic instruments. Lesions in the posterior knee compartment may also be easily missed [4]. The limitations of the arthroscopic field of view can result in missing lesions of the posterior meniscus, even when using a 70-degree arthroscope or trans-notch views [20]. This area has classically been named as the blind spot [20].

The posterior aspect of the knee, more specifically the popliteal fossa, is a high-risk area for direct surgical entry or arthroscopic portal placement [23]. Surgery in the popliteal fossa is challenging because it contains vital neurovascular structures, which can be difficult to avoid without an in-depth knowledge of the layout of these structures [9]. The popliteal artery (PA), popliteal vein (PV), tibial nerve (TN) and common fibular nerve (CFN) are of great clinical importance and should be avoided at all costs to prevent damage to the structures of the leg which result in severe disability [9]. Due to this high-risk factor for a direct posterior approach to knee surgery, many surgeons completely avoid this area for entry [23].

Currently, intra-articular knee pathologies are mostly accessed using an anterior approach to avoid the dense field of neurovascular structures and cause damage to these structures [9]. However, there are pathologies and acute injuries that may be more successfully visualized and treated by using a posterior approach to the knee [23]. These conditions include bony avulsions of the posterior cruciate ligament, arthroscopic assisted tibial plateau fractures and posterior horn meniscus lesions [6, 23, 27]. Postero-medial and postero-lateral portals have previously been described by Ogilvies-Harris et al. [22]. Typically, the posteromedial portal is established one centimetre above the joint line posterior to the MCL and the posterolateral portal one centimetre above the joint line between the LCL and the biceps tendon [22]. These portals endanger the saphenous vein and nerve medially and the fibular nerve laterally [22]. Until now only studies with small sample sizes assessed safety of either posterior-medial or lateral portal standard placement [1, 7, 19]. A comprehensive map of the course, relations and variations of these neurovascular structures, with reference to bony landmarks would therefore be helpful to reduce the risk of damage to the neurovascular structures. Hence, the purpose of this study was to define safe zones for arthroscopic posterior portal placements into the posterior knee by measuring the distance between reliable bony landmarks and neurovascular structures in the popliteal fossa. It was hypothesized that using reliable and reproducible landmarks will allow to define safe anatomic zones for safe placement of posterior knee arthroscopic portals.

Methods

This study was designed as a cross-sectional, quantitative study. Formalin preserved cadaveric specimens were obtained from the Department of Anatomy, University of XX. (blinded for review) (Ethics number: XXX/2019). These specimens were donated and used for the anatomy courses for medical and dental students. Prior to these courses, specimens were dissected by one independent researcher. These embalmed cadavers are used for training and research and comply with all the requirements set out in the National Health Act 63 of 2003. The following inclusions criteria were applied: no obvious macroscopic damage with an intact knee capsule, no obvious previous trauma with signs of previous surgery, pathology or fractures of the knee joint. Knees were excluded if there was evidence existed of previous surgery to the popliteal fossa including vascular repair or bypass surgery, vein stripping or nerve repair. Cadavers with Baker’s cysts, neurovascular damage in the popliteal fossa and severe degenerative osteoarthritis Kellgren Grade IV with osteophyte formation were also excluded.

Dissection Technique and Measurements:

The cadavers were placed in the prone position with the knee fully extended. Firstly, four easily identifiable bony landmarks were palpated and a pin was placed at each of these landmarks: the medial most point of the medial epicondyle of the femur (MEF), the medial most point of the medial condyle of the tibia (MCT), the lateral most point of the lateral epicondyle of the femur (LEF) and the lateral most point of the lateral condyle of the tibia (LCT) (Figure 1). These four points were virtually connected with lines and defined as the popliteal fossa (Figure 1). The neurovascular structures were then carefully exposed from the superficial to the deeper layers. Great care was taken not to disturb the relationships between structures by dissecting the surrounding soft tissue with sharp scalpels and scissors without mobilizing the structures of interest. A calibrated calliper was used to measure the distances between MEF, MCT and the midpoint between MEF and MCT for the medial cutaneous sural nerve (MCSN), small saphenous vein (SSV), tibial nerve (TN), popliteal vein (PV) and popliteal artery (PA). Similarly, the distances between LEF, LCT and the midpoint between LEF and LCT for the lateral cutaneous sural nerve (LCSN) and common fibular nerve (CFN) were measured. (Figure 2-4).

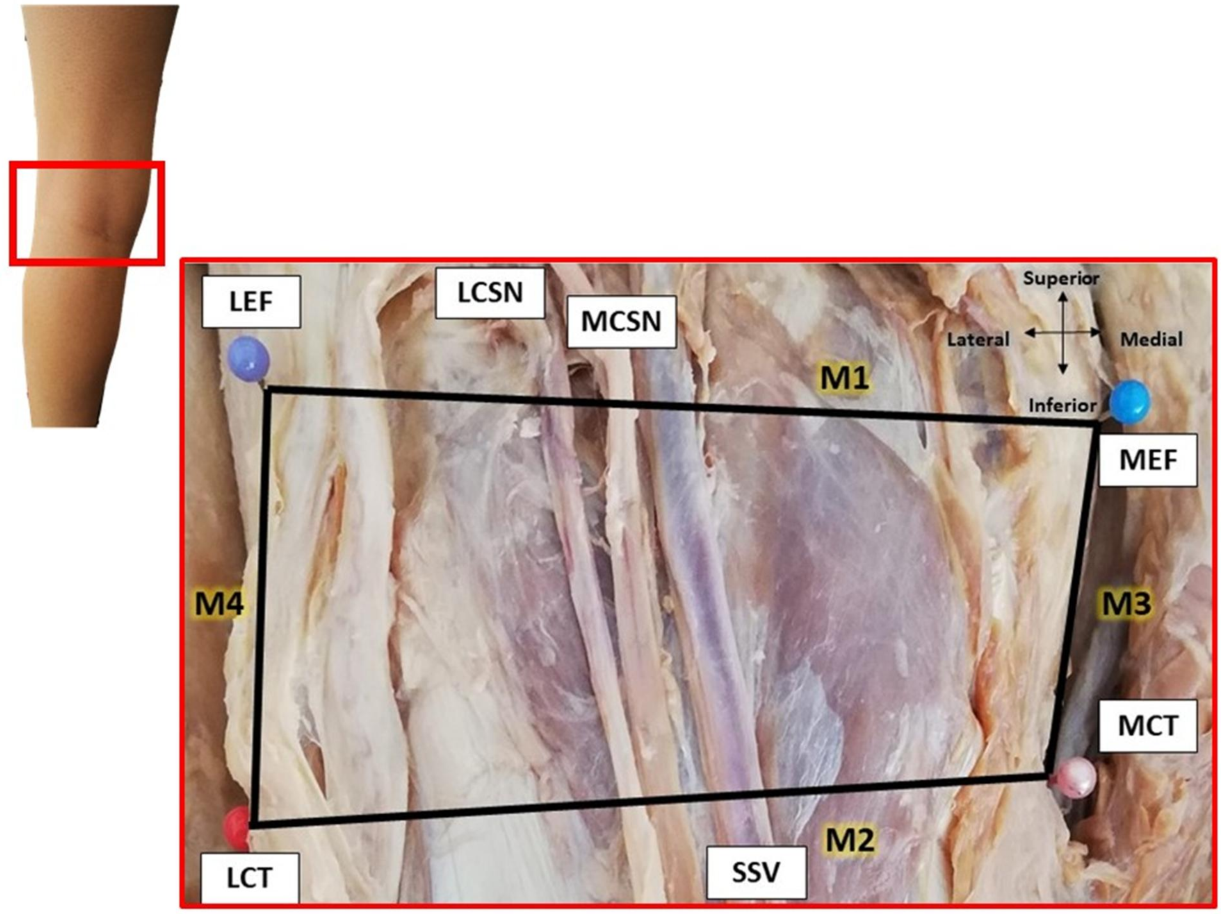

Fig. 1: The superficial dissection of the left popliteal fossa. The lateral most point of the lateral epicondyle of the femur (LEF) and the medial most point of the medial epicondyle of the femur (MEF) were identified and a pin was placed. Similarly, the lateral most point of the lateral condyle of the tibia (LCT) and the medial most point of the medial condyle of the tibia (MCT) were identified and marked with a pin. The superficial neurovascular structures are exposed: lateral cutaenous sural nerve (LCSN), medial cutaneous sural nerve (MCSN) and the small saphenous vein (SSV). Measurements 1-4 (M1-4) represent the distances between the four pinned bony landmarks.

Statistical analysis

Descriptive statistics were used for the distance measurements. Mean length, standard deviation, 99% confidence intervals and minimum and maximum values were calculated. Normal data distribution was assessed with the Shapiro-Wilks Test. Homogeneity of variance was verified with Levene's test. A series of unpaired t-tests was used to compare sex differences. In the event of significant differences male and female variables were analysed separately. Intra- and inter-rater reliability (ICC) were established by repeating the measures on two consecutive days in five cadaveric specimens. The algorithm of Landis and Koch [21] was used to assess the rate of agreement. Values above 0.80 represented excellent agreement, values between 0.62-0.79 were considered good agreement, values between 0.41-0.61 indicated moderate agreement, and values below 0.4 suggested fair to poor agreement [21]. Safe zones were calculated by adding and respectively deducting the values from the 99% confidence intervals from the mean values. To determine whether height and weight were predictors of the morphometric measures a linear regression model was utilized. For this part of the analysis an a-priori sample size calculation was performed using G*Power 3.1.9.2. With the selected input parameter of: two-tailed analysis, effect size 0.15, alpha 0.05, power 0.8, non-centrality parameter 2.569 and a critical t of 1.70, a total of 44 specimens were needed to achieve adequate power. All analyses were conducted using STATA SE (Version 12.0; StataCorp, College Station, Texas, USA) for Windows.

Results

The mean age of the embalmed cadavers was 65.8 ± 17.4 years. Of the sample of 45 adult knees, 20 were male and 25 were female. There were 28 left knees used and 17 right knees. All data sets were normally distributed. Intra- and inter-rater reliability (ICC) were scored between three raters and ranged from 0.89-0.98 for interrater reliability and 0.95-0.97 for intra-rater reliability which represents excellent agreement values [18]. Unpaired t-tests did not demonstrate statistical significance between left and right knees ($p = 0.36$), however, there was a significant difference between male and female knees ($p = 0.01$). Therefore, the statistical analysis was reported separately for males and female. Linear regression revealed that neither weight (r^2=0.265, p=0.309, F=1.481) nor height (r2=0.105, p=0.645, F=0.847) were predictors for any of the morphometric measures.

Table 1: Measurements for the lateral structures in the popliteal fossa

		MALE			**FEMALE**		
		Mean±SD*	Range*	99% CI	Mean±SD*	Range*	99% CI
LCSN	**LEF**	24.9 ±7.3	15.1-43.1	5.4	18.4 ±10.4	0-49.6	6.1
	Midpoint	25.9 ± 9.0	15.0-47.7	6.7	18.2 ±9.6	2.0-44.6	5.6
	LCT	27.3 ±10.8	16.7-50.9	8.1	19.9 ±9.0	6.3-40.3	5.3
CFN	**LEF**	13.4 ±8.2	0-37.0	3.8	8.4 ± .1	0-46.6	4.7
	Midpoint	10.3 ±6.6	0-27.6	3.8	6.7±7.8	0-38.8	4.0
	LCT	7.7 ± 4.8	0-18.1	4.8	5.3 ±6.0	0-26.0	3.1

*Measurements in mm

LCSN, lateral cutaneous sural nerve; CFN, common fibular nerve; LEF, most lateral point of lateral epicondyle of the femur; LCT, most lateral point of lateral condyle of the tibia

Table 2: Measurements for the medial and central structures in the popliteal fossa

		MALE			FEMALE		
		Mean±SD*	Range*	99% CI	Mean±SD*	Range*	99% CI
SSV	**MEF**	37.6±12.5	19.4-77.2	7.2	37.9±8.2	16.1-50.6	4.2
	Midpoint	34.2±13.4	16.5-76.5	7.7	34.2±9.0	16.1-50.6	4.6
	MCT	31.3 ±14.3	10.9-74.2	8.3	30.1±10.5	11.2-56.3	5.4
MCSN	**MEF**	39.2±14.0	16.8-75.5	8.3	38.8±10.1	13.6-56.0	5.3
	Midpoint	36.0±13.2	13.8-70.4	7.8	34.3±11.6	3.8-51.8	6.1
	MCT	32.4±12.7	8.5-61.9	7.5	33.1±10.0	19.7-51.7	5.2
TN	**MEF**	39.4±10.2	14.2-62.5	5.9	38.0±8.1	23.9-54.7	4.2
	Midpoint	35.0±8.8	15.1-57.0	5.1	34.8±7.3	22.6-47.4	3.7
	MCT	30.9±7.8	17.7-47.0	4.5	31.4±6.3	17.4-42.1	3.2
PV	**MEF**	38.4±12.9	12.7-70.5	7.4	32.8±5.6	22.6-42.1	2.9
	Midpoint	35.6±12.2	16.4-64.6	7.0	31.3±6.4	16.8-44.3	3.3
	MCT	32.4±11.8	17.7-55.6	6.8	30.2±7.5	13.0-45.3	3.9
PA	**MEF**	38.4±12.1	14.1-79.0	6.9	34.6±4.9	24.3-42.0	2.5
	Midpoint	36.4±9.6	21.1-67.5	5.5	33.0±6.1	18.4-41.4	3.1
	MCT	35.4±9.0	23.2-62.2	5.2	32.8±7.1	19.1-43.8	3.7

*Measurements in mm
SSV, small saphenous vein, medial cutaneous sural nerve; TN. Tibial nerve, PV, popliteal vein, PA, popliteal artery; MEF, most medial point of medial epicondyle of the femur; MCT, most medial point of medial condyle of the tibia

The results for the lateral structures (LCSN, CFN) are summarized in Table 1 and the results for the medial structures (SSV, MCSN, TN, PV, PA) are summarized in Table 2. The lateral cutaneous sural nerve coursed medial from the proximal aspect of the popliteal fossa to the distal aspect by a mean of 2.4 mm in males (9%) and only 1.5 mm in females (8%). The common fibular nerve ran more lateral inside the popliteal fossa and the nerve lateralized by 5.7 mm in males (42%) respectively 3.1 mm in females (37%). These changes were also clearly visualized in Figure 2. The small saphenous vein coursed from lateral to medial with a mean of 6.3 mm in males (17%) and 7.8 mm in females (20%). Similarly, the medial cutaneous sural nerve coursed from lateral to medial by 6.8 mm in males (17%) and 5.7 mm in females (15%). The superficial structures (LCSN, MCSN, SSV) were running in a parallel fashion and following a very similar course through the centre of the popliteal fossa (Figure 2). The MCSN and LCSN were present in 95.6% and 68.9% of the sample respectively. The tibial nerve crossed the popliteal fossa from more lateral to medial by a mean of 8.5 mm in males (28%) and 6.6mm in females (17%). The popliteal vein was superficial to the popliteal artery. The popliteal vein coursed from lateral to medial in the popliteal fossa by 6 mm in males (16%) and by 2.6 mm in females (8%) (Figure 3). The popliteal artery ran a very similar course to the popliteal vein and lay more medially at the MCT by 3 mm in males (8%) and 1.8 mm in females (5%). (Figure 4)

For males and females safe zones for medial portal should be established less than 20 mm medial to the MEF, MCT and midpoint. When considering these distances 99% of the portals will not cause any injuries to the neurovascular structures in the popliteal fossa. As these structures are coursing from medial to lateral in the

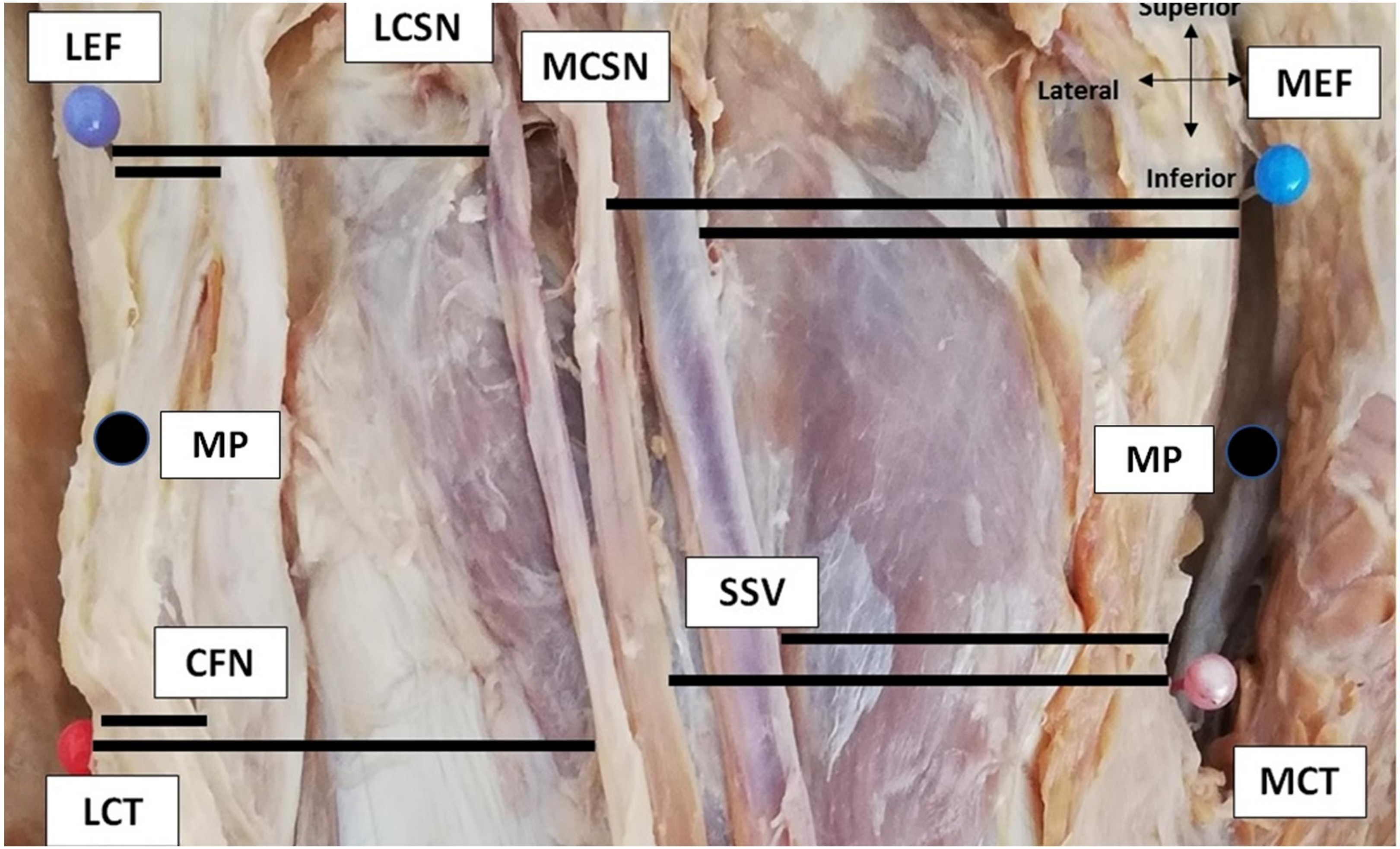

Fig. 2: The measurements of the medial cutaneous sural nerve (MCSN) and small saphenous vein (SSV) were performed from the medial epicondyle of the femur (MEF), medial condyle of the tibia (MCT) and the midpoint (MP) between these landmarks. The measures for the lateral cutaneous nerve (LCSN) and common fibular nerve (CFN) were performed from the lateral epicondyle of the femur (LEF), lateral condyle of the tibia (LCT) and the midpoint (MP) between these landmarks.

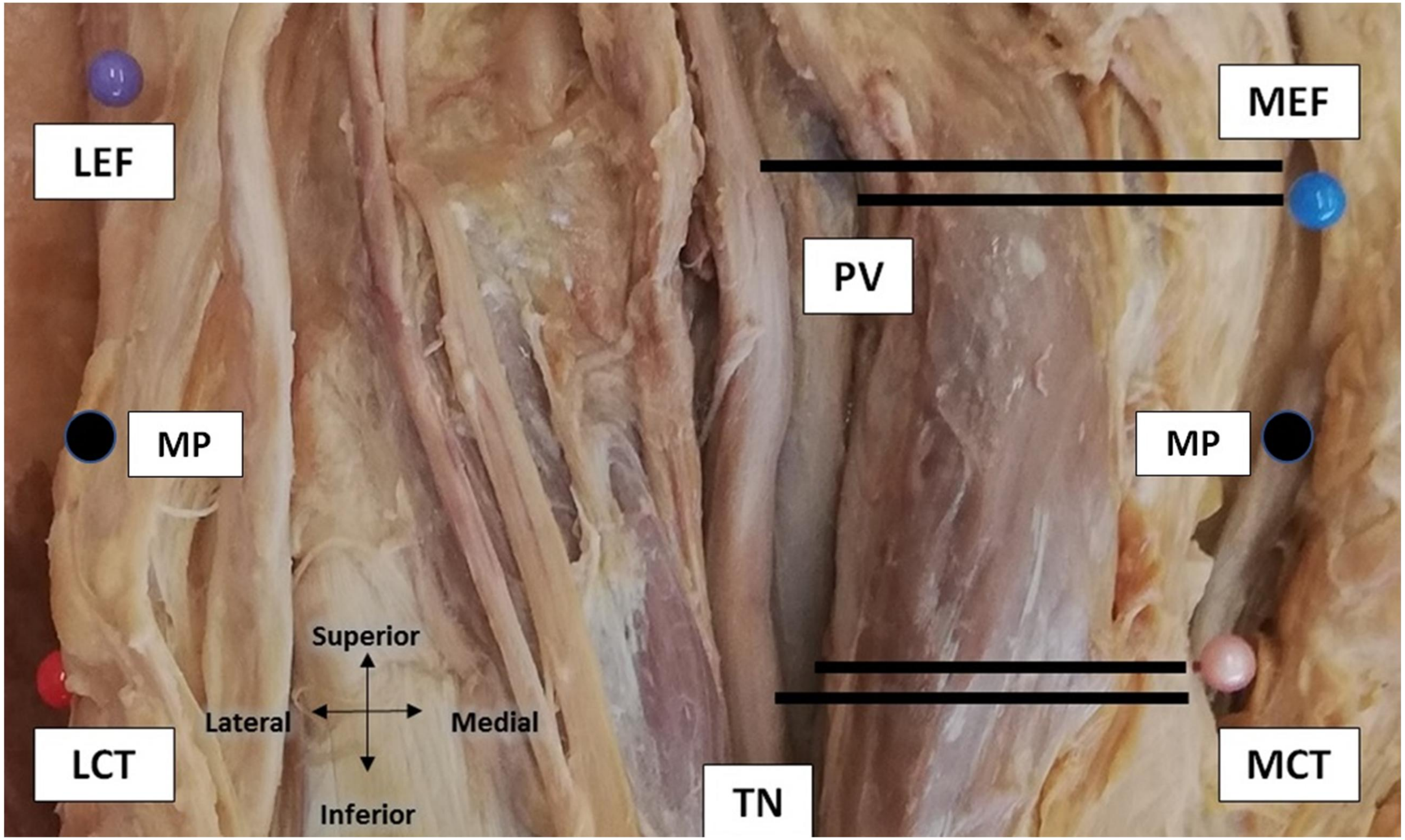

Fig. 3: The measurements of the popliteal vein (PV) and tibial nerve (TN) were performed from the medial epicondyle of the femur (MEF), medial condyle of the tibia (MCT) and the midpoint (MP) between these landmarks. The lateral epicondyle of the femur (LEF), lateral condyle of the tibia (LCT) and the midpoint (MP) between these landmarks are indicated.

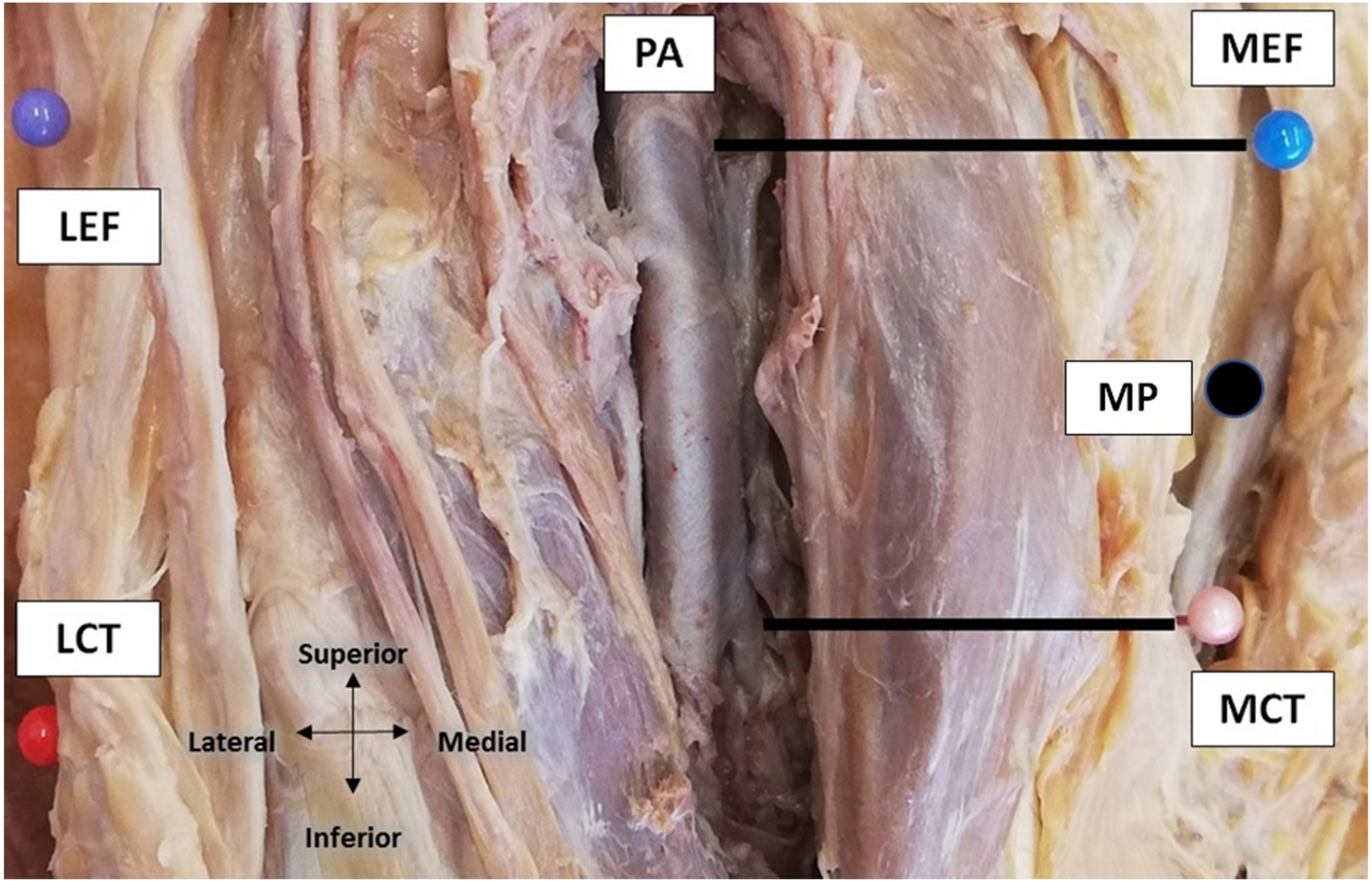

Fig. 4: The measurements of the popliteal artery (PA) were performed from the medial epicondyle of the femur (MEF), medial condyle of the tibia (MCT) and the midpoint (MP) between these landmarks. The lateral epicondyle of the femur (LEF) and lateral condyle of the tibia (LCT) are indicated.

popliteal fossa, medial portal placement in both males and females at this location can be considered safe in 99% of all cases. For the popliteal artery the safety zone is wider; placement less than 25 mm from the MEF, MCT and midpoint will avoid puncture of the artery in 99% of all cases.

In males the CFN is running 13.4 mm medial (99% CI: 3.8) to the LEF, 7.7 mm (99% CI: 4.8) to the LCT and 10.3 mm (99% CI: 3.8) at the midpoint. The LCSN is running 24.9 mm medial (99% CI: 5.4) at the LEF and 27.3 mm medial (99%: 8.1) at the LCT and 25.9 mm (95% CI: 6.7) at the midpoint. When considering these figures the lateral portal should be placed between 17-18 mm medial to the LEF and LCT. However, when considering that the typical portals are placed between the LEF and LCT close to the midpoint, the safe interval at that point is 16-18 mm. As these structures are coursing from medial to lateral in the popliteal fossa, lateral portal placement in males at 18 mm medial can be considered safe in 99% of all cases.

In females the CFN is running 8.4 mm medial (99% CI: 4.7) to the LEF, 5.3 mm (99% CI: 3.1) to the LCT and 6.7 mm (99% CI: 4.0) at the midpoint. The LCSN is running 18.4 mm medial (99% CI: 6.1) at the LEF, 19.9 mm medial (99%: 5.3) at the LCT and 18.2 (99% CI: 5.6) at the midpoint. When considering these figures, the lateral portal should be placed within 12 mm medial to the LEF and LCT. At the midpoint the safe zone is quite narrow and ranges from 11-13 mm. Safe portal placement could be considered around 11.5 mm medial to the midpoint. As these structures are coursing from medial to lateral in the popliteal fossa, lateral portal placement in females at 12 mm medial can be considered safe in 99% of all cases.

Discussion

This study demonstrated that the safe zone for medial portal placement in both males and females are very similar. Whether initial entry is performed at the MEF, MCT or the midpoint between these two landmarks, placement of the posteromedial portal is safe in 99% of all cases as long as the portal is established within 20 mm distance to these landmarks. The interval of safety to avoid injury to the popliteal artery is slightly wider and has an additional safety margin of 5 mm. The safe margin of the posteromedial compartment is consistently wider than the posterolateral compartment and the popliteal artery is located lateral to the posterior septum [17]. Injury to the popliteal artery can therefore be avoided by penetrating the septum in a lateral to medial direction [17]. The SSV, MCSN TN, PV and PA all presented with a medial deviation from proximal to distal within the popliteal fossa. Between the femoral epicondylar level and the tibial condylar level the SSV, MCSN, TN, PV and PA deviated medially by 6 mm, 7 mm, 8 mm, 6 mm and 3 mm respectively in males. In females the SSV, MCSN, TN, PV and PA deviated medially by 7 mm, 6 mm, 7 mm, 3 mm and 2 mm respectively. Portal placement at the level of the MCT has a smaller safety interval so placement at either the midpoint or at the level of the MEF is strongly suggested. Soma et al investigated posteromedial portal placement in 12 plastinated male cadavers and were also able to demonstrate that portal placement at the level of the medial epicondyle is safe and reproducible [27]. Similar to our study the popliteal artery is placed more medially.

Placement of a posterolateral portal should be considered high risk as the safety margin is quite narrow. In males and females respectively, the ideal entry point is 18 mm and 12 mm medial to either the LEF, LCT or the midpoint between the two anatomic landmarks. Typically, the posterolateral portal is established at the soft spot between the lateral collateral ligament and the lateral head of the gastrocnemius muscle, one centimetre above the joint line using a needle to orient as to the correct placement of the portal [22]. Pace and Wahl have shown that the mean distance between a standardized posterolateral portal and the fibular nerve is 40 mm ranging from 30 to 52 mm [25]. Similarly, Makridis et al. demonstrated a mean distance from the posterolateral portal to the common fibular nerve between 17 and 25 mm; the distance between portal and CFN increased with knee flexion from 30 to 90 degrees [18]. The authors recommended posterior portal placements at 90 degrees of knee flexion. In the present study safe zone intervals were investigated for a direct posterior portal placement making comparisons to the results of Pace and Wahl [25] and Makridis [18] difficult. When considering placement of a direct posterolateral portal it appears safe to consider placement of the portal more medially. The lateral cutaneous sural nerve, a sensory nerve supply only a small area on the lateral aspect of the knee and proximal leg, is at risk with this approach [24, 26]. Anatomic variations and course is highly variable in this nerve and is frequently used as a nerve conduit graft [24, 26]. Permanent disability is rare and over 90% of patients have only mild residual symptoms [12]. The anatomic course of the superficial nerves is highly variable, the LCSN unites with the MCSN in either the proximal two thirds or distal two thirds of the leg. The LCSN has also shown cases of no communication with the MCSN or one of the two nerves being absent. All four of the described branching patterns [2] were observed in the sample of the study. Of the study sample, 95.6% presented with a MCSN, whereas 68.9% of the sample presented with a LCSN. A study by Huelke demonstrated an 88% LCSN presence within a sample of 159 cadaveric limbs [14]. The course of the LCSN was also variable in this study and the distance from the LEF, LCT and midpoint ranged from 15 to 51 mm. However, in 99% of all cases the course was measured between 20-30 mm at the LEF, 20-32 mm at the midpoint and 19-35 mm at the LCT. This study therefore confirms that the standard posterolateral portal placement [22] at the soft spot closer to the LEF decreases the risk of injury to the lateral neurovascular structures. The MCSN, if present, and the SSV coursed in a bundle-like manner with the LCSN so despite the high variability of the structures, all were in close proximity [11]. In addition to the above comments the “nick and spread” technique could further reduce injuries to the neurovascular structures. The “nick and spread” technique has been developed to limit injury to branches of the saphenous nerve with postero-medial portal technique [4]. In principle a superficial stab incision is used followed by spreading the tissue with a straight haemostat and placement of a cannula.

The femoral epicondyles and the tibial condyles have shown to be reliable landmarks for neurovascular structures within the popliteal fossa [10,30]. The MEF in this study displayed the largest mean distance between the bony landmark and the neurovascular structures, which suggests that no neurovascular structures passed through that space, making it a good option for portal placement. Sora et al. [28] found the distances between the MEF and the medial borders of the PA, PV and TN to be 42-50 mm, 46-53 mm and 51- 55 mm respectively. This study found the distance between the MEF and the PA, PV and TN to be 33-45 mm, 31-34 mm and 33-45 mm respectively for males and 32-38 mm, 30-36 mm, and 34-42 mm respectively for females. The ranges of mean distances between the MEF and the above-mentioned structures were similar to Sora et al. [28].

The mean distance between the LEF and neurovascular structures is 18 mm in males and 13 mm in females, which is substantially smaller than that of the MEF. The CFN was observed to course directly over the LEF in 20% of the sample making it a risky area for portal placement. Thi et al. [29] demonstrated a mean distance between the lateral femoral condyle and the CFN of 29.6 mm, which is substantially more medial when compared to a mean of 11 mm in our study [29]. Unfortunately, Thi et al. [29] have failed to specify the exact anatomic landmark they have utilized for measurement making comparisons extremely difficult.

It is important to note that this study focussed on the knee in only one position: full extension. It has been documented that the neurovascular structures shift positions at different angles of flexion [17,18, 29, 31]. Kim et al. [17] and Yoo and Chang [31] independently noticed an increase in the distance between the PA and the posterior tibial cortex with an increasing degree of knee flexion. Thi et al. [29] documented a decrease in the distance between the CFN and the fibula head with an increasing degree of knee flexion [29]. The TN, PV and PA have shown to shift posterolateral when the knee is in 90-degree flexion compared to full extension [16]. Yoo

& Chang [31] also noticed the posterolateral movement of the PA when comparing its position in extension and subsequently 90-degree flexion of the knee [31]. This suggests that the safe interval for a direct posterior medial portal with reference to the MEF will increase with flexion of the knee due to the lateral movement of the neurovascular structures. Clearly these findings relate to standard posteromedial and posterolateral portal placement as described by several authors [17, 22, 23]. Ogilvie-Harris et al. have shown that the saphenous vein and nerve for posteromedial portal placement and also the common fibular nerve for posterolateral portal placement fell behind with knee flexion the allowing more clearance for these portals [22]. Effectively the posterior neurovascular structures became more loose falling behind the biceps femoris (CFN) or more medial [22]. In contrast to the standard portal placement described by Ogilvie-Harris [22], the current project utilized a straight posterior approach. Given that the neurovascular structures are tighter in extension, it could be argued that direct posterior portal placement in full extension might be safer and more reliable and reproducible as the neurovascular and posterior structures in both the popliteal fossa and knee joint are less mobile during penetration.

A flexion of 90-degrees of the knee is the clinically standard positioning when making already established portals such as the posteromedial, posterolateral and transseptal portals. These portals have shown a greater distance from the PA when comparing a 30-degree flexion to a 90-degree flexion of the knee. Makridis et al. [18] advised against the placement of posterior portals in a 30-degree flexed knee [18]. When making use of a transseptal portal, the PA will move away from this portal with the knee in 90-degree flexion when compared to full extension [5]. This project investigated anatomy with the knee in full extension and therefore can be considered to represent a worst-case scenario with regards to safe intervals.

At this stage clinical safety cannot be documented and further studies are required. Future research should explore the distance between the neurovascular structures in the popliteal fossa following placement of both lateral and medial posterior arthroscopic portals and determine the frequency of injury to the neurovascular structures with portal placement.

Limitations

This study has limitations. The inclusion and exclusion criteria of this study were strictly defined, but it cannot entirely exclude the possibility that the neurovascular structures within the posterior knee could have been compromised. It is acknowledged that embalmment of human tissue results in significant stiffness when compared to fresh or fresh frozen tissue [13]. However, it is unlikely that these biomechanical changes influence tissue anatomy unless viscoelastic properties are investigated [13]. Theoretically embalmment could also result in changes of anatomic morphology and increasing difficulty with dissection [8]. However, Kennel et al. [15] were able to demonstrate that embalming was unlikely to influence either dissection, tissue handling and anatomy [15]. An a-priori sample size calculation for the morphometric measures was not performed given the rather descriptive nature of this project. It is acknowledged that there is the possibility of a type II error. However, a detailed statistical analysis for the anatomic relationships was not performed reducing the risk of type I and II errors considerably.

Conclusions

The results of study suggest that posteromedial portal placement in arthroscopic knee surgery can be safely established at a distance of less than 20 mm from the medial femoral epicondyle, medial tibial condyle or the midpoint between the two anatomic landmarks. Differences between males and females were not observed. Posterolateral portal placement is of higher risk and the ideal entry point is ideal at a distance of 18 mm from the lateral femoral epicondyle, lateral tibial condyle or the midpoint between the two anatomic landmarks in males and 12 mm in females. These landmarks will allow safe portal placement in 99% of all cases.

Declarations

Funding

Not applicable

Conflict of Interest

Not applicable

Ethics approval

Ethics approval was obtained from the Ethics Committee of the University of XX. (blinded for review) (Ethics number: XXX/2019)

Consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and material

Raw data were generated at XXX. Derived data supporting the findings of this study are available from the corresponding author, XXX, on request.

Code availability

Not applicable

Authors 'contributions

1. Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND
2. Drafting the work or revising it critically for important intellectual content; AND
3. Final approval of the version to be published; AND
4. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

KG 1-4; RvZ 1-4; NK 1-4; EH 1-4

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