ORIGINAL PAPER

RJME
Romanian Journal of Morphology & Embryology
http://www.rjme.ro/

The relationship of neurovascular structures to the posterior medial aspect of the knee: an anatomic study using plastinated cross-sections

MIRCEA-CONSTANTIN SORA[1)], JAN DRESENKAMP[2)], ABIGAIL GABRIEL[3,4)], PETRU MATUSZ[5)], GEORG J. WENGERT[1)], REINMAR BARTL[6)]

[1)]*Morphology Centre, Medical Faculty, Sigmund Freud University of Vienna, Austria*

[2)]*Department of Trauma, Hand and Reconstructive Surgery, "Johann Wolfgang Goethe" University Hospital, Frankfurt, Germany*

[3)]*Department of Internal Medicine, Harlem Hospital Center New York, New York, NY, USA*

[4)]*Department of Anatomical Sciences, School of Medicine, St. George's University, Grenada, West Indies*

[5)]*Department of Anatomy, "Victor Babeş" University of Medicine and Pharmacy, Timisoara, Romania*

[6)]*Third Department of Orthopedics, Orthopedic Hospital Vienna-Speising, Austria*

Abstract

The purpose of this study was to evaluate the topography of the saphenous nerve branches and of the popliteal neurovascular bundle of knee and to establish a low risk placement position of the posteromedial knee portal (PmKP). A slice anatomy study, by using plastinated transparent knee cross-sections was performed on 12 intact right male cadaver lower limbs. The measurements were performed at the level of the medial epicondyle (MEc), at the joint line level and at the level of the tibial attachment of the posterior cruciate ligament (PCL). The popliteal artery (PA) is predicted to be 8.66±2.17 mm dorsal and the sartorial branch of the saphenous nerve (SBSN) at 4.27±0.05 mm posterior to the joint capsule at the level of the MEc. At the joint level, the PA is 7.86±2.26 mm away from the PCL and the SBSN is predicted at 2.41±0.12 mm posterior to the joint capsule. At the level of the tibial attachment of the PCL, the PA to PCL the distance is 5.93±3.61 mm and the SBSN is situated at 4.36±0.43 mm posterior to the joint capsule. Based on our anatomic data, a PmKP placed at the level of the MEc appears to be safe, effective, and reproducible. At the level of MEc, the PA is situated widely lateral to the MEc and the distance between the saphenous nerve branches and the articular capsule is greater than on the other levels. This study suggests that by placing the PmKP at the level of MEc, the risk of neurovascular injuries could be reduced.

Keywords: knee, saphenous nerve branches, popliteal neurovascular bundle, thin plastinated slices, planimetric measurements, three-dimensional reconstruction.

Introduction

The numbers of arthroscopies focused on the posterior aspects of the knee joint have aided in the development of progressive arthroscopic technology and the development of instruments. From total arthroscopic synovectomy, reparation or reconstruction of posterior cruciate ligament (PCL), to all-inside repair of the posterior horn of the medial meniscus, as well as the removal of debris, luxated tissue or tumors posterior to the PCL are all procedures, which involve the arthroscopic visualization of the posterior compartments of the knee [1–3]. Arthroscopy of the posterior knee joint is technically laborious and complex, and a detailed knowledge of the regional anatomy is necessary [4]. Under these assumptions, accurate posterior knee arthroscopy can be safely performed to provide an extended field of view and an increase maneuverability of instruments [5].

The posteromedial knee portal (PmKP), which was described by Ahn & Ha [6] and Louisia *et al.* [7], was created with the knee in a flexed position and from this position the arthroscope is placed under the transcondylar notch allowed for visualization and advancement as far medially as possible [6, 7]. The soft spot is delimitated by the medial collateral ligament, the medial head of the gastrocnemius, and the semimembranosus tendon with an incision approximately 1 cm above the joint space. The saphenous nerve runs along with the long saphenous vein distally and should lay approximately 10 mm posterior to the portal [8, 9]. The posterior horn of the medial meniscus has been described as the greatest source of misdiagnosis in standard arthroscopy. The PmKP allows improved visualization of the essential posterosuperior meniscosynovial junction. The neurovascular bundle and surrounding structures was investigated by anatomic dissection [8, 10–13], and magnetic resonance imaging or ultrasounds was performed [14]. Plastination produces transparent body slices with intact structures and transparent connective tissues, without producing any artifacts. This technique is unique because it offers the possibility to produce transparent slices that can be easily processed morphometrically [15–22].

The position of the popliteal neurovascular bundle was investigated without the manipulation of any structures, but by using the plastination method in order to find a safe zone to place the PmKP. This study therefore, investigates the position of the saphenous nerve, its branches, and the popliteal artery and the relationship to each other, in

order to define the proper position for the PmKP. Our hypothesis tests if the placement of the PmKP should be done at the level of the medial epicondyle, to minimize injury to the neurovascular structures at this level.

Materials and Methods

Twelve intact right male cadaver lower limbs were used. Given that arthroscopic knee maneuvers practiced more frequently in males, for this study twelve male lower limbs without knee osteoarticular pathology were selected. The cadaver age range was between 68 and 81 years, with a mean of 74.2 years. All specimens were frozen at -80^{0}C and then cut using a band saw, into slices with an average thickness of 1.5 mm, starting at 4 cm distal to the tibial tuberosity and finishing 5 cm proximal to the joint line. The original size of the frozen slices was recorded by scanning their caudal aspect *via* an EPSON GT-10000+ Color Image Scanner. Each slice was measured by four marked positions to determine the average thickness: 3 mm from the anterior, posterior, right and left borders of the slices. The slices were stored at -25^{0}C overnight, then dehydrated in cold (-25^{0}C) acetone series, and degreased with methylene chloride for one week. Impregnation was performed at +5^{0}C using E12 epoxy resin (Biodur E12). The slices were then placed between two sheets of tempered glass. Finally, the caudal surfaces of the plastinated slices were scanned at 300 dpi into a computer using an EPSON GT-10000+ Color Image Scanner. In every scan, a ruler was used as a calibration marker for planimetric measurements. By comparing the area data for the fresh and plastinated slices, the shrinkage rate could be determined for each slice, which was considered in calculations. For measurements, the UTHSCSA ImageTool (IT) ver. 3.0 for Windows software (The University of Texas Health Science Center in San Antonio) was also used. Each measurement was done three times and an average value was calculated. The overall measurements of the neurovascular structures were taken from the averages (Figure 1) and the statistics were performed using the SPSS 13.0 for Windows software.

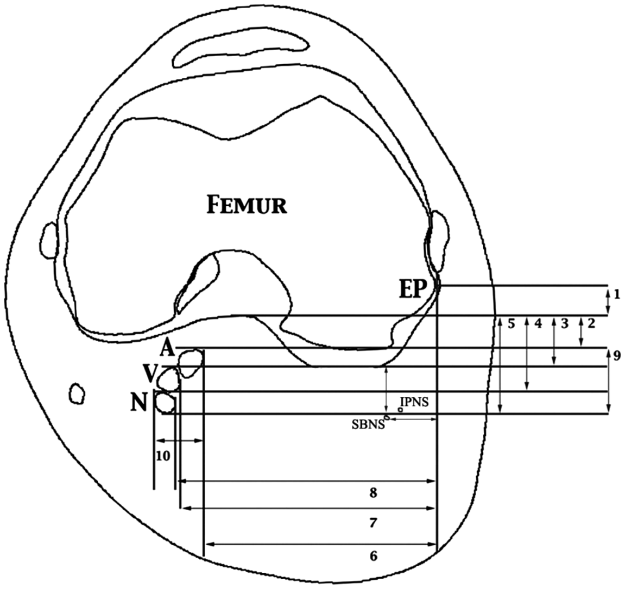

Figure 1 – ***Diagram indicating the sites at which the listed measurements were taken at the tip of the medial epicondyle. 1: Distance between the medial epicondyle and capsule (EP–C); 2: Distance between the capsule and popliteal artery (C–A); 3: Distance between the capsule and popliteal vein (C–V); 4: Distance between the capsule and ventral side of the tibial nerve (C–Nv); 5: Distance between the capsule and dorsal side of the tibial nerve (C–Nd); 6: Distance between the medial epicondyle and popliteal artery (EP–A); 7: Distance between the medial epicondyle and popliteal vein (EP–V); 8: Distance between the medial epicondyle and tibial nerve (EP–N); 9: Distance between the medial epicondyle and the sartorial branch of the saphenous nerve (EP–SBNS); 10: Distance between the joint capsule and the sartorial branch of the saphenous nerve (C–SBNS); 11: Distance between the sartorial and the infrapatellar branch of the saphenous nerve (SBNS–IPNS).***

After plastination, the knee with the neurovascular bundle was three-dimensionally reconstructed. Although the scanned images could have been used directly for computer modeling, manual tracing was included, so that alignment could by more closely controlled. Scanned images of the tissue slices were printed and manually traced; alignment guides were transferred to each tracing. Once scanned, these images (jpeg format) were loaded into WinSURF (SURFdriver 4.0; http://www.surfdriver.com) and traced from the monitor (according with the technique described by Lozanoff [23] and Moody & Lozanoff [24]). Once all contours were traced, the knee was reconstructed and visualized.

Results

The thin 1.5 mm slices produced were transparent and hard with good optical qualities. The finished E12 slices provided excellent anatomic detail down to the microscopic level (Figures 2–4). The measured sites onto the transparent plastinated slices are shown in Figure 1 and were performed at the level of the medial epicondyle, at the joint line level and at the level of the tibial attachment of the PCL. Data of the planimetric measurements obtained through knee plastination are shown in Tables 1–3. The shrinkage rate of the slices was calculated having a range from 2.95 to 4.30% and the measured values were adjusted accordingly.

The anatomical structures of the knee were easily identified and the borders were traced rapidly and reliably. The plastinated slices distinctively displayed the nerves, muscles, vessels, and bones of the ankle. The 3D knee model generated displays a morphology that corresponds qualitatively to the actual cadaver specimen (Figures 5 and 6).

As the most profound structure of the neurovascular bundle, the artery is situated based on our measurements, at a mean distance of 8.66 mm to the articular capsule at the medial epicondyle level. In the distal part of the popliteal fossa, at the level of the insertion of the PCL, the artery runs 3.69 mm away from the articular capsule. The popliteal vein ascends from the level of the tibial attachment of the PCL, where it is situated at 5.90 mm from the articular capsule to the proximal part of the

popliteal fossa, running at a distance of 13.99 mm from the articular capsule, at the level of the medial epicondyle. The tibial nerve descends in the popliteal fossa, being situated at the level of the medial epicondyle at 17.72 mm away from the articular capsule. At the level of the tibial attachment of the PCL, the tibial nerve is situated at a distance of 9.34 mm from the articular capsule. The sartorial branch of the saphenous nerve runs posterior to the infrapatellar branch and descends on the lateral side of the sartorius. The infrapatellar branch runs distally to supply the anteromedial aspect of the knee.

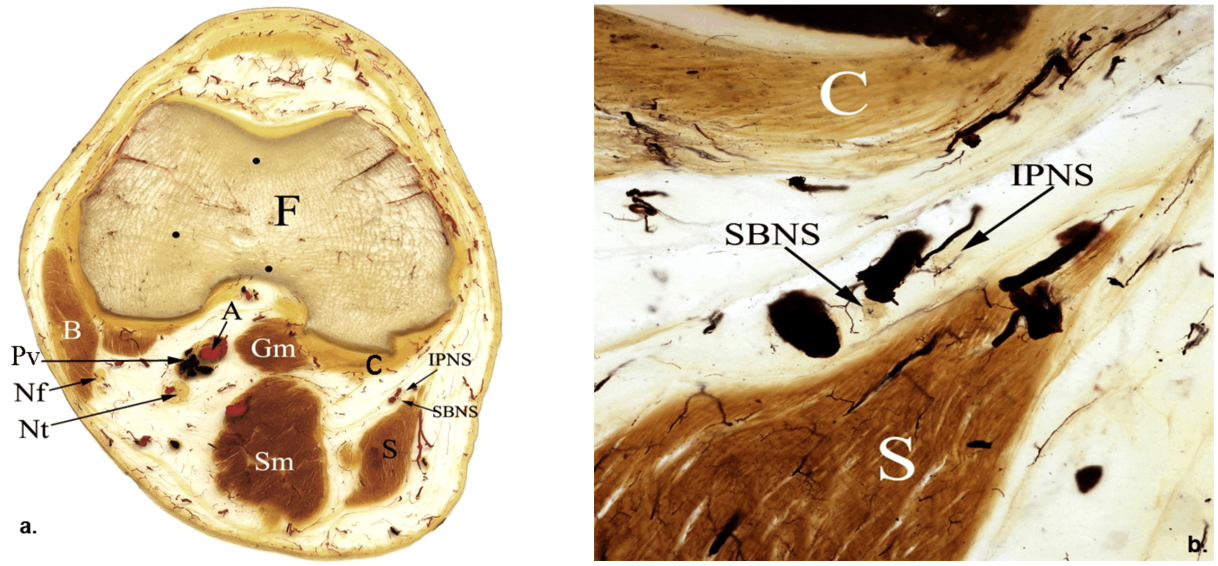

Figure 2 – *A plastinated cross-section of the level of the medial epicondyle, with a thickness of 1.5 mm. The vascular pattern was injected with an E12/E1 mixture and scanned at a resolution of 300 dpi. (a) Cross-section (1.5 mm) at the level of the medial epicondyle. Reconstruction markers (black) and the injection of the vascular pattern are evident. (b) Detail showing the branches of the saphenous nerve (SBNS and IPNS). A: Popliteal artery; B: Biceps femoris muscle; C: Joint capsule; F: Femur; Gm: Medial gastrocnemius; IPNS: Infrapatellar branch of the saphenous nerve; Nf: Fibular nerve; Nt: Tibial nerve; Pv: Popliteal vein; S: Sartorius; SBNS: Sartorial branch of the saphenous nerve; Sm: Semimembranous muscle.*

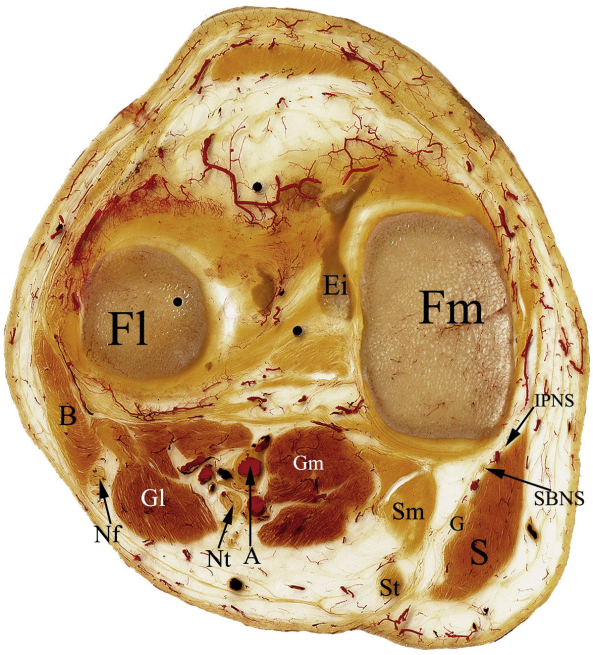

Figure 3 – *Cross-section at the level of the joint line, showing the intercondylar eminence of the tibia and the lower part of the femoral condyles. A: Popliteal artery; B: Biceps femoris muscle; Ei: Intercondylar eminence; Fl: Lateral condyle; Fm: Medial condyle; G: Gracilis; Gl: Lateral gastrocnemius; Gm: Medial gastrocnemius; IPNS: Infrapatellar branch of the saphenous nerve; Nf: Fibular nerve; Nt: Tibial nerve; S: Sartorius; SBNS: Sartorial branch of the saphenous nerve; Sm: Semimembranous muscle; St: Semitendinosus muscle.*

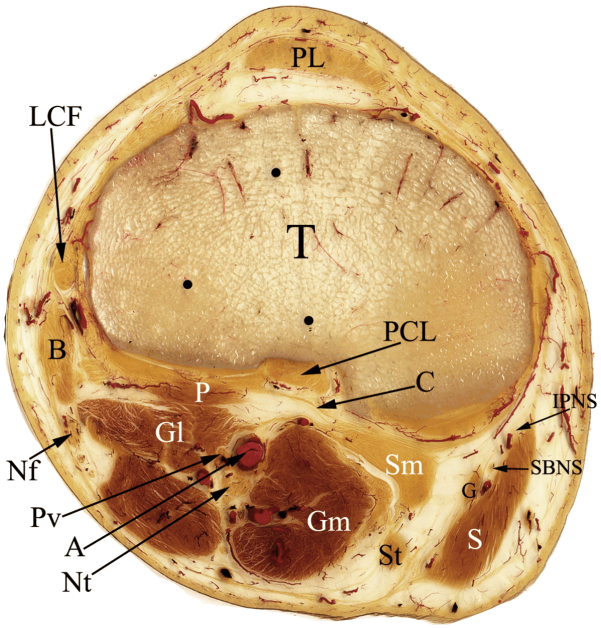

Figure 4 – *Cross-section at the level of the tibial attachment of the posterior cruciate ligament. A: Popliteal artery; B: Biceps femoris muscle; C: Capsule; G: Gracilis; Gl: Lateral gastrocnemius; Gm: Medial gastrocnemius; IPNS: Infrapatellar branch of the saphenous nerve; LCF: Fibular collateral ligament; Nf: Fibular nerve; Nt: Tibial nerve; P: Popliteus; PCL: Posterior cruciate ligament; Pl: Patellar ligament; Pv: Popliteal vein; S: Sartorius; SBNS: Sartorial branch of the saphenous nerve; Sm: Semimembranous muscle; St: Semitendinosus muscle; T: Tibia.*

Table 1 – ***Anatomic measurements of the distances at the level of medial epicondyle***

Distance between anatomical structures	Abbreviations	Range [mm]	Mean±SD
Distance between the medial epicondyle to the joint capsule	EP–C	11.29–23.18	16.35±4.57
Distance between the joint capsule and popliteal artery	C–A	6.41–11.12	8.66±2.17
Distance between the joint capsule and the popliteal vein	C–V	9.52–20.40	13.99±4.50
Distance between the joint capsule and the ventral side of the tibial nerve	C–Nv	12.47–22.92	17.72±4.71
Distance between the joint capsule and the dorsal side of the tibial nerve	C–Nd	17.87–25.96	22.18±3.42
Distance between the medial epicondyle and the popliteal artery	EP–A	42.31–49.73	45.58±3.27
Distance between the medial epicondyle and the popliteal vein	EP–V	46.02–53.52	49.17±2.95
Distance between the medial epicondyle and the tibial nerve	EP–N	51.16–55.20	54.00±1.67
Distance between the medial epicondyle and the sartorial branch of the saphenous nerve	EP–SBNS	12.38–9.42	10.39±0.21
Distance between the joint capsule and the sartorial branch of the saphenous nerve	C–SBNS	5.52–3.21	4.27±0.05
Distance between the sartorial and the infrapatellar branch of the saphenous nerve	SBNS–IPNS	3.43–1.00	1.62±0.18

Table 2 – ***Anatomic measurements of the distances at the joint line level***

Distance between anatomical structures	Abbreviations	Range [mm]	Mean±SD
Distance between the joint capsule and popliteal artery	C–A	1.69–4.89	2.84±1.20
Distance between the joint capsule and the popliteal vein	C–V	5.98–8.85	7.39±1.31
Distance between the joint capsule and the ventral side of the tibial nerve	C–Nv	7.25–11.81	9.34±1.92
Distance between the joint capsule and the dorsal side of the tibial nerve	C–Nd	11.46–16.18	13.82±2.03
Distance between the posterior cruciate ligament and the popliteal artery	PCL–A	9.39–6.22	7.86±2.26
Distance between the joint capsule and the sartorial branch of the saphenous nerve	C–SBNS	3.01–1.64	2.41±0.12
Distance between the sartorial and the infrapatellar branch of the saphenous nerve	SBNS–IPNS	4.26–2.87	3.71±0.48
Distance between the sartorial branch and the popliteal artery	SBNS–A	39.76–34.54	37.57±1.45

Table 3 – ***Measurements of distances at the level of the tibial attachment of the posterior cruciate ligament (PCL)***

Distance between anatomical structures	Abbreviations	Range [mm]	Mean±SD
Distance between the joint capsule and popliteal artery	C–A	1.18–9.36	3.69±3.30
Distance between the joint capsule and the popliteal vein	C–V	2.44–11.13	5.90±3.18
Distance between the joint capsule and the ventral side of the tibial nerve	C–Nv	3.21–13.99	9.34±4.23
Distance between the joint capsule and the dorsal side of the tibial nerve	C–Nd	6.15–19.89	13.18±5.21
Distance between the posterior cruciate ligament and the popliteal artery	PCL–A	7.36–3.88	5.91±3.61
Distance between the joint capsule and the sartorial branch of the saphenous nerve	C–SBNS	5.22–3.12	4.16±0.43
Distance between the sartorial and the infrapatellar branch of the saphenous nerve	SBNS–IPNS	9.26–6.77	8.44±0.55
Distance between the sartorial branch and the popliteal artery	SBNS–A	41.26–36.23	37.10±1.87

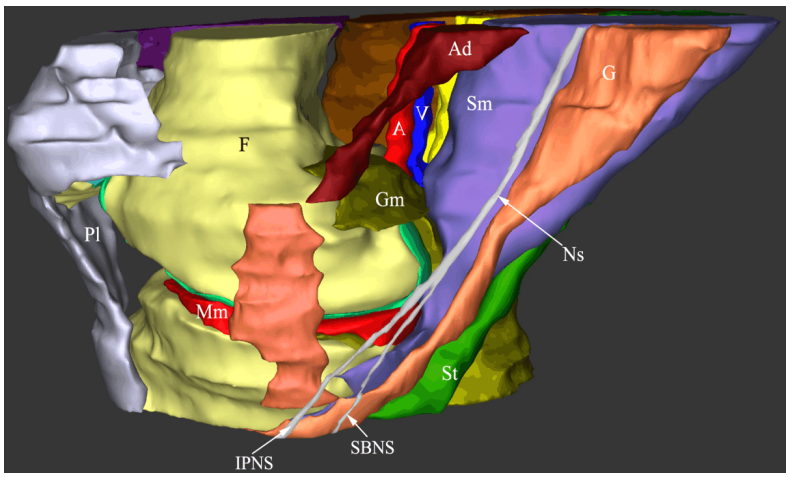

Figure 5 – ***Three-dimensional reconstruction of the knee, displaying the topographical relationship of the anatomical structures. Medial view with the Sartorius and the joint capsule removed. A: Popliteal artery; ACL: Anterior cruciate ligament; Ad: Great adductor; F: Femur; G: Gracilis; Gl: Lateral gastrocnemius; Gm: Medial gastrocnemius; IPNS: Infrapatellar branch of the saphenous nerve; Mm: Medial meniscus; Ns: Saphenous nerve; Pl: Patellar ligament; SBNS: Sartorial branch of the saphenous nerve; Sm: Semimembranous muscle; St: Semitendinosus muscle; V: Popliteal vein.***

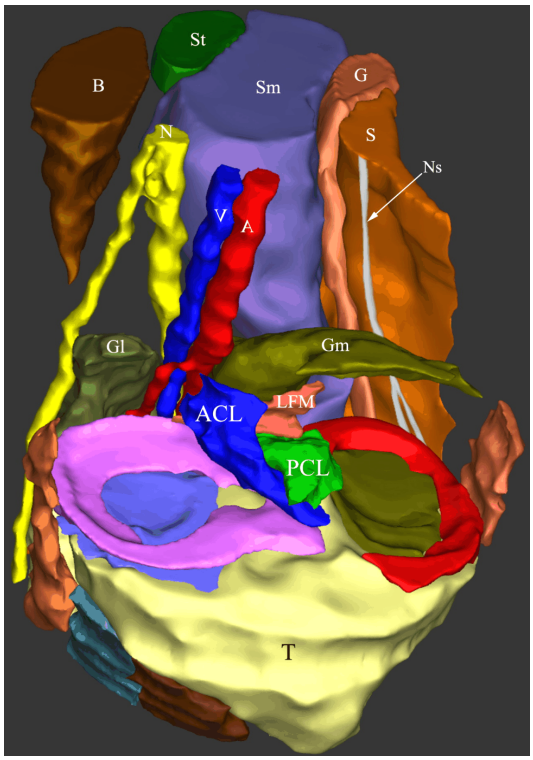

Figure 6 – ***Three-dimensional reconstruction of the knee joint. The plastinated slices, with a thickness of 1.5 mm, were scanned at a ratio 1:1. Proximal view with the femur and the patella removed. A: Popliteal artery; ACL: Anterior cruciate ligament; B: Biceps femoris muscle; Gm: Medial gastrocnemius; IPNS: Infrapatellar branch of the saphenous nerve; LFM: Meniscofemoral ligament; Mm: Medial meniscus; Ns: Saphenous nerve; PCL: Posterior cruciate ligament; S: Sartorius; SBNS: Sartorial branch of the saphenous nerve; Sm: Semimembranous muscle; St: Semitendinosus muscle; V: Popliteal vein; T: Tibia.***

The reconstructed images were of high quality, especially the spatial positions and complicated adjacent relationships of various ankle structures shown in direct viewing as displayed in the background of the bony substance.

Discussion

Arthroscopic viewing of the posterior aspects of the knee joint has increased the course of progressive arthroscopic technology and the development of instruments. Arthroscopy of the posterior knee joint is technically laborious and complex and therefore detailed knowledge of the regional anatomy is necessary.

Generally speaking, the knee joint arthroscopy is an uncomplicated intervention that can result in several complications. The total complication ratio of neurovascular injuries during knee arthroscopy is located between 0.01 to 0.08% [25, 26]. Injuries of the saphenous nerve develop in 7 to 22% [8, 27] of the patients after reconstruction of the medial meniscus. Vascular lesions during surgery, such as direct perforation or laceration, constitute only 1% of total neurovascular complications [26]. Acute injury of the popliteal artery is an extremely rare complication, but a serious and possibly fatal one, and ranges from pseudoaneurysm, acute occlusion, to the point of direct lacerations. There are several reports of popliteal injuries during surgery on the posterior horn of the lateral meniscus [28, 29], arthroscopic reconstructions of the PCL [30–32], and synovectomy in the posterior compartment [33]. Therefore, an adequate knowledge of topographical anatomy is absolutely essential to avoid these severe complications during accomplishing posterior arthroscopy of the knee joint.

In a magnetic resonance imaging study of cadavers, Smith *et al.* [34] found that two of nine healthy volunteers had anterior displacement of the popliteal vessels with knee flexion. Knee flexion does not always guarantee posterior displacement of the popliteal artery. By using the plastination method, morphological measurements can be performed easily and accurately [17, 19] since tissues are maintained in a non-collapsed and non-dislocated state. By slicing the knee in 1.5 mm sections, exact information about the neurovascular bundle and the saphenous nerve are obtained more accurately than by the careful dissection of this structure. The saphenous nerve, as a branch of the femoral nerve, passes medial to the femoral artery and enters the adductor canal. After passing the adductor canal, the saphenous nerve divides into two branches: the sartorial branch and the infrapatellar branch. The sartorial branch runs posterior to the infrapatellar branch and descends on the lateral side of the sartorius. The infrapatellar branch runs distally to supply the anteromedial aspect of the knee. Due to our measurements, the popliteal artery, as the most ventral structure of the neurovasculare bundle, is predicted to be at 8.66±2.17 mm dorsal to the joint capsule at the level of the medial epicondyle. At this level, the neurovascular bundle was situated 45.58±3.27 mm lateral to the medial epicondyle with the popliteal artery being the nearest structure. The sartorial branch of the saphenous nerve (SBNS) was situated at this level 10.39±0.21 mm lateral to the medial epicondyle and 4.27±0.05 mm dorsal to the joint capsule. The infrapatellar branch runs 1.62±0.18 mm anteromedial to the sartorial branch. At the joint line level, the PCL to popliteal artery distance was 7.86±2.26 mm. This data is similar with that presented by Matava *et al.* [35] and Ahn & Ha [6], with the knee being at 0^0, but differs from Pace & Wahl [5] because a capsulotomy was performed and therefore the distance is greater. At the same level, the sartorial branch of the saphenous nerve runs on the lateral side of the sartorius and was located at 2.41±0.12 mm posterior to the joint capsule. The infrapatellar branch runs at 3.71±0.48 mm anteromedial to the sartorial branch. The popliteal neurovascular bundle lays lateral to the sartorial branch at a distance of 37.57±1.45 mm. At the level of the tibial attachment of the PCL to the popliteal artery, the distance is 5.91±3.61 mm, and the sartorial branch is situated at 4.36±0.43 mm posterior to the joint capsule. The infrapatellar branch was situated at 8.44±0.55 mm in front and medial to the saphenous nerve. Between the saphenous nerve and the neurovascular bundle, the distance is 37.10±1.87 mm. The saphenous nerve was never found to run anterior to the sartorius at any of the described levels, which coincides with the findings of Dunaway *et al.* [8]. Usually, the posteromedial knee portal is placed in a soft spot between the medial collateral ligament, the medial head of the gastrocnemius, and the

tendon of the semimembranosus at the joint line [6, 7]. Based on our anatomic data, a portal made at the level of the medial epicondyle appears to be safer than a posteromedial knee portal placed more distally. At this level, the popliteal artery is predicted to be at 45 mm lateral to the medial epicondyle and the saphenous nerve is more dorsal to the articular capsule than at other levels of the knee. Therefore, a portal placement here would be advantageous and safer. Between the SBNS and the popliteal neurovascular bundle, there will be at least a 30 mm area, localized laterally to the sartorial branch of the saphenous nerve, where the incision and placement of a posteromedial knee portal could be performed risk-free.

An additional possibility at viewing the medial neurovascular course is the 3D reconstruction of the knee by using the plastinated slices (Figures 5 and 6). Once reconstructed, the measuring tool available in the reconstruction software was used to record measurements from the model. Quantitative measurements showed that the overall morphology was retained. The capability of reconstructing individual and combined images of knee structures, viewing them from all surgical angles, and allowing for accurate measurement of their spatial relationships, provides an important and useful research tool. The reconstructed model can also be used for residency education, planning an unusual surgery, and for the development of new surgical approaches. The slice anatomy study performed has no distortion and movement of anatomic structures, thereby making this method a valuable tool in the evaluation of anatomical relationships.

The main limitation of this study is the small number of the cadavers that reduces the possibility of a more detailed and thorough description. The prognostic impact of a condition, such as the neurovascular knee pattern, is sometimes difficult to study with an experimental design because of artifacts due to the different shrinkage behavior of tissues such as lipid, muscular, or connective tissue.

Conclusions

Based on our anatomic data, a posteromedial knee portal placed at the level of the medial epicondyle seems to be safe, effective, and reproducible. At the level of the medial epicondyle, the popliteal artery is situated widely laterally to the medial epicondyle, and the distance between the saphenous nerve branches and the articular capsule is greater than on the other levels.

Conflict of interests

The authors declare that they have no conflict of interests.

Acknowledgments

The authors express their gratitude to the donor cadavers and their families who participated in the donation program of Medical University of Vienna.

References

[1] Kim SJ, Kim SH, Chun YM, Hwang BY, Choi DH, Yoon JY. Clinical comparison of conventional and remnant-preserving transtibial single-bundle posterior cruciate ligament reconstruction combined with posterolateral corner reconstruction. Am J Sports Med, 2012, 40(3):640–649.

[2] Nam D, Macaulay A, Cross M, Shindle MK, Warren RF. Posterior cruciate ligament resection for ganglion cyst and associated ligament degeneration. Am J Orthop (Belle Mead NJ), 2011, 40(6):E110–E114.

[3] Wilson BF, Johnson DL. Posterior horn medial meniscal root repair with cruciate ligament/medial collateral ligament combined injuries. Orthopedics, 2011, 34(12):986–988.

[4] Kramer DE, Bahk MS, Cascio BM, Cosgarea AJ. Posterior knee arthroscopy: anatomy, technique, application. J Bone Joint Surg Am, 2006, 88(Suppl 4):110–121.

[5] Pace JL, Wahl CJ. Arthroscopy of the posterior knee compartments: neurovascular anatomic relationships during arthroscopic transverse capsulotomy. Arthroscopy, 2010, 26(5):637–642.

[6] Ahn JH, Ha CW. Posterior trans-septal portal for arthroscopic surgery of the knee joint. Arthroscopy, 2000, 16(7):774–779.

[7] Louisia S, Charrois O, Beaufils P. Posterior "back and forth" approach in arthroscopic surgery on the posterior knee compartments. Arthroscopy, 2003, 19(3):321–325.

[8] Dunaway DJ, Steensen RN, Wiand W, Dopirak RM. The sartorial branch of the saphenous nerve: its anatomy at the joint line of the knee. Arthroscopy, 2005, 21(5):547–551.

[9] Wilmot VV, Evans DJ. Categorizing the distribution of the saphenous nerve in relation to the great saphenous vein. Clin Anat, 2013, 26(4):531–536.

[10] Cross L, Hall J, Howdieshell TR, Colborn GL, Gale TF. Clinical anatomy of the popliteal blood vessels. Clin Anat, 2000, 13(5): 347–353.

[11] Kurtoglu Z, Aktekin M, Uluutku MH. Branching patterns of the common and superficial fibular nerves in fetus. Clin Anat, 2006, 19(7):621–626.

[12] Mochizuki T, Akita K, Muneta T, Sato T. Pes anserinus: layered supportive structure on the medial side of the knee. Clin Anat, 2004, 17(1):50–54.

[13] Pannell WC, Wisco JJ. A novel saphenous nerve plexus with important clinical correlations. Clin Anat, 2011, 24(8):994–996.

[14] Griffin N, Joubert I, Lomas DJ, Bearcroft PW, Dixon AK. High resolution imaging of the knee on 3-Tesla MRI: a pictorial review. Clin Anat, 2008, 21(5):374–382.

[15] Qiu MG, Zhang SX, Liu ZJ, Tan LW, Wang YS, Deng JH, Tang ZS. Plastination and computerized 3D reconstruction of the temporal bone. Clin Anat, 2003, 16(4):300–303.

[16] Sora MC, Strobl B, Staykov D, Förster-Streffleur S. Evaluation of the ankle syndesmosis: a plastination slices study. Clin Anat, 2004, 17(6):513–517.

[17] Sora MC, Genser-Strobl B. The sectional anatomy of the carpal tunnel and its related neurovascular structures studied by using plastination. Eur J Neurol, 2005, 12(5):380–384.

[18] Sora MC, Genser-Strobl B, Radu J, Lozanoff S. Three-dimensional reconstruction of the ankle by means of ultrathin slice plastination. Clin Anat, 2007, 20(2):196–200.

[19] Sora MC, Jilavu R, Grübl A, Genser-Strobl B, Staykov D, Seicean A. The posteromedial neurovascular bundle of the ankle: an anatomic study using plastination. Arthroscopy, 2008, 24(3):258.e1–258.e7.

[20] Sora MC, Matusz P. General considerations regarding the thin slice plastination technique. Clin Anat, 2010, 23(6):734–736; author reply 737–738.

[21] Sora MC, Matusz P. Study of the vascular architecture of bones using the plastination technique. Clin Anat, 2012, 25(2): 258–259.

[22] Sora MC, Jilavu R, Matusz P. Computer aided three-dimensional reconstruction and modeling of the pelvis, by using plastinated cross sections, as a powerful tool for morphological investigations. Surg Radiol Anat, 2012, 34(8):731–736.

[23] Lozanoff S. Accuracy and precision of computerized models of the anterior cranial base in young mice. Anat Rec, 1992, 234(4):618–624.

[24] Moody D, Lozanoff S. SURFdriver: a practical computer program for generating three-dimensional models of anatomical structures using a PowerMac. Clin Anat, 1998, 11:133.

[25] DeLee JC. Complications of arthroscopy and arthroscopic surgery: results of a national survey. Committee on Complications of Arthroscopy Association of North America. Arthroscopy, 1985, 1(4):214–220.

[26] Kim TK, Savino RM, McFarland EG, Cosgarea AJ. Neurovascular complications of knee arthroscopy. Am J Sports Med, 2002, 30(4):619–629.

[27] Mochida H, Kikuchi S. Injury to the infrapatellar branch of saphenous nerve in arthroscopic knee surgery. Clin Orthop Relat Res, 1995, 320:88–94.
[28] Potter D, Morris-Jones W. Popliteal artery injury complicating arthroscopic meniscectomy. Arthroscopy, 1995, 11(6):723–726.
[29] Tawes RL Jr, Etheredge SN, Webb RL, Enloe LJ, Stallone RJ. Popliteal artery injury complicating arthroscopic meniscectomy. Am J Surg, 1988, 156(2):136–138.
[30] Cohen SB, Boyd L, Miller MD. Vascular risk associated with posterior cruciate ligament reconstruction using the arthroscopic transtibial tunnel technique. J Knee Surg, 2004, 17(4): 211–213.
[31] Makino A, Costa-Paz M, Aponte-Tinao L, Ayerza MA, Muscolo DL. Popliteal artery laceration during arthroscopic posterior cruciate ligament reconstruction. Arthroscopy, 2005, 21(11):1396.e1–1396.e4.
[32] Wu RW, Hsu CC, Wang CJ. Acute popliteal artery occlusion after arthroscopic posterior cruciate ligament reconstruction. Arthroscopy, 2013, 19(8):889–893.
[33] Furie E, Yerys P, Cutcliffe D, Febre E. Risk factors for arthroscopic popliteal artery laceration. Arthroscopy, 1995, 11(3): 324–327.
[34] Smith PN, Gelinas J, Kennedy K, Thain L, Rorabeck CH, Bourne RB. Popliteal vessels in knee surgery. A magnetic resonance imaging study. Clin Orthop Relat Res, 1999, 367: 158–164.
[35] Matava MJ, Sethi NS, Totty WG. Proximity of the posterior cruciate ligament insertion to the popliteal artery as a function of the knee flexion angle: implications for posterior cruciate ligament reconstruction. Arthroscopy, 2000, 16(8):796–804.

Corresponding author
Petru Matusz, Professor, MD, PhD, Department of Anatomy, "Victor Babeş" University of Medicine and Pharmacy, 2 Eftimie Murgu Square, 300041 Timişoara, Romania; Phone +40729–016 260, Fax +40356–819 639, e-mail: matusz@umft.ro

Received: August 1, 2014

Accepted: October 20, 2015