Thieme

Novel Demonstration of the Anterior Femoral Cutaneous Nerves using Ultrasound

Darstellung der anterioren kutanen Hautäste des Nervus femoralis mittels Ultraschall

Authors
Christopher Pivec[1], Gerd Bodner[1], Johannes A. Mayer[2], Peter C. Brugger[3], Istvan Paraszti[3], Veith Moser[4], Hannes Traxler[3], Georg Riegler[1]

Affiliations
1 Department of Biomedical Imaging and Image-guided Therapy, Medical University Vienna, Austria
2 Department of Surgery, Division of Plastic and Reconstructive Surgery, Medical University Vienna, Austria
3 Department of Anatomy, Center for Anatomy and Cell Biology, Medical University Vienna, Austria
4 Department of Trauma Surgery, Lorenz Boehler Hospital, Vienna, Austria

Key words
ultrasonography, peripheral nerve, iatrogenic disease, anatomic variation

received 25.05.2017
accepted 11.10.2017

Bibliography
DOI https://doi.org/10.1055/s-0043-121628
Published online: February 7, 2018
Ultraschall in Med 2018; 39: 318–327
© Georg Thieme Verlag KG, Stuttgart · New York
ISSN 0172-4614

Correspondence
Dr. Georg Riegler
Biomedical Imaging and Image-guided Therapy,
Medical University Vienna, Währingergürtel 18–20,
1090 Wien, Austria
Tel.: ++ 43/1/40 40 04 81 80

ABSTRACT

Purpose Neuropathy of the intermediate (IFCN) and medial femoral cutaneous nerve (MFCN) is a potential iatrogenic complication of thigh surgery and its diagnosis is limited. This study aimed to evaluate the possibility of the visualization and diagnostic assessment of the IFCN and MFCN with high-resolution ultrasound (HRUS).

Materials and Methods In this study, HRUS with high-frequency probes (15 – 22MHz) was used to locate the IFCN and the MFCN in 16 fresh cadaveric lower limbs. The correct identification of the nerves was verified by ink-marking and consecutive dissections at sites correlating to nerve positions (R1 – 3), namely, the origin, the mid portion, and the distal portion, respectively. 12 cases with suspected IFCN and MFCN lesions referred to our clinic for HRUS examinations were also assessed.

Results Anatomical dissection confirmed the correct identification of the IFCN in 16/16 branches at all of the different locations (100 %). MFCN was correctly identified at R1 + 3, in all cases (16/16; 100 %), and in 14/16 cases (88 %) at (R2). 12 cases of patients with IFCN and MFCN pathologies (all of iatrogenic origin) were identified. 9 instances of structural damage were visible on HRUS, and all pathologies were confirmed by almost complete resolution of symptoms after selective HRUS-guided blocks with 0.5 – 1 ml lidocaine 2 %.

Conclusion This study confirms that the IFCN and the MFCN can be reliably visualized with HRUS throughout the course of these nerves, both in anatomical specimens and in patients.

ZUSAMMENFASSUNG

Ziel Iatrogene Schädigungen der Rami cutanei anteriores des Nervus femoralis, die einen intermediären und einen medialen Ast aufweisen (IFCN und MFCN), können eine schwer zu diagnostizierende Pathologie sein. Ziel dieser Studie ist es, zu untersuchen, ob die bildgebende Darstellung und Diagnostik des MFCN und IFCN, mittels hochauflösendem Ultraschall (HRUS), möglich ist.

Material und Methoden In dieser Studie wurde mittels hochauflösenden Ultraschallsonden (15 – 22MHz) versucht, den IFCN und MFCN bei 16 frischen Kadavern aufzusuchen, und im Verlauf darzustellen. Die korrekte Identifikation des jeweiligen Nervs, wurde durch ultraschallgezielte Farbmarkierung und anschließende anatomische Präparation bestätigt. Hierbei wurde sowohl der IFCN, als auch der MFCN an jeweils drei Stellen (proximal, Mitte und distal, R1 – 3) markiert. Zusätzlich wurden zwölf Patienten unserer Klinik, mit Verdacht auf IFCN und MFCN Pathologien, mittels hochauflösendem Ultraschall untersucht. Die anatomische Präparation bestätigte die korrekte Identifikation des IFCN und MFCN in 16 von 16 Fällen. Der Verlauf des MFCN konnte in allen Fällen (16/16; 100 %) korrekt dargestellt und farbmarkiert werden

Downloaded by: Universitaetsbibliothek - Med. Universitaet Wien. Copyrighted material.

(R1,2,3). Der Verlauf des IFCN konnte in 14 von 16 Fällen (88 %) korrekt dargestellt und farbmarkiert werden (R2).

Ergebnisse Zwölf Patienten mit iatrogenen IFCN und MFCN Pathologien wurden identifiziert. In neun Fällen konnten morphologische Schädigungen des jeweiligen Nervs mittels HRUS gefunden werden. Diese Schädigungen wurden durch erfolgreiche HRUS-gezielter Blockade mit 0.5 – 1 ml Lidocain 2 % als ursächlich bestätigt.

Schlussfolgerung Diese Studie bestätigt, dass sowohl der IFCN, als auch der MFCN zuverlässig mit hochauflösendem Ultraschall visualisiert und im gesamten Verlauf dargestellt werden können, sowohl an Kadavern als auch an Patienten.

Introduction

The intermediate (IFCN) and medial femoral cutaneous nerves (MFCN) are two large anterior cutaneous branches of the femoral nerve that provide sensory skin innervation to the anteromedial thigh and, in particular, motor innervation to the sartorius muscle [1, 2] (▶ **Fig. 1**). Anatomical studies show a high variability of these nerves with regard to their branching pattern, course, and distribution, especially in the anteromedial knee region [2 – 5].

The main clinical relevance of these two nerves is possible iatrogenic injury. Postsurgical neuropathies of the MFCN may be seen after total knee arthroplasty [6, 7] and arthroscopically assisted anterior cruciate ligament reconstruction [4]. Further involvement of the IFCN during varicose vein stripping and surgery [8 – 11] or after femoral artery reconstruction has also been reported [12]. Other neuropathies, such as neurofibromatosis [13], penetrating trauma [14], or diabetic neuropathies [15], are rare.

To date, the evaluation and location of these branches has been restricted to electrophysiological assessment [16, 17], as well as clinical testing using landmarks [18] or unguided nerve blocks. [6] Interestingly, although extensively reported for the lateral femoral cutaneous branch [19 – 22], high-resolution ultrasound (HRUS) visualization currently does not play a role in assessing the MFCN and the IFCN.

Visualization of the branches with HRUS may provide diagnostic as well as therapeutic benefits for patients with MFCN and IFCN neuropathies. HRUS may detect morphological nerve changes or guide selective blockade to make the exact diagnosis. Moreover, determination of the exact location of the MFCN and IFCN may avoid confusion with other branches, such as the infrapatellar branch of the saphenous nerve, which is anatomically paired with the MFCN on the anteromedial knee side [23], and therefore, improve therapeutic treatment options for pain management, such as cryodenervation [18] prior to knee surgery and neurectomy [6, 7] after knee surgery.

Since HRUS offers excellent tissue differentiation for the examination of superficial structures, we hypothesized that evaluation of the IFCN and the MFCN would be possible.

This study, therefore, aimed to (i) confirm the correct identification of the IFCN and the MFCN by HRUS with ink marking and consecutive dissection in anatomical specimens, and to (ii) present cases with MFCN and IFCN pathologies detected with HRUS.

Materials and Methods

Study approval

This was a single-center study with approval by the local institutional review board of the Medical University of Vienna (EC-number 1377/2016). The study was performed in accordance with the World Medical Association Declaration of Helsinki.

Ultrasound technique

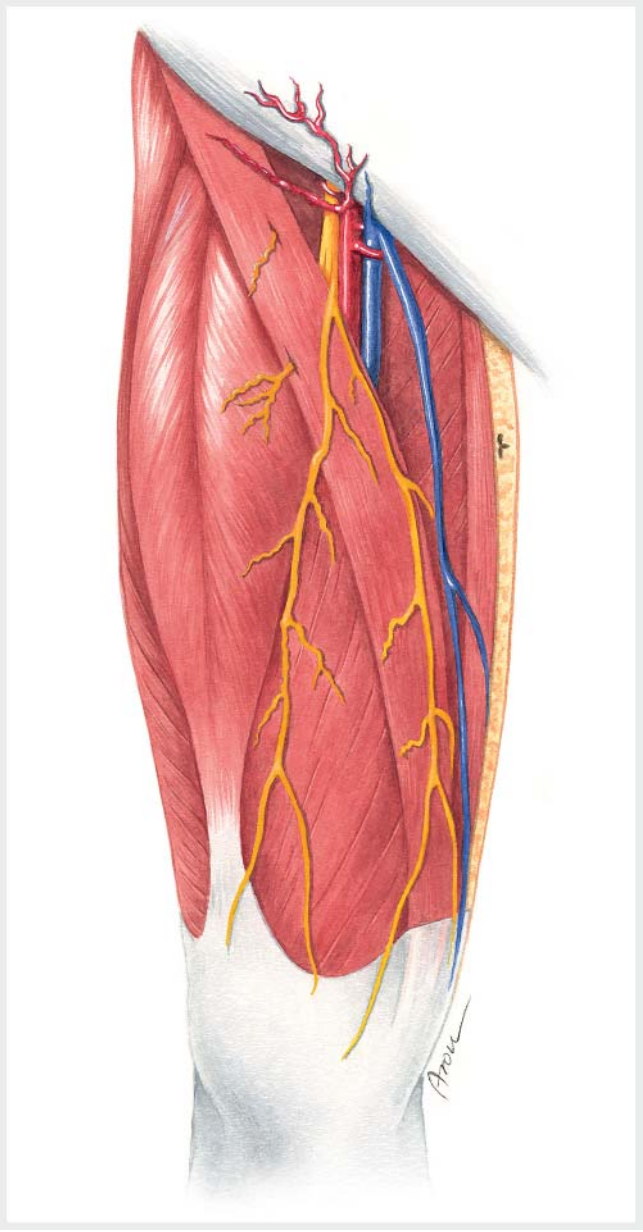
HRUS examinations were performed using a GE LOGIQ E9 and a GE LOGIQ e (GE Healthcare, Wauwatosa, U.S.A.) ultrasound platform with high-frequency probes (GE ML 6 – 15-D, GE L8 – 18i-D, GE L10 – 22-RS). Two radiologists, one with more than 20 years of experience (G.B.) and one with five years of experience (G.R.) in peripheral nerve imaging, carried out all examinations. G.R. and G.B. performed interventions on anatomical studies, whereas G. B. carried out all procedures on patients with suspected medial femoral cutaneous nerve (MFCN) and intermediate femoral cutaneous nerve (IFCN) neuropathies.

The examination followed a standardized assessment protocol. All participants were examined in the supine position, with the knees extended. Ultrasound examinations started with the transverse view at the middle/distal third of the anterior thigh superficial to the sartorius vastus medialis and rectus femoris muscles. The subcutaneous fat overlying these muscles was then carefully screened distally and proximally for tubular, in contrast to fat, hyperechoic structures that were presumed to be the MFCN and the IFCN. The IFCN was explored at the level overlying the vastus medialis, rectus femoris, and, sometimes, the sartorius muscle, whereas the MFCN was explored further medially in the region of the vastus medialis and sartorius muscle. If detected, the branches were followed proximally to assess the origin from the femoral nerve so as not to confound the branches with the lateral femoral cutaneous nerve, and, further, distally, to assess its most distal visible parts.

To obtain a better overview of the area, the examination always started with the 6 – 15-MHz probe. After identification of the nerves, the transducer was changed, and an 8 – 18-, or 10 – 22 probe was used to better delineate the branches. Depending on the subject's thigh/subcutaneous fat thickness and the course of the branches, careful adaptation of the depth and angulation of the transducer to avoid anisotropy must be carried out to ensure that the nerve was in full view and not distorted in the image.

US still images and videos were captured to record the cross sections and course of the nerve segments. To avoid confusion

Downloaded by: Universitaetsbibliothek - Med. Universitaet Wien. Copyrighted material.



▶ **Fig. 1** Illustration of the course of the intermediate (the left one shown in yellow) and medial (the right one shown in yellow) femoral cutaneous nerves.

of the nerve with adjacent vessels, color Doppler was used in all patients.

Ultrasound in anatomical specimens

In 16 randomly selected fresh anatomical limbs in the legal custody of the Division of Anatomy, Medical University of Vienna, HRUS was prospectively performed as described.

None of the thighs showed macroscopic signs of disease or scarring. After identification of the nerves, visibility was rated using a five-point scale as: excellent – sharply defined border and visible internal nerve structure with excellent diagnostic quality [5]; good – good diagnostic quality, clearly distinguishable from surrounding tissue, internal nerve structure visible; [4], moderate – identifiable, but no sharp border from surrounding tissue, no internal nerve structure visible; [3], poor – identified with difficulty and only possible if adjacent nerve sections were followed; [2] or not visible [1]. The visibility of the nerves was rated at the three different locations: at its origin from the femoral nerve (R1); the mid portion of the thigh (R2); and just above the most distally visible point (R3).

Then, a small amount of purple (for the IFCN) and black (for the MFCN) dye mixed with glue (0.1 ml) was injected into the nerve/adjacent to the nerve under HRUS guidance (22-gauge needle, in-plane technique) at three different locations, as described above. Subsequent anatomical dissection was performed to confirm the exact location of the dye injection. The plastic surgeon (J.M.) and anatomist (P.C.B.) who performed the dissections determined the exact location of the ink application. Correct dye injection was noted if a small amount of dye was injected into the nerve sheath at all three distinct locations. In all specimens, distribution of the injected ink was documented by photography.

Ultrasound in patients

We retrospectively included patients who, after extensive neurological anamnesis and testing, were referred for HRUS to the Department of Biomedical Imaging and Image-guided Therapy, because of pain and/or paresthesia (for at least three months) within the MFCN/IFCN territory, especially after having undergone surgery in the MFCN/IFCN region, and, therefore, being possibly subjected to injury to the MFCN/IFCN, between January 2015 and January 2017. As electrophysiological testing of these small nerves is not done on a regular basis in our clinic, we could not use this as an inclusion criterion. Patients with a clear history of nerve root compression were excluded. HRUS was performed according to the method described above. After the MFCN and IFCN were identified, they were followed proximally and distally as far as possible and screened for signs of alterations, such as sectional swelling or neuromas likely in combination with any structures presumed to irritate them. Consecutively, selective HRUS-guided diagnostic blockade of the nerves using 0.5 ml to 1 ml lidocaine 2 %, a 22- gauge needle, an in-plane technique was performed in most patients to ensure that any peripheral origin of pain was within the MFCN/IFCN territory. The success of the blockade was tested through sensitivity to light touch and visual analogue scores (VAS). Any further reported surgical treatment, such as neurectomy and follow-up of the patients, was noted.

Statistical analysis

Descriptive statistics were performed using IBM SPSS Statistics for Windows Version 22.0.0.2 (IBM, Armonk, New York). For the nerve visibility score, the median, minimum, and maximum were used.

Downloaded by: Universitaetsbibliothek - Med. Universitaet Wien. Copyrighted material.

Results

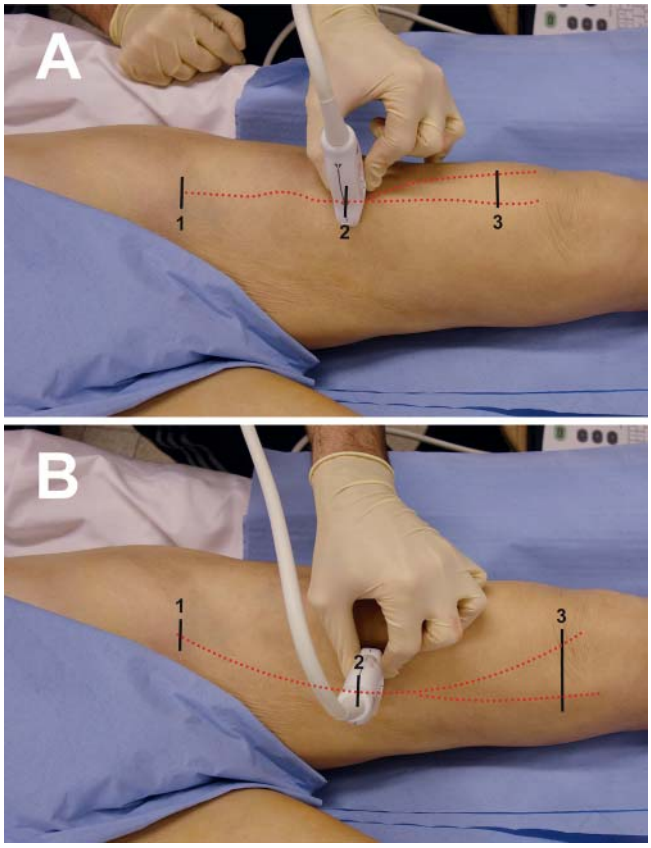
Ultrasound accurately pinpoints the anterior and medial femoral cutaneous nerves in anatomical specimens.

To determine whether the application of ultrasound to the anteromedial thigh would assist in predicting the exact location of the anterior femoral cutaneous nerves, anatomical specimens were used. During ultrasound, small amounts of dye were injected at sites that correlated to nerve positions R1 – 3, namely, the origin, the mid portion, and the distal portion, respectively. ▶ **Fig. 2** shows an illustration of the different anatomical locations. Dissection confirmed the correct identification of the intermediate femoral cutaneous nerve (IFCN) in 16/16 branches at all of the different locations (100 %). The medial femoral cutaneous nerve (MFCN) was correctly identified at its origin from the femoral nerve (R1), and at the most distally visible point (R3) in all cases (16/16; 100 %), and in 14/16 cases (88 %), in the mid portion of the thigh (R2). In two of the infiltrated and dissected cases, we confounded MFCN with the infrapatellar branch of the saphenous nerve (IPBSN), which was almost always paired in this region, with the MFCN ending at the medial edge of the patella and the IPBSN always coursing further distally to reach the infrapatellar region. An example of a dissection finding is shown in ▶ **Fig. 3**.

In IFCN, the most frequently recorded pattern of the branches was one main trunk that permanently extended small cutaneous branches, often dividing into two major branches at the mid-portion/distal third of the thigh. The (see ▶ **Fig. 4A**) of the nerve was fairly constant with the branches coursing distally in the fascia lata/sartorius fascia lateral of the femoral artery for a short distance after piercing it and reaching the subcutaneous fat (of the anterior aspect of the thigh) overlying the anterior thigh muscles.

Regarding an MFCN pattern, there appeared to be one main constant anterior branch overlaid on the subcutaneous fat superficial to the sartorius muscle, sometimes entering the fascia lata and coursing to the medial edge of the patella. A quite variable pattern was observed further medially at the medial edge of the sartorius muscle, where, sometimes, there were several branches that connected with the anterior branch, or one main trunk that coursed distally with the saphenous vein, reaching the region below the knee joint line. In three cases (19 %), we found MFCN penetrating the sartorius muscle. With regard to origin, the MFCN showed a remarkably inconsistent pattern as follows: (i) paired with IFCN in the fascia lata/sartorius fascia; (ii) crossing the femoral artery and coursing medially; (iii) coursing distally medial to the femoral artery and reaching the superficial subcutaneous fat by penetrating the sartorius muscle; or (iiii) at the posterior border of the sartorius muscle.

The median of visibility was 5 (min 4; max 5) at the mid portion of the thigh (R2) for both branches, 5 [4, 5] for the IFCN, and 4 [2, 5] for the MFCN at the most distally visible point (R3). At the origin (R1), the median of visibility was 5 [3, 5] for the IFCN and 4 [2, 5] for the MFCN. ▶ **Fig. 3** shows examples of sonographic findings.



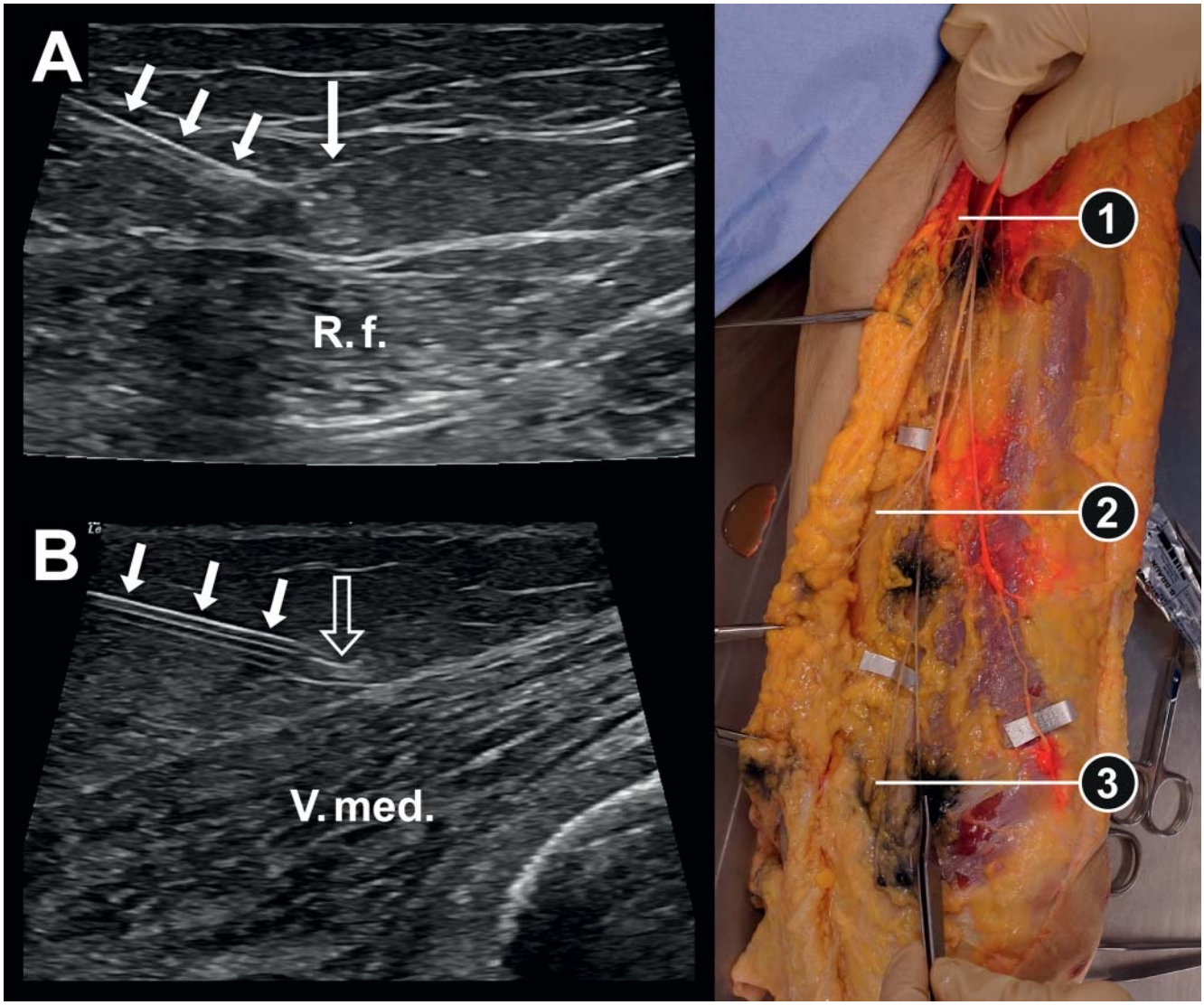
▶ **Fig. 2** Ultrasound probe positioning for intermediate femoral cutaneous nerve **A** and medial femoral cutaneous nerve **B** evaluation at three different anatomical locations: origin from the femoral nerve (R1); the mid portion of the thigh (R2); and just above the most distally visible point (R3). To obtain transverse views of the nerves, the probe orientation must be perpendicular to the red dotted lines.

Ultrasound successfully identifies anterior femoral cutaneous neuropathies

A total of twelve patients underwent HRUS of the anteromedial thigh between January, 2015 and January, 2017. Both branches were affected in seven cases: the MFCN in four cases and the IFCN in three cases. In four cases, the IPBSN was also affected. Patient histories are summarized in ▶ **Table 1**.

In eleven of twelve patients, selective MFCN/IFCN blockade was performed approximately 5 – 10 centimeters above the suspected nerve damage, which resulted in numbness of the medial or anterior part of the thigh compatible with the expected innervation territory of the MFCN/IFCN, and all patients showed a significant reduction in VAS scores. Therefore, all blocks were rated successful. The causes of the neuropathies were iatrogenic in 11 and direct trauma in one case. In six cases, neurectomies for pain relief were performed. In all six cases, the nerve was marked on the patient's skin preoperatively. Two different locations for nerve damage were observed. All cases of IFCN neuropathies were located in the proximal thigh next to the origin of the branch, whereas all MFCN cases were obtained distally next to the knee. The patients are presented in detail below. ▶ **Fig. 5, 6** provide examples

Downloaded by: Universitaetsbibliothek - Med. Universitaet Wien. Copyrighted material.



▶ **Fig. 3** Examples of ultrasound-guided ink markings of the intermediate **A** and medial femoral cutaneous nerve **B**. (Right corner) Example of a finding in a dissection after high-resolution ultrasound (HRUS)-guided intranerval ink marking of the intermediate femoral cutaneous nerve (purple) and the medial femoral cutaneous nerve (black).

of ultrasound findings, perioperative management, as well as intraoperative findings for selected patients.

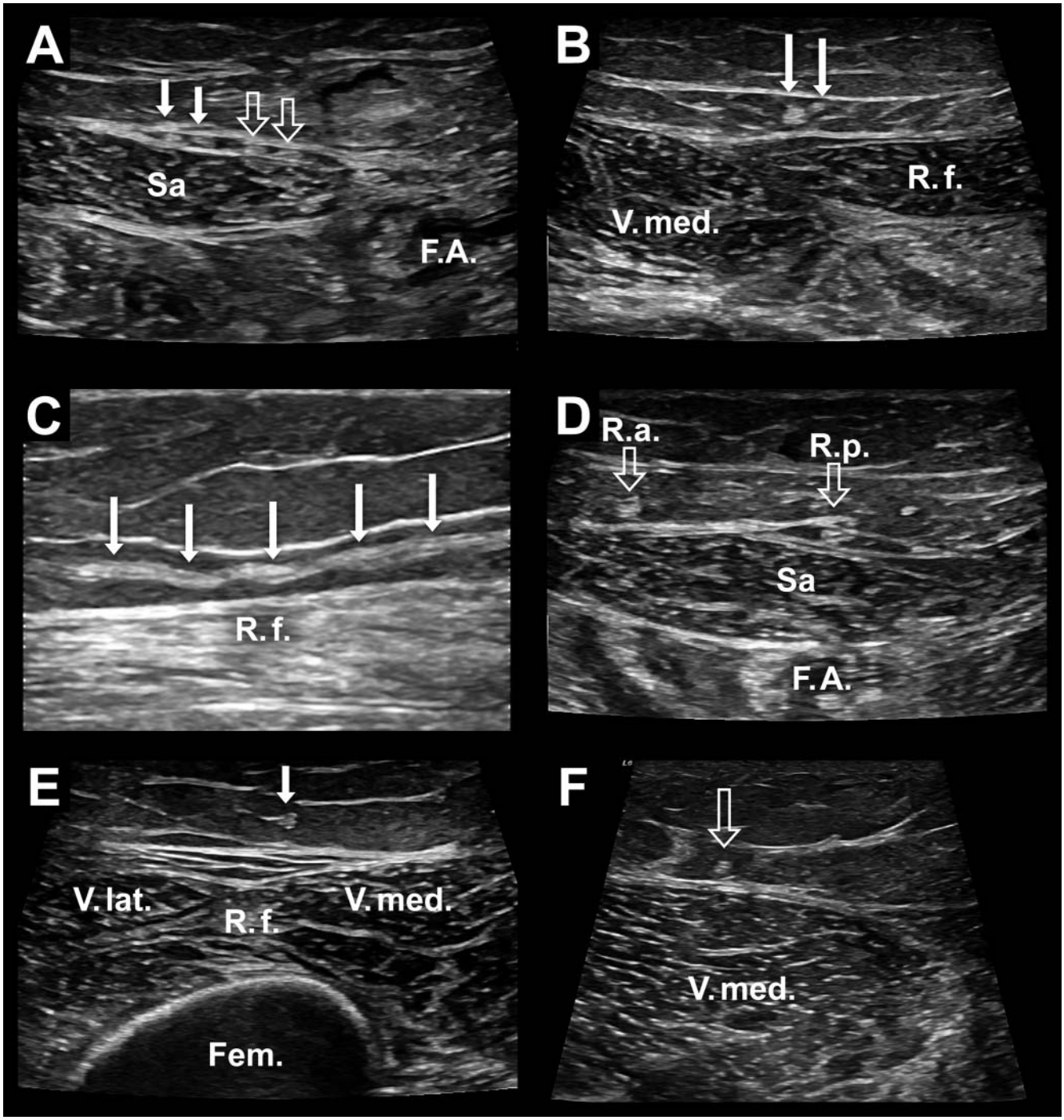
Thus, ultrasound was accurate at pinpointing the femoral cutaneous nerves in anatomical specimens and correctly diagnosed the associated neuropathies in patients, and the suitability of this technique is discussed.

Discussion

The anterior femoral cutaneous nerves may be injured during several limb surgeries, sometimes leading to postoperative neuropathic sensations and pain for patients. Furthermore, the variable course and pattern of these branches complicates efforts to locate them prior to surgery. Ultrasound was shown to be accurate at pinpointing the intermediate femoral cutaneous nerve (IFCN) and the medial femoral cutaneous nerve (MFCN) when applied to anatomical specimens. Moreover, using ultrasound, we were able to correctly diagnose patients with suspected neuropathies of the anterior femoral cutaneous nerves.

With regard to the previously reported cases in the literature [7 – 15], the incidence of neuropathic pain due to damage of the anterior femoral cutaneous nerves seems to be relatively low. This is in contradiction to the findings of our study, where we could observe 12 cases with clinical symptoms in a relatively short period of two years. Possible explanations for this discrepancy may be a lack of diagnostic capabilities to detect nerve damage, or a misinterpretation of pain in the anterior thigh (e. g., as radiculopathy of the second or third lumbar nerve root). As presented in this study, HRUS may overcome at least some of these limitations and therefore enhance patient management and confidence. Using the assessment protocol described above, the branches could be detected and followed over their entire course, although they did not show a supposedly consistent pattern that has gained support

Downloaded by: Universitaetsbibliothek - Med. Universitaet Wien. Copyrighted material.



▶ **Fig. 4** Ultrasound images of the anterior femoral cutaneous nerves just distal to their origin **A**, the mid third of the thigh **B–D,** including a longitudinal scan **C**, and the distal third of the thigh **E**, **F**. Please note that the appearance and the course of the presented nerves do not represent a consistent pattern and may be different in other anatomical specimens. (Arrows: intermediate femoral cutaneous nerve branches; Blank arrows: medial femoral cutaneous nerve branches. Sa: sartorius muscle; FA: femoral artery; V. med.; vastus medialis muscle; V. lat.; vastus lateralis muscle, R.f.; rectus femoris muscle, R.a.: ramus anterior; R.p.: ramus posterior; Fem: femur).

from the rarely available inconsistent literature about the anatomy of the branches. Some authors have proposed a constant pattern of two main branches for the IFCN and the MFCN [3], whereas others showed one main trunk with several branches extending out [5] or a network of branches with no definable main trunk [2]. Although it was not the main goal of this study, we did detect all different patterns. This variability may further support our theory of a far higher incidence of damage to these nerves due to an unpredictable course.

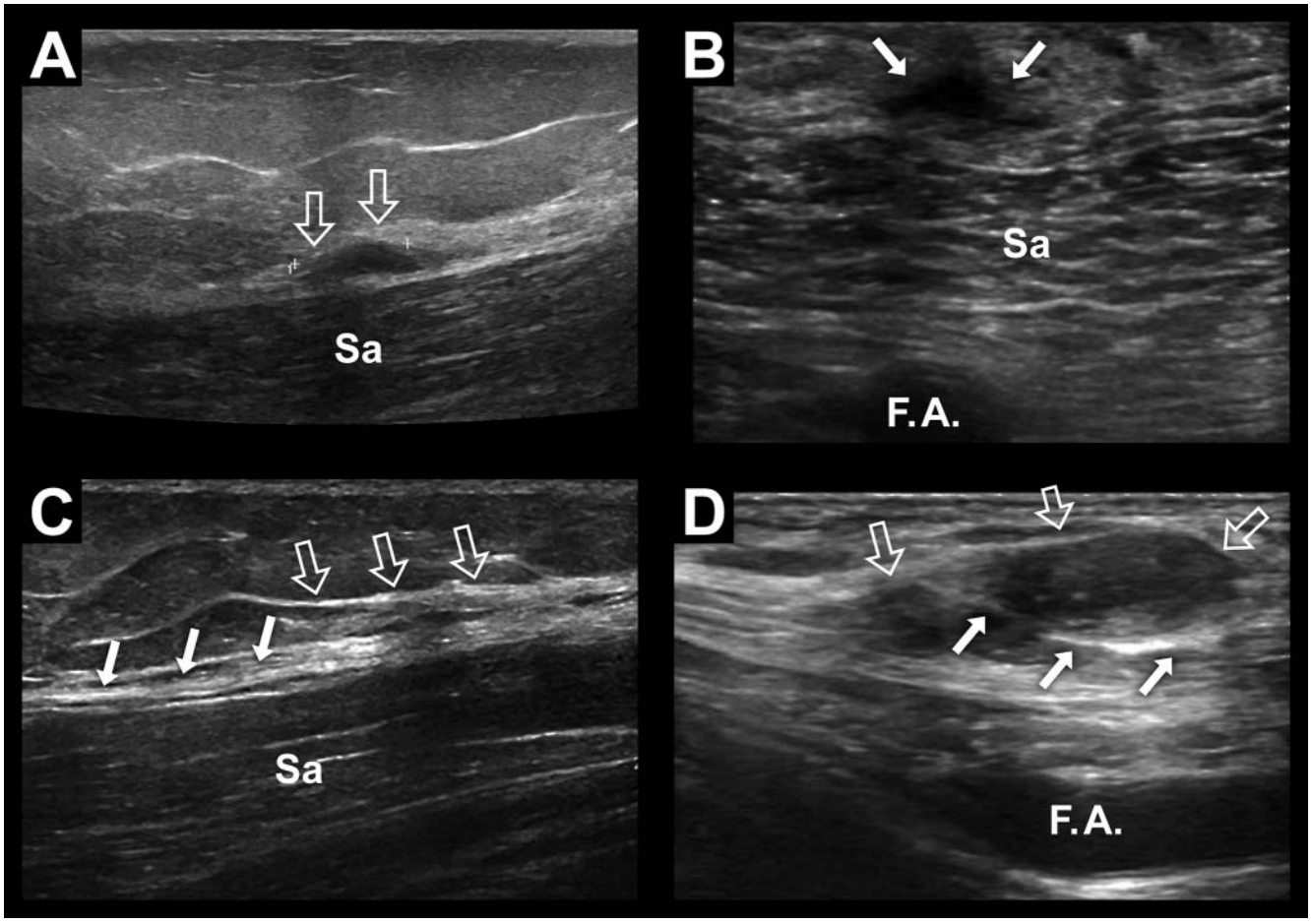
With respect to suspected anterior femoral cutaneous nerve neuropathies, high-resolution ultrasound (HRUS) may guide patient management, as presented in this study. HRUS allows for

Downloaded by: Universitaetsbibliothek - Med. Universitaet Wien. Copyrighted material.

▶ **Table 1** Summary of patient histories and HRUS findings for those cases identified at our department.

no.	gender	age	history	HRUS findings	blockade	treatment operative
1	m	51	Patient developed stabbing pain on the medial side of the right knee after TKA	Scar tissue on the medial side of the patella; MFCN embedded in scar	1 ml lidocaine MFCN VAS reduction: 8 – 2	Neurectomy planned
2	f	29	After leg twisting injury and neurectomy of the IPBSN, persistent pain on the medial knee side, next to scar tissue	Neuroma of the MFCN next to the IPBSN surgery scar	0.5 ml lidocaine MFCN VAS reduction: 9 – 0	Neurectomy of the MFCN next to its origin VAS reduction after two-month follow-up: 9 – 1
3	f	71	Patient presented with stabbing knee pain on the medial knee side after TKA six years ago	Scar tissue surrounding the IPBSN and MFCN	1 ml lidocaine IPBSN VAS reduction: 7 – 5 1 ml lidocaine MFCN) VAS reduction: 5 – 2	No follow-up
4	f	62	Patient underwent multiple surgeries after TKA due to neuropathic pain; patient suffered multiple neuromas and scars in all femoral cutaneous nerves after these operations	Multiple scars, neuromas and partial hitches of the MFCN, IFCN, LFCN	0.5 ml lidocaine IPBSN VAS reduction: 10 – 8 1 ml lidocaine MFCN VAS reduction: 8 – 4 1 ml lidocaine IFCN VAS reduction: 4 – 2	High neurectomy of the MFCN and IFCN; removal of scar tissue
5	m	36	Patient developed medial-sided stabbing knee pain after patella luxation and subsequent surgical intervention	None	1 ml lidocaine MFCN VAS reduction: 7 – 2	Neurectomy planned
6	m	49	Patient developed stabbing lateral and medial-sided knee pain after TKA	None	1 ml lidocaine FCL VAS reduction: 8 – 5 0.5 ml lidocaine MFCN VAS reduction: 5 – 1	Neurectomy of the MFCN and FCL VAS reduction: 8 – 2 Burning pain returned two months later (VAS 5)
7	f	73	After TKA and previous neurectomy of the saphenous nerve, the patient still suffered medial-sided stabbing knee pain	None	1 ml lidocaine MFCN VAS reduction: 6 – 1	Neurectomy of the MFCN and medial retinacular nerve Significant pain relief after six-month follow-up (VAS 2)
8	f	66	Patient developed stabbing pain at the anterior thigh after surgical removal of a large abscess formation in the anterior subcutaneous tissue	Scar tissue surrounding and entrapping the IFCN	0.5 ml lidocaine IFCN Immediate pain relief after both procedures No VAS score obtained	Neurectomy planned No reported follow-up
9	f	47	Patient developed stabbing pain in the anterior thigh approximately 10 cm above the knee after lipoma resection	Scar embedded IFCN into the side of the previous lipoma resection	0.5 ml lidocaine IFCN VAS reduction: 6 – 1	Neurectomy planned No reported follow-up
10	f	61	Patient developed stabbing pain after vein stripping at the upper anterior thigh	11x4 mm neuroma of the IFCN, with intraneural sutures just below the inguinal ligament	No block performed	Neurectomy performed VAS reduction: 9 – 3
11	m	88	Patient developed stabbing pain at the anterior upper thigh after a patch plastic of the femoral artery	Neuroma and scar tissue surrounding the IFCN	1 ml lidocaine IFCN VAS reduction: 7 – 3	Neurectomy planned No reported follow-up
12	m	54	Patient developed stabbing pain at the anteromedial thigh after bypass surgery	Small neuroma of the MFCN	0.5 ml lidocaine MFCN VAS reduction: 8 – 3 1 ml lidocaine IPBSN VAS reduction: 3 – 0	Neurectomy of the IPBSN and MFCN Significant pain relief after six-month follow-up (VAS 2)

Downloaded by: Universitaetsbibliothek - Med. Universitaet Wien. Copyrighted material.



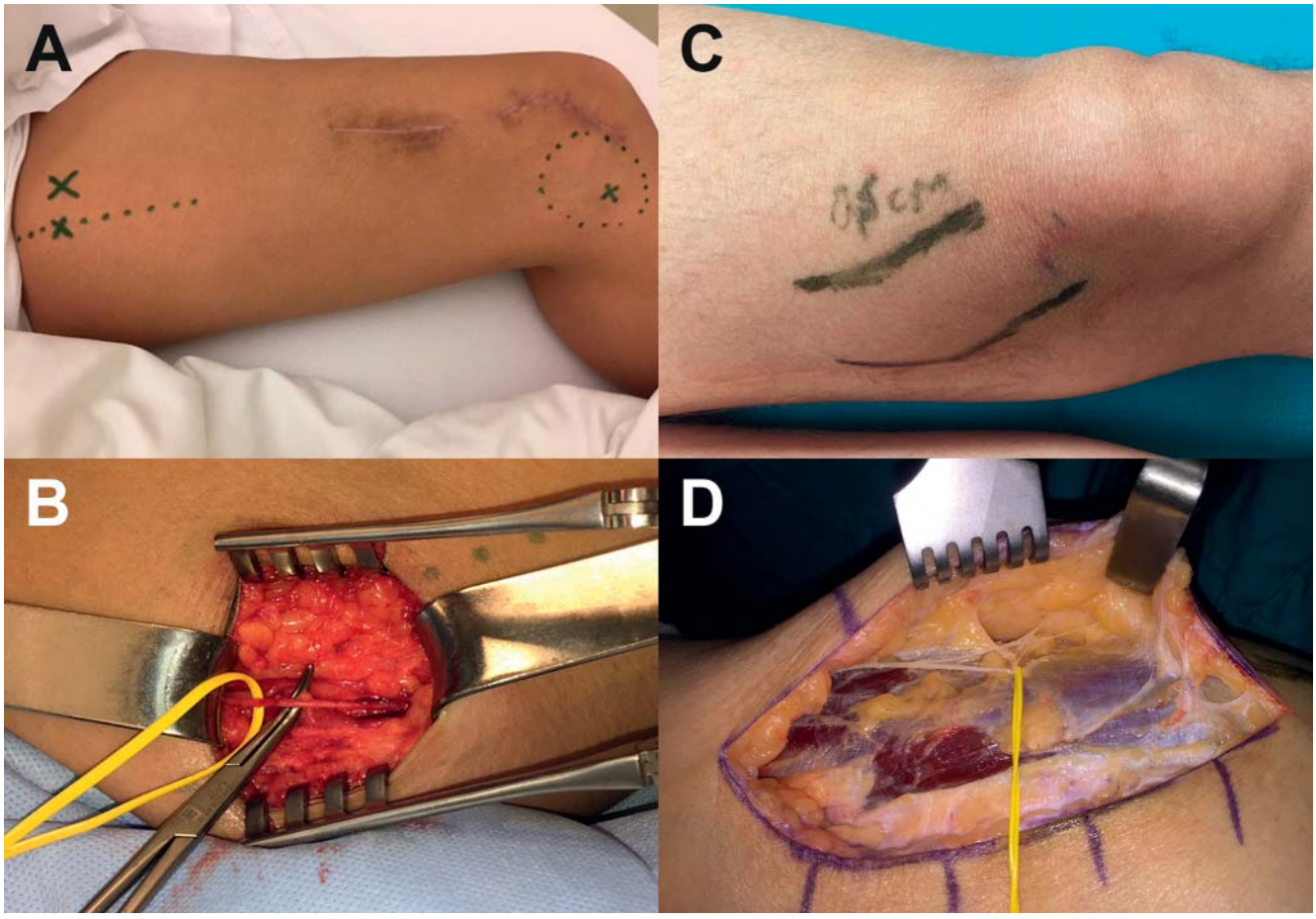
▶ **Fig. 5** Examples of ultrasound findings in patients. **A** MFCN neuroma (blank arrows) just superficial to the sartorius muscle (Sa) in the distal portion of the thigh. **B** IFCN neuroma superficial to the sartorius muscle (Sa) in the proximal portion of the thigh. **C** Scar tissue (void arrow) surrounding the IFCN (arrow). **D** Huge IFCN neuroma (blank arrows) superficial to the femoral artery (F.A.). Note surgical sutures (arrows) within the neuroma (MFCN: medial femoral cutaneous nerve, IFCN: intermediate femoral cutaneous nerve).

direct visualization of nerve damage (e. g., neuroma formation) or structures (e. g., scars) that can irritate the nerve. In case of no (in)direct signs of nerve pathologies (e. g., cases 5, 6, and 7 in this study), ultrasound-guided nerve blocks are another potential diagnostic tool to rule out anterior femoral cutaneous nerve neuropathies. HRUS allows for excellent visualization and precise guidance of the needle to the target. This enables selective blockade of these very small nerves with a low amount of local anesthetic (0.5 – 1 ml in this study), thus avoiding concomitant blockade of surrounding nerves. In our study, all affected nerves of our patients were successfully blocked only in the suspected cutaneous territories of the nerves. In our opinion, unguided blocks to rule out possible anterior femoral nerve neuropathies are not feasible due to the variable course and proximity to other nerves. For example, the MFCN is anatomically paired with the infrapatellar branch of the saphenous nerve at the anteromedial side of the knee [23] or the IFCN is next to the MFCN, saphenous nerve and muscular branches in the femoral triangle [2] which makes them prone to concomitant blockade.

When the clinical cases of our study were analyzed, two different anatomical locations seemed to be risk zones for the anterior femoral cutaneous nerves. In all cases except case number 9, the IFCN was damaged in the proximal thigh just below the inguinal ligament, while MFCN neuropathy occurred in the medial knee region. Except for one case (case 2), all causes for neuropathies were iatrogenic, which is supported by the existing literature [7 – 10]. This may explain the different anatomical locations of iatrogenic nerve damage due to surgical artery or vein procedures in the proximal thigh and knee procedures in the distal thigh.

This study has strengths as well as limitations. The main strength is that this study showed for the first time that HRUS could correctly identify the anterior femoral cutaneous nerves in anatomical specimens and in patients with suspected anterior femoral cutaneous nerve damage. The main limitation represents the fact that our presented cases were retrospectively evaluated and not matched with controls, and that the sample size of n = 16 in cadavers and n = 12 in patients could be higher for better statistical power. We also did not perform double reading. In this study, a single rater performed the examination and measurements, while the other rater watched the procedure. We think we obtained reliable measurement results with this approach.

Downloaded by: Universitaetsbibliothek - Med. Universitaet Wien. Copyrighted material.



▶ **Fig. 6** Preoperative skin marking of the medial femoral cutaneous nerve **A** for proximal denervation procedure with intraoperative findings **B**. Preoperative skin marking of the medial femoral cutaneous nerve (upper branch) and infrapatellar branch of the saphenous nerve (lower branch) for distal denervation procedure **C** with intraoperative findings **D**. The infrapatellar branch of the saphenous nerve has already been removed. The medial femoral cutaneous nerve is shown.

In conclusion, this study confirms the ability to reliably visualize the anterior femoral cutaneous nerves with HRUS, in anatomical specimens and in patients with suspected neuropathies to the branches. Therefore, HRUS may enhance the diagnostic and therapeutic management of patients with anterior thigh pain, and we suggest that it be used whenever there is a history of surgery followed by pain at the anteromedial thigh.

Conflict of Interest

Dr. Riegler reports grants from Medical Scientific Fund of the Mayor of the City of Vienna, during the conduct of the study.

Acknowledgments

The authors thank Mary McAllister for her comments on the manuscript and Aron Cserveny for his help with graphical illustrations. Further, we thank the plastic surgeons Prof. Oskar Aszmann, Prof. Wolfgang Happak, and Dr. Andreas Gohritz for the nice collaboration.

References

[1] Anloague PA, Huijbregts P. Anatomical variations of the lumbar plexus: a descriptive anatomy study with proposed clinical implications. The Journal of manual & manipulative therapy 2009; 17 (4): e107 – 14

[2] Thiel W. Photographic atlas of practical anatomy. Berlin New York: Springer; 1999. v. <2 > p

[3] Gray H, Clemente CD. Anatomy of the human body. 30th American ed. xvii Philadelphia: Lea & Febiger; 1985: 1676

[4] Mochizuki T, Akita K, Muneta T et al. Anatomical bases for minimizing sensory disturbance after arthroscopically-assisted anterior cruciate ligament reconstruction using medial hamstring tendons. Surgical and radiologic anatomy: SRA 2003; 25 (3): 192 – 199

[5] Zhang Q, Qiao Q, Gould LJ et al. Study of the neural and vascular anatomy of the anterolateral thigh flap. Journal of plastic, reconstructive & aesthetic surgery 2010; 63 (2): 365 – 371

[6] Dellon AL. Partial joint denervation II: knee and ankle. Plastic and reconstructive surgery 2009; 123 (1): 208 – 217

[7] Dellon AL, Mont MA, Mullick T et al. Partial denervation for persistent neuroma pain around the knee. Clinical orthopaedics and related research; 1996; (329): 216 – 222

Downloaded by: Universitaetsbibliothek - Med. Universitaet Wien. Copyrighted material.

[8] Ginanneschi F, Filippou G, Frediani B et al. Injury of cutaneous branches of the femoral nerve following varicose vein surgery. Acta Neurol Belg 2013; 113 (3): 355 – 356

[9] Milone M, Di Minno MN, Maietta P et al. Great saphenous vein stripping and nerve injury: the role of stripping direction. Int Angiol 2015; 34 (3): 238 – 242

[10] Subramonia S, Lees T. Sensory abnormalities and bruising after long saphenous vein stripping: impact on short-term quality of life. Journal of vascular surgery 2005; 42 (3): 510 – 514

[11] Wood JJ, Chant H, Laugharne M et al. A prospective study of cutaneous nerve injury following long saphenous vein surgery. European journal of vascular and endovascular surgery: the official journal of the European Society for Vascular Surgery 2005; 30 (6): 654 – 658

[12] Belsh JM. Anterior femoral cutaneous nerve injury following femoral artery reconstructive surgery. Archives of neurology 1991; 48 (2): 230 – 232

[13] Shetty GM, Murari AS, Song HR et al. Neurofibromatous sensory neuropathy of the thigh in a 7-year-old boy. Archives of orthopaedic and trauma surgery 2008; 128 (10): 1093 – 1097

[14] Lo YL, Lee KT, Rikhraj IS. Isolated medial femoral cutaneous neuropathy. Muscle & nerve 2004; 30 (6): 812 – 813

[15] Said G, Goulon-Goeau C, Lacroix C et al. Nerve biopsy findings in different patterns of proximal diabetic neuropathy. Annals of neurology 1994; 35 (5): 559 – 569

[16] Lee HJ, Bach JR, DeLisa JA. Medial femoral cutaneous nerve conduction. American journal of physical medicine & rehabilitation / Association of Academic Physiatrists 1995; 74 (4): 305 – 307

[17] Oh SJ, Hatanaka Y, Ohira M et al. Clinical utility of sensory nerve conduction of medial femoral cutaneous nerve. Muscle & nerve 2012; 45 (2): 195 – 199

[18] Dasa V, Lensing G, Parsons M et al. Percutaneous freezing of sensory nerves prior to total knee arthroplasty. Knee 2016; 23 (3): 523 – 528

[19] Bodner G, Bernathova M, Galiano K et al. Ultrasound of the lateral femoral cutaneous nerve: normal findings in a cadaver and in volunteers. Regional anesthesia and pain medicine 2009; 34 (3): 265 – 268

[20] Coraci D, Santilli V, Padua L et al. Ultrasound in Anatomical Variation of Lateral Femoral Cutaneous Nerve. Pain physician 2016; 19 (7): E1097 – E1098

[21] Moritz T, Prosch H, Berzaczy D et al. Common anatomical variation in patients with idiopathic meralgia paresthetica: a high resolution ultrasound case-control study. Pain physician 2013; 16 (3): E287 – E293

[22] Onat SS, Ata AM, Ozcakar L. Ultrasound-Guided Diagnosis and Treatment of Meralgia Paresthetica. Pain physician 2016; 19 (4): E667 – E669

[23] Horner G, Dellon AL. Innervation of the human knee joint and implications for surgery. Clinical orthopaedics and related research; 1994; (301): 221 – 226

Downloaded by: Universitaetsbibliothek - Med. Universitaet Wien. Copyrighted material.