HIGH-RESOLUTION ULTRASOUND VISUALIZATION OF THE SUBCUTANEOUS NERVES OF THE FOREARM: A FEASIBILITY STUDY IN ANATOMIC SPECIMENS

THOMAS MORITZ, MD,[1] HELMUT PROSCH, MD,[1] CHRISTOPHER H. PIVEC, MD,[1] ALEXANDER SACHS, MD,[1] MICHAEL L. PRETTERKLIEBER, MD,[2] LUKAS KRIECHBAUMER, MD,[3] WOLFGANG HAPPAK, MD,[4] and GERD BODNER, MD[1]

[1] Department of Biomedical Imaging and Image-guided Therapy, Medical University of Vienna, Waehringer Guertel 18–20, Vienna 1090, Austria
[2] Center for Anatomy and Cell Biology, Department of Applied Anatomy, Medical University of Vienna, Vienna
[3] Department Trauma Surgery, Medical University of Vienna, Vienna
[4] Division of Plastic and Reconstructive Surgery, Medical University of Vienna, Vienna

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ABSTRACT: *Introduction:* The aim of this ultrasound-anatomical study was to evaluate the ability of high-resolution ultrasound (HRUS) to visualize and infiltrate small subcutaneous nerves of the forearm in anatomic specimens. *Methods:* Seven nonembalmed human bodies (4 men, 3 women; mean age at death, 60 years) were included in the study. Two investigators scanned the anatomic specimens using 15-MHz and 18-MHz HRUS transducers. The lateral, medial, and posterior antebrachial cutaneous nerves were scanned and interventionally marked with ink using HRUS-guidance. Subsequently, dissections were performed to assess the anatomical correlation of HRUS findings. *Results:* All 3 nerves were identified consistently using HRUS. The precision of the ink-markings was excellent, with good correlation with the small peripheral branches of all 3 nerves. *Conclusions:* HRUS can identify precisely the small subcutaneous nerves of the forearm and may aid in both diagnosis and therapy in cases of neuropathy.

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High-resolution ultrasound (HRUS) has revolutionized the diagnosis of disorders of the peripheral nervous system. In particular, recent technical progress in HRUS has led to entirely new possibilities for small nerve imaging in the periphery.[1,2] HRUS enables both precise visualization of the nerve course and morphological changes to aid diagnosis and accurate HRUS-guided diagnostic and therapeutic interventions.

Previous research has underlined the feasibility of HRUS to detect and evaluate the major nerves and branches of the upper and lower limbs, as well as the diagnostic and therapeutic implications of such evaluation.[1–5]

In recent years, facilitated by strong technical progress, there has been increasing interest in visualization of small peripheral nerves.[6–11] Neuropathies of these nerves affect a relevant portion of patients, for example in pudendal neuralgia or lesions of the spinal accessory nerve, as well as the small nerves of the arm and leg.[3,5,7–13] However, electrodiagnostic and clinical work-up is typically difficult in these patients, and the diagnosis can be delayed significantly.[14,15] Therefore, new techniques that offer confident visualization of small peripheral nerves could become essential diagnostic and therapeutic tools in peripheral nerve pathologies.

The aim of this ultrasound-anatomical study was to evaluate the ability of HRUS to visualize precisely and infiltrate small subcutaneous nerves in human anatomic specimens.

MATERIALS AND METHODS

The study was conducted in accordance with the Helsinki Declaration and was approved by the Ethics Review Board of the Medical University of Vienna.

Anatomical Specimens. Both forearms of 7 nonembalmed human bodies (4 men, 3 women; mean age at death, 60 years, n = 14 forearms) were included in the study, which was performed between July 2012 and June 2013. All participants had voluntarily donated their bodies to the Center for Anatomy and Cell Biology of the Medical University of Vienna for teaching and research. This study was conducted in accordance with the "Guidelines for Good Scientific Practice of the Medical University of Vienna" and was approved by the Ethics Review Board of the Medical University of Vienna.

Research Design. ***High-Resolution Ultrasound Procedure.*** Two investigators, with 30 (G.B.) and 2 years (A.S.) experience in sonography jointly scanned the arms of the human anatomic specimens using GE Logiq e9 US-Equipment (General Electric, Fairfield, USA), with 2 high-frequency linear ultrasound transducers (GE ML6–15-D and GE L8–18i). Both investigators scanned all forearms and decided upon the nerve course and injection sites in consensus.

For this study, all 3 sensory nerves of the forearm were investigated: the lateral, medial, and

Abbreviations: HRUS, high-resolution ultrasound; LABC, lateral antebrachial cutaneous nerve; MABC, medial antebrachial cutaneous nerve; PABC, posterior antebrachial cutaneous nerve
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Correspondence to: T. Moritz; e-mail: thomas.moritz@meduniwien.ac.at

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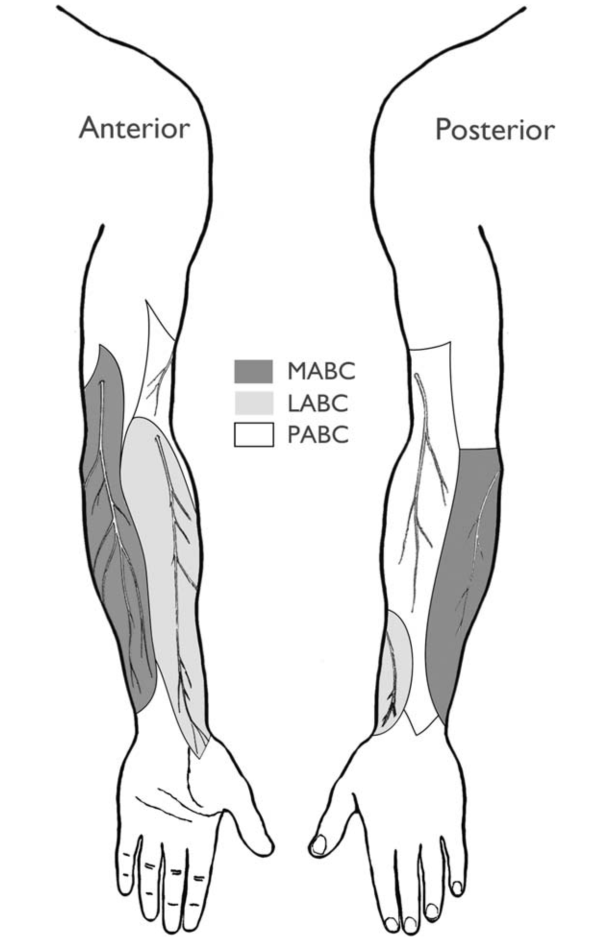

FIGURE 1. Typical sensory distribution of the Medial, Lateral and Posterior Antebrachial Cutaneous nerves of the forearm (MABC, LABC, PABC, respectively).

posterior antebrachial cutaneous nerves (LABC, MABC, PABC, respectively). The LABC is the final branch arising from the musculocutaneous nerve that innervates the radial portion of the forearm. The MABC is a branch from the medial cord of

FIGURE 2. US-guided injection technique using a high-frequency linear US-transducer (GE L8–18i), a 25G injection needle, and a 1-ml syringe in an in-plane technique.

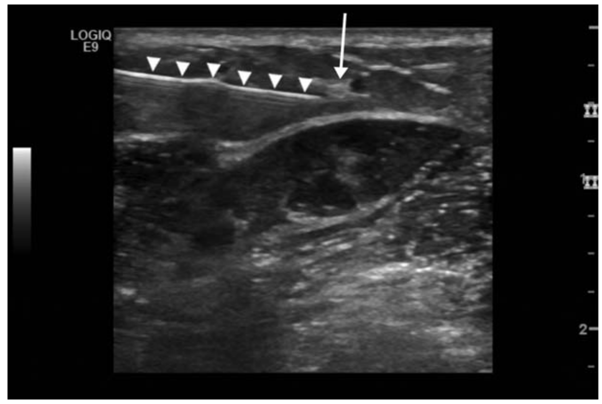

FIGURE 3. HRUS image showing needle placement (arrowheads) adjacent to a branch of the LABC (arrow).

the brachial plexus. Its anterior and posterior branches innervate the medial portion of the forearm. The PABC is a branch that typically innervates the dorsal aspect of the forearm and arises from the radial nerve (Fig. 1).

After identification of the nerves, documentation was performed using video sequences and still images that were archived for subsequent evaluation. To prove the accuracy of HRUS imaging and to correlate with the findings in the anatomical dissections, a series of HRUS-guided infiltrations were performed. The infiltrations were performed using a 1-ml syringe and a 25-G needle to inject 0.01 to 0.05 ml of blue ink adjacent to the nerves (see Figs. 2–4). Injections were performed by both investigators in active collaboration in 2- to 3-cm steps from the cubital fossa to the most distal point of the nerve as identified by HRUS.

Anatomical Correlation. The anatomy of the LABC, MABC, and PABC was correlated in both forearms of the human anatomic specimens by stratigraphic dissection. Using an Adson tissue forceps and a

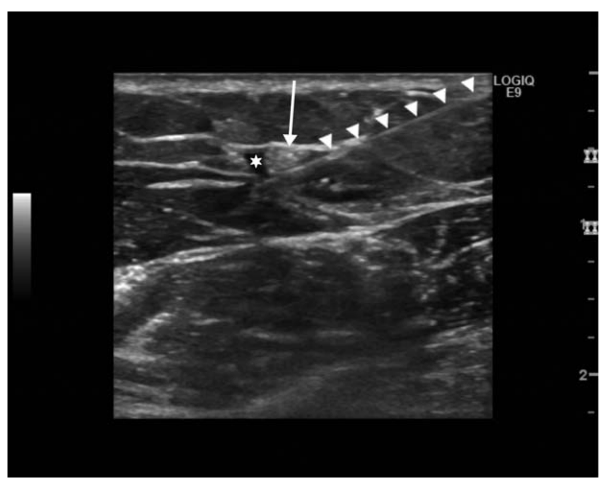

FIGURE 4. HRUS image showing injected fluid (asterisk) around the MABC (arrow). The injection needle (arrowheads) is still adjacent to the nerve.

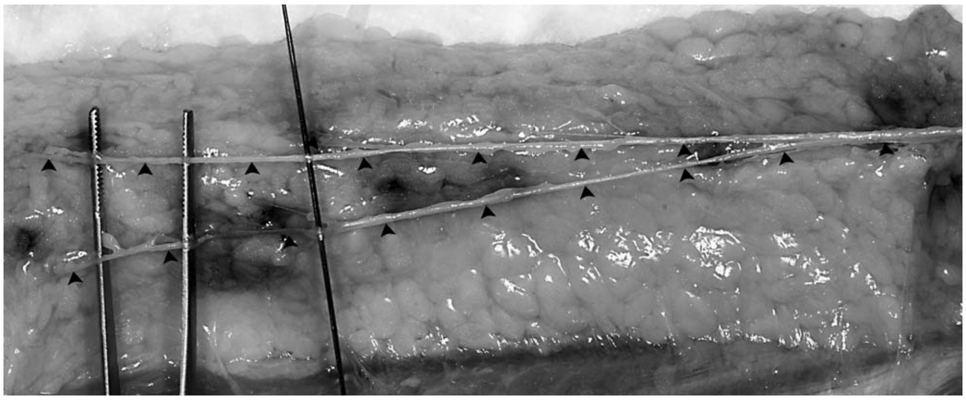

FIGURE 5. Anatomical preparation of the anterior ramus of the MABC showing the ink markings both at the ramus and the final branches.

sharp scalpel, the skin and subcutaneous fat tissue were separated carefully from the antebrachial fascia to create a flap of skin and subcutaneous tissue. All 3 nerves were then identified along their typical path and carefully exposed under the supervision of an experienced anatomist (M.P.). A reference scale was used to document the precision of the US-guided ink markings during photo documentation.

RESULTS

The diameters of the LABC, MABC, and PABC, both anatomically and on HRUS, were approximately 1–2 mm at dissection, decreasing from proximal to distal. The LABC was identified by locating the musculocutaneous nerve piercing the coracobrachialis muscle and following it distally where it runs lateral to the biceps brachii tendon and subsequently pierces the superficial antebrachial fascia. The course of the nerve was confirmed by anatomical dissection in all cases. Overall, Investigator 1 (G.B.) performed 26 ink markings in 3 anatomic specimens, and Investigator 2 (A.S.) performed 78 ink markings in 8 forearms. All the ink markings of both investigators in all specimens were in contact with the nerve sheath or within 1 mm of the nerve.

The MABC was identified running parallel to the brachial and basilic vein until it pierced the superficial antebrachial fascia, where it was then followed distally in the subcutaneous tissue. The division into the anterior and posterior rami was identified readily using HRUS. This result was verified further by anatomical dissection. Again, the ink markings of the MABC and of the anterior and posterior rami were found within 1 mm of the nerve (see Fig. 5).

The PABC was identified with HRUS; it accompanied the radial nerve at the radial canal and subsequently pierced the lateral intermuscular septum of the arm to run in the subcutaneous tissue close to the cephalic vein. The HRUS-guided ink markings matched the nerve course in all specimens (see Figs. 6 and 7).

The HRUS visibility of all 3 nerves was rated independently as excellent by both investigators.

DISCUSSION

This study demonstrates the ability of HRUS to identify the small subcutaneous nerves of the forearm with high confidence. To identify and perform

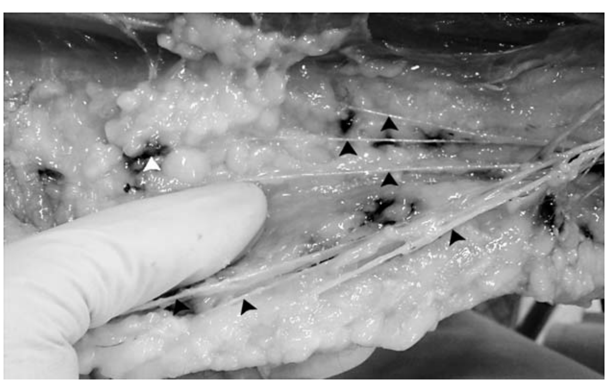

FIGURE 6. Anatomical preparation of the LABC demonstrating multiple branches, all showing US-guided ink-markings.

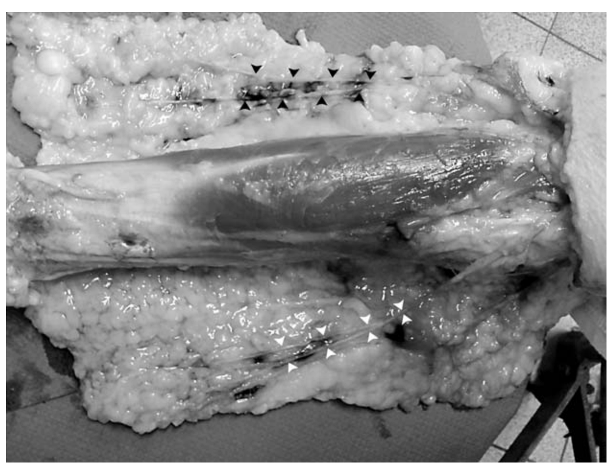

FIGURE 7. Anatomical preparation demonstrating the PABC (black arrowheads) and LABC (white arrowheads) and branches with adjacent ultrasound-guided ink-markings.

US-guided injections in these nerves, a standardized approach is advisable to identify them at certain anatomical sites in the proximal forearm.

The LABC is best identified by following the musculocutaneus nerve from within the coracobrachialis muscle distally. The MABC can be found following the brachial vein and basilic vein distally to the point where the nerve enters the subcutaneous fatty tissue by piercing the cubital fascia, while the PABC can be identified running through the lateral intermuscular septum of the arm and descending parallel to the cephalic vein.

Identification and targeted infiltration of the subcutaneous nerves of the forearm has gained increasing attention recently. Various neuropathies of the subcutaneous nerves of the forearm have been reported in the literature, ranging from traumatic or strain injuries to iatrogenic and positional injuries.[9,16–20] These nerves are considered to be sensory nerves, and their injury usually results in pain or hypesthesia. However, more recent studies have found that these nerves also carry considerable amounts of sympathetic fibers.[21] Those findings support the hypothesis that these subcutaneous nerves may play a role in the pathogenesis of complex regional pain syndrome (CRPS), and there have been reports about induction of CRPS after injury to these nerves.[17,22,23]

The ability to visualize the small subcutaneous nerves of the forearm *in vivo* may make these nerves accessible to diagnostic, therapeutic, and anesthetic interventional procedures. Based on the findings mentioned above, therapeutic interventions in these nerves may be of value not only in sensory disorders and anesthesiology, as demonstrated previously in the MABC,[6] but also may provide an entirely new and targeted access to the sympathetic nervous system. Of interest, a similar approach, supported by the theory of sympathetically maintained pain,[24] has been used in surgical therapy of chronic CRPS by successful *en bloc* resection of these subcutaneous nerves, thereby not only reducing the pain but also the signs of neurogenic inflammation.[25]

The results of this study also indicate that HRUS-guided access to the cutaneous nerves of the forearm can be performed with high precision, even with a limited level of experience. This was underlined by the very high success rate of the somewhat less experienced investigator in our study. This study can represent an entry point for further investigations into the pathophysiology and clinical application of diagnostic and therapeutic interventions in the cutaneous nerves of the forearm.

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