DOI: 10.1111/ijcp.13956

LETTER
NEUROLOGY

THE INTERNATIONAL JOURNAL OF CLINICAL PRACTICE WILEY

Ultrasound imaging, anatomy and histology of nerves and fasciae: They never walk alone

Dear Editor,

Ultrasound (US) imaging is an important diagnostic complement to clinical and electrophysiological assessments as regards peripheral nerve pathologies, eg compressive/traumatic injuries, polyneuropathies and tumors.[1] In this sense, it has been established as the first-choice method for imaging the peripheral nerves in the extremities.[2] Technically, depending on the topographic anatomy, either curvilinear or linear transducers are used during scanning, and eventually the cross-sectional area of the nerve and/or the loss of fascicular echotexture are the (semi)quantified parameters in many of the studies.[2] While the advantages US imaging over magnetic resonance imaging (MRI) in the assessment of peripheral nerve pathologies are its low-cost, better soft tissue resolution, ability to scan the entire nerve dynamically/comparatively, the main disadvantage is perhaps its operator dependency, requiring a long learning curve.[3]

Of note, an US examination should not be confined to only the pertinent nerve itself but should comprise evaluation of all the anatomical structures around the nerve as well. Bignotti et al[2] demonstrated that in 22.4% of the patients with peripheral nerve disorders, US evaluation has shown extraneural findings. In addition to the well-known impact of muscles and vessels in various dynamic nerve entrapment syndromes, Stecco et al[4] also highlighted the possible role of neighbouring fascial layers in the causation of the entrapments. Likewise, being aware of the fact that nerves and fasciae naturally run together, fascial planes have recently been targeted for nerve blocks in anesthesiology.[5] Furthermore, the relationship between the cutaneous nerves and the subcutaneous layers have also been reported.[6] To this end, in this study, the aim of the authors is to clarify the relationship among fasciae and nerves and the need why fasciae have to be included in the sonographic nerve imaging.

First and foremost, the nerves are coated and immersed in fascial layers, ie they use the spaces between the two adjacent fascial layers to be aligned throughout the body. This way, the fasciae protect the nerve as well as (with the loose connective tissue in between) allow its gliding during movements. Second, each nerve is enveloped by connective tissue layers that are organised as a telescopic structure.[7] Anatomically, axon groups constitute the nerve fascicles, ie the functional units of a peripheral nerve. Each individual axon is surrounded by the endoneurium, while the perineurium surrounds each group of axons forming a nerve fascicle. Nerve fascicles can be grouped together by connective and adipose tissues that contain blood vessels. Finally, the peripheral nerve is covered by a thin layer of connective tissue, the epineurium, which limits the spread of injected fluids but allows its physiological diffusion. The paraneurium (perineural sheath), which is composed of connective and adipose tissues, covers the epineurium and connects the nerve to the neighbouring structures (Figure 1)—also allowing enough gliding and preventing nerve impingement. Any modification in this

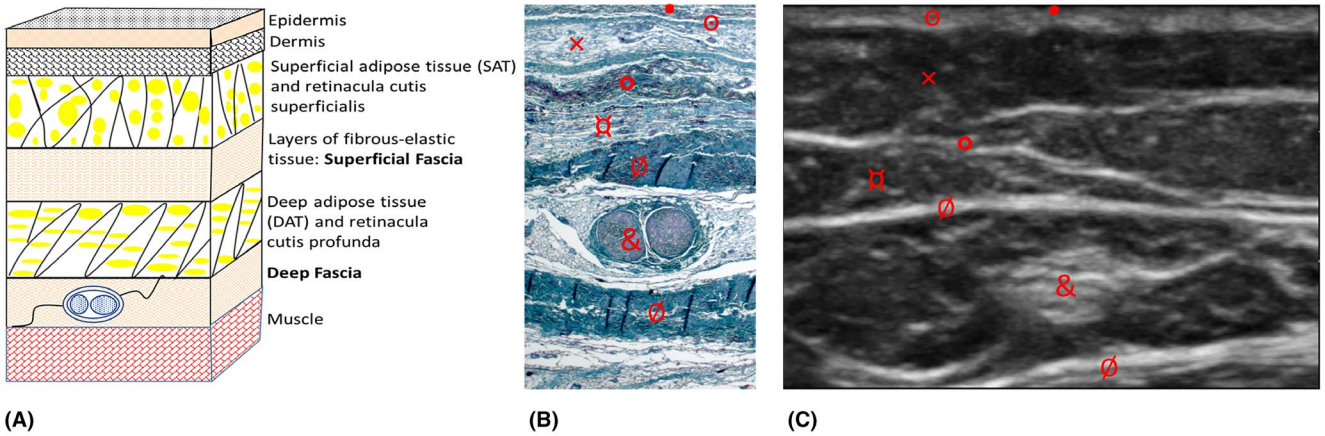

FIGURE 1 Scheme representing the anatomy and histologic characteristics of the fascial layers around the nerve as seen on US imaging (A). Histologic specimen with Azan-Mallory staining (B) and the zoomed US image (C) showing the organisation of fascial layers around the cutaneous branch of anterior femoral cutaneous nerve in the anterior compartment of the thigh. ·: epidermis; ⊙: dermis; ×: superficial adipose tissue (SAT); °: superficial fascia; ¤: deep adipose tissue (DAT); Ø: deep fascia; &: nerve

microenvironment (deep fascia, intermuscular septa, epineurium, perineurium) can be translated into change in mobility, eventually decreasing the 'independency' of the nerve leading to an entrapment and "internal stretch lesion".[4] Besides, fasciae and nerves are anatomical elements that interact in a dynamic way, whereby US imaging would be the (only) method for prompt examination of the (lack of) gliding and compression.

Herein, it is important to distinguish the two types of fascia. While the superficial fascia is connected to the skin, the deep fascia is more related to the muscles. It is noteworthy that these two fasciae are totally different both for their histological features and for their relationships with the nerves. The former is connected to the skin and to the deep fascia by fibrous septa (retinaculum cutis superficialis and profundus, respectively) which impart specific mechanical properties to the subcutis.[8] Again, the two retinacula also differ considerably.[8] While the deep ones appear as rare, thin and oblique bands allowing great autonomy between the superficial and deep fasciae; the superficial ones are short, vertically oriented and dense, connecting the superficial fascia to the skin. The deep muscular fascia is a fibrous layer that envelops not only the muscles but also the tendons, joints and ligaments—connecting several elements of the musculoskeletal system and transmitting muscular forces over a distance.[8]

Concerning the relationship with peripheral nerves; the superficial fascia envelopes and protects the cutaneous nerves and the deep fascia is related with the deep nerves which usually have both sensory and motor functions. Stecco et al[8] reported that the superficial fascia has the same innervation map as the related dermatome, but that the deep fascia follows a different pattern of innervation, defined as "fasciatome".[8] According to the anatomical study, the deep fascia is stretched along the direction of movement by myofascial expansions activating the free endings embedded in the deep fascia. A movement can activate a specific pattern of free endings giving radiated pain patterns that can simulate a nerve compression, but the nerve is intact.[8]

Ultrasound (US) imaging can readily distinguish different types of fasciae[9] as well as the peripheral nerves.[1] Actually, both structures aid in the easier localisation of the other. The paraneurium and epineurium are visualised as hyperechogenic layers, and the space between them is visualised as hypoechogenic layer.[10] Taking into consideration this intimate association, it would not be unsound to say that both of these structures should be assessed carefully while imaging for a pathology of either of them.[7] Future studies are awaited for providing insight into better understanding the possible impact of this type of dual scanning on the clinical outcome and health expenses. Last but not least, similar to the already used techniques, additional interventional procedures can also be described for nerve blocks in various clinical conditions.

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