Peripheral Nerve Ultrasound

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4.1 Introduction

Peripheral nerve ultrasound (US) is a tool complementary to clinical and electromyographic examinations. Neurophysiology provides functional data about nerves, while US supplies morphological information. In the last decades, nerve US is increasingly becoming a routine technique in neurophysiology labs for the information that can add usefulness of nerve US for diagnosis and therapeutic approach [1].

In the past, US systems were used in submarines for object detection, during the World War, and they were known as SONAR [2]. After the war, the same technology was used in medical practice as treatment tool, based on heat production by ultrasound with beneficial effects upon tissues [3]. Today this application of US is still used in physical medicine and rehabilitation.

The diagnostic use of US began during the 1940s. Development of technology, in the next 20 years, provided high-resolution images useful for diagnosis, like detection of obstetric disorders and gestation management [4]. Today US is widely employed in gastroenterology, urology, surgery, cardiology, and neurology, especially carotid and transcranial Doppler imaging [5]. Application to peripheral nervous system was less common and often overlooked.

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During the last 10–15 years, peripheral nerve and muscle imaging has become a topic of high interest. High-frequency US can assess both the nerve and muscle, and its usefulness in the diagnosis of neuropathies and muscle disorders is increasingly recognized [6, 7].

US are mechanical waves and its application in medicine is based on the properties of body tissues that transmit and reflect sound waves. Differences between the water content and structural organization of the different tissues, which represent differences in acoustic impedance, allow the creation of ultrasonographic images and the possibility to distinguish the different tissues.

The ultrasonographic beam arrives to the tissues and is reflected, scattered, transmitted, or absorbed, depending on the different properties of the tissues. The beam is produced by a transducer consisting of crystals able to vibrate when an electrical signal is applied. The same crystals can transform a mechanical vibration, when the sound waves are reflected back to the transducer, into an electrical signal. This is the piezoelectric effect. This last electric signal is translated into the visual image that can be seen on the screen of US machine. For nerve US, high-frequency probes (>12 MHz) are generally used. These high frequencies allow high image resolution but low penetration in the soft tissues [8].

US present many advantages in comparison to the other imaging techniques. US systems use small devices which can be taken to the patient's bedside; furthermore, US equipments are much less expensive than other systems. Examination time is very short, and patient safety is guaranteed; in fact no adverse effects exist and no contraindications are present for subjects with metal implants or similar. Finally, each body part can be assessed in every position with the possibility to perform dynamic scanning. These features make nerve US an extension of the clinical "eye" (Fig. 4.1).

Some disadvantages are however present, especially operator dependency and limited field of view (frequency restricts the assessable depth and bone represents an almost absolute obstacle).

Fig. 4.1 Linear array transducers

4.2 Normal Peripheral Nerves

Peripheral nerves are mainly scanned in cross-sectional (axial) plane; the longitudinal (sagittal) plane can be used, but its utility is more limited (Fig. 4.2). Ultrasonographic nerve structure shows hypoechoic structures, the fascicles, embedded in a hyperechoic background, the epineurium. Nerves have low anisotropy, i.e. their appearance does not significantly modify with the change of transducer angle. This property is helpful for differentiating nerves from tendons, having the latter high variation of echogenicity (from hyper- to hypoechoic) [9] (Fig. 4.3).

Being made by soft tissues, the nerves are deformable, and the shape can change, from round to oval, depending on the anatomic sites and the relationships with the surrounding structures. Furthermore, the nerves are mobile, and they can change their position during dynamic US evaluation. Even if normal nerve echogenicity is quite uniform along the course, there are some points in which it can be different. In particular, when the nerve is inside an osteofibrous channel (e.g., carpal tunnel), the nerve may present a more homogeneous hypoechoic appearance (Fig. 4.4).

Fig. 4.2 Axial scanning of median nerve

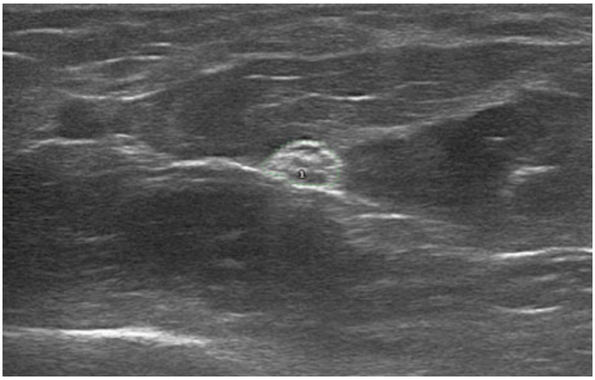

Fig. 4.3 Median nerve at forearm

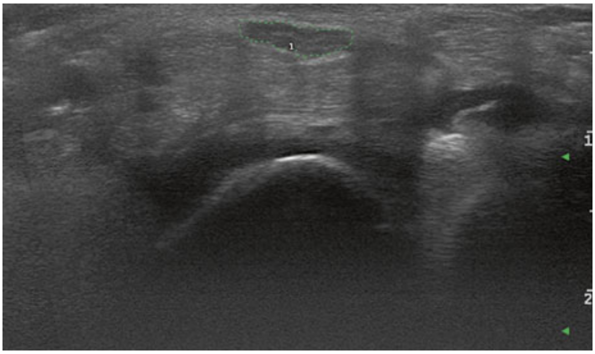

Fig. 4.4 Median nerve at wrist

The nerves of limbs can be displayed to their superficial position and absence of bone interference. The nerves in the upper limbs are more visible and assessable, because of their anatomical position. US depiction of the other nerves is not possible along the whole course. In fact, most cranial nerves and dorsal, lumbar, and sacral roots cannot be visualized, especially due to interposition of bony structures.

4.3 US in Peripheral Nerve Diseases

Nerve US has become a useful technique in different diseases of peripheral nervous system. Entrapment neuropathies, traumatic nerve lesions, nerve tumors, and immune-mediated and hereditary neuropathies are the conditions in which morphological information provided by US support the physician in diagnosis, prognosis, and treatment approach and in general patient management.

4.3.1 Entrapment Neuropathies

Nerve compressions in entrapment sites are common cases of mononeuropathies. Clinical and neurophysiological examinations are the basis for the diagnosis, but US reveals more information about the specific patient disease. US pattern of an entrapped nerve is characterized by a hypoechoic nerve presenting an increased cross-sectional area in axial plan. US is able to find the point of higher nerve suffering giving important information about the precise site of compression. This finding is crucial for the surgeon because it can avoid surgical failure and the possible relapse. Finally, US can depict the possible anatomical variants (e.g., bifid median nerve in case) [10].

4.3.2 Traumatic Nerve Lesions

The most important contribution of US in traumatic nerve lesions in this type of lesion is the possibility to distinguish axonotmesis from neurotmesis.

Neurophysiology is not able to discriminate between these two situations, but understanding the real characteristic and the degree of damage of the injured nerve allows us to recognize which kind of therapeutic approach we need. Furthermore, in cases of neurotmesis, US can measure the distance between the nerve stumps and particularly between the functional remaining parts. These data are essential for the surgical decision (suture or graft) [1].

4.3.3 Immune-Mediated Neuropathies

A focal enlargement of the nerve, often associated with a hypoechoic pattern, is usually the sign of a focal damage. In case of immune-mediated neuropathies, enlargement is the sign of inflammation and demyelination.

However, US pattern can change over the time and can indicate the phase of the disease. Recently, Padua et al. have published a study in which three main US patterns of nerve can be found in chronic inflammatory demyelinating polyradiculoneuropathy (CIDP). The first is a typical enlargement associated with hypoechoic structure, this occurs in the early stage of disease; the second pattern is characterized by enlargement and mixed hypo- and hyperechoic nerve fascicles; the last pattern is a nerve with normal dimension and hyperechoic structure. Finally, US changes can reveal the response to drug treatment: reduction in dimension and normalization of echogenicity show a good response to therapy [11].

Conclusions

Nerve US has no risks in patients of every age and situations, without, for example, the restrictions of magnetic resonance. It is able to evaluate the morphological relationships between nerve and other structures (anatomical or extrinsic) even in dynamic circumstances. The evaluation of morphological features of a nerve gives more essential information than the simple clinical and neurophysiological assessment.

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