Chapter 16

The Role of Ultrasound for Botulinum Neurotoxin Injection in childhood Spasticity

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Introduction

Botulinum neurotoxin type A (BoNT-A) injections are established as a standard procedure for the treatment of functional shortening of different muscles in spastic or dystonic children. Preconditions for beneficial effects are:

* a functional problem resulting from dynamic hyperactive muscle shortening without major structural changes
* a focal problem caused by hyperactivity of a few muscles
* application of the BoNT in the target muscle close to the neuromuscular junctions
* a sufficient dose
* no antibodies to BoNT-A.

Muscles that are superficial and palpable are easy to inject. In contrast, exact placement of the needle is more difficult and less controllable in muscles that are not palpable and deeply situated (e.g., iliopsoas) or are small and difficult to selectively identify (such as forearm muscles). Exact needle placement is, however, essential for optimal functional result, avoidance of side effects and evaluation of therapeutic failures.

To localize the target muscle and to control the placement of the injection needle several techniques are available:

* orientation at anatomical landmarks and palpation supported by moving the distal joint to observe the motion of the needle placed in the target muscle (Buchthal technique)
* electromyography
* electrical stimulation
* real-time ultrasound
* computed tomography (CT).

Clinical application of BoNT has been shown to be inaccurate except for the gastrocsoleus complex (Chin *et al.*, 2005). Electromyography is good, but many muscles may be simultaneously active. Control by electrical stimulation is quite uncomfortable and painful and often requires anesthesia. Guidance under CT is not appropriate for routine use because of the exposure to radiation and high costs. By comparison, the advantages of the ultrasound-guided technique are obvious:

* real-time observation of the injection
* readily available
* easily applicable after a manageable learning period
* cost effective
* no serious side effects.

Technical Prerequisites

For muscle sonography, a linear-array transducer is used. This provides a considerable contact area and, therefore, good coupling, as well as a geometrically exact image. Depending on the depth of the target muscle, different ultrasound frequencies are indicated: superficial muscles are best assessed by probes working at high frequencies (frequency band 7.5–12 MHz), and deep muscles best at lower frequencies (5–7.5 MHz). The penetration depth of a 12 MHz transducer is about 4 cm and of a 7.5 MHz transducer about 8 cm. Ideally, a multifrequency transducer is used.

Ultrasound Morphology of Muscles

The anatomy of a skeletal muscle is shown in Fig. 16.1. The echotexture of normal skeletal muscles has a hypoechoic background, which corresponds to the muscle fascicles, and multiple hyperechoic structures consistent with fibroadipose septa (perimysium).

Within the muscle, there might be a hyperechoic band where the fascicles converge, which is the aponeurosis. The muscle itself

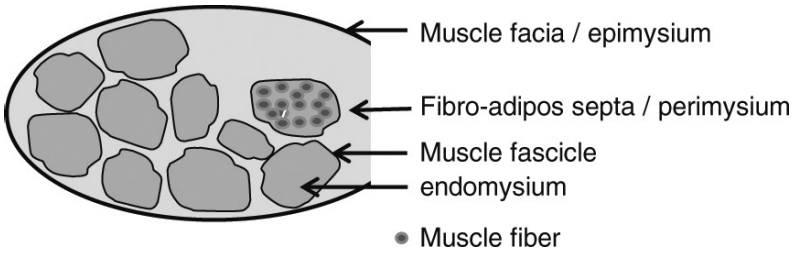

Fig. 16.1 Cross-section of muscle.

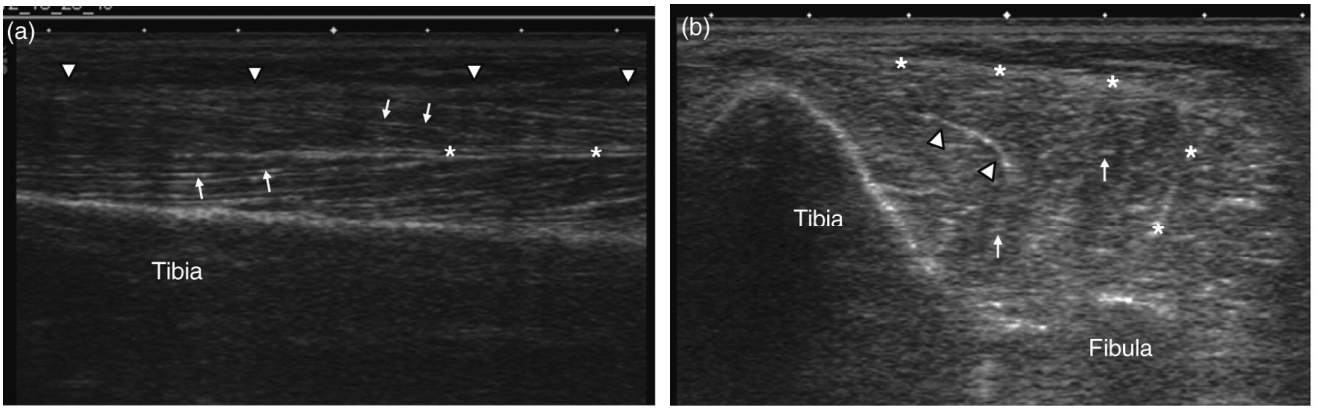

Fig. 16.2 Ultrasound of skeletal muscle. Longitudinal (a) and transverse (b) scans.

is surrounded by a hyperechoic fascia (epimysium). The ratio between the hypoechoic and the hyperechoic components gives information about the proportion of connective tissue and muscle fascicles, which is variable and differs among muscles. On longitudinal scans, the fibroadipose septa appear as straight, almost parallel, hyperechoic lines (Fig. 16.2a). On transverse scans, the fibroadipose septa appear as small dot-like reflectors (Fig. 16.2b) (Zamorani and Valle, 2007).

Patient Preparation

The patient should be placed as comfortable as possible and in a way that the target muscle can be reached without major difficulties. Standard disinfectant fluid can be used as contact medium. Alternatively, before performing the ultrasound, standard skin desinfection can be performed and the injection carried out through the standard bacteriostatic gel (Berweck and Heinen, 2005).

Ultrasound-Guided Injection Technique

The target muscle is identified and scanned by ultrasound in the longitudinal and transverse planes. The optimal injection area is located where most of the motor endplates are assumed to be (Campenhout and Molenaers, 2011). The EUROMUSCULUS/USPRM approach techniques respect these innervations zones and describe them in detail (Kara *et al.*, 2018; Kaymak *et al.*, 2018).

There are two ways to place the needle with ultrasound guidance:

Indirect technique. The puncture site is marked by ultrasound and the depth of the target region is measured. The needle is then placed blindly perpendicular to the skin surface and as deep as measured before. There is no real-time control of the injection itself.

Real-time technique. The target region is shown by ultrasound and the needle is advanced under direct ultrasound control. This technique is preferred.

The muscle can be viewed in a longitudinal or transverse plane. The transverse projection allows the differentiation of structures in the neighborhood and the identification of the muscles based on their characteristic pattern. This is especially helpful when injecting smaller muscles such as those of the upper extremity. For iliopsoas injection, the longitudinal view is favored.

For the injection, two basically different approaches are described: needle parallel to the long axis of the probe and needle perpendicular to the long axis of the probe.

Needle Parallel to the Long Axis of the Probe

The needle is inserted approximately 1 to 2 cm distal to the probe and advanced under real-time control in the longitudinal axis of the probe (Fig. 16.3); the advancement of the needle can be followed as a hyperechoic line. The higher the injection angle is relative to the ultrasound beam, the better will be the visualization of the needle. If the needle advancement cannot be followed directly, the position can be estimated indirectly by imaging the movements of the surrounding soft tissues during real-time observation. After correct placement and control aspiration, BoNT is injected under real-time observation mode. The solution of BoNT in saline presents mostly as a hyperechoic area within the muscle, sometimes with a dorsal echo-extinction. By changing the position of the needle, the BoNT can be well distributed in the muscle belly.

Needle Perpendicular to the Long Axis of the Probe

The target region should be focused in the middle of the screen. In this way, it is possible to place the injection needle in the middle of the probe and, from that point, inject into the

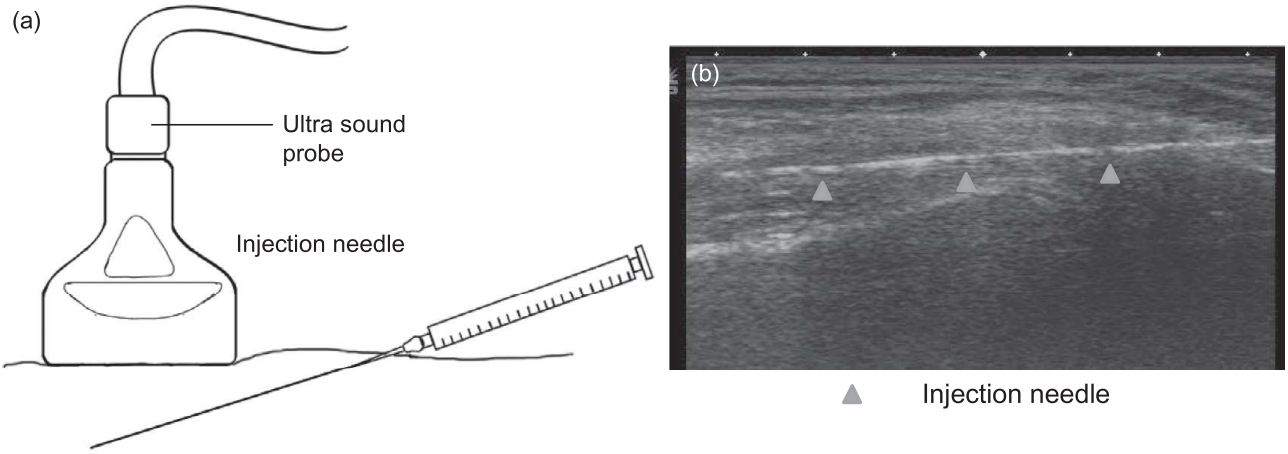

Fig. 16.3 Injection technique with the needle parallel to the long axis of the probe. (a) The relationship of the probe to the needle. (Illustrated by Mayank Pathak.) (b) Ultrasound view with the arrowheads indicating the position of the needle.

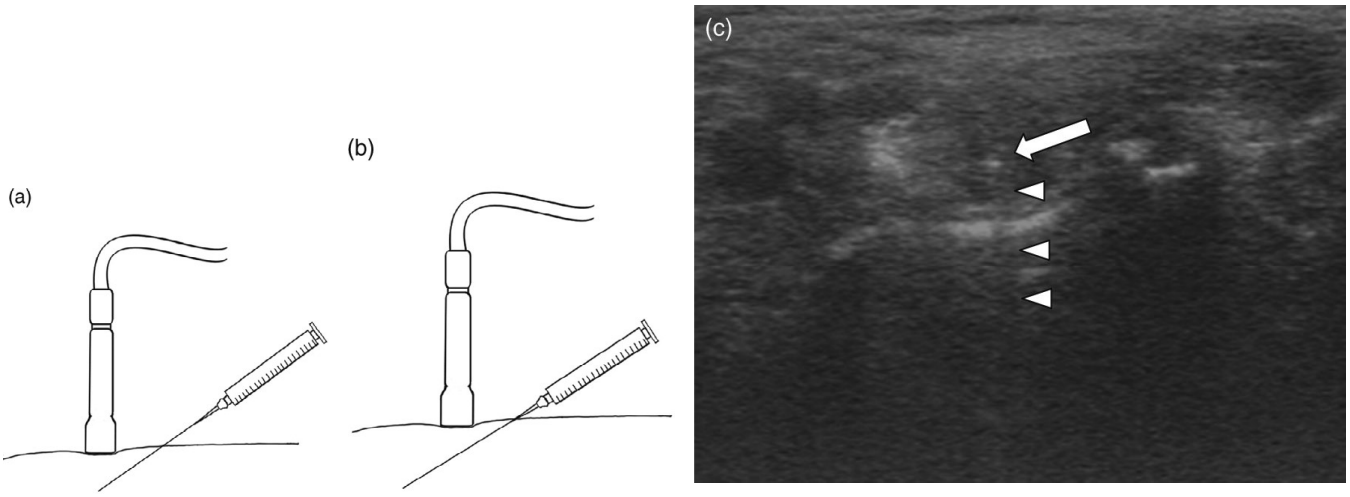

Fig. 16.4 Injection technique with the needle perpendicular to the long axis of the probe. (a) The tip of the needle is positioned under the probe in the target region; in this position the injection should be made. (b) The tip of the needle should be advanced further and is no longer located in the target region; the shaft of the needle will be visualized by the ultrasound image. (Illustrated by Mayank Pathak.) (c) In the ultrasound image, the hyperechoic dot (arrow) corresponds to the needle. There is no difference in the image whether it shows the tip or the shaft. A wave-extinction can be identified (triangles) with ultrasound waves completely reflected at the "changeover" between soft tissue and needle; consequently, behind the needle no echo can be seen.

muscle. By swaying the probe around its longitudinal axis, the advancement of the needle may be followed as a hyperechoic dot; the tip of the needle can also be identified as a hyperechoic dot that appears on the screen while advancing the needle and holding the probe position stable. In that moment, the target region is reached, and the needle should not be advanced further. The distribution of the BoNT can be followed on the screen.

The problem with this technique is that the tip cannot always be identified with certainty, as the echoic reflection of the tip and the shaft looks the same (Fig. 16.4b,c). The needle length required depends on the anatomical location of the target region and the injection technique: if the needle is inserted parallel to the probe it has to be longer.

As an example, the injection of the iliopsoas muscle from the distal approach is described in detail (Westhoff *et al.*, 2003). The patient lies in supine position and standard disinfectant fluid is used as contact medium. The iliopsoas muscle is examined in the groin by a 5.0 or 7.5 MHz linear transducer in the longitudinal plane. The femoral head serves as a bony landmark and is identified in the groin in the standard longitudinal sectional plane (Fig. 16.5a). The relationship between the iliopsoas muscle and the femoral vessels is demonstrated in the transverse sectional plane (Fig. 16.5b). The iliopsoas muscle is in direct contact with the capsule over the femoral head. For an optimal placement of the BoNT injection, the transducer is moved cranially following the iliopsoas muscle. The injection needle is introduced distal to the inguinal

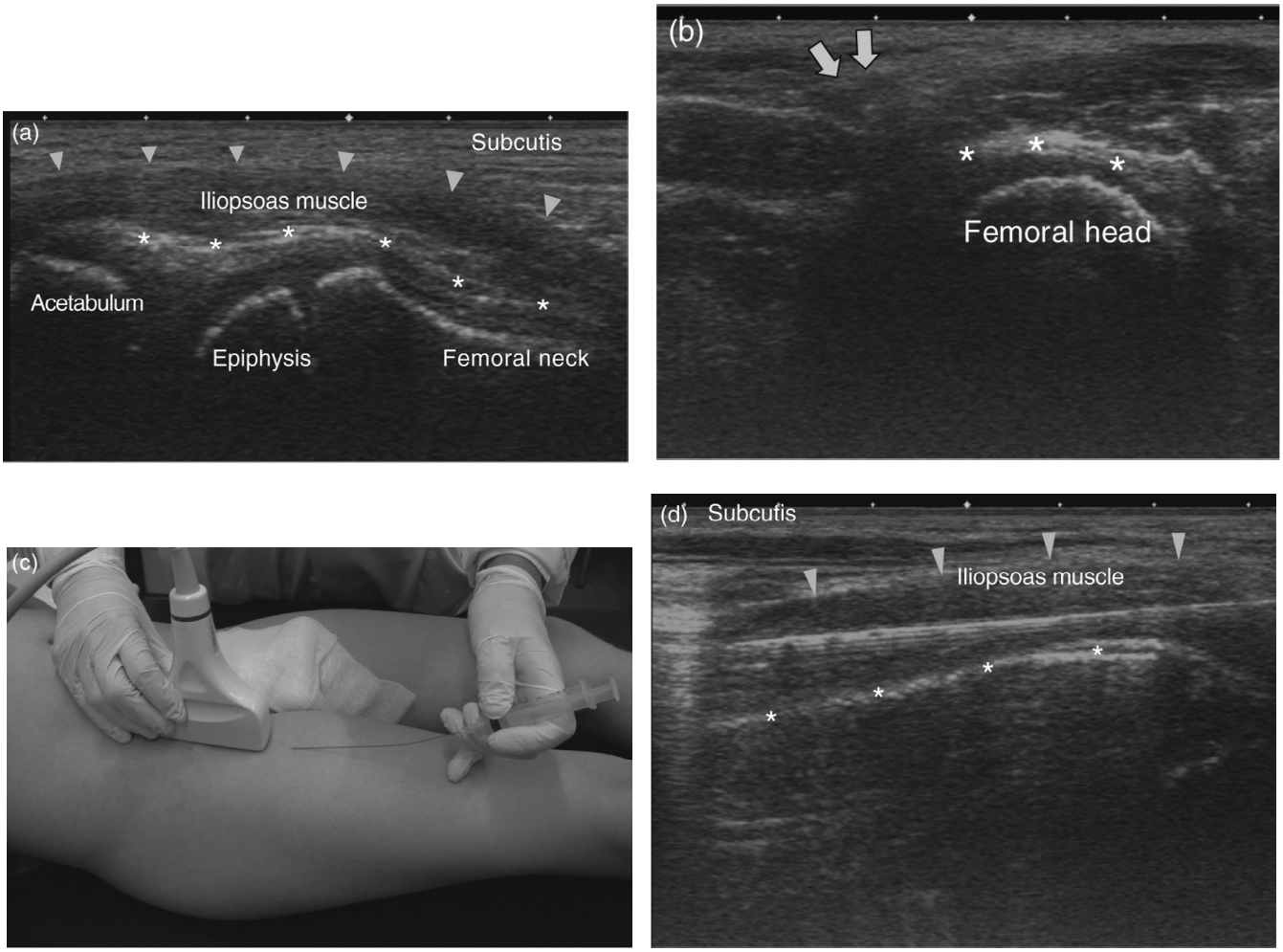

Fig. 16.5 Injection of the iliopsoas muscle (a) Longitudinal ultrasound view of the hip joint; the iliopsoas muscle lies directly on the joint capsule (*); the triangles mark the border to the subcutis. (b) Transverse ultrasound view of the iliopsoas at the level of the femoral head; the arrows marks the femoral vessels. During real-time imaging, pulsation can be followed. (c) Clinical picture showing needle and probe during injection. (d) Ultrasound showing the needle placed in the iliopsoas muscle; the triangles mark the border of the iliopsoas muscle; the injection needle is identified as a hyperechoic white line; in this case an artifact is visible as there are further white lines behind the needle itself (repeating echos); *corresponding to the OS ilium.

ligament and approximately 1 to 2 cm distal to the transducer (Fig. 16.5c); it is advanced cranially and placed into the iliopsoas muscle under real-time ultrasound control (Fig. 16.5d). We use a TSK-Supra 0.8-gauge, 12 cm length injection needle (TSK, Tochigi/Japan). The needle is located either directly as the typical hyperechoic structure or indirectly by imaging the movements of the surrounding soft tissues during real-time observation. After correct placement and control aspiration, the BoNT is injected under real-time observation mode. By changing the position of the needle, the BoNT can be distributed safely in the muscle belly. The needle is introduced up to 12 cm depending on the patient's stature.

This technique for the iliopsoas injection is well suited for children. In adults, the motor endplate zone might be too far proximal and, therefore, cannot be reached from the groin. It is located at about 30% and 70% of the distance between T12 and the passing of the psoas under the inguinal ligament (Campenhout *et al.*, 2010).

References

Berweck S, Heinen F (2005). *Blue Book. Treatment of Cerebral Palsy with Botulinum Toxin. Principles, Clinical Practice, Atlas*, 2nd ed. Berlin: Child & Brain.

Campenhout A, Hubens G, Fagard K, Molenaers G (2010). Localization of motor nerve branches of the human psoas muscle. *Muscle Nerve*, **42**, 202–7.

Campenhout A, Molenaers G (2011). Localization of the motor endplate zone in human skeletal muscles of the lower limb: anatomical guidelines for injection with botulinum toxin. *Dev Med Child Neurol*, **53**, 108–19.

Chin T, Nattrass G, Selber P *et al.* (2005). Accuracy of intramuscular injection of

botulinum toxin A in juvenile cerebral palsy: a comparison between manual needle placement and placement guided by electrical stimulation. *J Pediatr Orthop*, **25**, 286–91.

Kara M, Kaymak B, Ulasli AM *et al.* (2018). Sonographic guide for botulinum toxin injections of the upper limb: EUROMUSCULUS/USPRM spasticity approach. *Eur J Phys Rehabil Med*, 54, 469–85.

Kaymak B, Kara M, Tok F *et al.* (2018). Sonographic guide for botulinum toxin injections of the lower limb: EUROMUSCULUS/USPRM spasticity approach. *Eur J Phys Rehabil Med*, **54**, 486–98.

Westhoff B, Seller K, Wild A, Jäger M, Krauspe R (2003). Ultrasound-guided botulinum toxin injection technique for the iliopsoas muscle. *Dev Med Child Neurol*, **45**, 829–32.

Zamorani MP, Valle M (2007). Muscle and tendon. In Bianchi S, Martinoli C (eds.) *Ultrasound of the Musculoskeletal System*. Berlin: Springer, pp. 46–50.