Pronator quadratus imaging

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Abstract Our objectives are to review the sonographic features of the pronator quadratus muscle, to explain the major advantages of ultrasonography as compared to other imaging modalities and to identify the clinical applications in routine wrist ultrasound examination.

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The pronator quadratus muscle is the poor relation when it comes to modern imaging, be it ultrasoundography, CT scan, or MRI. Even in conventional radiology, it is little known. And yet, obliteraton of the pronator quadratus, and especially the thin fat pad that covers it and separates it from the flexor digitorum profundus group, has been described on a strict lateral radiograph of the wrist as a soft tissue sign of distal fracture of the radius or ulna: that sign is called the “Pronator Quadratus Sign” [1]. More recently, the pronator quadratus muscle has been used as an additional landmark for ultrasound diagnosis of carpal tunnel syndrome [2]. We therefore thought it would be interesting to linger a bit over this muscle, inasmuch as it is known to orthopedic surgeons for procedures such as volar plate osteosynthesis of a radial fracture, harvesting a graft to treat osteonecrosis of the scaphoid, filling significant tissue losses, or even for “aspirin” muscle flap treatment of neuromas of the wrist [3–7].

Anatomy

Located in the deep, distal part of the anterior compartment of the forearm, the clinically “im palpable” pronator quadratus originates on the ulna and inserts onto the radius. With a mean length of 6 cm and mean width of 3.5 cm, the pronator quadratus muscle is confined in a small closed compartment, delimited by the distal side of the interosseous membrane dorsally and by its own fascia on the volar surface [8]. The pronator quadratus is composed of a deep head and a superficial head, with these two components most often facing in opposite directions [9] (Figs. 1 and 2). In coordination with the pronator teres muscle, the superficial head enables pronation of the forearm and hand, while along with three other anatomical elements — the triangular fibrocartilage complex, extensor carpi ulnaris muscle, and interosseous membrane — the deep head, by inserting onto the joint capsule, provides stability for the distal radioulnar joint [10]. Another particular feature of the pronator quadratus muscle is its proximity to the flexor pollicis longus muscle and the median nerve laterally, and the flexor carpi ulnaris muscle and the ulnar nerve medially (Fig. 3). Acting with the abductor pollicis brevis muscle, the pronator quadratus muscle is innervated — as are the flexor pollicis longus muscle and the flexor digitorum profundus

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Pronator radiotransparent fleshy it differences induced membrane CT pronator the muscles — by the anterior interosseous nerve, a branch of the median nerve (C8-T1). It is vascularized by the anterior interosseous artery, which passes near the interosseous membrane (Fig. 4a). The active pronating action of the pronator quadratus muscle is tested clinically with the elbow flexed, since this eliminates the action of the pronator teres muscle. Impairment of the pronator quadratus muscle may be suspected when pain of the anterior face of the wrists is induced by active pronation and passive supination [11].

**Imaging**

In conventional radiology, the pronator quadratus appears on a lateral radiograph of the wrist in the form of a fleshy lenticular opacity. It is located anterior to the distal metaphyseal-epiphyseal region of the radius, and a fine radiotransparent line highlights it superficially [1] (Fig. 1a).

On a CT scan, the pronator quadratus appears in the form of a mass with muscle tissue density, slightly less dense than the overlying flexor tendons (Fig. 1b and Fig. 2c). Based on differences in spontaneous “muscle/tendon/bone” density, it can be depicted by 3-D volume rendering [12] (Fig. 2d). In addition, its vascularization can also be assessed with the CT angiography technique [13,14].

On an MRI, the pronator quadratus muscle appears in the form of a fleshy trapezoidal mass, usually as a hypointense signal in a T1-weighted sequence (Fig. 1c and Fig. 2b). However, in 79% of normal patients, particularly with fluid-sensitive sequences, the pronator quadratus signal appears higher (+17%) than that of the neighboring flexor muscles, regardless of the subject’s age and sex. This hyperintense signal — through the “magic angle effect” — is apparently created by the opposite directions of the superficial and deep muscle fibers of the pronator quadratus muscle. This variant should not be confused with damage to the anterior interosseous nerve. In that case, in the denervated muscles (i.e., the pronator quadratus, flexor pollicis longus, and flexor digitorum profundus muscles), water from the intracellular compartment is displaced to the extracellular compartment. This displacement, comparable to edema, is responsible for the MRI signal elevation in the denervated muscles [15].

On an ultrasonography, in a longitudinal view, the pronator quadratus muscles have a stippled hypoechochogenic fusiform appearance (Fig. 1d). In a cross-sectional view, the pronator quadratus most often has a “sandwich” appearance where the two layers are distinguished from one another by alternating echogenicity (Fig. 2a). On an ultrasonography, it is also possible to visualize the anterior...
Figure 2. Transverse views: ultrasound (a), MRI (b), CT scan (c), and 3-D volume rendering (d). Anatomy of the pronator quadratus muscle: the pronator quadratus muscle is composed of a superficial (large*) head and a deep (small*) head. Their different directions explain their alternating ultrasound structure by an anisotropic effect and their relative hyperintense MRI signal by the magic angle effect. However, on CT scans, more spontaneous differences in "muscle/bone/tendon" density are seen.

Figure 3. Ultrasound transverse views of the anterior face of the wrist. Muscle-tendon ratios of the pronator quadratus muscle: laterally (radial side) the pronator quadratus muscle is related to the flexor pollicis longus (FPL) muscle and the median nerve (MN). Medially (ulnar side) the pronator quadratus muscle is related to the flexor carpi ulnaris (FCU) muscle and the ulnar nerve (UN). PQ: pronator quadrates; SF: superficial flexors; DF: deep flexors.
Figure 4. Transverse (a) and sagittal (b) ultrasound views. Anterior interosseous neurovascular pedicle: a, b: Doppler (a) makes it possible to more easily distinguish the anterior interosseous neurovascular pedical, which passes near the hyperechogenic interosseous membrane (IOM). The sharp appearance of the proximal edge of the pronator quadratus, under which the anterior interosseous nerve passes, is rendered well by the sagittal view (b). PQ: pronator quadrate; A: anterior interosseous artery; AIN: anterior interosseous nerve; Rad: radius; Uln: ulna; UA: ulnar artery. c, d: transverse ultrasound views of the pronator quadratus muscle and the interosseous membrane. Integrity of the interosseous membrane: a line (dotted red line) tangent to the cortical bones of the radius and ulna clearly stands out against a normal interosseous membrane (iom), both at rest (left) and with pressure applied to the back of the wrist (right). R: radius; U: ulna; iom: interosseous membrane; PQ: pronator quadrates.

Figure 5. Dynamic transverse ultrasound views of the pronator quadratus muscle. Dynamic images in pronosupination. The contours of the muscle change during pronosupination movements; in supination, it appears flatter. The surface of the ulna appears roundest in supination (green arrows) and straightest in pronation (yellow arrows). The distance separating the radius from the ulna is greatest in pronation (A > B). PQ: pronator quadratus; R: radius; U: ulna.
interosseous neurovascular pedicle, which passes between the pronator quadratus muscle at the surface and the interosseous membrane below (Fig. 4a). It is also possible, in cross-section, to test the distal part of the interosseous membrane via a volar approach, by exerting pressure on the dorsal face of the wrist. When the interosseous membrane is normal, it remains below a line tangent to the cortical bones of the radius and ulna (Fig. 4b) [16]. Dynamic ultrasound sequences in supination and pronation also show, in cross-section, the stability of the distal radioulnar joint, as well as the change in morphology of the bone and muscle contours (Fig. 5). Against the deep side of the distal ulnar insertion of the pronator quadratus muscle and in the extension of the distal radioulnar joint, it is sometimes possible to see the volar recess of the distal radioulnar joint. On supination—the requisite position for examining the pronator quadratus muscle—under normal conditions, this recess appears in the form of a small, flat anechoic pocket with regular contours (Fig. 6) [17].

Clinical applications
The pronator quadratus muscle has recently been described as an additional measurement landmark for calculating the cross-sectional area from the median nerve to the wrist. That measurement increases the accuracy of a diagnosis of carpal tunnel syndrome (Fig. 7) [2].

With regard to diagnosis, it is not always easy to clinically determine the etiology of pain or swelling of the volar face of the forearm or wrist, a pronosupination deficit, or loss of strength [18]. Imaging studies are therefore necessary, the simplest pairing being X-ray and ultrasound. The most common problems with the pronator quadratus are traumatic in nature, either through direct injury by a fracture of the distal end of the radius or though indirect injury during treatment of such a fracture (Fig. 8). This may involve incarceration of the muscle in the fracture, its pinning by osteosynthesis material (Fig. 9a), or its disinsertion (Fig. 9b) [3,11,19]. There may be a concurrent injury to the interosseous membrane, as in an Essex-Lopresti injury, inasmuch as the distal

Figure 6. Transverse arthrosan (a) and ultrasound (b) views. Volar recess of the distal radioulnar joint: a volar recess in the distal radioulnar joint (x) can be seen below the medial side of the pronator quadratus muscle. Normal when small, anechoic, and regular (a), when larger it may mean a noncommunicating defect of the triangular fibrocartilaginous complex (b). Note the presence of an old corticalized avulsion fracture of the dorsal face of the distal radioulnar joint (arrow). FCU: flexor carpi ulnaris muscle; UN: ulnar nerve.

Figure 7. Transverse ultrasound views according to Klauser [2]. Additional surface area measurements of the median nerve. The surface area of the median nerve measures 6 mm² at the carpal tunnel (CSAc, a) and 5 mm² at the pronator quadratus muscle (CSAp, b). There is practically no difference between the two measurements in normal subjects, but very significant differences in subjects with carpal tunnel syndrome.
part of the interosseous membrane is much finer than its proximal or medial part [16,20]. The pronator quadratus muscle may also be necrotic due to an iatrogenic burn caused by an ID bracelet on the wrist during an MRI [21]. A compartment syndrome may result, requiring surgical decompression [22]. On the ultrasound, this potentially serious compartment syndrome may appear as increased thickness of the pronator quadratus muscle, a blurring of its contours, infiltration of the fascia that covers it, diffuse hyperechogenicity, and loss of its characteristic fibrillar structure (Fig. 10) [23]. Like any other muscle, the pronator quadratus may also be the site of neoplastic, infectious, or granulomatous processes (Fig. 11) [14,24]. In the event of an anterior interosseous syndrome – known as Kiloh-Nevin syndrome – the pronator quadratus muscle may, on the contrary, appear atrophied and hyperechogenic 3–6 weeks after the nerve trauma, like the flexor pollicis longus muscle and the flexor digitorum profundus muscles, since all these muscles are innervated by the anterior interosseous nerve [25–27].

Figure 9. Radiograph and ultrasound — sagittal views. Conflict with osteosynthesis material: a: the osteosynthesis pin pierces the pronator quadratus (PQ) muscle and is in conflict with the flexor pollicis longus (FPL), where there is tenosynovitis. The ultrasound was performed as a workup for pain, swelling and loss of thumb flexor strength. The artefact created by the metal material (dotted line) and the conflict are much more clearly visible on a video sequence than on the static image; b: ultrasounds — axial and longitudinal views. Disinsertion of the pronator quadratus muscle: after hyperextension, the patient complained of sharp pain in the anterior face of the wrist. On the two orthogonal ultrasound views, at the deep face of the radial edge of the pronator quadratus, there is a lenticular anechogenic area indicating a hematoma. The muscle surface is also unusually convex.
Conclusion

After conventional radiography, any exploration of the anterior face of the wrist and forearm should include cross-sections and longitudinal views of the pronator quadratus muscle at rest and during dynamic maneuvers. In fact, this muscle, which is often neglected even in techniques focusing on soft tissues, both in ultrasonography — which typically focuses on the median nerve, carpal tunnel, and “long” tendons — and in MRI — which has too narrow a focus — may be the cause of a mass, swelling, pronosupination disorders, and acute compartment syndrome, or may reveal anterior interosseous nerve damage.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References