Pathologic Conditions of the Hypothenar Eminence: Evaluation with Multidetector CT and MR Imaging

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Pain, weakness, and sensory loss occur frequently in the hypothenar eminence. However, clinical examination is difficult and nonspecific, and the prescribed imaging technique may be inadequate, or images may be misinterpreted. Different imaging modalities have various degrees of usefulness for the diagnosis of painful pathologic conditions of the hypothenar eminence. Radiography, multidetector computed tomography (CT), multidetector CT arthrography, and magnetic resonance (MR) imaging of the wrist are useful for surveying the anatomy of the hypothenar eminence, the Guyon canal, and the ulnar nerve and artery and for determining the cause of pain or other symptoms. A fracture of the pisiform bone or the hook of the hamate bone, osteoarthritis or osteochondromatosis of the pisotriquetral joint, Guyon canal syndrome, hypothenar hammer syndrome, tendinopathy of the flexor carpi ulnaris, an anomalous muscle, a ganglion cyst, or a tumor may be responsible for ulnar neuropathy. Specific radiographic views, such as the semisupinated oblique view and the lateral view with the hand radially deviated and the thumb abducted, often provide a sufficient basis for the diagnosis of acute fracture of the hook of the hamate or the pisiform bone. Multidetector CT angiography is an efficient method for diagnosing hypothenar hammer syndrome, and multidetector CT arthrography is well suited for evaluation of the pisotriquetral joint. MR imaging is the modality of choice for depiction of the ulnar nerve.

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Abbreviation: SE = spin echo

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Introduction
The hypothenar eminence is the fleshy mass at the medial side of the palm. Hypothenar eminence pain or tenderness is quite common. Acute pain may be due to a fracture or dislocation of the pisiform bone or a fracture of the hook of the hamate. Chronic pain may be due to tendinopathy at the insertion site of the flexor carpi ulnaris, to a misdiagnosed fracture, or to pisotriquetral osteoarthritis or instability. Guyon canal syndrome and hypothenar hammer syndrome are two pathologic entities that most often occur separately in the hypothenar eminence; however, they also may be associated, and, in that case, they are more difficult to diagnose. Finally, various soft-tissue tumors may affect the hypothenar eminence.

The suspicion that any of these entities is present should lead to imaging with a specific protocol that is based on standard radiography and that includes, if appropriate, ultrasonography (US), multidetector computed tomography (CT), or magnetic resonance (MR) imaging (1,2). This article describes the various entities that may affect the hypothenar eminence and the most effective imaging techniques for detecting their presence.

Relevant Anatomy
The hypothenar eminence is the prominent part of the palm of the hand, above the pisiform bone, the hamate bone, and the base of the fifth finger. It corresponds to the hypothenar space, the Guyon canal, and the pisotriquetral complex.

Pisiform Bone
Located next to the anterolateral portion of the triquetrum, the pisiform bone forms the medial border of the Guyon canal. It looks like a cook’s hat, with a flat dorsal ovoid surface (the hat base) that articulates with the triquetrum. It is the only carpal bone with a tendinous insertion of a forearm muscle (the flexor carpi ulnaris). Whether the human pisiform bone is a sesamoid bone remains controversial. The bone also includes insertions of various other structures (see “Pisotriquetral Complex”).

Hook of the Hamate (Hamulus)
The hamulus, a curved hook-like process, is located at the lower section of the palmar surface of the hamate bone. This process provides sites of attachment at its apex to the flexor retinaculum and the tendon of the flexor carpi ulnaris and on its medial surface to the flexor digiti minimi and opponens digiti minimi muscles. Its lateral surface is grooved to cover and protect the flexor tendons of the fifth finger. The ossification center of the hamulus may be unfused because of abnormal development, and, in such cases, the so-called os hamuli proprium should not be confused with a fracture of the hamulus.

Pisotriquetral Complex
The pisiform bone provides sites of attachment for various structures that form a complex suspension unit and provide stability to the pisotriquetral joint: the tendon of the flexor carpi ulnaris; the flexor retinaculum and extensor retinaculum; the pisohamate and pisometacarpal ligaments; the abductor digiti minimi muscle; and the meniscal homologue of the triangular fibrocartilage complex (3) (Figs 1, 2).

The transverse carpal ligament is divided into two fibrous bands on its ulnar side, the ligamentum carpi palmae and the ligamentum flexorum,
which delimit the Guyon canal. In 64% of cases, the pisohamate and pisometacarpal ligaments insert into the palmar distal aspect of the pisiform bone. In 36% of cases, the pisohamate ligament inserts into the radial side of the bone, deep to the insertion site of the pisometacarpal ligament (4,5).

**Flexor Carpi Ulnaris Tendon**

The tendon of the flexor carpi ulnaris inserts into the pisiform bone (Figs 1, 2). Some of its fibers extend over the pisiform bone and converge with fibers of the pisohamate and pisometacarpal ligaments, extending toward the hook of the hamate and the fifth metacarpal bone. On axial images at a level immediately above the pisiform bone, the flexor carpi ulnaris tendon often has the appearance of the letter C, with a dorsal concavity. The mean tendinous width (transverse diameter) and thickness (anteroposterior diameter) are 8.3 and 3.2 mm, respectively.

**Pisotriquetral Joint**

The pisotriquetral joint is connected to the radiocarpal joint in 82%–88% of cases. It includes a large superior recess and a smaller inferior one (Fig 3). In a study by Theumann et al, the length of the superior recess in the sagittal plane was 3–12 mm (mean, 7.8 mm), and that of the inferior recess was 0–4 mm (mean, 2.3 mm) (4).

**Pisiform Bone Kinematics**

The pisotriquetral complex contributes to the mechanical stability of the ulnar column by preventing triquetral subluxation. It also acts as a fulcrum for the flexor carpi ulnaris muscle. Pisotriquetral complex failure may lead to pisiform bone dislocation or instability as well as to secondary osteoarthritis (6,7).

A tough but mobile fibrous pisotriquetral joint capsule allows extensive mobility between the pisiform bone and the triquetrum. Knowledge of

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**Figure 2.** MR images of the pisotriquetral complex. (a) Sagittal T1-weighted image shows the flexor carpi ulnaris tendon (black arrow), the pisometacarpal ligament (white arrow), and the abductor digiti minimi muscle (1). (b) Sagittal T1-weighted image shows the pisohamate ligament (arrow). (c) Coronal T1-weighted image shows the pisohamate ligament (arrow) and the abductor digiti minimi (1) and flexor digiti minimi (2) muscles. $H$ = hamatum, $h$ = hamulus, $M5$ = fifth metacarpal bone, $P$ = pisiform bone, $T$ = triquetrum, $U$ = ulna.

**Figure 3.** The pisotriquetral joint. Sagittal CT arthrogram of the wrist shows a large superior recess (red arrow) and a smaller inferior recess (yellow arrow) after a contrast medium injection in the radiocarpal joint.
Figure 4. Axial T1-weighted MR images of the Guyon canal. (a) At the inlet of the canal, the ulnar nerve (green arrow) is seen just deep to the radial aspect of the flexor carpi ulnaris (black arrow), on the ulnar side of the ulnar veins (blue arrows) and ulnar artery (red arrow). (b) The proximal end of the canal, at the level of the pisiform bone, corresponds to zone 1. Here the cross-sectional shape of the canal is generally triangular, with the base of the triangle directed toward the pisiform bone (P). The canal is delimited ulnarly by the pisiform bone, posteriorly by the ligamentum flexorum (white arrowheads), and anteriorly by the ligamentum carpi palmaris (black arrowheads). The ulnar nerve and its branches (green arrows) lie between the pisiform bone and the flexor carpi ulnaris tendon (black arrow) on the ulnar side and the ulnar veins and artery (red arrow) on the radial side. (c) At its middle, between the pisiform bone and the hamulus, the canal appears triangular or ovoid in cross section. Note the appearance of the abductor digiti minimi muscle (1), the ulnar artery (red arrow), and the bifurcation of the ulnar nerve into superficial (yellow arrow) and deep (green arrow) branches. (d, e) Zones 2 and 3 (at the level of the hamulus and just below it) are clearly identifiable in the distal portion of the canal. The flexor digiti minimi (2 in e) and the opponens digiti minimi (3 in e) are apparent. Zone 2 contains the deep motor branch (green arrow in d) of the ulnar nerve and its branches (green arrowheads in e) and the deep branch of the ulnar artery (red arrowhead). Note the pisometacarpal ligament (white arrow in d) on the ulnar side of the base of the hamulus. Zone 3 contains the superficial sensory branches (yellow arrows) of the ulnar nerve.
pisiform bone kinematics is mandatory for accurate analysis of radiographic findings and correct diagnosis of pisiform bone dislocation. The flexor carpi ulnaris pulls at the pisiform bone during flexion, while the triquetrum is more rigidly bound to the lunate, capitate, and hamate bones. The vertical translation of the pisiform bone in relation to the location of the triquetrum during movement of the wrist from maximal flexion to maximal extension is about 1 cm. The proximal extent of pisiform bone migration usually is greater than the distal extent.

During wrist flexion, the space between the pisiform bone and the triquetrum increases, whereas during wrist extension the two bones are pressed together. With the wrist in the neutral position, the pisotriquetral joint space is less than 3 mm. The normal upper limit of the pisotriquetral joint space during flexion is 6 mm (6).

The pisotriquetral angle, formed by the intersection of two imaginary lines drawn along the articular surfaces of the pisiform bone and the triquetrum, may form a wedge that points in the distal direction during wrist flexion or in the proximal direction during extension. The pisotriquetral wedge angle values when the wrist is in the neutral position average 5° proximally (range, 10° distally to 15° proximally). The pisotriquetral angle may reach 30° proximally with the wrist in extension and 30° distally with the wrist in active flexion. With the wrist deviated in the ulnar direction, the triquetrum extends and deviates farther in that direction than does the pisiform bone (6,7).

**Guyon Canal and Ulnar Nerve**

The Guyon canal, described by French surgeon Jean C. F. Guyon in 1861, is a fibro-osseous tunnel located along the anteromedial portion of the wrist. It is not a rigid conduit but rather a space of varying dimensions that conducts the ulnar neurovascular bundle and its divisions from the forearm through the wrist (8).

The Guyon canal comprises three zones that are defined by the ulnar nerve bifurcation (9,10). Zone 1 is the area proximal to the bifurcation of the nerve, zone 2 encompasses the deep (motor) branch of the bifurcated nerve, and zone 3 encompasses the superficial branch of the bifurcated nerve.

The anatomic structures that define the boundaries of the Guyon canal vary from the proximal end to the distal end. MR imaging is the modality of choice for evaluating this anatomic region (Fig 4).

At the inlet of the canal, the ulnar nerve is seen just deep to the radial aspect of the flexor carpi ulnaris muscle, on the ulnar side of the ulnar veins and artery. The proximal end of the canal (at the level of the pisiform bone) corresponds to zone 1. Its shape is generally triangular, with the base of the triangle directed toward the pisiform bone. The greatest mean transverse width is 11 mm ± 5, and the greatest mean anteroposterior depth is 7 mm ± 4 (11). The limits of the Guyon canal are, ulnarily, the pisiform bone; dorsally, the ligamentum flexorum; and ventrally, the ligamentum carpi palmaris. The ulnar nerve lies between the pisiform bone and the ulnar veins and artery. In 77% of cases, it is bifurcated into a deep branch and a superficial branch just past the distal edge of the pisiform bone. However, it also may be bifurcated into radial and ulnar trunks or trifurcated.

In the midsection of the Guyon canal (between the pisiform bone and the hamulus), the cross-sectional shape of the tunnel is either triangular or oval, and the abductor digiti minimi muscle is apparent. The greatest mean transverse and anteroposterior dimensions are 14 mm ± 5 and 5.5 mm ± 4, respectively (11).

Zones 2 and 3 are clearly identifiable in the distal portion of the tunnel (hamulus level and below). The opponens digiti minimi and the flexor digitii minimi muscles are apparent. Zone 2 contains the deep motor branch of the ulnar nerve and the deep branch of the ulnar artery. Its general configuration is biconvex or discoid. It is 14 mm ± 5 wide and 5.5 mm ± 2 deep. Zone 3 contains the superficial sensory branches of the ulnar nerve and the superficial branch of the ulnar artery. The superficial branch of the ulnar artery also provides a motor nerve branch for the palmaris brevis muscle.
Ulnar Artery and Hand Collateral Circulation

The radial artery and the ulnar artery provide most of the blood supply to the hand (Fig 5). Additional circulation may come from the median artery or the interosseous arterial system. The radial artery and the ulnar artery form four circuits in the hand: the anterior and posterior carpal arches at the level of the carpal bones, and the superficial and deep palmar arches at the midcarpal level. The deep palmar arch and, most important, the superficial palmar arch are the most significant of these circuits, as they supply blood to each finger. In our experience, multidetector CT angiography is the best technique for evaluating these circuits.

Variations in the termination of the radial artery and ulnar artery are common, although there is always a significant anastomosis between these two arteries. The superficial palmar arch is considered complete (66%–96% of cases) if it supplies all the fingers and the ulnar side of the thumb or incomplete if it does not supply the thumb (12–14).

The distal end of the superficial palmar arch of the ulnar artery communicates with the radial artery in only 34% of cases. The classic configuration (complete palmar arch with anastomoses to the superficial palmar branch of the radial artery) is found in only 10% of cases (12–14).

The deep palmar arch is described as complete (76%–96% of cases) when the deep palmar portion of the radial artery has a connection with the deep palmar branch of the ulnar artery. Normally, the deep palmar branch of the ulnar artery arises above the level of the hamulus. Uncommonly, the origin of this branch is more distal and is located below the level of the hamulus. A median artery is found in 3.6%–6% of cases (13).

Relation of the Ulnar Nerve and Artery to the Hamulus

The anatomic relationship between the ulnar neurovascular bundle and the hamulus determines the risk of injury to these structures in cases of acute or repetitive trauma. With the hand in the neutral position, the ulnar nerve is normally located medial to the hamulus; however, variations in the normal location occur frequently. In a study by Omokawa et al, the location of the ulnar artery varied from a point 7 mm from the hamulus in the ulnar direction to a point 2 mm from the hamulus in the radial direction (15). In a study by Netscher et al, the position of the ulnar artery was, on average, 0.7 mm to the radial side of the hamulus and ranged from 7.8 mm in the radial direction to 2.8 mm in the ulnar direction. The ulnar nerve was found, on average, 3.6 mm to the ulnar side of the hamulus. Its position with regard to the hamulus ranged from 5.8 mm in the radial direction to 7.5 mm in the ulnar direction. Flexion and extension of the wrist induced ulnar and radial displacement, respectively, with regard to the hook of the hamate (16).

Hypothenar Space

The hypothenar space is one of the three palmar spaces of the hand. Unlike the thenar and midcarpal spaces, the hypothenar space is not traversed by the flexor tendons of the digits. Instead, it contains the three hypothenar muscles, which are, from the most superficial to the deepest, the abductor digiti minimi, the flexor digiti minimi brevis, and the opponens digiti minimi (Figs 2, 4).

The abductor digiti minimi muscle originates from the pisiform bone, the tendon of the flexor carpi ulnaris, the pisometacarpal ligament, and the pisohamate ligament. It inserts into the ulnar side of the base of the proximal phalanx and into the extensor apparatus of the fifth finger. In most cases, the abductor digiti minimi has two bellies (17).

The flexor digiti minimi brevis muscle originates from the hamulus, the adjacent ulnar portion of the flexor retinaculum, and the radial portion of the pisiform bone. The flexor digiti minimi

Figure 5. Volume-rendered CT angiogram of the ulnar artery and collateral circulation in the hand shows a classic configuration of the superficial palmar arch (2), the deep palmar branch of the ulnar artery (1), the supply to the thumb (3), and the superficial palmar branch of the radial artery (4). h = hamulus, P = pisiform bone, RA = radial artery, UA = ulnar artery.
brevis fuses distally with the abductor digiti minimi. The flexor digiti minimi brevis may be missing (17).

The opponens digiti minimi muscle has two original layers. The superficial layer originates in the distal part of the hamulus and inserts into the distal ulnar side of the fifth metacarpal shaft. The deep layer originates in the part of the ulnar flexor compartment wall adjacent to the hamulus and inserts into the proximal ulnar side of the metacarpal shaft of the fifth finger. The deep branch of the ulnar nerve passes between the superficial and deep layers of the opponens digiti minimi (17).

Other Muscles

The palmaris brevis is a thin subcutaneous muscle that extends across the proximal part of the hypothenar eminence. It arises from the flexor retinaculum and the palmar aponeurosis and inserts into the skin on the ulnar side of the hand.

Accessory or anomalous muscles within the Guyon canal are common findings (22%–35% of cases) and have clinical significance because they may cause ulnar nerve compression (11,18–20). They are mainly represented by accessories of the abductor digiti minimi that are located on the volar side of the ulnar neurovascular bundle and that fuse with the abductor digiti minimi distally (Fig. 6). The proximal end of the accessory muscle may be identified at the level of the pisiform bone or beyond its proximal margin. In most cases, the origin of this muscle is the antebrachial fascia. The accessory muscle may join the palmaris longus muscle and insert into the pisiform bone (21). In a recent study performed with US in 116 wrists of asymptomatic volunteers, anomalous muscles were identified in 47% of the volunteers and in 35% of the wrists (prevalence, 50% for men and 21% for women). All of the anomalous muscles were variants or accessories of the abductor digiti minimi. Bilateral accessory muscles were present in 50% of index cases from both sexes. Mean muscle thickness was 1.7 mm overall (range, 0.5–3.7 mm), with no variation between the sexes. Muscle thickness did not vary with hand dominance or manual employment (20). Since the prevalence of anomalous muscles in the Guyon canal is high, care must be taken in defining their role in the etiology of ulnar nerve compression. The authors suggest that the thickness of an anomalous muscle may be an important determinant of its significance as a cause of ulnar nerve compression in the Guyon canal.

Many other aberrant muscles have been identified that originate from the pisiform bone, the palmar aponeurosis, or the flexor retinaculum. Some lie between the ulnar nerve and artery and may be responsible for ulnar nerve compression; these include anomalous flexor digiti minimi brevis muscles, accessory palmaris muscles, and duplicate tendons of the flexor carpi ulnaris accompanied by splitting of the ulnar nerve.

Determining Which Bone Is Affected by Acute Trauma

Acute trauma to the hypothenar eminence may lead to a fracture of the pisiform bone, the triquetrum, or the hook of the hamate. Pisiform bone dislocation is very rare, whereas the frequency of osteochondral fractures of the pisiform bone is probably underestimated. Some of these lesions may be overlooked and may lead to secondary osteoarthritis of the pisotriquetral joint. Loose bodies of the pisotriquetral joint also may result from osteochondral fractures of the pisiform bone.

A history of trauma (typically, a fall on the ulnar side of the outstretched hand) and a specific location of pain are characteristic clinical findings that should lead to the implementation of a simple, quick, and efficient radiographic protocol. CT should be performed only when clinical findings suggest a fracture and radiographic findings are questionable. MR imaging is very accurate for the diagnosis of occult fractures and is indicated when a tendon or an ulnar nerve lesion is suspected to be the cause of pain.

Clinical Examination

The pisiform bone is seated over the triquetrum. To locate the pisiform bone, palpate along the flexor carpi ulnaris from a proximal position toward the wrist. The pisiform bone is at the level of
the wrist crease. The hamulus may be located by identifying the pisiform bone and then palpating along a line from the pisiform to the head of the second metacarpal bone. The hamulus is situated approximately 2 cm from the pisiform bone. The pisotriquetral joint is situated on the ulnar side of the wrist, at the level of the pisiform bone.

**Radiographic Examination**

The radiographic protocol always includes the acquisition of posteroanterior and lateral views; however, these views are not sufficient, as superimposed bone may hide the lesions. A semisupinated oblique view and, in cases in which a hamate bone fracture is suspected, a lateral view with the hand radially deviated and the thumb abducted are recommended (22–24).

The semisupinated oblique view highlights the pisiform bone and the pisotriquetral joint and shows the palmar portion, but not the base, of the hook of the hamate. A suspected fracture of the hook of the hamate therefore requires an additional view. A carpal tunnel view or a slightly supinated oblique view with wrist and thumb hyperextension may be obtained. However, because it may be painful for the patient to maintain the necessary position, images may be difficult to obtain and of poor quality. Thus, we advocate the acquisition of radially deviated, thumb-abducted lateral radiographic views, which are easily acquired without causing the patient pain. In this view, the forearm is placed in a neutral position with the thumb maximally actively abducted and the hand radially deviated. The x-ray beam is perpendicular to and centered on the thumb web space. The resultant radiographs provide good depiction of the entire hook of the hamate, including the base (Fig 7).
Fracture of the Pisiform Bone

Pisiform bone fractures are very rare, but their frequency also may be underestimated because of inadequacies in the standard radiographic examination (24). In a study by Fleege et al, only five of 10 pisiform bone fractures could be diagnosed on the basis of posteroanterior radiographs (25). However, such fractures are well depicted on semisupinated oblique radiographs or on axial CT images (Fig 8). Small osteochondral fragments in the pisotriquetral joint recesses may be suggestive of a fracture of the pisiform bone (Fig 9).

Fracture of the pisiform bone often results from a fall on the outstretched and supinated hand, with a direct impact on the pisiform bone. Isolated cases are the most frequent, but associations with carpal dislocation and distal radial fracture have been reported. Fatigue fracture of the pisiform bone in volleyball players also has been described. Excision of the pisiform bone is usually required.

Dislocation of the Pisiform Bone

Pisiform bone dislocation is very rare (26). The diagnosis is reached on the basis of posteroanterior radiographic views in cases of medial dislocation of the pisiform bone, which is seen on the medial side of the triquetrum. In cases of palmar displacement of the pisiform bone, the lateral and semisupinated oblique views show a widening of the pisotriquetral space by more than 4 mm. CT may be helpful for identifying dislocation of the pisiform bone and any associated lesions (Fig 10).
Pisiform bone dislocation may occur in association with osteochondral fracture of the pisiform bone or the triquetrum, hamate dislocation, or distal radial fracture. Open reduction and osteosynthesis are necessary to correct such injuries.

Osteochondral Fracture of the Triquetrum
Triquetral fractures are generally classified into two groups: body fractures and dorsal-type fractures. Osteochondral fracture of the triquetrum also has been described. This lesion is associated with subluxation or dislocation of the pisiform bone and is very rare (27).

Osteochondral fracture of the triquetrum results in impaction of the pisiform bone (which is displaced by trauma from its normal position) on the triquetrum. This impaction causes a disruption of the ligamentous attachment of the bone. The edge of the pisiform bone may exert shear force on the volar, distal, and ulnar surfaces of the triquetrum. CT is probably the best technique for identification of this type of fracture. CT arthrography also may reveal an associated tear of the triangular fibrocartilage complex (Fig 11).

Fracture of the Hook of the Hamate
Fractures of the hook of the hamate are the most frequent type of hamate fracture. These fractures may occur during a fall on an outstretched hand in which there is an impact on the ulnar side of the wrist. However, they most often occur when swinging a baseball bat, golf club, or racket. Hamate fracture may result from repetitive stress or from the direct blow of a club on the ground. In sports in which a racket is used, hamate fractures typically affect the dominant hand; in baseball, hockey, or golf, they usually occur in the nondominant hand.

Fractures of the hook of the hamate are often overlooked in the clinical setting (28). At clinical examination, there may be tenderness or pain over the hook. Grip weakness and pain with resistance to flexion of the fifth finger are often observed. Paresthesia of the fourth and fifth fingers may be present. Injury to the flexor digitorum profundus muscle also may occur (29). Failure to promptly diagnose and treat such fractures may result in fifth-finger flexor tendon rupture, ulnar nerve palsy, or hook nonunion.
Radiography is essential for diagnosis. On posteroanterior views, a fracture may be suspected if the hook is not depicted (Fig 12) or if its cortical density is lower than normal (30). The appearance of a completely sclerotic hamulus suggests hamulus nonunion with avascular necrosis (Fig 13). However, these findings are neither specific nor very sensitive. The accuracy of radially deviated, thumb-abducted lateral views is probably much greater than that of posteroanterior views (Fig 7). CT should be performed only if clinical findings are suggestive of a fracture and radiographic findings are questionable or to evaluate the hamulus for displacement (31). CT is probably more accurate than MR imaging, as distal fractures are difficult to identify on MR images.

MR imaging is indicated when the presence of a lesion of the tendon or ulnar nerve is suspected (Figs 14, 15). Tenosynovitis of the flexor tendons in the fifth finger is frequent. Generally, it is easy to differentiate a hamulus fracture from an unfused ossification center of the hamulus, a so-called os hamuli proprium. The latter appears ovoid or pyramidal, with a peripheral area of cortical bone. Very uncommonly, an os hamuli proprium is associated with tendonitis in the flexor tendons of the fifth finger (Fig 16), ulnar nerve neuropathy, or hypothenar hammer syndrome.

A cast is applied to treat undisplaced fractures. Fractures with displacement greater than 1 mm are best treated with open reduction and internal fixation. Nonunited fractures of the hook of the hamate are often resected.

Figures 12, 13. (12) Posteroanterior radiograph in a case of hamulus fracture shows the absence of the hook of the hamate. (13) Nonunion with avascular necrosis of the hamulus. (a) Posteroanterior radiograph shows a sclerotic hamulus. (b) Axial CT scan helps confirm nonunion and necrosis of the hamulus (arrow).
Chronic Pain and Syndromes Caused by Overuse

Flexor Carpi Ulnaris Tendonitis
Compared with other lesions of the wrist tendons, flexor carpi ulnaris tendonitis is infrequent. Flexor carpi ulnaris tendonitis is usually observed in players of games that involve the use of a racket (particularly racquetball, squash, and badminton) and in golfers. It may be associated with pisotriquetral osteoarthritis or chondromalacia of the pisiform bone (so-called player pisiform). Pain is
noticeable over the pisiform bone and the distal portion of the flexor carpi ulnaris tendon during resisted wrist flexion and ulnar deviation. Associated ulnar nerve symptoms may be present.

Standard radiographs (semisupinated oblique views) may reveal tendon calcifications near the pisiform bone or evidence of pisotriquetral osteoarthritis (Fig 17). Clinical and radiographic findings are usually unequivocal. US, CT, and MR imaging are rarely indicated and are used mostly to rule out another cause of hypothenar eminence pain. US and MR images show degeneration of the terminal portion of the tendon close to the pisiform bone and sometimes peritenon inflammation. No tenosynovitis is observed, because this tendon does not have a sheath (Fig 18).

**Tenosynovitis of the Fifth-Finger Flexor Tendons**

Isolated tenosynovitis of the flexor tendons of the fifth finger is usually related to a fracture of the hook of the hamate (29). Other causes are rare (Figs 14, 16, 19).
Pisotriquetral Joint Dysfunction and Osteoarthritis

Primary osteoarthritis is the main cause of pisotriquetral joint osteoarthritis (5,32,33), which usually affects patients older than 50 years, especially women. Secondary osteoarthritis is usually a sequela of a misdiagnosed fracture of the pisiform or triquetrum or subluxation of the pisiform bone. Pisotriquetral joint osteoarthritis (player pisiform) in players of games that involve the use of a racket also has been described: Chronic overuse injuries may result in chondromalacia of the pisotriquetral joint with associated mild subluxation of the pisiform bone (34).

Pisotriquetral joint pain occurs in 1% of patients after median nerve decompression. One hypothesis incriminates a mild medial translation of the pisiform bone, secondary to resection of the flexor retinaculum (35).

Pisotriquetral osteoarthritis is associated with local pain and tenderness, which are exacerbated by grinding of the pisiform bone dorsally against the triquetrum (Table). Instability is subtle, subjective, and therefore difficult to diagnose.

Injection of a local anesthetic or corticosteroid, combined with the acquisition of a semisupinated oblique radiograph, enables the diagnosis of pisotriquetral joint dysfunction. Semisupinated oblique views clearly demonstrate loose bodies in the superior and inferior recesses of the pisotriquetral joint in cases of associated secondary os-
teochondromatosis (Fig 20). These loose bodies are often missed on other views.

CT arthrography or MR imaging may be indicated before surgical treatment, to detect all the loose bodies (which sometimes adhere to synovium) and any synovial cysts (36,37). Injection of a contrast medium after direct puncture of the pisotriquetral joint is a good technique for evaluation of joint abnormalities. The additional administration of a corticosteroid may reduce symptoms for a few months (Fig 21). Osteoarthritis of the pisotriquetral joint may be associated with a synovial cyst, which most often communicates with the superior recess (Fig 22). Synovial cysts also may extend into the Guyon canal and cause ulnar nerve compression.

Ulnar Neuropathy (Guyon Canal Syndrome)
Because of its anatomic position, the ulnar nerve is subject to entrapment and injury. The wrist (Guyon canal) is the second most common site of ulnar nerve entrapment, after the elbow, but median nerve entrapment is far more common (38,39).

Ulnar neuropathy often affects athletes who are involved in cycling (handlebar palsy), martial arts, racket sports, and other activities in which repetitive and continuous pressure or repetitive wrist motion may cause ulnar nerve compression injury. Handlebar palsy is particularly frequent.
among mountain bikers and off-road cyclists because the rugged terrain increases the severity of vibrations and shocks that pass through the handlebars. Ulnar neuropathy also may affect workers who are exposed to frequent vibrations, such as those who work in foundries or with pneumatic drills. Finally, ulnar nerve compression may be due to adjacent masses such as ganglion cysts (Fig 23) or lipomas, anomalous muscles, a fibrous palmar arch, an ulnar artery aneurysm, accessory or anomalous abductor digiti minimi or flexor digiti minimi brevis muscles, anomalous flexor carpi ulnaris tendons, osteoarthritis of the pisotriquetral joint, a fracture of the hamulus, an os hamuli proprium, or dislocation of the pisiform bone (40–43).

Nerve entrapment may cause a loss of motor function, a sensory loss, or a combination of the two, depending on the site of compression. Compression in zone 1, the area proximal to the bifurcation of the ulnar nerve, causes both a loss of motor function and a sensory loss. Compression in this zone most commonly is caused by a fractured hook of the hamate or a ganglion cyst.

Compression in zone 2, the area that encompasses the motor branch of the ulnar nerve (after the bifurcation), causes a loss of motor function in all of the muscles in the hand that are innervated by the superficial branch of the ulnar nerve except the palmaris brevis. Ganglion cyst and fracture of the hook of the hamate are the most common causes.

Compression in zone 3, an area that encompasses the superficial or sensory branch of the bifurcated nerve, causes sensory loss to the hypothenar eminence, the fourth finger, and part of the fifth finger, but no deficit of motor function. Common causes of compression in this zone are ulnar artery aneurysm, thrombosis, synovial inflammation, and fracture of the hook of the hamate.

Clinically, patients may present with paresthesia in the ulnar nerve distribution and with a variable amount of weakness, depending on the extent of motor nerve involvement. At physical examination, there is tenderness and a Tinel sign (tingling) over the Guyon canal, with radiation of tingling to the fourth and fifth fingers. The strength of the grip should be tested; 40% of the grip strength is due to ulnar nerve–innervated muscles. Radiographic studies are usually negative. Electrophysiologic testing may be helpful, but normal test results do not rule out a diagnosis of ulnar neuropathy.

Treatment of Guyon canal syndrome begins with rest and splinting of the wrist. Cryotherapy and nonsteroidal antiinflammatory drug therapy may be useful, particularly in acute cases. Persistent sensory or motor compromise is an indication for CT or MR imaging to determine whether compression of the ulnar nerve is a causal factor. If compression is present, surgical decompression may be performed.

**Hypothenar Hammer Syndrome**

The hypothenar hammer syndrome, first described by Conn in 1970, is caused by blunt repetitive injury to the ulnar artery and superficial palmar arch from impact against the hamulus. Typically, the resultant trauma to the hypothenar eminence is chronic, although severe acute episodes of the syndrome have been reported (44–46).

Because of the anatomic configuration of the Guyon canal, the ulnar artery is particularly vulnerable to mechanical injury due to its entrapment between a hammer (external force) and an anvil (the hamulus). Intimal hyperplasia is almost invariably present in hypothenar hammer syndrome, along with duplication and fragmentation of the internal elastic lamina (46). Arterial wall damage may lead to aneurysm formation with or without vessel thrombosis and to microemboli formation and compression of the sensory branch of the ulnar nerve (44,45). The position of the ulnar artery relative to the hamulus and the site of impact over the hypothenar eminence may determine the risk of an ulnar artery lesion. A cork-
screw configuration related to preexistent fibro-dysplasia might make the ulnar artery particularly liable to traumatic injury (44). Incomplete palmar arches increase the risk and the potential consequences of ulnar artery occlusion. Smoking is probably an additional risk factor.

Although usually found in men of working age with industrial occupations that involve repetitive blunt trauma to the hands, hypothenar hammer syndrome also has been observed in athletes (handball, baseball, tennis, squash, and golf players) with sports-related injuries, patients involved in martial arts, and break-dancers (47–50).

Patients may present with intolerance to cold, pain in the palm, numbness in the fourth and fifth fingers, Raynaud syndrome, ischemia of the fingers (usually the fourth and fifth), and a tender mass in the hypothenar eminence. Results of several studies suggest a high prevalence of subclinical disease among workers who use the hand as a hammer or who use vibrating tools (44–46). Physical examination usually enables differentiation between vascular causes and isolated ulnar nerve compression. A Tinel sign may be present because of ulnar nerve compression. The Allen test is specific for arterial insufficiency.

The diagnosis can be confirmed easily with US (51). However, conventional angiography, CT angiography, or MR angiography is required to determine the most appropriate treatment (52,53). In our experience, multidetector CT angiography is the examination of choice for the detection of lesions and for precise vascular mapping. The radial and ulnar arteries, the palmar arches, and the first few centimeters of the digital arteries are well depicted with this technique. Moreover, it can be used to rule out a hamate fracture and to show the relationship between the ulnar artery and the hamulus.

Lesions of the ulnar artery may include wall thickening, stenosis, saccular or fusiform aneurysm, occlusion, and corkscrew configuration (44,54). Palmar arches and digital arteries also may be occluded, and it might be difficult to distinguish an incomplete superficial palmar arch from a segmental arterial occlusion (Figs 24, 25).

Figures 24, 25. (24) Hypothenar hammer syndrome in a 48-year-old man with acute pain and a tender mass in the hypothenar eminence and with paresthesia of the fourth and fifth fingers. (a, b) Axial CT image (a) and coronal three-dimensional volume-rendered CT image (b) show an occluded aneurysm of the ulnar artery (arrow). (c) Axial T1-weighted MR image shows an area of high signal intensity in the vessel lumen, a finding indicative of an occluded ulnar artery aneurysm (arrow). (25) Hypothenar hammer syndrome in a 47-year-old man, a manual worker and smoker with fourth-digit coolness and cold intolerance. Three-dimensional volume-rendered CT image demonstrates a small fusiform aneurysm of the ulnar artery (open arrow) at the level of the hamulus, a segmental occlusion in the superficial palmar arch (solid arrow), a corkscrew configuration of the superficial palmar arch (arrowhead), and occlusion of the lateral digital artery of the fifth finger.
The superficial palmar arch is more often affected than is the deep palmar arch (J.P.Z., unpublished data, 2005).

Treatment consists of rest from the offending activity, cessation of smoking, and therapy with vasodilators such as calcium channel blockers. The thrombosed segment may require surgical excision and reconstruction with a vein graft.

### Hand-Arm Vibration Syndrome

Frequent use of vibrating handheld tools may cause a variety of vascular and neuromuscular symptoms collectively named hand-arm vibration syndrome. The clinical manifestations are often confusing, as workers frequently present with multiple symptoms of hand-arm vibration syndrome, often in conjunction with other work-related musculoskeletal disorders (55).

The sensory manifestations may include episodic tingling, numbness, paresthesia, poor coordination, and, quite commonly, pain. The digital nerves are most commonly affected, and the median nerve is more often affected than the ulnar nerve.

Vascular manifestations typically have a longer latency period than do sensorineural effects. The first vascular manifestation is usually the Raynaud phenomenon. Vascular lesions may include digital microangiopathy, digital vasoplastic phenomenon, arterial thrombosis, and hypothenar hammer syndrome.

A possible association with degenerative bone changes is debated, but there seems to be an overrepresentation of ganglion cysts, Kienböck disease, and osteoarthritis among patients with hand-arm vibration syndrome (55).

Characteristically, there is a latency period; however, the duration of exposure to vibration that precedes manifestation of the syndrome cannot be readily defined. CT or MR imaging is indicated in cases of hypothenar hammer syndrome or ulnar neuropathy.

### Tumors and Other Lesions

In a study of 134 palpable masses of the hand by Capelastegui et al, 27% of the masses were ganglia, 25% were benign tumors, and 2% were malignant tumors (56). In a study of 71 hand masses by de la Kethulle de Ryhove et al, 62% were benign tumors, 8% were ganglion cysts, 10% were malignant tumors, and the remaining 20% were pseudotumoral masses (57). Benign tumors of the hand are represented primarily by lipomas, schwannomas, and hemangiomas.

Most symptomatic bone tumors of the hypothenar eminence are osteoid osteomas. Malignant bone tumors of the hand are uncommon. The more common types include chondrosarcoma, osteogenic sarcoma, Ewing sarcoma, and metastatic tumors.

### Ganglion Cyst

The most common soft-tissue masses in the hand and wrist are ganglion cysts, which account for 50%–70% of masses in this anatomic region (56,57). Volar ganglion cysts, which are less frequent than dorsal cysts, account for 18%–20% of ganglion cysts of the hand and wrist; few of them are located on the ulnar side of the hand (58,59). Ganglion cysts may occur at any age but are most prevalent during the 2nd, 3rd, and 4th decades of life. Women are affected three times as often as are men. Most investigators agree that ganglion cysts arise from modified synovial or mesenchymal cells at the synovial-capsular interface, in response to repetitive minor injury. Repetitive stretching of the capsular and ligamentous sup-
porting joint structures appears to stimulate the production of hyaluronic acid. Most cysts contain a highly viscous clear jellylike fluid. The viscosity of the fluid is attributed to a high concentration of hyaluronic acid and other mucopolysaccharides. The cyst wall consists mainly of collagen fibers and has no synovial lining. Adherence of ganglion cysts to arteries and nerves is frequent (Fig 23).

US and MR images demonstrate a cystic lesion with a hypervascularized thin and regular wall. Ganglia complicated by hemorrhage, trauma, or infection may have an atypical appearance on radiologic images (60–62).

A distinction should be made between a ganglion cyst and a synovial cyst because the two are treated differently. A synovial cyst in the hypothenar eminence is usually associated with pisotriquetral joint osteoarthritis, joint synovitis, or both, and the connection between the cyst and the pisotriquetral joint recess is clearly visible. A ganglion cyst, in contrast, is often the only visible lesion, with no joint alteration. A pedicle frequently connects a ganglion cyst of the hypothenar eminence with the pisotriquetral joint; however, because of its small caliber, it is sometimes overlooked (Fig 26). CT arthrography may be indicated to demonstrate a connection between the cyst and the pisotriquetral joint. However, the small size of the pedicle and the highly viscous fluid within the cyst may limit cyst enhancement after contrast medium injection. Delayed CT arthrography may be valuable for detection of such a connection (63).

Schwannoma

Schwannomas are rare in the upper extremities; they account for only 5% of soft-tissue tumors of the arm (64). Patients often present with a slow-growing mass. Pain and neurologic symptoms are uncommon. Clinical misdiagnosis may occur because symptoms and signs, including tingling sensations, local tenderness, and the Tinel sign, are not distinctive. In fact, neurologic symptoms do not seem to be related to the size of the tumor but appear to depend on the caliber of the nerve canal and the degree of compression, especially in cases of Guyon canal involvement (65).

Schwannomas of the hand are easily detected with US, but MR imaging is often needed to characterize these lesions. It is difficult to distinguish between a schwannoma and a neurofibroma because both appear isointense on T1-weighted images and slightly heterogeneous and hyperintense on T2-weighted images. Distinctive features that are suggestive of a neurogenic tumor include a location in the region of the ulnar nerve, depiction of the nerve entering or exiting the mass, a fascicular appearance on T2-weighted images, a target sign on T2-weighted images, and central enhancement (Fig 27). Schwannomas of the hand...
and wrist may be mistaken for ganglion cysts because they are well encapsulated and occasionally exhibit cystic changes (65).

**Vascular Lesions**

Hemangioma is the most frequently encountered vascular soft-tissue abnormality (66). Other vascular lesions are very uncommon in the hypothenar eminence. It is estimated that hemangiomas account for 7% of benign soft-tissue tumors. Hemangiomas may be classified as either infantile hemangiomas or vascular malformations. Vascular malformations can be further categorized as either high-flow (arteriovenous) or low-flow (capillary, cavernous, venous, or mixed) vascular lesions. MR imaging is useful for characterizing and determining the extent of vascular lesions. The combination of MR imaging and MR angiography allows differentiation between high- and low-flow lesions. CT angiography is another good technique for determining the architecture of a vascular lesion (66,67).

Most vascular lesions of the hand are low-flow venous malformations. Radiographs often demonstrate calcifications (phleboliths). MR imaging is the best technique for diagnosis and characterization of these vascular lesions, and the extent of a lesion is best determined on T2-weighted images. The lesions appear as multiple high-signal-intensity lobules that resemble a bunch of grapes. In some cases, phleboliths, fibrous tissue, and areas of thrombosis may be depicted as round low-signal-intensity structures within the lesions on T2-weighted images; however, they may be overlooked at MR imaging, and phleboliths are better depicted with CT. Fatty tissue also may be identified within the lesions. MR angiography and multiphase CT highlight cystic vascular spaces with a gradual increase in enhancement (Figs 28, 29).
High-flow vascular malformations are less frequently observed than are low-flow lesions. CT angiography and MR angiography depict prominent serpentine arteries that feed the lesion, high-flow vascular spaces, and numerous veins that drain the malformation (Fig 30).

**Lipoma**

Lipoma is the most common soft-tissue neoplasm, accounting for almost 50% of soft-tissue tumors (68). Lipomas are much more frequent than liposarcomas (estimated frequency ratio, 100:1) (64,68). They may be located subcutaneously (superficial lipomas), within the muscle, or in the deep spaces of the hand (deep lipomas). Lipoma of the Guyon canal is a rare cause of ulnar neuropathy (41,69–71). Lipomas in the Guyon canal are elongated and assume the shape of the canal. They may extend 7 cm along the long axis (64). Superficial and intramuscular lipomas are manifested as soft, nontender, slow-growing masses. The US appearance of a lipoma is that of a hyperechoic mass. MR images show a homogeneous fatty tumor with no septa or with very thin septa (less than 2 mm thick) (Fig 31). Enhancement of the fibrous capsule at gadolinium-enhanced MR imaging occurs in some cases but generally is absent (68).
Osteoid Osteoma

Osteoid osteomas of carpal bones are often misdiagnosed because the clinical symptoms are confusing (72,73). Imaging techniques also may be inaccurate because of the very small size of a nidus. Three-phase technetium 99m bone scintigraphy could be useful for assessing a pathologic condition of the bone. However, both CT and MR imaging also may be needed to achieve the final diagnosis: MR imaging depicts bone marrow edema, whereas CT depicts the nidus more clearly (Fig 32).

Conclusions

Pathologic conditions of the hypothenar eminence are frequent but often are misdiagnosed. Specific radiographic views such as the semisupinated oblique view and the radially deviated, thumb-abducted lateral radiographic view are often sufficient to reach a diagnosis of acute fracture of the hamulus or pisiform bone. Multidetector CT angiography is very efficient for the diagnosis of hypothenar hammer syndrome, and multidetector CT arthrography with puncture of the pisotriquetral joint is well suited for the evaluation of this joint. MR imaging is the modality of choice for evaluating the ulnar nerve.

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References


Pathologic Conditions of the Hypothenar Eminence: Evaluation with Multidetector CT and MR Imaging

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The Guyon canal comprises three zones that are defined by the ulnar nerve bifurcation. Zone 1 is the area proximal to the bifurcation of the nerve, zone 2 encompasses the deep (motor) branch of the bifurcated nerve, and zone 3 encompasses the superficial branch of the bifurcated nerve.

Variations in the termination of the radial artery and ulnar artery are common, although there is always a significant anastomosis between these two arteries.

Since the prevalence of anomalous muscles in the Guyon canal is high, care must be taken in defining their role in the etiology of ulnar nerve compression.

In cases of palmar displacement of the pisiform bone, the lateral and semisupinated oblique views show a widening of the pisotriquetral space by more than 4 mm.

Injection of a local anesthetic or corticosteroid, combined with the acquisition of a semisupinated oblique radiograph, enables the diagnosis of pisotriquetral joint dysfunction.