The elbow is a complex joint. It links the shoulder and the hand, enhances the flexibility of hand motion, and transmits generated forces. The most common elbow injuries are related to chronic overuse, although the joint is vulnerable to acute trauma as well. It may also be affected by disease or infection.

MRI has become the secondary procedure of choice, after plain-film x-ray, for evaluating elbow abnormalities. The modality can visualize ligament and tendon injuries, compressive or entrapment neuropathy, bone injuries, inflammatory and synovial conditions, and soft-tissue masses. Congenital abnormalities in the elbow are rare. The most common is radial head dislocation, which may affect one or both elbows. Another congenital anomaly is synostosis, or osseous fusion of tubular bones between the proximal portions of the radius and ulna. Fusion may be complete or fibrous, and it may limit forearm supination. Synostosis is often bilateral and may be accompanied by other anomalies. MRI is rarely used in such cases, but it may be applied to evaluate the relation between soft tissues and osseous structures.

Infections to the elbow are most often due to Staphylococcus aureus. Osteomyelitis, for example, results from hematogenous spread of bacteria or bacterial spread from surrounding tissues. The thinness of the soft-tissue layer covering the elbow means that osteomyelitis is commonly caused by direct inoculation from an open fracture or surgery. Other causes of elbow infection include septic arthritis, septic olecranon bursitis, and pyomyositis. Infection may appear as areas of cortical interruption or periostitis. Its extension into surrounding soft tissues may result in cellulitis, abscess, phlegmon, and sinus tract formation.

MRI is useful for diagnosing or excluding osteomyelitis and evaluating its extent. It can also help determine the location and size of abscesses and identify areas of phlegmonous or necrotic tissue that may need surgical management.

Bone tumors are not common in the elbow, and those that do occur are more often benign than malignant. It is extremely important to obtain plain-film x-rays prior to MRI so that suspected tumors can be diagnosed and characterized. MRI is indicated whenever the tumor appears aggressive, has a soft-tissue component, is not clearly seen on x-ray, or requires further anatomic delineation. Intravenous contrast is often helpful but not always necessary. Some benign osseous tumors (e.g., osteoid osteoma, osteochondroma, and enchondroma) have a characteristic appearance on MRI. Other benign tumors found relatively frequently in the elbow are chondroblastoma, fibrous dysplasia (Figure 1), giant cell tumor, aneurysmal bone cyst, and unicameral bone cyst.

Primary malignant osseous tumors are very rare in the elbow. Plain-film x-ray should always be obtained first. MRI is particularly useful for defining tumor extent and also helps in tumor staging, which can affect prognosis and therapy. Many malignant elbow tumors are metastases, though this is not a common site for them. Primary cancers that frequently metastasize to bone include melanoma and lung, breast, and kidney cancers. MRI is not generally indicated for evaluating a known elbow fracture. Unsuspected fracture or contusion, however, may be demonstrated in patients with elbow pain following trauma. Osteochondritis dissecans of the elbow usually affects the capitellum. This condition, which often occurs in adolescents and may be asymptomatic in its early stages, can be related to repetitive trauma. Osteochondritis dissecans primarily affects subchondral bone. The underlying articular cartilage surface is initially preserved, but necrosis and softening of subchondral bone secondary to fracture may cause the articular cartilage to separate. This injury eventually leads to osteoarthritis in more than 50% of patients.
Osteochondritis dissecans can be mistaken on MRI for a pseudodefect of the capitellum that is related to the normal anatomy of radiocapitellar articulation. It should also be distinguished from the osteochondrosis known as Panner's disease, which occurs in boys aged four to 10 years old. Imaging findings of Panner's disease are similar to those of avascular necrosis of the femoral head. Osteochondral lesions appear as well-defined focal areas of abnormal marrow signal intensity in the subchondral bone, particularly in the capitellum. Osteonecrosis is relatively rare in the elbow, but it can occur, most often in the capitellum. The condition is caused by repetitive stress and/or microtrauma in children. Additional triggers in adult patients include immunocompromise and use of corticosteroids, alcohol, and tobacco. Adults can acquire stress fractures of the olecranon, which are usually associated with throwing activities such as pitching. MRI is highly accurate in diagnosing stress fractures that are occult or equivocal on x-ray.

**LIGAMENTS, NERVES, TENDONS**

The elbow is stabilized by the medial (ulnar) and lateral (radial) collateral ligaments. The medial collateral ligament, extending from the medial humeral epicondyle to the coronoid process of the ulna, is the most important of the two. It has three portions, the largest and most important being the anterior band. The lateral collateral ligament is a less robust structure that extends from the lateral epicondyle to the annular ligament. Clinical evaluation of collateral ligament injuries involving pain and subjective instability can be difficult. Although radiography does not show ligaments directly, x-rays should be obtained to rule out soft-tissue and bone abnormalities in the joint space. Partial or complete ligament tears can be demonstrated easily on MRI. Collateral ligament injuries will show ligament thickening or thinning, high-signal edema and/or hemorrhage around the ligament, ligament waviness or laxity, and ligament discontinuity.

Medial collateral ligament lesions often occur with valgus stress in throwing sports. Acute tears to this ligament can occur together with elbow dislocations due to joint hyperextension. Lateral collateral ligament injuries are rare, but they may occur in association with elbow dislocations or fractures. MRI can visualize associated capsular and annular ligament tears (Figure 2). The major nerves (ulnar, radial, and median) are each subject to various entrapment and compression neuropathies specific to their particular anatomic locations and dynamic forces at the elbow. Prior to MRI, physicians relied principally on clinical findings and electromyography to assess neurologic disease. Now MRI can determine the exact location of compression, visualize loose bodies, and exclude soft-tissue masses such as ganglion, lipoma, hematoma, inflammatory pannus, osteophytes, ectopic calcification, and ossification.

The ulnar nerve is injured more frequently than the other two, due to its position within the fibro-osseous tunnel posterior to the medial humeral epicondyle. MRI will show an entrapped ulnar nerve to be thickened within and above the tunnel, tapering more distally. An absent arcuate ligament allows subluxation of the ulnar nerve in some cases. Resulting friction against the medial epicondyle can lead to neuritis. The instability, which usually occurs during arm flexion, may also be asymptomatic.

The radial nerve and its branches are at risk from direct trauma to the elbow or pressure from a space-occupying mass such as a ganglion or lipoma. The median nerve is also at risk from external or internal compression (Figure 3), most often from a soft-tissue mass. T2-weighted images are useful for assessing edema and signal intensity changes within and around the nerves and for accentuating soft-tissue masses that have displaced them.

Changes to muscles affected by neuropathy can be seen on MRI as well. Muscular edema is the most significant sign of neuropathy, though it is not specific. Edema has also been associated with intense muscular exertion or intramuscular hemorrhage, tumors, polymyositis, acute inflammation or infection, effects of ionizing radiation, and rhabdomyolysis. Muscle atrophy can be observed as muscular edema in the acute/subacute stage of neuropathy. A decrease in muscle diameter is seen from day 21 onwards following denervation. Irreversible fatty changes are seen in patients with chronic neuropathy that has lasted more than six months. MRI can additionally depict changes to both the common flexor and common extensor tendons. The spectrum of pathologic changes is the same regardless of whether the medial or lateral side is involved, the latter (tennis elbow) being more common. The appearances of lateral and medial epicondylitis on MRI are similar.

Tendinosis is a degenerative process. Its least severe manifestation is demonstrated as normal to increased tendon thickness with intermediate signal intensity on T1-weighted MRI. Ligaments are seen with either intermediate to low signal intensity, resulting from fibroplastic proliferation, or high signal intensity, owing to fibrovascular proliferation and mucoid degeneration. Partial tears are
seen on T2-weighted MRI as tendon thinning with high signal intensity. A complete tear is usually caused by a tendon failing within a region of mucoid degeneration. This is seen as tendon disruption and discontinuity, and it is best appreciated on T2-weighted images. Injuries to the elbow's muscles are common, and these can be detected and characterized on MRI. Distal biceps tendon has been reported with increased frequency since the introduction of MRI. Injury is typically due to an acute traumatic event with forced elbow hyperextension in midflexion. This results in complete avulsion of the tendon from its insertion in the radial tuberosity (Figure 4). Partial tendon tears and myotendinous junction tears are much less common.\(^1\)

MRI can help determine the location and degree of tendon injury as well as the amount of tendon retraction. Sagittal images are optimal for determining the size of the gap. An axial image should be obtained from the myotendinous junction through the radial tuberosity. Radial bicipital bursitis sometimes appears on T2-weighted MRI as a high-signal fluid collection interposed between the distal biceps tendon and radial tuberosity. Rupture and partial tear of the triceps tendon are rare.\(^14\)

SYNOVIAL AND SOFT-TISSUE ABNORMALITIES

Synovial proliferation may accompany a variety of disease processes, including rheumatoid arthritis, septic arthritis, neuropathic osteoarthropathy, crystal deposition disorders, pigmented villonodular synovitis, and idiopathic synovial osteochondromatosis (Figure 5). Effusion is common with all of these diseases. It is recognized easily on T2-weighted spin-echo MRI as fluid with high signal intensity.\(^15\)

Rheumatoid arthritis and other synovial inflammatory disorders lead to proliferation of the synovial membrane and fluid accumulation. Capsular distention or rupture and synovial cyst formation may also be seen. Altered dynamics at the proximal radioulnar joint and elbow may contribute to the production of cysts, and these may be an early sign of disease. Signal intensity characteristics of the abnormal synovium and fluid are similar on standard MRI sequences. Inflammatory tissue enhances if gadolinium contrast is administered.\(^16\)

Idiopathic synovial osteochondromatosis, related to metaplasia of the synovial lining, is accompanied by synovial proliferation and formation of intrasynovial cartilage nodules. These may calcify, ossify, or become free within the joint cavity and later embed in a distant synovial site.\(^17\) Ganglion cysts and bursitis (olecranon and biceps tendon bursitis) are common around the elbow. Intra-articular osteocartilaginous loose bodies are usually found in association with osteochondritis dissecans, osteochondral fractures, and synovial osteochondromatosis. Trauma is the most common reason for the elbow's articular surface to disintegrate. Free bodies tend to migrate to the olecranon and coronoid fossa.\(^17\)

Soft-tissue tumors are not common in the elbow. Those that do occur can affect a large number of the joint's significant structures.\(^18\) Soft-tissue masses are difficult to evaluate on plain-film x-ray, making MRI an essential tool for assessing these pathologies. Multiplanar imaging enables unequaled soft-tissue discrimination and precise definition of local tumor extent. Although MRI is often nonspecific for tumors, the modality can characterize some soft-tissue lesions. These include common benign lipoma (Figure 6), and vascular hemangioma. The value of MRI in differentiating benign and malignant soft-tissue tumors nonetheless remains controversial.\(^19\)

The prognosis and treatment of malignant tumors is influenced by their location and extent as well as their histological grade. These criteria form the basis of musculoskeletal tumor staging. MRI should be performed prior to biopsy, as postbiopsy images may be affected by anatomic distortion and heterogeneous signal intensity caused by hemorrhage, inflammation, and edema.\(^20\) MRI is used after surgery, radiation therapy, and chemotherapy, however, to check for residual tumor, disease recurrence, and healing. Differentiation between recurrent tumor and postoperative changes can be difficult, especially because obliteration of soft-tissue planes, scarring, hemorrhage, or infection may occur postoperatively.

In addition to its use in evaluating injury, disease, and infection of the elbow, MRI can help clarify diagnostic doubts raised by x-ray and CT. This could include evaluation of an implant site and/or checking for osteointegration in patients with nonmetallic prostheses (Figure 7) or checking whether a resorbable screw remained in the elbow.

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