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Review Article

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Magnetic Resonance Arthrography of the Elbow: A Narrative Review

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Abstract

Magnetic Resonance Arthrography (MRA) is an advanced imaging modality to investigate elbow disorders. Its excellent contrast resolution enables the evaluation of elbow anatomy in particular capsule and ligaments. Magnetic Resonance Arthrography add further information about intra-articular pathology, compared to standard MR. The main applications of MRA of the elbow are the evaluation of capsule, ligaments, loose bodies and osteochondral lesions in both the settings of acute trauma, degenerative changes, and chronic injury due to repeated microtrauma and overuse. In this review, we discuss the normal anatomic findings, technical approach for image acquisition, and the main pathologic findings that can be encountered in MRA of the elbow. Intra articular injection modality both with fluoroscopy and ultrasound guidance and appropriate contrast medium selection will be widely discussed

Keywords: Elbow arthrography; Magnetic Resonance Arthrography; Intra-articular injection; Magnetic resonance imaging; Elbow anatomy; Osteochondritis dissecans; Ulnar collateral ligament tear; Osteochondritis dissecans; Radiocapitellar approach; Transtriceps approach. Fluoroscopy; Ultrasound guidance.

Introduction

Magnetic Resonance Arthrography (MRA) was first introduced in 1987, and, over the past decades, it has gained recognition as a highly accurate modality for evaluating intra-articular structures, including the elbow joint. It extends the capabilities of conventional MR because contrast solution distends the joint capsule, outlines intraarticular structures, and leaks into abnormalities [1, 2, 3, 4].

Although MRA introduces a level of invasiveness to an otherwise non-invasive imaging modality, its advantages are substantial. Advances in MRI technology in recent years - including higher field strengths (1.5-3T MRI), optimized imaging sequences, and enhanced surface coils - have further improved image quality, enhancing the sensitivity and specificity of MRA in detecting elbow joint abnormalities.

In response to the growing clinical utility of MRA, the Standards and Guidelines Committee of the Society of Skeletal Radiology (SSR) convened a dedicated panel to develop a comprehensive white paper [3]. This ad hoc panel, composed of twelve SSR members recognized for their expertise in direct MRA, was charged with systematically reviewing the literature and formulating consensus-based recommendations on the application of direct MRA [3].

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This narrative review seeks to outline the current indications, applications, recent advancements, and future directions of MRA as an imaging modality [3, 4].

Clinical indications for magnetic resonance arthrography of the elbow

Direct arthroscopy is seldom utilized as a first-line diagnostic approach, given the high diagnostic accuracy of MRA and CT arthrography (CTA) in visualizing key pathologic findings [5, 6, 7].

Direct MRA offers improved diagnostic accuracy over conventional MRI for detecting and grading cartilage, fibrocartilage or ligament injuries [2, 3, 5, 6, 8]. It offers improved sensitivity for detecting subtle partial-thickness ligament tears and early focal osteochondral lesions, often surpassing the capabilities of non-contrast MRI [2, 3, 5, 6, 8].

Direct MRA demonstrates superior sensitivity in detecting joint capsule injuries, synovial-based or adherent pathologies, and non-ossified or cartilaginous intra-articular bodies [2, 3, 5, 6, 8]. Despite these diagnostic advantages, MRA comprises only about 5% of all musculoskeletal MR imaging, with its use more prevalent in orthopedic-specialized centers. Among joint-specific applications, elbow MRA is performed less frequently than shoulder or hip MRA [2, 3, 5, 6, 8].

One key advantage of MRA over CTA is the absence of ionizing radiation, making MRA a preferred choice, particularly for younger patients. However, CTA may excel in detecting small or low-grade cartilage lesions.

In case of joint effusion, typically in the first two weeks after a traumatic event, MRA may be unnecessary, as the intra-articular fluid serves as an effective intrinsic contrast agent on fluid-sensitive sequences [4, 6, 8].

Indication for Mra in Diagnosing Elbow Pathologies

Posterolateral Rotatory Instability

Posterolateral rotatory instability (PLRI) is the most common pattern of recurrent elbow instability (Figure 1). The typical mechanism of injury is a fall with the hand extended and the shoulder abducted. Chronic medial instability can be caused by trauma or overuse [7].

Conventional MRI provides high accuracy and direct visualization of the radial collateral ligament (RCL) complex, comprising the radial collateral ligament (RCL), the lateral ulnar collateral ligament (LUCL), the annular ligament and meniscus [4, 9].

Radial and ulnar collateral ligaments are thickenings of the joint capsule that can degenerate and tear with or without injury to the overlying flexor or extensor tendons. Radial collateral ligament complex is weaker and thinner than the UCL complex, it provides varus stability and is rarely stressed in athletes [4].

The LUCL, prone to injury from elbow dislocation, can be effectively evaluated using MRA, with contrast extravasation indicating ligament tears [4]. Most tears of the LUCL occur at the humeral attachment.

Unsuspected ruptures of the RCL may also be accompanied by tears of the common extensor tendon (Figure 2) and the meniscus (Figure 2, 3).

Magnetic resonance arthrography has shown to be more accurate in the detection of full-thickness extensor tendon and full-thickness RCL tears compared to conventional MRI [10]: RCL tears are challenging to detect on conventional MRI due to the oblique course of the ligament and its relatively small size compared to the UCL.

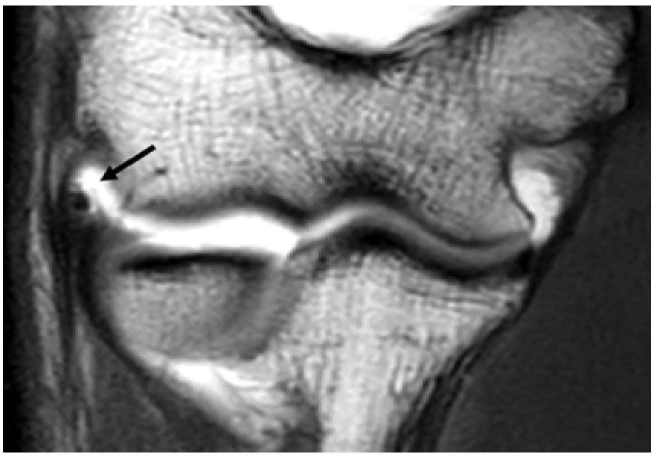

Figure 1: Coronal T1-weighted image: complete tear of the proper radial collateral ligament with intact common extensor tendon insertion.

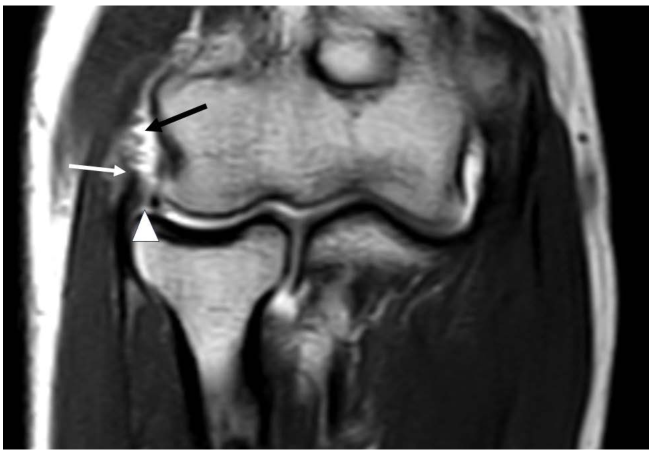

Figure 2: Coronal T1-weighted image: complete tear of the RCL (white arrow), complete tear of the meniscus homologous (arrowhead) and torn insertion of the common extensor tendon (black arrow).

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Furthermore, MRA has shown to be more accurate in distinguishing scar tissue formed around a previous tendon or ligamentous tear compared to conventional MRI (Figure 3, 4).

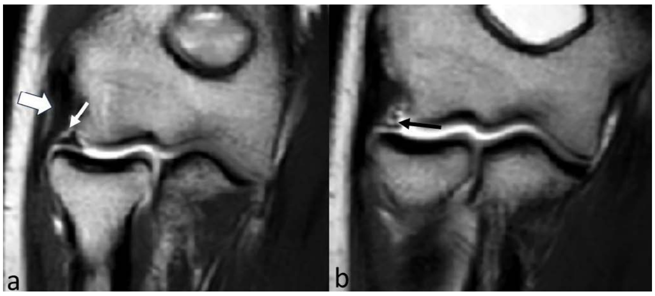

Figure 3: Coronal T1-weighted images: RCL fibrous thickening (white big arrow) and meniscus homologous tear (white arrow in "a" and black arrow in "b").

Figure 4: Coronal T1-weighted image: hypointense fibrous thickening of the proper radial collateral ligament (arrows).

Ulnar Collateral Ligament (UCL) Injury and Valgus Instability (Thrower's Elbow)

Medial joint pain represents the most frequent indication for MRA of the elbow, particularly in overhand athletes [6].

Continue overuse and repetitive value force may lead to weakening and laxity of the UCL and eventually to complete ligamentous detachment or rupture [1, 11, 12].

The UCL complex consists of three parts: the anterior, posterior, and transverse bundles. The major ligament is the anterior oblique bundle, which is taut with extension and inserts on the ulna along the medial aspect of the coronoid process (sublime tubercle). The insertion on the sublime tubercle is tight, and there should be little or no contrast material or fluid between the ligament and the sublime tubercle [4, 11, 13]. The anterior bundle is a cord-like structure 27 mm in mean length and 4–5 mm in mean width [14]. The anterior bundle can be anatomically distinguished from the anterior portion of the medial joint capsule [14].

A layer of synovium separates the anterior bundle from the more superficial tendon of the flexor digitorum superficialis muscle. There is variability in the distal insertion of the anterior bundle, and this suggests that caution should be exercised in the diagnosis of its partial detachment from the sublime tubercle of the ulna [14].

Direct MRA is useful in documenting the presence and severity of injury to the anterior bundle of the UCL in throwing athletes [13, 14], especially for undersurface partial-thickness tears in the anterior bundle of the UCL, critical for stabilizing against valgus forces [3] (Figure 5, 6).

Figure 5: Coronal PD-fs image: same patient as figure 8. Fibrous thickening of the anterior bundle (arrow) of the UCL without tears.

Figure 6: Coronal T1-weighted image: complete disruption of the anterior bundle of the UCL (arrow).

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Osseous abnormalities were seen more frequently in younger athletes, although evidence of chronic avulsion injury was seen in the older age [15]. Proximal UCL tears detection can be challenging and combining MRA with stress ultrasound may enhance diagnostic accuracy [3].

UCL Reconstruction

In the setting of UCL injury with complete tears, ligament reconstruction is the principal surgical procedure available to restore stability and function and to relieve pain with activity. Patients returning to a high level of activity after UCL reconstruction can experience postoperative symptoms.

Postoperative MRA can evaluate the integrity of the transposed UCL and adjacent stabilizing structures, with contrast indicating potential pathologic changes and diagnosing persistent joint laxity and the presence of abnormal ossification [3, 12, 16].

A study shows that the normal intact UCL graft can have a variable appearance. In comparison with the native UCL, the graft can appear thickened. This is not unexpected because these were double bundle grafts and the native ligament is sutured, not excised. Although the graft may be thickened, it should be taut. If the graft appears wavy, it may be torn or may not be providing adequate stability, particularly in flexion. The proximal attachment of the thickened and heterogeneous graft is much broader than the native UCL. Hence, common flexor pathology can be confused with proximal graft pathology [16]. In few cases, contrast material extended between the distal reconstructed UCL and the sublime tubercle in grafts, not to be confused with the well-recognized sign of partial distal tear of the native UCL (the "T-sign"). This suggests that this false T-sign does not carry the same significance in the setting of reconstruction [16]. Degeneration of the graft is evidenced by diffuse intermediate signal within an enlarged graft on T1 weighted imaging. On T2-weighted imaging, there is mild hyperintensity and thickening of the graft. These signal characteristics may generate difficulties in discerning between graft degeneration and normal grafts that contain nonspecific intermediate signal [16].

Plica

Direct MRA can be useful in evaluating elbow plica, synovial fold remnants that may become inflamed with repetitive trauma [3]. No direct comparative studies have been conducted between conventional MRI and MRA for plica evaluation, but it is best visualized in the presence of joint effusion or using arthrography [3].

Osteochondral Injuries and Osteochondritis Dissecans (OCD)

Excessive valgus stresses across the elbow cause infractions and infarction of subchondral bone with preservation of articular cartilage. Continued microtrauma may cause progressive bony necrosis and softening, resulting in separation of articular cartilage and secondary chondral injury. Untreated osteochondritis dissecans may result in osteoarthritis, intraarticular loose bodies, and locking (Figure 7, 8, 9) [11, 17].

Osteochondral lesions of the elbow usually occur on the anterior aspect of the humeral condyle and occur more frequently in young athletes owing to mechanical overload with valgus stress [3, 6, 7, 8].

Differentiating between stable and unstable non-displaced in-situ fragments is essential for surgical planning. Instability is confirmed when fluid in MR or contrast media in MRA are observed along the entire interface between the fragment and underlying bone.

Figure 7: Coronal T1-weighted image: stable osteochondral lesion of the capitulum humeri. To note how the fragment (arrow) is not displaced and there is no penetration of contrast media between the fragment and the subchondral bone.

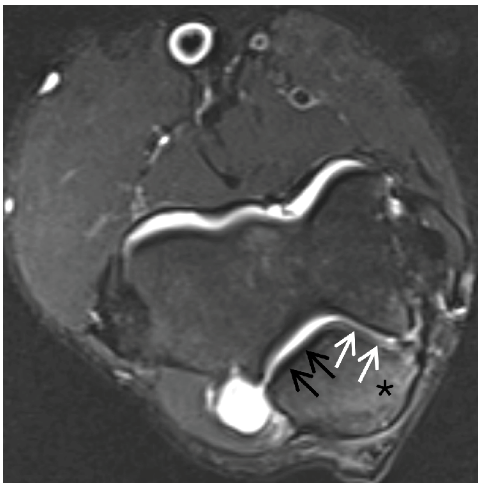

Figure 8: Axial PD-fs image: trochlear chondropathy with asymmetry of the medial (white arrows) compared to the lateral facet (black arrows), with reactive oedema of the subchondral bone (*).

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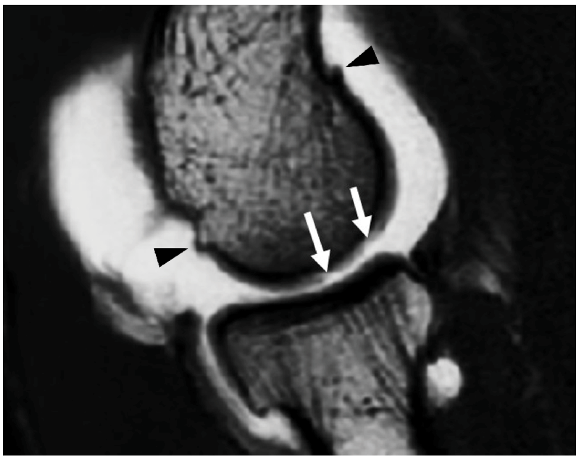

Figure 9: Sagittal T1-weighted image: erosive chondropathy of the capitulum humeri: to note tiny irregularities of the cartilage surface (withe arrows) and small osteophytes (black arrowheads).

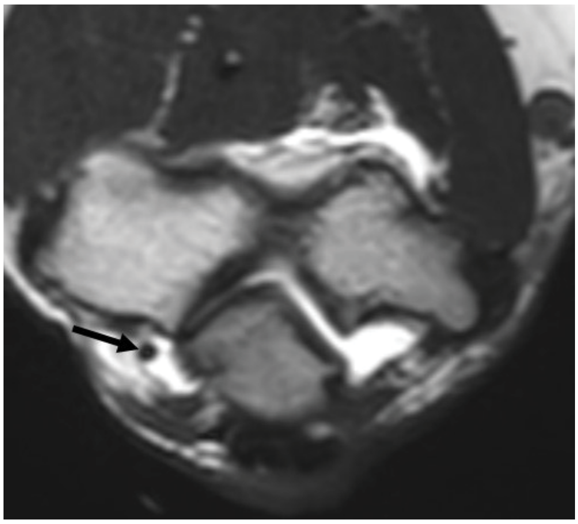

Figure 10: Axial T1-weighted image: intra-articular loose body in the postero-medial capsular recess (black arrow).

Differentiating between stable and unstable non-displaced in-situ fragments is essential for surgical planning. Instability is confirmed when fluid in MR or contrast media in MRA are observed along the entire interface between the fragment and underlying bone.

Post-Operative Evaluation of Chondral and Osteochondral Abnormalities

Various techniques are available for the restoration of chondral and osteochondral injuries, including marrow stimulation, osteochondral transplantation (either autologous or allogeneic), autologous chondrocyte implantation, and implantation of allogeneic particulate cartilage fragments [3]. Direct MRA can be a valuable tool for visualizing defects at the cartilage interface following repair and assessing the graft-to-host bone junction in osteochondral repairs [3].

Intra-Articular Bodies

Intra-articular bodies may develop in the absence of prior injury, often leading to restricted range of motion, pain, mechanical catching, or joint locking. Imaging plays a crucial role in confirming the diagnosis and facilitating surgical planning. While ossified intra-articular bodies can be detected through radiography, this modality is frequently insufficient for comprehensive assessment [2, 3, 5, 6, 8]. Conventional MRI is generally effective in identifying intra-articular bodies, particularly in the presence of joint effusion [3]. However, direct MRA may offer added sensitivity for detecting smaller intra-articular bodies (Figure 10) [17].

Imaging Technique and Technical Considerations

Patient positioning

The patient may be positioned either in the prone position with the elbow extended overhead (referred to as the "Superman" position) or in the supine position with the elbow extended along the body. Imaging is performed in axial, coronal, and sagittal planes. For coronal acquisitions, a reference plane intersecting the medial and lateral humeral epicondyles is used, while sagittal images are obtained from the plane perpendicular to the coronal plane [5, 6].

The "Superman" position is advantageous for larger patients or when using scanners that do not support off-center imaging. However the prone position can be relatively uncomfortable for the patient, which may increase motion during the examination. The significant forearm pronation and radioulnar joint rotation associated with this positioning may complicate the evaluation of the collateral ligaments and the common flexor and extensor tendons in the coronal plane [3, 5].

Alternatively, the patient may lie in the supine position, with the arm resting in the anatomic position by the patient's side. The elbow is positioned at the periphery of the magnetic field, outside the isocenter of the magnet, resulting in a reduced signal-to-noise ratio and diminished effectiveness of spectral fat saturation techniques. However, this supine position is more comfortable for the patient, it minimizes forearm rotation and proximal radioulnar joint rotation relative to the distal humerus, thereby optimizing the visualization of the collateral ligaments and the common flexor and extensor tendons in the coronal plane [3, 5].

Coils

When available, dedicated extremity coils should be used, however, several types of coils can be used for imaging the elbow. For smaller adults and children, a wrist coil can be employed when a large field of view is not required. Larger patients can be imaged with a flexible coil, anterior neck coil, shoulder coil, or knee coil [1, 3, 5].

Sequence Protocols

Image acquisition should be performed within 15-30 minutes of arthrography to minimize the absorption of contrast solution and loss of capsular distension (Figure 11). Different field strengths can be used with 1.5 T being the most common, but also low-field MRI (0.2T, 0.4T) with dedicated coils can lead to optimal image quality. Some authors have explored the possibility to perform MRA with low-field systems leading to similar results when compared to 1.5T scanners [18]. Another advantage of low-field scanner is that the patient can lie more comfortably in supine position with the elbow perfectly in the isocenter of the magnet.

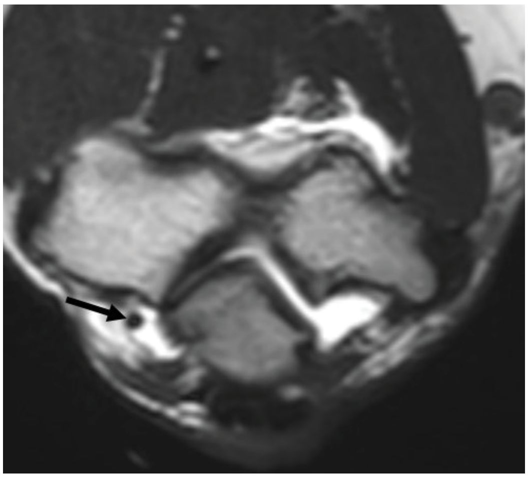

Figure 10: Axial T1-weighted image: intra-articular loose body in the postero-medial capsular recess (black arrow).

All sequences are performed with a field of view between 12 and 14 cm and a matrix of either 256x192 pixels or 256x256 pixels [5]. The transverse sequences should cover at least 5 cm both proximally and distally from the humeroradial joint, ensuring the biceps tendon attachment at the radial tuberosity is not missed [2].

The exact sequences used for routine imaging of the elbow can vary widely across institutions (Table 1) [5].

Fat-suppressed T1-weighted sequences are performed in

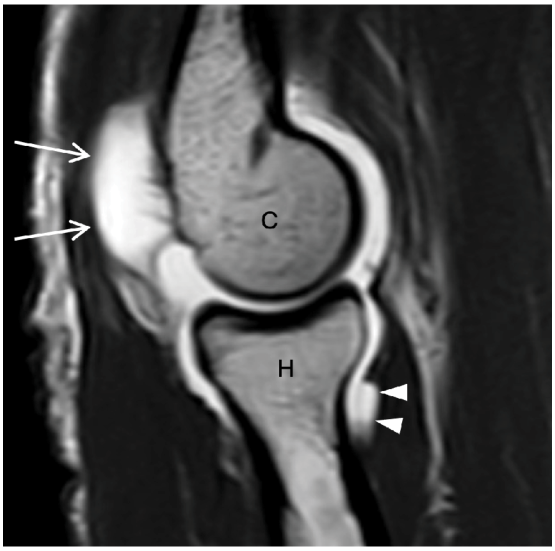

Figure 11: Sagittal T1-weighted image: huge posterior (arrows) and radial head (H, arrowheads) capsular recesses with minimal anterior dislocation of capitulum humeri (C) in a case of capsular laxity.

all three planes: axial, coronal, and sagittal. Some institutions suggest omitting T1 fat suppression in one or all planes to better evaluate the bone marrow and soft tissue fat planes [3].

Fluid-sensitive sequences, such as proton density or T2-weighted FSE/TSE with fat-suppression in at least one plane, are necessary for evaluating marrow signal abnormalities and soft tissue structures, particularly those involving extra-articular structures [3].

Three-dimensional gradient or FSE/TSE sequences with thinner slices can be added for multi-planar reformats, the latter being more sensitive [3, 6].

A STIR sequence can be used instead of fat-suppressed PD or T2-weighted FSE sequences, especially when imaging systems have poor chemical fat suppression. However, gadolinium signal may inadvertently be nulled in some cases [5, 3].

Table 1: An example of MRA protocol. FOV: field of view; RT: repetition time; ET: echo time; NSA: number of signal averages.

Acquisition plane/ sequence	FOV (max.)	Thickness	RT (ms)	ET	Matrix (min.)	Pixel size	NSA
Axial T2	14 cm	3 mm	4000	80	256x256	0.8	1
Coronal T2	14 cm	3 mm	4000	80	256x256	0.8	1
Coronal T1	14 cm	3 mm	500	18	256x256	0.6	1
Axial T1	14 cm	3 mm	500	18	256x256	0.6	1
Sagittal T1	14 cm	3 mm	500	18	256x256	0.6	1
Coronal PD-fs	14 cm	3 mm	4000	10	256x256	0.8	1
Axial PD-fs	14 cm	3 mm	4000	10	256x256	0.8	1
Axial PD isotropic 3D (optional)	14 cm	0.9 mm	1000	26	256x256	0.54	1.4

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The routine use of gradient-echo sequences for imaging the elbow is debated: T2*-weighted gradient-echo sequences are very sensitive to magnetic susceptibility changes, so they should not be used in patients with prior elbow surgery [5].

Metal Artifact Reduction

Metal artifact reduction techniques, including high receiver bandwidth, view angle tilting, and multi-spectral imaging techniques, may be applied to any pulse sequence. If spectral fat-suppression fails due to non-isocentric positioning or the presence of metallic implants, T1-weighted sequences may be performed without fat-suppression, or dixon techniques may be used [3].

Complications and Pitfalls

Complications can arise from improper arthrographic techniques. One common issue is the injection of gadolinium-based contrast agents outside the optimal concentration range (0.7–3.4 mmol/L), which can result in lower signal strength of the injectate [4]. If the concentration is too low, standard fluid-sensitive sequences from conventional MRI protocols can salvage the exam.

Even a small amount of gas in the joint may simulate intra-articular bodies, leading to a misdiagnosis. Gas bubbles can be recognized by their tendency to migrate to the upper regions of the joint, whereas loose bodies tend to sink. If gas simulates pathology, re-imaging the patient in a prone position may help mobilize the gas to a different location [2, 3, 19].

If the injectate is entirely outside the joint, such as in a bursa, completing the MRI exam with a non-contrast protocol is recommended. It is best to inform the patient of this occurrence and, if agreeable, perform a repeat injection before finishing MRA. Alternatively, the patient can be asked to return for a repeat procedure [3].

Interruption of Exams

Occasionally, MRA exams may be interrupted due to MRI scanner failures, patient motion, or intolerance. In such cases, converting to CTA can be considered if iodinated contrast was included in the injectate [3]

Contrast Injection Technique

Image guidance in direct MRA is strongly recommended to improve the accuracy of injections, providing superior precision when compared to unguided (blind) techniques [3].

Ultrasound

When utilizing imaging modalities that involve radiation exposure, strict adherence to the "as low as reasonably achievable" (ALARA) principle is critical in minimizing the radiation dose to both the patient and the operator, thus ensuring safety during the procedure [3].

For ultrasound-guided injections, preprocedural scanning is used to plan the needle trajectory, identify the target site, and localize adjacent neurovascular structures and tendons to be avoided [20].

Once the intra-articular needle position is confirmed, the gadolinium-based contrast agent can be injected slowly [2]. The injected contrast can be easily visualized as it flows out of the needle and distends the joint capsule [21]. In the end, ultrasound guidance also helps avoiding damage to articular fibrocartilages (labra and menisci), and some practitioners report that this technique also results in less pain for patients [21].

Fluoroscopy

Under fluoroscopic guidance, optimal needle positioning is achieved when the needle can be inserted along the X-ray beam's direction without the need for tube angulation. Ideally, the needle tip should be superimposed over the needle hub in fluoroscopic images. Upon contacting bone, the needle is withdrawn slightly, and the injection is tested using an anesthetic agent.

Alternatively, gradual insertion of the needle can be performed while exerting gentle pressure on the anesthetic syringe plunger, with intra-articular placement confirmed upon feeling a decrease in resistance [3, 6, 8, 20].

The use of iodinated contrast material allows fluoroscopic visualization to ensure accurate intra-articular needle positioning. If no resistance is felt during the injection of local anesthetic, the needle position is confirmed by slowly injecting 1 mL of nonionic iodine-based contrast media, which is connected to the needle through a tube [2, 4, 21]. The contrast should flow freely, and the opacification of both the anterior and posterior recesses confirms adequate needle placement [2, 21].

Intra-Articular Injection approaches

Lateral Radiocapitellar Approach

This is the most commonly used approach for accessing the elbow joint, particularly favored due to the ease of radial head palpation and the reduced risk of introducing contrast into the frequently injured medial capsule [3, 20, 21, 22]. This approach targets the anterior half of the radiocapitellar joint in the humeroradial compartment. The patient is typically positioned prone on the table with the arm extended overhead, the hand pronated, and the elbow flexed at 90° [2, 3, 8, 20, 21]. In some cases, the patient may be seated next to the X-ray tube or ultrasound machine with the elbow flexed at 90° and in supination, with the thumb pointing toward the ceiling; however, the prone position is preferred to minimize the likelihood of vasovagal reactions [2, 6].

The radiocapitellar joint can be visualized under ultrasound guidance or fluoroscopy, and, in the second case, the injection target is marked on the skin [6]. The injection may

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be performed in the central area of the lateral compartment, just above the radial head, or via a postero-lateral approach, between the radial head, olecranon, and humerus. The latter approach has the advantage of avoiding the radial collateral ligament, thereby decreasing the risk of iatrogenic contrast leakage into the lateral compartment of the elbow, which could complicate the diagnosis [2, 3].

Posterior Transtriceps Approach

This approach is often preferred for its diagnostic benefits and reduced risk of complications. The positioning involves selecting a posterior needle entry, centered between the epicondyles and directed toward the olecranon fossa, which serves as a depth guide [3, 20]. To begin, the posterior fat pad superior to the olecranon is palpated, and the entry site is marked in line with the deepest aspect of the olecranon fossa under fluoroscopic or ultrasound guidance [20, 22]. Less than 1 cc of iodinated contrast is injected to confirm joint placement, ensuring visualization of joint opacification, in case of fluoroscopic guidance. In case of ultrasound guidance, the patient is laid supine with the flexed arm resting on the body; once the needle has been inserted, the gadolinium injection proceeds directly. Lidocaine is usually not necessary.

Recent studies found that the transtriceps approach is more comfortable for the patient, reduces extra-articular contrast leakage and decreases diagnostic uncertainty compared to the lateral approach [3, 22].

Posteromedial approach

The posteromedial approach is less commonly used but may be chosen when there are concerns about the lateral ligament complex. The patient is positioned supine with the shoulder abducted over the head and the elbow in approximately 30° of flexion and pronation. The medial epicondyle is identified, and the entry site is marked approximately 1 cm lateral to the epicondyle on the posterior aspect of the arm, minimizing the risk of injury to the ulnar nerve. The needle is directed anterolaterally toward the olecranon fossa, and the procedure proceeds similarly to the lateral approach [6].

Materials and preparation

As with any invasive procedure, written informed consent must be obtained prior to the injection. Sterile technique is used, including mask, sterile gloves, and sterile preparation [20].

A 20-to-25-gauge needle, approximately 4 cm in length, is recommended for the injection [2, 3, 6, 21]. Finest needles are used for the radiocapitellar approach.

To minimize the risk of air introduction into the joint, efforts should be made to reduce syringe exchanges, clear bubbles from extension tubing, and pre-fill the needle hub with the injectate before connecting it.

If resistance or excessive pain is encountered during injection, needle rotation may facilitate the penetration of the joint capsule.

In cases of ultrasound-guided injection, the accumulation of fluid around the tip of the needle or excessive pain suggests a periarticular location, and repositioning of the needle is necessary [3].

Upon confirmation of proper intra-articular placement, a variable combination of diluted gadolinium-based contrast, normal saline, iodinated contrast, and/or anesthetic is injected, depending on the type of guidance [3]. If an US guided approach is used, the iodinated contrast is not necessary. Volume management is crucial, as insufficient volume may limit joint distension, while excessive volume may lead to iatrogenic leakage. Studies indicate that the intra-articular capacity of the elbow joint averages 12 mL. However, a total volume of 7 to 10 mL of injected fluid is typically sufficient to adequately distend the joint capsule [2]. The recommended composition is 3 mL of iodinated contrast material and 7 mL of gadolinium in saline solution [3, 4].

Following the injection, the needle is removed, and a bandage is applied to the injection site.

Injected agents

Gadolinium-based contrast agents (GBCAs) are commonly preferred for direct MRA, although the saline-only technique is occasionally used due to its lower risk of contrast reactions and potential cost-saving benefits [3].

It is important to note that the intra-articular injection of GBCAs is not approved by the United States Food and Drug Administration (FDA) and is considered an off-label use [3]. Despite this, the small volume of gadolinium typically used in clinical practice for direct MRA is generally regarded as safe, although in vitro studies have shown mixed results regarding potential chondrotoxic effects on chondrocytes [3].

One preclinical study in rats detected gadolinium accumulation in joint tissues, bone marrow, and kidneys following intra-articular injections of both linear and macrocyclic GBCAs [3]. However, the clinical implications of this finding remain unclear. Notably, intracranial gadolinium deposition has not been observed following intra-articular administration at standard clinical doses, as demonstrated in both preclinical and clinical studies [3].

The preferred dilution may vary depending on the specific GBCA concentration (typically ranging from 0.25 to 1 mol/L, with 0.5 mol/L being the most common), and whether iodinated contrast material is included in the injectate [3].

The inclusion of iodinated contrast in the injectate facilitates real-time needle positioning confirmation during fluoroscopy-guided procedures and, when used in sufficient quantities (25–50% of the total injectate), enables conversion to CTA if needed [23].

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Intra-articular administration of iodinated contrast agents is FDA-approved and generally considered safe, though in vitro studies have suggested potential chondrotoxicity and transient increases in cartilage stiffness, which may elevate the risk of tissue damage during weightbearing [3].

Emerging preclinical evidence suggests that local anesthetics may have chondrotoxic effects [3]. As such, minimizing intra-articular anesthetic use or selecting less chondrotoxic options, such as ropivacaine, may be advisable [3].

Contraindications and Complications

The complication rate for intraarticular injections is low. The most frequently reported complications, including pain and bleeding at the injection site, are easily managed. More serious complications, such as septic arthritis, are exceedingly rare, occurring in fewer than 1 in 10,000 cases [20].

The primary contraindications for direct MRA include suspected peri-articular or intra-articular infection in which case the needle may carry infectious agents into a previously non-infected joint [20, 21]. In addition, intra-articular contrast material does not add diagnostic information in septic arthritis [21]. Early signs of synovitis may even be obscured in the presence of hyperintense intra articular contrast material. In septic arthritis, the typically present joint fluid serves as a natural contrast material. Intravenous injection of contrast medium is useful in the presence of soft tissue and joint infections, because even subtle synovitis may be demonstrated [21].

Anaphylactoid reactions, including urticaria, are rare, occurring in approximately 0.4% of cases, while severe anaphylaxis is exceedingly uncommon, with an incidence of 0.003% [3, 20].

The rate of vasovagal reactions closely aligns with the general arthrography complication rate of 1.4% [3, 20, 21]. Neurovascular complications, while extremely rare, remain a potential risk, particularly dependent on the needle trajectory and path [3, 20, 21].

Testing international normalized ratio (INR) is not routinely necessary since studies have shown that no bleeding complications occurred over many injections in patients continuing direct oral anticoagulants, antiplatelet or warfarin therapies [3, 20, 21]

Arthrography is painful in avascular necrosis, presumably due to the increased intra articular pressure caused by the injected contrast material, so it is preferred to avoid MRA in avascular necrosis, because there is little additional information after the injection of intra-articular contrast medium [21].

While these potential risks are minimal, they should be clearly communicated to patients as part of the informed consent process.

Conclusion

Magnetic Resonance Arthrography remains a foremost technique in musculoskeletal radiology. Through joint distension and enhanced spatial resolution, MRA provides delineation of structures and defects that might otherwise remain occult on conventional MR imaging. Generally, MRA improves diagnostic confidence and has proven especially beneficial in differentiating between full-thickness and partial-thickness tears, evaluating joints post-surgery, and assisting in pre-surgical planning.

However, MRA also has disadvantages. The overall examination time is longer, primarily due to the addition of a guided articular injection, but experienced hands can minimize the amount of injection time required. Furthermore, T1-weighted sequences provide additional time benefits, potentially reducing magnet time compared to conventional MR. While MRA converts a noninvasive examination into an invasive one, this invasiveness results in minimal morbidity and may be mitigated by considering alternatives, such as diagnostic arthroscopy, even if equivocal imaging study might ultimately result in the patient undergoing diagnostic arthroscopy.

The additional information gained from MRA can help clinicians determine which patients will require further surgical treatment and which can be managed conservatively. This determination is especially important in managing professional athletes and active individuals, where delays or errors in treatment can negatively affect their performance or lifestyle.

The introduction of an isotropic three-dimensional imaging technique has shown promise in the visualization of anatomy and pathologic conditions of the elbow, as well as cartilage quantification.

Future perspectives include performing MRA with low-field MR systems compared to high-field MRA as new low-field MR machines with dedicated coils have optimal image quality and can reduce patient discomfort (due to “superman” position or claustrophobia) thank to open magnet system, compared to conventional 1.5 or 3T MR.

Finally, we should prefer ultrasound guidance over fluoroscopy for intra-articular injection while avoiding unnecessary exposure to x-rays.

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