CT Arthrography (CTR)
It's not Always About the Magnet

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GENERAL PRINCIPLES

Introductory Comments: Direct MR arthrography (MRR) consists of MR imaging of a joint after injecting dilute gadolinium or straight saline into the joint. Over the last decade, this technique has become widely accepted for imaging numerous intraarticular disorders. Prior to that, CT arthrography (CTR) had been gaining steam as an improvement in imaging some joints over standard contrast arthrography and arthrotomography, in which planar tomograms are performed following standard arthrography. Advances in MRI without contrast, indirect MRR (MRI of a joint after intravenous administration of gadolinium), and ultrasound present additional options for non-surgical diagnosis of joint derangements. With all of these options, it can be difficult to know the best method to image a joint in various clinical scenarios. The purpose of this talk is to present the techniques for CTR, typical indications, strengths and weaknesses of the techniques, and several case examples. This accompanying document will augment the first three items above.

General Indications for CTR: Before I decided to give this talk the first time, I was under the assumption that CTR is primarily useful as a bailout for MR arthrography. While this remains a common reason for us to perform CTR, it turns out that CTR enjoys more widespread use in some centers, especially in Europe. CTR provides some advantages over MRI or MRR. Some studies have demonstrated equivalency or supremacy for CTR over MRI or MRR in diagnosing various entities. In the last few years, the development of helical scanners with multiple rows of detectors has resulted in much faster CT scan times, which has the added benefit of reduced motion, and the capability of isotropic or near isotropic voxels, which results in vastly improved detail on multiplanar reformatted images. Also, modern CT scanners with multiple detector rows using overlapping reconstructions reduce artifacts from metal that may be present in or near the joint.

When dealing with the issues of indications for CTR, the subject is complicated by several facts: technology is changing and advancing rapidly, for MRI, MRR, CT, and CTR—so at any one time a new advancement for one technique may obviate any previous research; many of the available comparison studies do not use current techniques or those preferred by practitioners at our or your facility—for example, some

CTR studies use double contrast. Also, machine availability may direct procedure choice at some institutions.

There are some basic concepts that are important to the discussion of indications. First, iodinated contrast used in CTR is FDA approved for joint injection, whereas gadolinium is not. Straight saline is an alternative to dilute gadolinium for MRR, but would not be expected to allow quite the same signal to noise because it requires T2-weighted imaging. Second, much of the power of CTR lies in the sub-millimeter resolution capability of current generation multi-detector scanners. Third, another powerful feature of CTR is the incredible contrast between calcium (cortex), soft tissues (such as hyaline cartilage), and the iodinated contrast material. With MRR, one may generate sequences that provide excellent contrast between gadolinium/saline and cartilage, but the delineation between cortex and cartilage/soft tissues often is quite indistinct. So CTR may often be superior in defining morphologic cartilage defects. This is one of the areas in which future advances in MR technology may change the playing field. Fourth, a powerful feature of MR is its ability to define differences between various types of soft tissue; that sort of soft tissue contrast is very limited with CT techniques. This may come into play if one is evaluating for alterations of cartilage without morphologic defects, for instance. Fifth, CTR will usually be a much quicker procedure. One or at most two volumes of data are sufficient to provide adequate multiplanar reformatted images tailored to the clinical question, and the individual scans are much quicker than MR sequences, reducing motion artifacts. Sixth, CTR and MRR bring on certain risks, such as ionizing radiation for the former and high strong magnetic fields for the latter. Seventh, CTR is better at defining calcified structures, such as the Bennett lesion in the posterior glenoid labrum of the shoulder and chondrocalcinosis.

With all of these considerations, at the University of Wisconsin, CT arthrography remains primarily a poor man's MRR. Our wait times for MR scanners are not sufficiently long for us to search for an alternative to MRR. So, our primary indications for CTR include:

- Patient scheduled for MRR, injected, but then cannot tolerate the magnet due to claustrophobia
- Patient requiring multiplanar cross sectional imaging of a joint with arthrogram effect, but with contraindications to MR scanning
- Evaluation of the postoperative joint with significant intra-articular metal (for instance, suture anchors in the shoulder)

Secondary indications for CTR include:

- Evaluation for hyaline cartilage defects
- Evaluation for calcified structures within the joint in addition to internal derangement

Within each specific joint discussed below, I will reference some of the recent published literature. These studies do not represent the sum of all scientific data on the subject but are meant to be a representation of the available information.

MR Arthrography Technique: Why talk about MRR in a presentation on CTR? Many of our patients that undergo CTR do so as a salvage imaging procedure. These are patients scheduled for MRR who get their joints injected for the scan but then cannot tolerate the scanner. Because they are screened prior to the injection, these patients do not have standard contraindications for MRI, but turn out to be claustrophobic and unable to enter the magnet. If one has injected an effective solution for MRR or CTR, then these patients can be fit into the CT schedule and appropriate images still obtained. Thus, it is important to include iodinated contrast as part of the joint injection if one has CT scanners alongside one's MR scanners.

To that end, our usual solution for MRR consists of one-half lidocaine 1% or ropivacaine 0.5 % (ropi for hip), one-quarter saline, and one-quarter nonionic iodinated contrast. Our iodinated contrast is 300 mg/ml. A tiny amount of gadolinium is then added to achieve roughly 1:200 dilution of gadolinium (1:100-1:250 is the published range). So, if we are drawing up a total of 20 ml in our syringe, it will consist of 10 ml lido/ropi, 5 ml saline, 5 ml iodinated contrast, and 0.1ml gadolinium. A 25% solution of iodinated contrast is not ideal for CTR; however, our experience and published data note that greater concentrations of iodinated contrast will negatively affect MRR images, especially above 1.5T. We believe our current contrast solution renders diagnostic images if CTR has to be employed as a bailout to failed MRR.

We typically inject the following quantities for each joint:

- Shoulder: 12-15 mL
- Elbow: 3-6 mL
- Wrist: 1-4 ml (DRUJ 1, mid-carpal 1-2, radiocarpal 4)
- Hip: 12-15ml
- Knee: 40ml
- Ankle: 2-5ml

Based on these numbers, one should draw up 20 ml total for all joints except the knee. For the knee, draw up 40 ml. That keeps the math simple.

CT Arthrography Technique: If we are prospectively performing a CTR, we use single contrast. Double contrast with air and a small volume of positive contrast has been advocated in some reports, and was formerly our choice for the shoulder and elbow. However, we believe that one achieves more reliable contrast delineation of pathology and effective coating by filling the joint with positive contrast media. Many of the more recent publications agree with this approach, and several authors note that the high quality of current CT scans and the ability to alter the window and level at PACS work stations allow accurate differentiation between contrast and all other structures when single contrast is employed. Our choice is to use our standard nonionic contrast agent that we use in all our other musculoskeletal applications. Concentration in the bottle is 300mg/ml. We cut that in half with lidocaine or ropivacaine. Ropivacaine is our choice for the hip only—for that joint our arthroscopist specifically expects us to comment on relief of the patient's pain after the injection. He believes the longer action of ropivacaine will allow patients sufficient time to evaluate the hip in all activities that provoke their pain. For the other joints, we report pain relief also, but that information is less consistently sought by referring clinicians. As much as anything, the anesthetic in the fluid helps the patient tolerate the joint distention.

As with any invasive technique, we obtain written informed consent prior to the procedure. We perform all injections for CTR in a fluoroscopy suite, although there are reports of use of CT fluoroscopy or even routine CT as guidance modalities, and some practitioners develop sufficient comfort and skill injecting certain joints to be able to inject them without guidance. After standard prep and drape, local anesthesia is achieved with 1% lidocaine buffered with sodium bicarbonate. For the hip and sometimes shoulder, we use a 22-gauge spinal needle. For the other joints, our 1.5 inch 25-gauge anesthesia needle is usually long enough. When tactile feedback and fluoro images suggest the needle is in the joint, the solution is injected. Contrast injected intra-articularly will flow quickly away from the needle tip and spread throughout the joint, often following pathways of least resistance first. The injection is terminated when there is a palpable sense of an increase of pressure while injecting or if one reaches the upper limit of the typical volume injected. Quantities are the same as for MRR above, although many authors inject only 20 mL for the knee.

Fluoroscopic monitoring is not required for the entire injection and can be halted after confirmation of intra-articular positioning of the needle. Further details for each joint are included in their respective sections below.

The CT scan after joint injection is straightforward. As with most of our musculoskeletal imaging, we scan helically, reconstruct axial images 0.625 mm thick at 0.3 mm intervals, and then create multiplanar reformats, typically at 1 or 2 mm intervals. A small scanning field-of-view should be employed. The technical parameters include kV of 120 or 140 and at least 200 mA: if there is metal in the joint or the joint is larger (hip or shoulder), higher mA values may be helpful (350).

SPECIFIC JOINTS

SHOULDER

Technical Considerations: For injection of the shoulder, we prefer the rotator interval approach with the patient supine. A sandbag on the hand helps to hold the shoulder in external rotation. Using the 1.5 inch deeper anesthesia needle (22-27 gauge), the initial target is the upper medial surface of the humeral head, above the level of the coracoid and below the top of the glenoid. This drives the needle through the rotator interval and avoids the biceps tendon. Once one contacts bone, slight bouncing of the needle will help to ensure it lies within the joint. Some practitioners prefer to enter the joint via the standard anterior approach or posteriorly; those approaches will not be discussed in this document.

One should avoid overfilling the shoulder. Overfilling will often encourage extensive contrast extravasation, especially into the subscapularis recess, and will reduce the amount of contrast within the joint proper. Likewise, the shoulder is the one joint that we do not exercise before sending the patient to the scanner, in hopes of diminishing extravasation.

In the scanner, we acquire one volume of data with the arm in neutral or internal rotation. Axial, oblique sagittal, and oblique coronal images are then reformatted. The obliquity of the latter two is selected to lie perpendicular and parallel to the orientation of the supraspinatus muscle belly, respectively. As with our MR scans, we often will tilt our axial planes also, from posterior/superior to anterior/inferior, bringing the Bankart (anterior inferior) portion of the labrum into straight cross section.

We formerly performed a second set of images with the shoulder held in external rotation, as many centers did. This pulls taught the anterior capsulolabral complex and makes Bankart labral tears more conspicuous. However, in the last few years we have adopted the ABER position (ABduction External Rotation) from our standard MRR protocol to our CTR protocol to achieve the same or better results. To accomplish this position, the patient simply places the palm of the hand under his/her head, which necessarily abducts and externally rotates the shoulder. After acquiring an axial volume of data, reformat oblique sagittal images in the plane of the humeral shaft—monitoring this requires some knowledge of the ABER plane at MRR.

Indications and Findings: The shoulder is the second most common joint studied with CTR in the literature; nevertheless, reports are few and some of the data are incomplete. However, just in the last few years several studies have surfaced in the literature. Using the planes described above, CTR is probably very accurate in describing tears of the glenoid labrum. The status of the glenohumeral ligaments should be easy to assess, though this has only been mentioned and not studied in the literature. Reports conflict, but there is probably no significant advantage over MRR regarding these diagnoses; either technique is superior to MRI without contrast.

CTR is excellent for evaluating full-thickness rotator cuff tears and articular-sided partial thickness cuff tears, approaching 100% accuracy in one report. These lesions are simply seen as defects of the cuff tendons. CTR accurately demonstrates the size of tears and the degree of retraction present. MRI and MRR would have an advantage in detecting bursal-surface partial tears, of course, since T2 images would be able to show these lesions but contrast would not enter them. Atrophy of torn cuff muscles is also visible on all modalities.

In one study by De Filippo et al (*Acta Radiol* 2008; 5:540-549), 42 virgin shoulders were studied, demonstrating sensitivity and specificity for rotator cuff tears between 95 and 100%; sensitivity and specificity for labral and capsular pathology ranged from 87 to 96%. The same study also included 28 previously operated shoulders, with nearly identical accuracy numbers for the cuff and labrum; in this latter group, MRI was also performed, with much worse accuracy ranging from 19 to 31%. A recent study by

Lecouvet and coworkers (*Eur Radiol* 2007; 17:1763-1771), CTR sensitivity for high grade (full thickness and deep partial thickness) cartilage lesions of the glenohumeral joint was 89-96% and specificity was 98%.

CTR has an advantage in detecting calcified forms of pathology, including calcific tendonitis and the Bennett lesion, which is a posterior enthesophyte in throwers with posterior instability. CTR may be especially useful in the postoperative patient, when metal suture anchors in a repaired labrum or rotator cuff may create too much artifact on MR scans. Of course, bioabsorbable anchors do not present the same drawbacks, and tiny micro-metallic debris usually is not a significant detractor from MR imaging of the shoulder. Intraarticular fragments are probably equally detected with most modalities. Anatomic bone deformities, such as glenoid hypoplasia and Hill Sachs impaction fractures, should be sought on CTR.

ELBOW

Technical Considerations: At our facility, the elbow is seldom studied with either MRR or CTR. Injecting the joint is usually a straightforward procedure. The patient is either prone with the upper extremity extended over the head and flexed at the elbow, or the patient can be sitting on a stool with the elbow flat on the exam table and flexed 90 degrees, with the lateral aspect directed toward the ceiling. The key step in this process is angling the fluoroscopy tube to profile the lateral elbow joint appropriately, with no overlap of the radial head and capitulum. Once the fluoro tube is aligned, minimal skin anesthesia is necessary for this superficial joint. After that, a 1.5 inch 25-gauge anesthesia needle is more than enough to reach the joint. Target the anterior half of the joint.

If the patient can fully extend the elbow, and there is not limiting shoulder pain, it is best to scan the elbow with the patient prone and the arm fully extended overhead, with full extension of the elbow. In that position, a single axial volume of data can be reformatted into axial, sagittal, and coronal planes. If the elbow must be flexed, it is best to achieve 90 degrees flexion if possible, making the planes as orthogonal as possible. If the arm cannot go above the head for the short scanning time, it must be placed at the patient's side. This will introduce additional beam hardening artifact from the torso in the scanning field.

Findings and Indications: CTR of the elbow has been promoted for the detection of intra-articular fragments ("loose bodies"). The elbow is a frequent victim of intra-articular fragments, despite the fact that it is not a weight bearing joint. These bodies often limit motion and cause pain. However, the utility of CTR in finding these lesions remains in question. In a recent article in the British version of the *Journal of Bone & Joint Surgery*, CTR did not show a significant advantage over MRI or even radiographs!

If one does use CTR of the elbow to search for fragments, scanning with the elbow both prone and supine has been advocated to assist in depicting mobile fragments, but is probably not warranted given the extra radiation burden this entails.

CTR should be an ideal technique for examining the stability of osteochondral lesions of the articular surfaces. However, these lesions are often evaluated in younger patients, in whom the ionizing radiation is more of an issue.

As with MRR, CTR can evaluate the integrity of articular cartilage and both techniques demonstrate a high degree of accuracy for detection of partial and full thickness cartilage lesions in the elbow. A study of 26 cadavers by Waldt and colleagues (*Eur Radiol* 2005; 15:784-791) compared CTR and MRR of the elbow for detection of cartilage lesions. For CTR, sensitivity was 87% and specificity 94%; for MRR, sensitivity was 85% and specificity 95%. Likewise, both techniques can depict partial and full thickness tears of the ulnar collateral ligament with CTR enjoying an advantage for partial thickness UCL tears. Ultrasound has recently been shown to be accurate in evaluating for this last lesion.

WRIST

Technical Considerations: There remains a fair amount of controversy regarding the optimal method of imaging the wrist. While MRI is the typical cross-sectional study for most indications, MRR and CTR have both been advocated and some prefer conventional 3-compartment arthrography without subsequent cross-sectional imaging. Recently, more authors have touted either MRR or CTR when looking at the fine ligaments of the wrist and the triangular fibrocartilage, stating that these techniques offer the best chance at depicting the exact site and extent of tears.

Injecting the wrist is usually straightforward. As with the elbow, the patient may lie prone on the table with the wrist overhead, or the patient can sit on a stool with the wrist on the table. One enters from a dorsal approach. For most patients, access is gained through the radiocarpal joint, typically in the more peripheral aspect of the joint. Again, as with the elbow, the key component for success of the procedure is proper orientation of the fluoroscopy tube. The image should show a clear path between radius and scaphoid to the joint, noting that the normal radius has a prominent dorsal lip that may block the path if a straight PA approach is taken. To avoid this, the tube may be angled or the wrist may be draped over a rolled towel to open the joint. Another approach is to drive the needle directly onto the dorsal surface of the proximal scaphoid, which should be inside the capsule of the radiocarpal joint. If the patient has predominantly radial sided pain, the joint can be entered from the ulnar side. This is accomplished by targeting the notch between the triquetrum and pisiform and injecting anesthetic while advancing; when there is a release, you're in. When the midcarpal joint needs to be filled with contrast, it is straightforward to target the space at the confluence of the lunate, capitate, and hamate bones; injecting the distal radioulnar joint (DRUJ) is accomplished by targeting the radial surface of the distal ulna, about 1 cm proximal to the wrist. All wrist injections can be accomplished with a short 1.5 inch needle.

Unlike other major joints, evaluation of the wrist under fluoroscopy at the time of injection is frequently very illuminating. Evaluating ligament tears as the contrast first passes through them is much easier than after two or all three joint spaces (distal radioulnar, radiocarpal, and midcarpal) are full of contrast. If one has the capability of saving images from fluoroscopy, doing so can be especially beneficial in discussions with a knowledgeable hand/wrist surgeon. A variety of passive and active range of motion movements may augment the likelihood of detecting small perforations and tears.

After the injection, the wrist should be placed over the head for CT imaging if at all possible.

Findings and Indications: Sports related cartilage loss is not a big issue for the wrist and does not drive imaging. In a few instances CTR has shown excellent depiction of cartilage abnormalities of the wrist, but radiologists will seldom have the opportunity to image these abnormalities beyond radiographs.

One study by De Filippo et al (*Eur J Radiol* 2009 in press) includes CTR of 43 wrists, 15 of which had undergone prior surgery. Sensitivity and specificity were 92-94% for triangular fibrocartilage (TFC) tears; 80-100% for the scapholunate and lunatotriquetral interosseous ligaments; and 94-100% for cartilage lesions. A study by Bille and coworkers (*J Hand Surg* 2007; 32A:834-841) on 76 wrist CTRs reports the following:

- Central TFC tears: sensitivity 88-91%, specificity 85-95%
- Peripheral TFC tears: sensitivity 30-40%, specificity 94-97%
- SL ligament: sensitivity 94%, specificity 82-86%
- LT Ligament: sensitivity 85-97%, specificity 79-81%
- Cartilage: sensitivity 45-58%, specificity 93-97%

HIP

Technical Considerations: Using current technology and sequences, CTR probably outperforms MRI or even MRR in evaluating for hyaline cartilage defects in the hip. The spatial resolution and contrast of CTR cannot yet be matched by MR scanning in the hip. Now that hip arthroscopy is reaching widespread availability, evaluation of the acetabular labrum should be a goal of all these techniques. To that end, CTR imaging should include not only 3 standard orthogonal planes of reconstructions but also the "oblique sagittal/axial) plane along the axis of the femoral neck that is typically useful for MRR of the hip. Performing the coronal plane with slight obliquity to mirror the anteversion of the femoral neck is an option we don't employ for CTR or MRR.

Injecting the hip is almost always simple. One key element is to palpate the femoral vessels and stay well away from them. A 3.5 inch 22-gauge spinal needle is almost always sufficient. Some choose to send the needle straight down onto bone of the upper femoral neck, in the middle of the bone. Others choose to skirt the lateral cortex. Either way, a tight joint capsule from severe osteoarthritis can sabotage the procedure, but this usually is solved simply by repositioning the needle. If the needle passes just below the center of the femoral neck, one may enter the zona orbicularis, a prominent bandlike thickening of the joint capsule that is tightly applied to the neck. This should be avoided. Occasionally a tendon (iliopsoas or rectus femoris) will pass immediately over the joint and the needle will come to rest within the tendon sheath—so you must make sure the contrast flows freely around the joint.

<u>Findings and Indications</u>: Until the last decade, open inspection of the hip joint was limited to open arthrotomy, which may require disarticulation of the hip and can risk osteonecrosis. Thus, there was less impetus for defining internal derangement of the joint. This is probably the reason the literature on CTR of the hip is so paltry, with no articles discussing detection of labral tears. One would expect CTR to be very accurate at diagnosing labral tears. It has been shown to be excellent at determining significant cartilage defects and more sensitive than MRI. As in other joints, CTR probably is moderately accurate in defining intra-articular fragments, but not enough to warrant the use of the technique solely for that indication.

Labral tears should be visible as contrast interrupting the substance of the labrum or interposed between the labrum and the cortex. The pitfalls we continue to discuss and debate with MRR of the labrum should also be seen with CTR. The limitations of CTR of the hip primarily revolve around poor differentiation of soft tissues. Many of the processes that affect the hip are extra-articular and involve soft tissue structures. Examples include bursitis and muscle strains. These entities and some marrow findings, such as transient osteoporosis, osteonecrosis (despite reports otherwise), and stress response, often will be occult on CTR. MRI probably remains the study of choice when the clinical differential is wide.

<u>KNEE</u>

<u>Technical Considerations</u>: Knee injections are fairly simple in the majority of cases, once one gets over the steep but relatively narrow learning curve. We use a lateral patellofemoral approach with the patient supine. After skin anesthesia, the 1.5 inch 25-gauge anesthesia needle is advanced with the lidocaine syringe attached, puffing in anesthetic as the needle advances. The start point is between the patella and femoral condyle, at the midpoint of the patella. When one enters the retropatellar joint space, the anesthetic will flow freely. Remove the syringe and attach the contrast syringe with tubing. Contrast will flow freely and first passes into the gutters of the suprapatellar recess. The occasional patient with severe lateral patellofemoral DJD will not admit a needle using the standard approach. An alternative is the anterior approach, starting just medial to the patellar tendon and angling upward until contacting the medial femoral condyle. Upon initially entering the joint, any excess joint fluid should be removed if possible; this may require use of a larger access needle if a large effusion is palpated prior to the procedure. After injection, the knee should be exercised with walking and deep knee bending to ensure sufficient coating of all joint surfaces.

We usually perform the CT scan with the knee extended, but Vande Berg and colleagues, who have written extensively on the topic, flex the knee 15-25 degrees. Axial images through the joint should be as thin as possible to provide the most information about the menisci.

Findings and Indications: CTR has been shown to be accurate in assessment of the menisci and cruciate ligaments in both unoperated and postoperative knees. In virgin knees, accuracy numbers surpass 90% for both menisci, especially for unstable tears. Several authors suggest it should be the study of choice in the postoperative knee when the primary question is recurrent/residual meniscal tear. The high spatial resolution allows excellent detail of cartilage damage. On the other hand, the remaining ligaments and tendons certainly are better evaluated with MRI or MRR. Parameniscal cysts, ganglion cysts, Baker cysts, and other fluid collections are less evident at CTR unless they freely communicate with the joint. CTR has variable success at depicting intra-articular fragments. One must be particularly careful not to confuse the presence of chondrocalcinosis inside a meniscus with contrast entering a meniscal tear.

In the postoperative meniscus, unstable tears are diagnosed when one finds meniscocapsular separation, a defect through the entire substance of the meniscus, displaced meniscal fragments, or a partial thickness defect involving at least one third of the height or depth of the meniscus. CTR is especially helpful in the setting of post-meniscectomy pain because the top two diagnoses in this scenario are recurrent meniscal tear and local cartilage defects. After ACL reconstruction, CTR is able to define ligament disruptions that indicate graft failure, but poorly details fibrotic scar tissue in Hoffa's fat pad and the Cyclops lesion. Ganglion cysts within the tibial tunnel usually do not fill with contrast but may be indirectly evident because of tunnel ballooning. Finally, the evaluation of osteochondritis dissecans is probably well suited to CTR. In our facility, these lesions are studied with MRI first, followed by noncontrast CT if a decision has been made to go to surgery. A CTR could give reasonable estimations of stability of an OCD lesion while accurately depicting size and number of osseous fragments for surgical planning.

A study of CTR of 37 post-operative knees by De Filippo and colleagues (*Eur J Radiol* 2009; 70:342-351) reports 96% sensitivity and 100% specificity for meniscal tears; 86-91% sensitivity and 100% specificity for ACL tears; and 91-95% sensitivity and 93% specificity for hyaline cartilage defects. MRI performed on the same cohort achieved sensitivity of 50-68% and specificity of 27-53% for all abnormalities.

ANKLE

Technical Considerations: Injection of the ankle joint is best achieved via an anterior approach. Access is through a portal between the extensor hallucis longus and the extensor digitorum longus, taking care to avoid the dorsalis pedis artery. After anterior tendon palpation, the level of access is chosen using the lateral view, and the 1.5 inch 25-gauge anesthesia needle is viewed approaching and entering the joint from the lateral perspective. This allows one to enter the joint without impaling the needle on the anterior lip of the tibia. Contrast injection may be limited to just a few ml, but occasionally will require more than half of a 10 ml syringe, especially when the ankle joint has a communication with the posterior subtalar joint. CT imaging includes reconstructions in the sagittal, direct axial, and mortise coronal planes.

Findings and Indications: The ankle has been evaluated with multiplanar CT and CTR for longer than most joints because one can position the joint for direct coronal imaging in the scanner with the aid of gantry angulation, in addition to standard direct axial imaging. Current generation scanners obviate the need for this maneuver.

The primary indication for CTR of the ankle has been evaluation of cartilage defects. The high resolution of current multichannel CT is very helpful in joints like the ankle that have very thin cartilage layers covering their articular surfaces. CTR outperformed MRR for this indication in one study and outperformed SPGR MRI in another. Evaluation of osteochondral lesions for stability was not assessed in either study, but one would suspect CTR would perform well there too. In another study (Hauger O. *AJR* 1999; 173:685-690), CTR was very accurate in defining abnormal scar tissue in patients with anterolateral impingement syndrome at subsequent ankle arthroscopy. Patients with this diagnosis demonstrated nodularity or irregularity and fraying of anterolateral synovial surfaces at preoperative CTR. MRR has been suboptimal in accurately diagnosing this and other ankle impingement syndromes.

One would not expect CTR to be particularly helpful in most ligament injuries of the ankle, but could define full thickness ligament tears when they allow contrast to extend beyond the normal confines of the joint in typical locations. Such tears might include injuries to the deep deltoid and calcaneofibular ligaments and the ankle syndesmosis, but these suggestions have not been proven. Certainly, the regional tendons and soft tissues are not well depicted by CTR (beyond frank tears or entrapment), and CTR does not evaluate most marrow lesions well. Thus, patients with numerous possibilities remaining in the differential are probably better served by MRI or even MRR.

CONCLUSION

CT arthrography (CTR) is an effective method to salvage an attempted MR arthrogram (MRR) that has failed due to patient claustrophobia or excessive motion. It is also an effective technique to use in patients who have contraindications to MRR, such as pacemakers or intra-ocular metal. The utility of CTR extends beyond these backup roles, though. Due to its excellent spatial resolution and the inherent high contrast between contrast media and cartilage and between cartilage and bone, CTR is an excellent tool for evaluating hyaline cartilage defects. CTR also provides high accuracy in the postoperative meniscus and for rotator cuff and labral lesions of the shoulder. It often offers improved visualization of important structures in the presence of postoperative metal within the joint. With improvements occurring rapidly in both CT and MR technology, the indications for various techniques represent moving targets. The best utilization of these techniques remains to be fully established, and some of the decisions may ultimately rest upon scanner availability and cost in different settings.

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