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Review article

Optimizing joint-imaging: (CT)-arthrography

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Abstract. The technique of CT arthrography and arthrotomography of the major joints is discussed. Also, the types of contrast media, double or single contrast technique, film-screen combinations, injection techniques and additional pain testing are discussed.

Key words: Arthrography – Arthrotomography – CT arthrography – Pain testing – Joints

Introduction

Arthrography has been a very useful technique in joint imaging for the past decades, but part of it has now been gradually replaced by MRI. There are still some strong indications for arthrography with or without a combination of multidirectional tomography or CT. Also, combinations of arthrography and an anaesthetic test by mixing the contrast medium with an anesthetic, e.g. in the wrist joint, is a useful technique. Sometimes, arthrography is only used for pain testing, e.g. in the subtalar joint in order to have an objective test when surgery is considered.

Methods of CT arthrography

General methods

For optimizing joint imaging by use of an iodinated contrast medium with or without the combination of air (double contrast), one should use a contrast medium which, in joints, is proven to be superior to others. That is generally a dimer [1–2] which showed a slower penetration in the cartilage (imbibition) and hence less quick blurring of the cartilage contours.

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In case of a prolonged need of a contrast medium, such as in arthrotomography or CT arthrography, one should add some epinephrine (0.2–0.3 cc epinephrine 1:1000) to the contrast medium [3]. The CT arthrography can be performed by means of double contrast as in the shoulder or in the other joints for diagnosing free bodies and/or cartilaginous damage by means of single contrast with air.

Shoulder

The indication for shoulder arthrography with regard to a rotator-cuff rupture has now been taken over by MRI or US. Use of CT arthrography of the shoulder, on the other hand, is still superior to MRI for demonstrating labral and ligament tears especially when there is no fluid in the joint.

The CT arthrography of the shoulder can best be performed by injection of 1 cc contrast medium mixed with 0.2 cc epinephrine 1:1000 and 14 cc air together in one syringe with an extension tube, first injecting the liquid by vertically positioning the syringe and then the air. The patient is best positioned supine with the arm in exorotation. The needle should be directed to the medial lower quadrant of the humeral head and somewhat to the joint-sided border of the head; in this way one can avoid the labrum. By meeting the cartilage of the head, the needle is adjusted in the joint. The extension tube should be used to avoid exposure of the hands during injection. When the contrast medium flows quickly away from the needle tip, the position of the needle is correct; if not, one should rotate the needle somewhat and try again; if still not successful, some medial repositioning is necessary. After filling the joint and taking some plain film, the CT examination can be performed.

The best positioning of the patient is supine and rotated somewhat on the affected side, with the arm of the not-affected side along the head (to avoid too many structures to penetrate, which would deteriorate the image). The arm is positioned in endorotation to expand

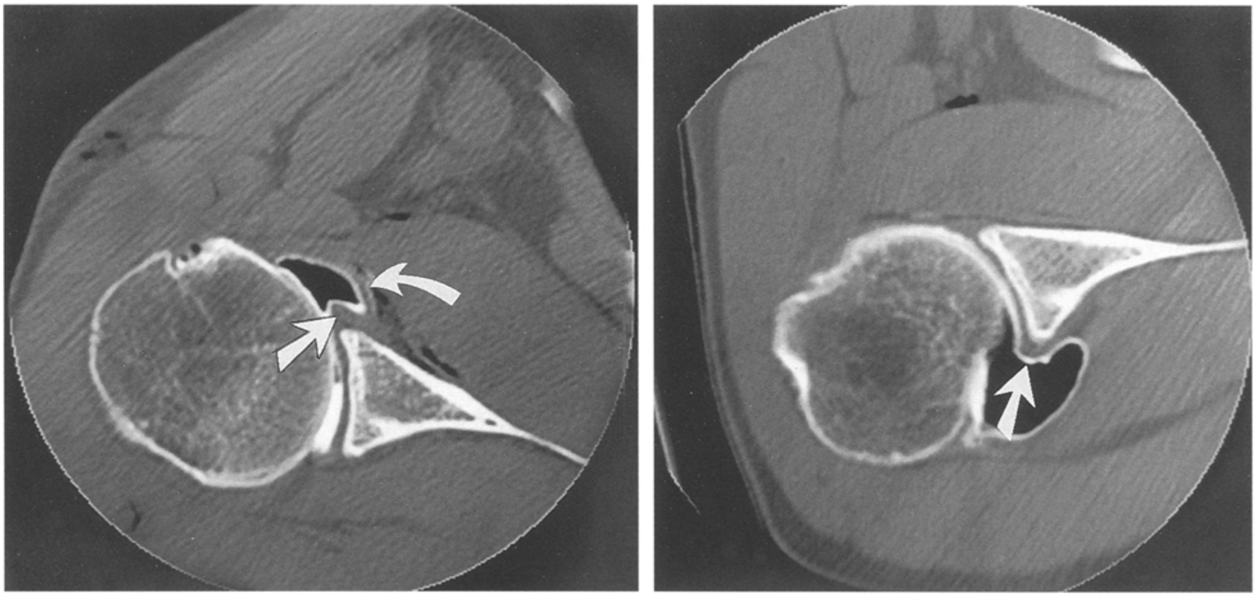

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Fig. 1 a, b. Shoulder CT arthrography. **a** Arm in endorotation and patient semisupine. Air and contrast at the ventral side. Delineation of ventral labrum *(arrow)*, and in this patient, the medial glenohumeral ligament *(curved arrow)*; 2-mm slice. **b** Arm in exorotation. Patient semiprone. Air and contrast accumulation at the dorsal side. Delineation of dorsal labrum *(arrow)*; 5-mm slice

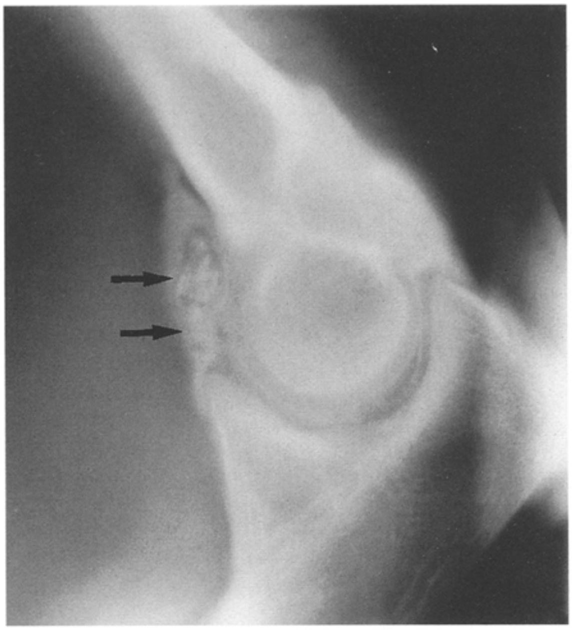
Fig. 2. Double-contrast arthrotomography of the elbow. Demonstration of cartilaginous free body *(arrow)* near radiohumeral joint

the joint at the ventral side in case there is interest in the ventral labrum and capsular ligaments (Fig. 1 a). For optimal visualizing the dorsal labrum, when necessary, the patient should be positioned prone and somewhat on the affected side with the arm in exorotation to get the air around the dorsal labrum (Fig. 1 b). The shoulder can be imaged with 5-mm-thick slices at the cranial and caudal side and in between with 2-mm slices with an interval of 3 mm. For good visualization a zoom at which only the glenohumeral joint is imaged should be made.

Elbow

The main indications for elbow arthrography are the demonstration of bony and cartilaginous free bodies. Also, the cartilage and the capsule can be judged. Because of the complicated anatomy of the elbow joint, a pluridirectional tomography or CT should follow contrast agent administration. In fact, the elbow joint consists of three different articulations: the radiohumeral joint, the ulnohumeral joint and the proximal radioulnar joint. Arthrography (CT) is superior to MRI in demonstrating free bodies. Because of the orientation of the planes of the articulations, arthrotomography is preferred over CT arthrography. In cases of osseous free bodies on the plain elbow radiographs, it is better to perform first a tomogram without contrast to pick up small osseous free bodies which theoretically could be missed on a double-contrast arthrotomogram. The cartilaginous loose bodies can only be picked up on arthrotomography (Fig. 2).

The best positioning of the patient is prone on the X-ray table with the arm along the head and toward the end of the table with the elbow flexed 90°. The examiner is seated at the end of the X-ray table. The puncture can best be done between the radial head and the capitulum from laterally with the elbow in 90° flexion [4]. One cubic centimetre contrast medium mixed with 0.2 cc epinephrine 1:1000 and 9 cc air should be injected, all mixed in one syringe. The positive contrast medium should be injected first. When the contrast medium flows away from the needle tip, one is in the joint. After injection, under fluoroscopic control some plain arthrographic views can be made, after which a lateral and an anteroposterior (AP) pluridirectional tomogram with a slice interval of 3 mm should be performed. Using one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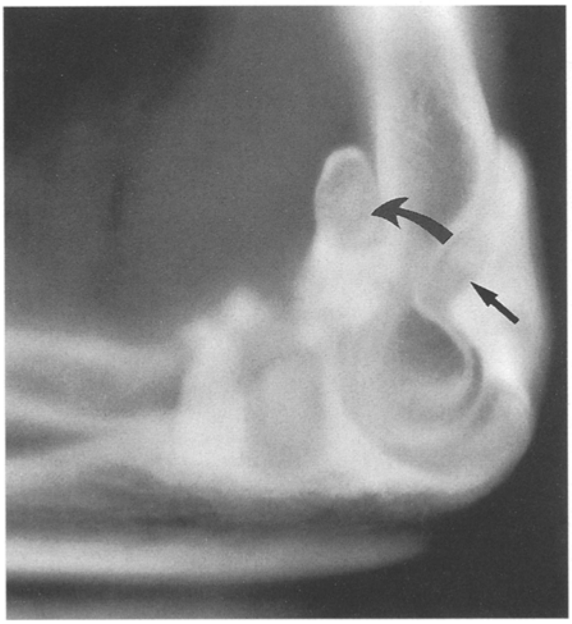
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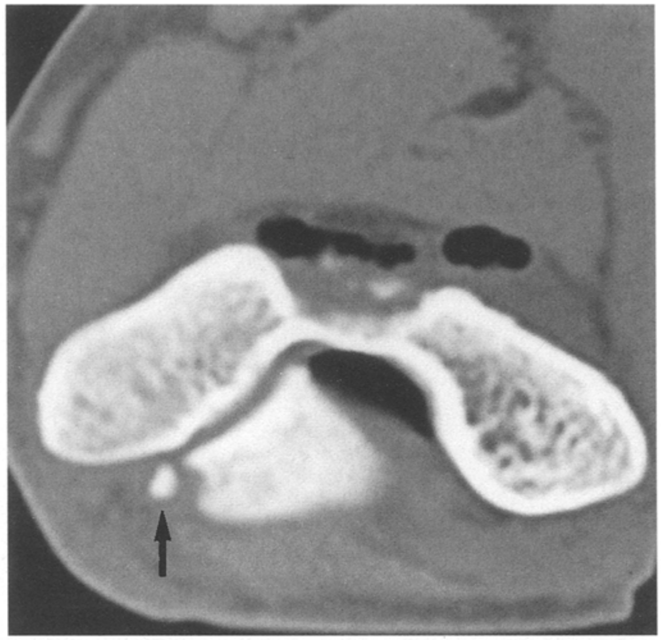
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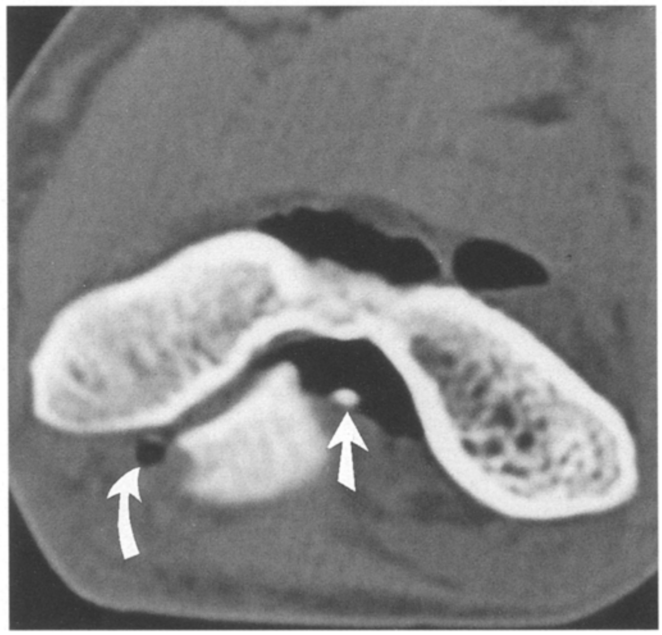
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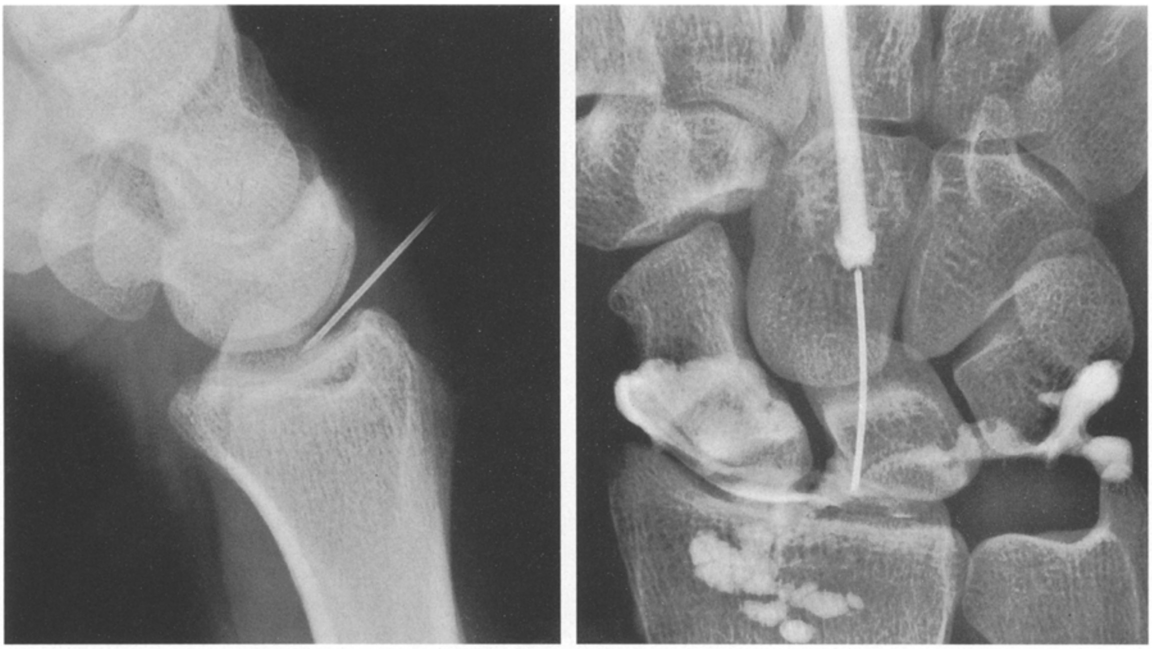
Fig. 3. Arthrotomography of the elbow. Mixed cartilaginous–osseous free bodies volarly near the ulnohumeral joint *(arrows)*

Fig. 4. Arthrotomography of the elbow. Osseous bodies volarly and dorsally. The dorsal one *(arrow)* is fixed to the bottom of the olecranon fossa, which results in a reduction in extension. The volar one *(curved arrow)* is fixed to the capsule (contrast not entirely around the body)

Fig. 5 a, b. CT arthrography of the elbow; 2-mm slices. **a** First scan. Bony density near joint capsule *(arrow)*, not surrounded by air. **b** Second scan. After elbow motion and reposition, displacement of bony particle *(arrow)* as proof of a free body in the joint. Notice former location of the loose body now filled with air *(curved arrow)*

emulsion film (e.g. Min R-MA, Kodak, Odijk, The Netherlands) exposed in a cassette with one intensification screen (e.g. Min R single fine screen, Kodak, Odijk, The Netherlands) in the tomographic device will provide excellent radiographic examples of bodies in the joint (Figs. 3 and 4).

When no pluridirectional tomography is available, the alternative is CT arthrography with air. The position during injection is the same as mentioned above. It is only somewhat more difficult to notice the air entering the elbow joint. Ten cubic centimetres of air is adequate. The CT scan should be performed with 2- or 3-mm-thick slices with the arm extended. When in doubt, if a piece of bone or cartilage is completely loose in the joint, one should also perform a CT scan with the arm in another position in order to notice a change of position in the loose body to appreciate its real loose status (Fig. 5).



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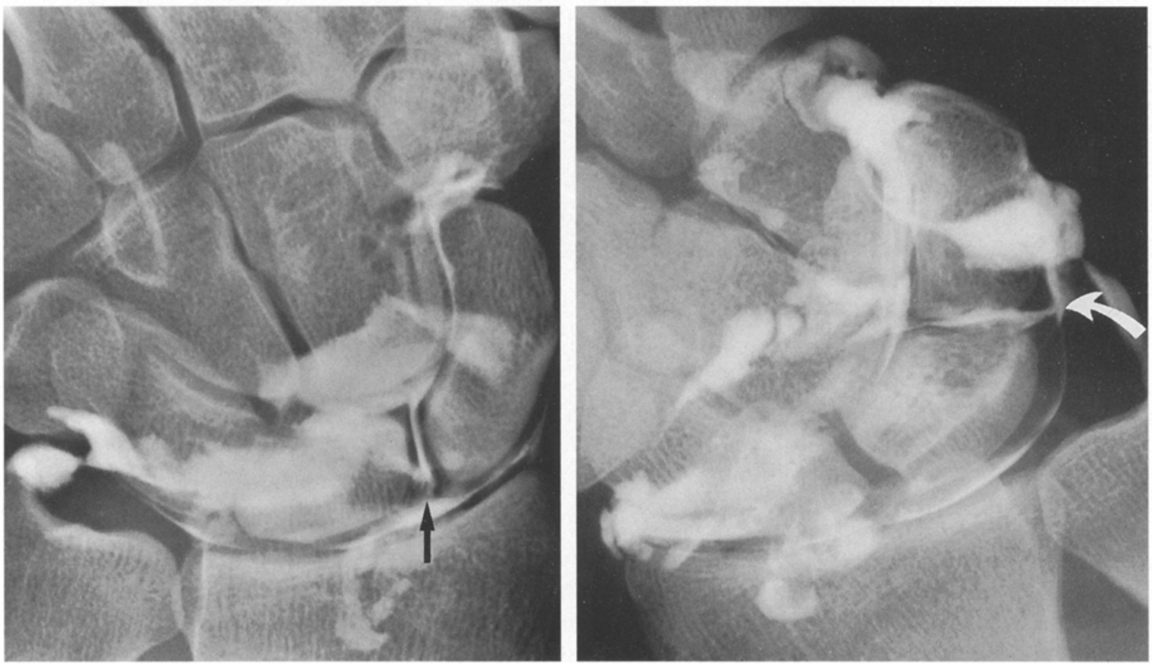

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Fig. 6 a, b. Puncture-technique radiocarpal arthrogram. **a** Direction of needle obliquely to the radiocarpal joint under fluoroscopic guidance. **b** After rotating the hand to a frontal position and projecting the scapholunate and lunotriquetral joint space free, the contrast fluid is injected and the course of it is closely observed

Fig. 7 a, b. Radiocarpal arthrogram. **a** Contrast leakage through the scapholunate interosseous ligament *(arrow)* only after ulnar stress deviation. **b** Contrast leakage through the lunotriquetral interosseous ligament *(curved arrow)* after radial stress deviation only. Both are examples of a small rupture. (From [8])

In demonstrating loosening of an elbow prosthesis one should puncture the elbow form laterally or dorsally. Unfortunately, one cannot give much pressure in the elbow joint before leakage from the capsule will show up (as in the knee joint in case of a total knee). So unlike in demonstrating loosening of a prosthesis in the hip joint, in the elbow and knee joints it is more difficult to force the contrast medium between the prosthesis or cement and the bone.

Wrist

The main indications for wrist arthrography are the demonstration of interosseous ligament and disc ruptures. Other indications, as in every joint, are the demonstration of free bodies and cartilage damage. Arthrography is still somewhat superior to MRI with regard to demonstrating scapholunate and lunotriquetral interosseous ligament ruptures and disc ruptures in the case of a thin disc. A radiocarpal arthrogram is most sufficient for demonstrating interosseous ligament and disc ruptures especially after injection a lot of stressing of the joint is performed after which most tears will open to allow the contrast medium to flow to the midcarpal and/or distal radioulnar joint. On indication (when the symptoms are there) also the midcarpal joint or the distal radioulnar joint can be injected. One should be aware of the fact that capsular ligaments cannot be very well demonstrated by arthrography. There are now promising articles about demonstrating them with multiplanar reconstructions of 3D Fourier transform MRI [5–7].

The best way of injecting the radiocarpal joint is by positioning the patient prone on the X-ray table with the arm along the head and towards the end of the table. The examiner should be seated at the end of the X-ray table [8]. The puncture can be done between lunate and radius or between scaphoid and radius. The best way is to mark the puncture place and to inject with the hand in a lateral position with somewhat volar flexion. The needle should be pointed to the joint space of the radiocarpal joint under fluoroscopic control (Fig. 6). When the needle is deep enough, the hand should be rotated back to a frontal position in such a manner that the joint space between scaphoid and lunate, and between lunate and triquetrum, is projected free. Then the contrast medium can be injected whereby the flow of it can be followed under fluoroscopic control. A total of 1–2 cc contrast medium is enough. Only in case of a connection between the radiocarpal joint and the midcarpal joint and/or distal radioulnar joint does one need somewhat more.

To inject some cubic centimetres of a mixture of 3 cc contrast medium with 2 cc xylocaine 2 % gives a good density and an additional test to correlate symptoms with the intra-articular pathology. Preferably, one should use a fluoroscopic unit with the tube under the table and the image intensifier and cassette holder above the table. The tube should have a very fine second focal spot of 0.3 or 0.4 mm! This can provide good magnification views when the cassette holder stays ± 25 cm above the tabletop. Also, by using one emulsion film (e.g. Min R-MA, Kodak, Odijk, The Netherlands) exposed in a cassette with one intensification screen (e.g. Min R single fine screen, Kodak, Odijk, The Netherlands) provides good-quality radiographs (Figs. 6–9). After injection, the wrist should be manipulated forcefully is to open every possible perforation or tear of the scapholunate and/or lunotriquetral interosseous ligament or articular disc (Fig. 7). Where the contrast fluid runs through a ligament or disc to another compartment there is a perforation or tear. By stressing the wrist in ulnar and radial deviation the size of an interosseous ligament rupture can be judged (small, intermediate or large; Figs. 7 and 8).

The articular disc often shows a slit-like perforation at the radial side of the disc (Fig. 9). This is often seen independent of the age of the patient, the thickness of the disc, and the clinical symptoms, and should not be considered as pathology. Ruptures of the articular disc (or TFC) at the ulnar side are of clinical importance, but are difficult to appreciate with arthrography or MRI.

When one is looking for a partial detachment of the interosseous ligaments, at the midcarpal joint side an injection dorsally between the scaphoid, capitate and trapezoid is the easiest.

For judging partial tears at the distal radioulnar joint side of the articular disc, one can perform an arthrogram of that joint. The needle can best enter the distal radioulnar joint from dorsally just ulnarly of the joint space between radius and ulna and just on the ulnar head cartilage.

It is important to correlate the diagnosed ligament or disc tears or ruptures with the clinical symptoms, because not all these (incomplete) tears cause symptoms.

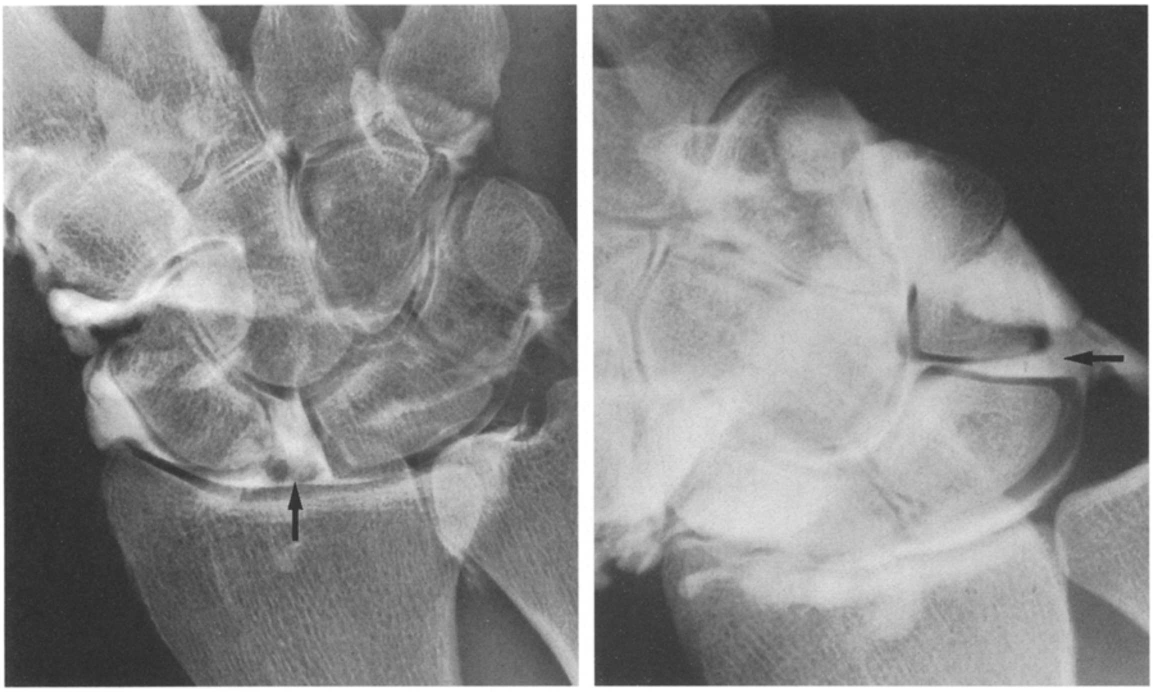
Hip

Currently, MRI provides the best information of the adult and infant hip. In cases of dislocated hips in an infant can an arthrogram still be performed in the operating room to show what is happening when attempting a close reduction of the hip. If the labrum or adhesions prevent reduction of the hip, an open reduction should follow; if not, the hip is to be put in plaster directly after the arthrogram and after reduction. After an open reduction, of course, the hip is to be put in plaster also. The best way of injecting an infant hip, dislocated or not, is to inject ventrally and pointing to the cartilaginous head. When meeting the cartilaginous head one is always in the joint.

Arthrography is still indicated in cases of suspected joint-prosthesis loosening. The joint should be punctured ventrally at the head–neck transition of the prothesis, and when meeting "metal" one is in the joint. After that, aspiration or flushing of the joint should be performed to obtain material for culture. A mixture of a contrast medium and an anaesthetic can then be injected under high pressure to get as much contrast material around the prosthesis or the cement of the prosthesis. When there is much pain and lymph-channel filling the pressure is high enough, and one should stop injecting. The cup is by arthrographic definition loose when the contrast comes between the bone and the prosthesis in all three zones (zones 1–3). The stem is loose when there is contrast between the prosthesis and the bone in two or more zones (zones 1–7). A subtraction technique can be performed, but one should be aware of the fact that the patient should not move at all, which, in case of much pressure, is not always possible because of the provoked pain. In case of aspiration of cloudy fluid, it is better to avoid high-pressure performing the arthrogram; otherwise, a sepsis can be provoked.

Knee

Presently, MRI is indicated for demonstration of meniscal and cartilaginous pathology and, of course, also for ligamentous, capsular and bone disorders. An exception is the demonstration of loose bodies to see if these are



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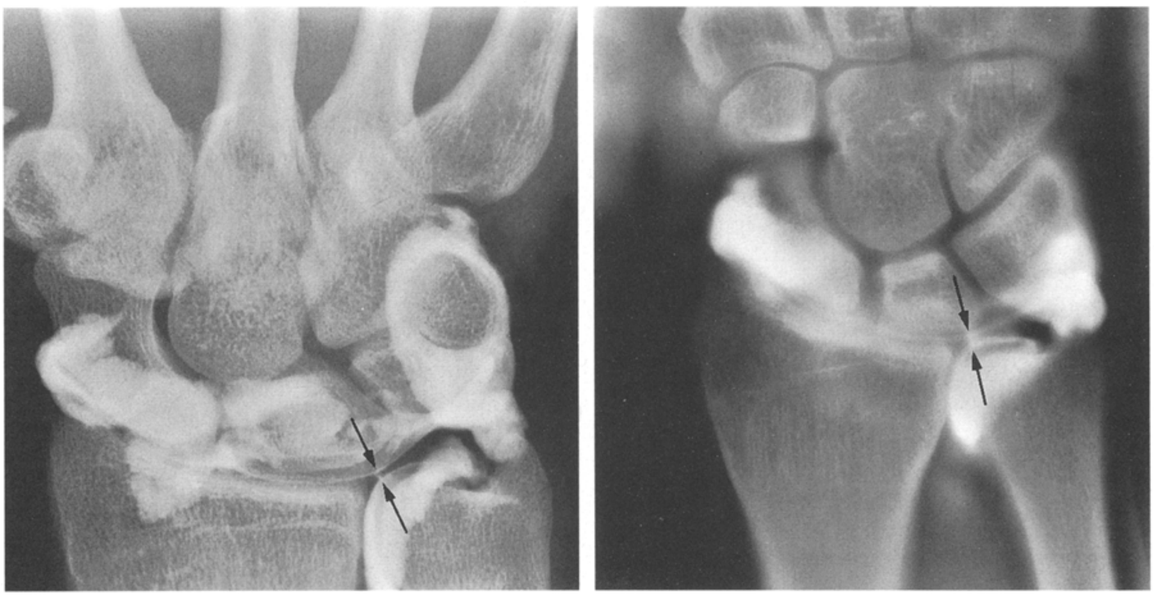

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Fig. 8a, b. Radiocarpal arthrogram. **a** Considerable or complete interosseous ligament rupture with remnant of ligament *(arrow)* and considerable diastasis at the scapholunate joint; also, disc perforation. **b** Considerable or complete ligament rupture *(arrow)*. Considerable diastasis at the lunotriquetral joint during radial deviation stress and no ligament. (From [8])

Fig. 9a, b. Radiocarpal arthrogram. Slit-like perforation of the disc *(arrows)*. **a** Profiling the disc with the perforation by elevating the hand from the table top. **b** Tomogram of same wrist. This slit-like perforation at the thinnest and radial side of the disc is often not associated with symptoms. (From [8])

actually loose. For this diagnosis a CT arthrography with air is needed. The air can be injected with the patient lying on the table of the CT scanner. One should first aspirate all the joint fluid and then inject approximately 60 cc of air in order to get the joint capsule very well distended. The best way is to scan with thin slices the whole region where the air is.

When cartilaginous or bony bodies are completely surrounded by air they are actually loose; when not, one should turn the patient to another position. When the positions of the bodies are changed they are actually loose; when not, they are fixed to the capsule and there is no need for an operation or scopy (Fig. 10).

Another indication for arthrography is still demonstrating joint-prosthesis loosening and adhesive capsulitis. As in the elbow, in the knee joint it is difficult to obtain much pressure before leakage out of the capsule will show up in the case of a joint prosthesis.

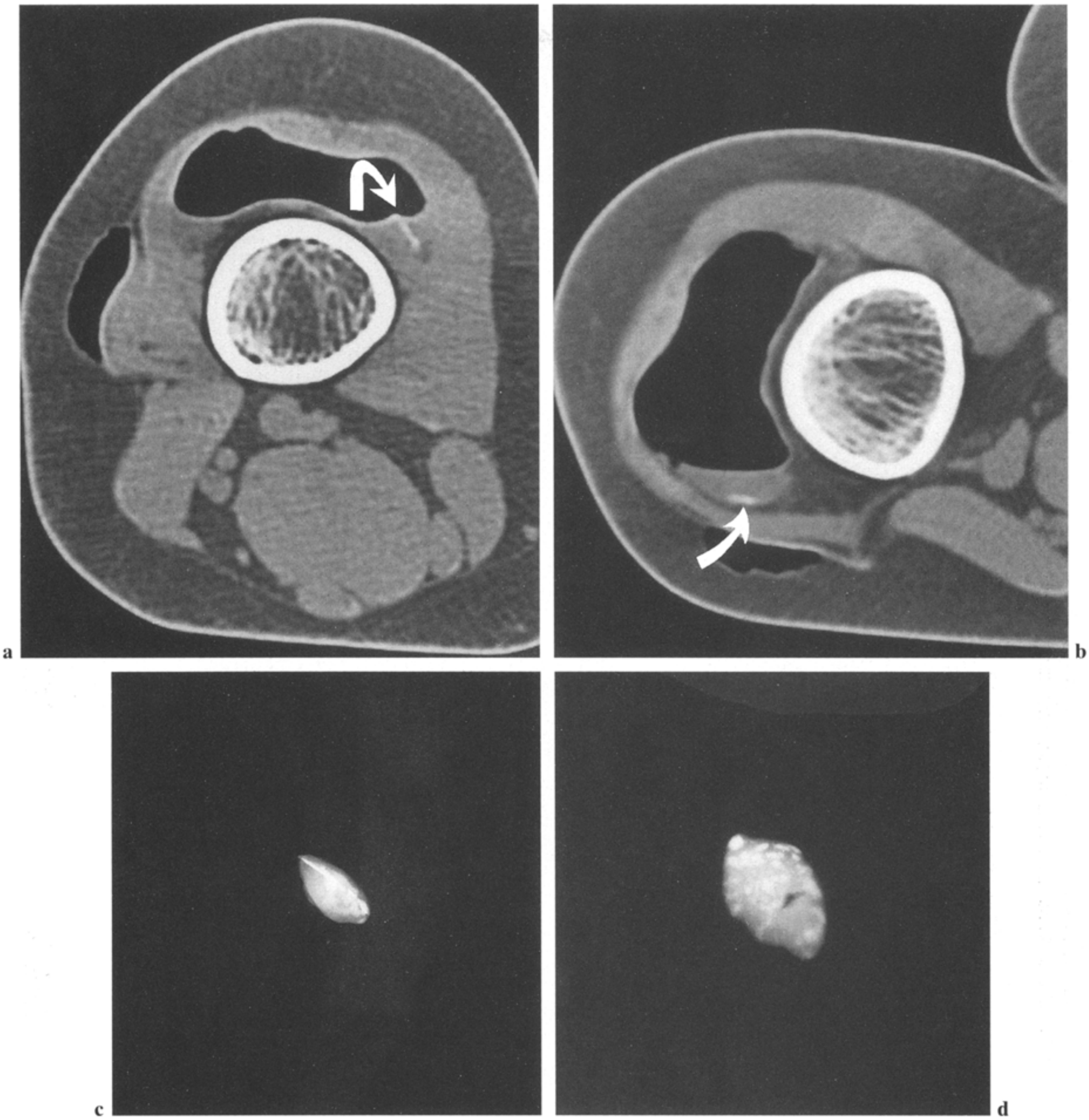
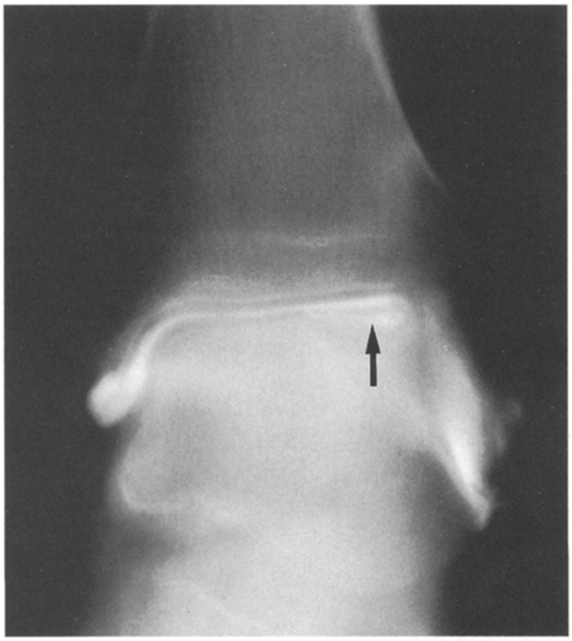


Fig. 10a–d. CT arthrography of the knee and corresponding radiographs of removed free body. **a** Supine position; 2-mm slice. Needle-like density near medial capsule of joint *(arrow)*. See corresponding projection of free body in **c**. **b** After repositioning of the knee on the lateral side, displacement of the density laterally *(arrow)* as proof of a free body surrounded by some joint fluid (5-mm slice). **c, d** Corresponding radiographs of free body in two different projections

Ankle

The MRI scan shows cartilaginous and subchondral bone disorders very well, but visualization with MRI of intra-articular free bodies in the absence of joint effusion is difficult. If performing arthrotomography or CT arthrography free bodies can be picked up and still the cartilage can be judged. Because of plane selection, arthrotomography is preferred over CT arthrography. In the ankle single contrast is preferred. Injection of air bubbles can be prevented by entering the soft tissues during slow injection. A mixture of 6 cc contrast medium and 0.2 cc epinephrine 1:1000 can be made. A total of 3–5 cc of this mixture should be injected under fluoroscopic control. The amount depends on the capacity of the joint. After marking the dorsalis pedis artery, the needle should approach the ankle joint obliquely in a lateral position (as in the radiocarpal joint) to avoid the ventrodistal lip of the tibia. When the needle is in the joint, the foot should be rotated back in a frontal position to follow the flow of the contrast medium. The flow sometimes goes under the cartilage in the case of an osteochondral fracture, and this can be well documented by taking radiographs (same film-screen combination as in wrist arthrography). After injection, some plain arthrographic views should be made, after which a lateral and an AP tomogram should be performed. The slice interval can be 3 or 4 mm. Also, the same



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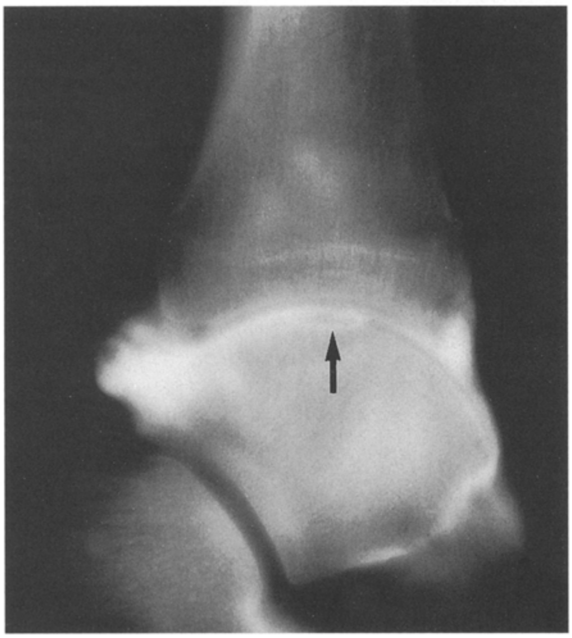

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Fig. 11 a, b. Anteroposterior (AP) and lateral arthrotomogram of the ankle with subchondral fracture. Notice contrast medium under the surface of the cartilage *(arrows)*

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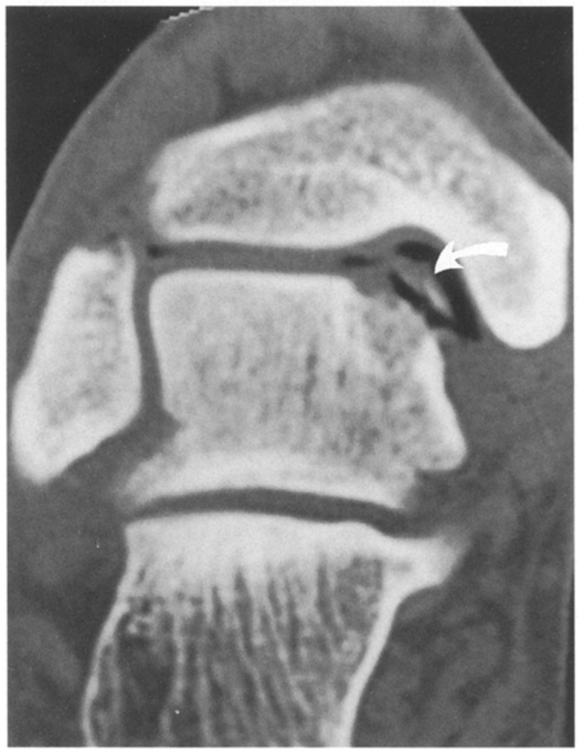

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Fig. 12. Lateral arthrotomogram of the ankle at the medial side. Osseous–cartilaginous free body *(arrow)* as a saving in the (single) contrast medium

Fig. 13. CT arthrography of the ankle joint. Subchondral fracture (old) with air under the surface of the cartilage *(arrow)*

film-screen combination as mentioned previously for the arthrotomography of the elbow can be used. Examples of osteochondral fractures and free bodies are shown in Figs. 11 and 12. As in the elbow joint in cases of small bony fragments, sometimes a plain tomography before the injection of contrast fluid can be useful.

When no pluridirectional tomography is available, CT arthrography with air should be performed. The injection technique is the same as mentioned above. It is only somewhat more difficult to observe the air entering the ankle joint. Approximately 6 cc of air is sufficient.

The CT scan should be performed with thin slices. The best position is with the foot of the patient flat on the table and to angulate the gantry cranially in order to get the ankle joint into an AP projection. The joint cartilage can also be judged in this position (Fig. 13).

When in doubt about whether a cartilaginous or osseous body actually loose, one should perform an additional CT scan in another position in order to see a change in position of such a body as proof of a actually loose status.

Other joints

Arthrography of other joints is done mostly for verification of intra-articular needle position in testing a painful joint by an anaesthetic or by injection of a corticosteroid. After studying the anatomy, the best approach to a certain joint can be chosen. One should be aware of the fact that the joint space can be difficult to approach by overhanging bony prominences. The best way to puncture, for example, the dorsal part of the subtalar joint is laterally just behind the lateral malleolus. Except for the knee joint, which is mostly injected laterally, all joint injections should be made under fluoroscopic guidance with a syringe with an extension tube and an appropriate (small) needle.

References

1. Obermann WR, Kieft GJ (1987) Knee arthrography: a comparison of iohexol, ioxaglate sodium meglumine, and metrizoate. Radiology 162: 729–733
2. Obermann WR, Bloem JL, Hermans J (1989) Knee arthrography: comparison of iotrolan and ioxaglate sodium meglumine. Radiology 173: 179–201
3. Hall FM (1974) Epinephrine-enhanced knee arthrography. Radiology 111: 215–217
4. Hudson T (1979) The elbow. In: Freiberger RH, Kaye JJ (eds) Arthrography. Appleton-Century-Crofts, New York, pp 261–276
5. Totterman SMS, Miller R, Wasserman B, Blebea JS, Rubens DJ (1993) Intrinsic and extrinsic carpal ligaments: evaluation by three-dimensional Fourier transform MR imaging. AJR 160: 117–123
6. Smith DK (1993) Dorsal carpal ligaments of the wrist: normal appearance on multiplanar reconstructions of three-dimensional Fourier transform MR imaging. AJR 161: 119–125
7. Smith DK (1993) Volar carpal ligaments of the wrist: normal appearance on multiplanar reconstructions of three-dimensional Fourier transform MR imaging. AJR 161: 353–357
8. Obermann WR (1994) Wrist arthrography: a clinical study. In: Obermann WR (ed) Radiology of carpal instability: a practical approach. Elsevier, Amsterdam, pp 131–172

Book reviews

European Radiology

M. S. Van der Knaap, J. Valk: Magnetic Resonance of Myelin, Myelination and Myelin Disorders. Springer Verlag: Heidelberg, Tokyo, New York, 1995, ISBN 3-540-59277-6, 558 pp, 248 figures, £ 173.00

This second edition reflects the immense gain of knowledge in MR on myelin and its diseases since publication of the first edition in 1989. The book has grown form 390 to 558 pages, and the information included has grown even more due to a change in the size of the letters and in the formatting. The number of figures has doubled, and in contrast to the first edition, the authors have succeeded in providing MR images of almost all and even very rare disorders covered by the text, which has been thoroughly revised. Even the order of authors has been changed, which may reflect the importance of the clinical information included in this book.

The first four chapters provide basic information on myelin, the classification of myelin disorders, selective vulnerability of white matter as well as on normal and abnormal myelination and its course on MR imaging. The subsequent 65 chapters cover the whole spectrum of hereditary and acquired diseases affecting the white matter from acute disseminating encephalomyelitis to Zellweger's syndrome. Each chapter deals with one disease and provides profound information on the clinical and laboratory findings, the course and varieties of the disease, its pathology and pathogenesis, and a comment about possible therapies. Finally, the findings on MRI are discussed and illustrated.

A very important and helpful chapter is on pattern recognition in MRI in myelin disorders. The authors propose an approach to image analysis which allows the diagnosis in a significant number of disorders, and they provide information on the specificity of the MR diagnosis in various disorders of myelin. A final chapter on MR spectroscopy gives an overview of the technique and its application in white matter disease. The book is completed by a list of references covering more than 90 pages. The quality of the illustrations is excellent, and with few exceptions of very rare disorders, state of the art. A significant number of MR scans were taken from the first edition, a fact which reflects the excellence of the work done by the authors.

The amount and quality of information on myelin diseases make the purchase of this second edition almost mandatory for all neuroradiologists and radiologists performing MRI. It is also a source of relevant information to neuropaediatricians, neurologists and all physicians confronted with patients with metabolic diseases affecting the brain.

G. Schuierer, Münster

Mettler F. A. Jr., Upton A. C.: Medical effects of ionizing radiation. Philadelphia: W. B. Saunders, 1995, second edition, 448 pages, 122 illustrations, £ 96.00, Hb 07216 66469

This basic work on medical effects of ionizing radiation contains 430 pages and multiple comprehensive tables, graphics, radiologic pictures, as well as microscopic and macroscopic photographs of organ lesions.

Two introductory chapters discuss basic radiation physics, chemistry, biology and sources of radiation exposure.

Extensive chapters are devoted to effects on genetic material, carcinogenesis, direct effects of radiation on the different organs and radiation exposure in utero.

Other chapters concern the effects of radiation in combination with other agents, the probability of causation of lesions in an individual, the perception and acceptance of risk and the effects of uranium and plutonium.

Most chapters end with a short summary and all chapters are followed by an extensive list of references.

Despite the absence of a chapter concerning measures of radioprotection, this book is a highly valuable work for every physician interested in the basic medical effects caused by ionizing radiation.

E. Ponette, Leuven