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Original article

Real-time MR-guided joint puncture and arthrography: preliminary results

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Abstract. The purpose of this study was to evaluate interactive MR-guided joint puncture with intra-articular application of contrast agent. MR-guided arthrography of the shoulder joint was successfully performed in three patients using an interactive guidance system implemented in an open-configuration MR system. Visualization of the needle pathway and contrast inflow was comparable to that with conventional X-ray fluoroscopy. The position of the intra-articular needle tip was accurately confirmed and subsequent MR arthrography was diagnostic in all cases.

Key words: MR arthrography – Open-configuration MR – Interactive guidance system

Introduction

Magnetic resonance (MR) arthrography of the shoulder has been advocated as diagnostically useful by several authors [1, 2]. Recent studies have documented the superior performance of MR arthrography compared with conventional MR imaging of the shoulder regarding the detection of pathologic conditions in the rotator cuff, glenoid labrum and joint capsule [3, 4]. MR arthrography is typically performed by accessing the shoulder joint under fluoroscopic guidance and injecting diluted paramagnetic contrast following confirmation of correct needle positioning with a small amount of iodinated contrast medium. Relative to conventional MR imaging of the shoulder, joint puncture under fluoroscopic control prolongs the examination time. In addition the procedure requires patient and physician access to both X-ray fluoroscopy and an MR system. Depending on local conditions, transferring the patient from one room to another can be rather cumbersome. In addition, both in vitro and in vivo studies have shown that the presence of even small amounts of iodinated contrast material, injected for confirmation purposes, can lower the signal intensity of low-osmolality gadolinium solutions, thereby complicating subsequent diagnostic analysis [2].

MR-guided interventional techniques are currently being explored as an alternative to a variety of fluoroscopic, sonographic and CT-guided procedures [5, 6]. The advantages of MR-based guidance pertain to the excellent tissue contrast as well as the multiplanar reconstructive abilities inherent in the MR technique. The latter allow even the most complex needle trajectories to be achieved with ease [7]. The development of open-configuration MR imaging system allows direct access to the patient and the near-real-time control of needle position [8]. This report outlines a technique for real-time MR-guided shoulder puncture permitting visualization of contrast inflow.

Material and methods

MR-guided arthrography of the glenohumeral joint was performed in three patients (2 male; 1 female) with ages ranging between 22 and 67 years. Approval for the intra-articular injection of gadopentetate dimeglumine (Magnevist; Berlex, Wayne, N.J.) was obtained from our Institutional Review Board for Human Investigation. Written informed consent was obtained from all patients. Procedures were performed by an experienced radiologist.

All imaging was conducted on a 0.5-T superconducting, open-configuration MR system (Signa SP; General Electric Medical Systems, Milwaukee, Wis.). A 58 cm wide vertical imaging space located between two coils that induce the main magnetic field can be freely accessed by the interventionalist. A flexible transmit/receive coil (paired configuration) was placed around the shoulder. In order to place the shoulder as close to the center as possible, the patient was positioned supine slightly off-center with regard to the magnet. The arm was placed at the side of the body, and slightly externally rotated. Fast-multiphase spoiled gradient echo (FMPSPGR) images were collected in the coronal plane to confirm the correct position of the coil with the following parameters: TR/TE 150/3.9 ms, flip angle 60 °, slice thickness 10 mm, interslice gap 5 mm, field of view 34 × 34 cm. The coil position was adapted when necessary.

For MR guidance of the needle itself, a three-dimensional digitizer system (Flashpoint 5000; Image Guided Technologies, Bould-

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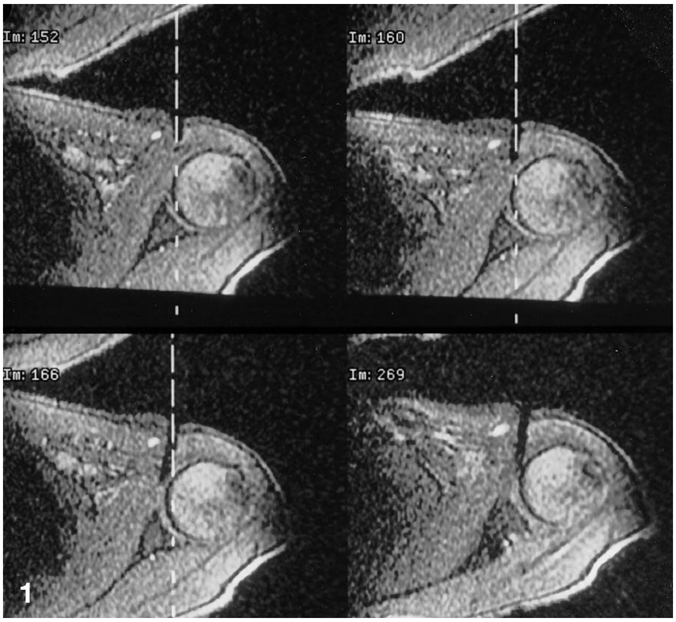

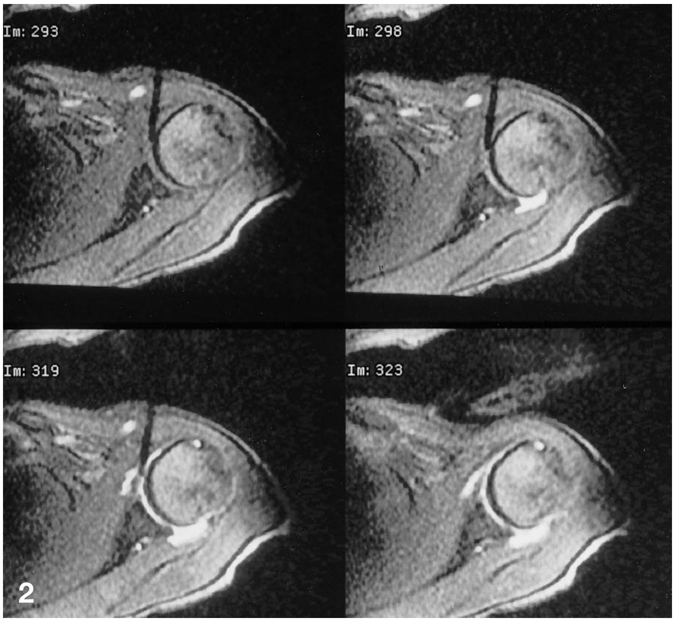

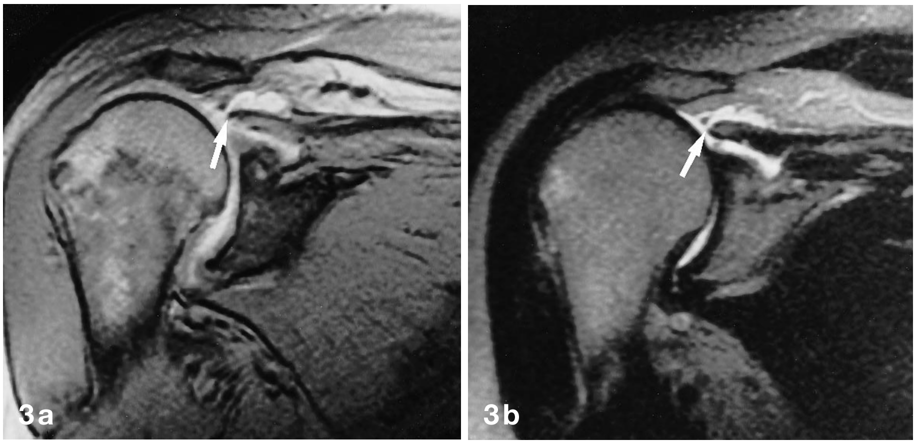

Fig. 2. Inflow of contrast medium into the shoulder joint can be monitored in real time. Axial images depict an increasing amount of paramagnetic contrast agent in the glenohumoral joint space

Fig. 3. Coronal FMPSPGR (**a**) and T2-weighted (**b**) images with intra-articular gadolinium. Complete tear of the supraspinatus muscle *(arrow)* is demonstrated

Fig. 1. Puncture of the glenohumeral joint from an anterolateral position. The computer-generated icon of the needle trajectory *(long dashed line),* the extended centerline of the needle trajectory *(short dotted lines),* and the artifact of the needle (black signal void beneath needle icon) can be visualized throughout the duration of the procedure on a screen positioned in front of the interventionalist. A discrepancy between the calculated and true position of the device is seen *(lower left)*

er, Colo.) [6, 8] was used in conjunction with a FMPSPGR sequence: TR/TE 51/4.8 ms, flip angle 45 °, slice thickness 5 mm, field of view 22 × 16 cm, and a 256 × 128 matrix. Images were updated every 5 s. Under sterile conditions, the scan plane pointer was used to simulate the needle trajectory and to confirm the skin puncture site in a manner similar to that described for targeting other organs [6, 9]. For the actual puncture, a 22-gauge MR-compatible needle (E-Z-EM, Westbury, N. Y.) was connected to the scan plane pointer. Following the application of a local anesthetic (1 % lidocaine), the needle was advanced into the glenohumeral joint from an anterior approach. Near-real-time MR imaging (3 s per image) was used to guide the needle into the articular space with imaging planes defined by the long axis of the scan plane pointer. The needle position could thus be visualized at any given time [9] and was projected on an LCD screen attached to the scanner just in front of the interventionalist. The computed trajectory of the device was displayed on the image as a computer-generated icon (Fig. 1).

Once the needle had penetrated the body it became visible on the MR images by virtue of the associated susceptibility-induced signal void. The needle trajectory was corrected interactively, while it was followed on images acquired in three different planes relative to the long axis of the needle. Once the needle tip was considered to have reached the articular space, an axial imaging plane traversing the calculated position the needle tip was chosen. Scanning was changed to the freeze mode. In this mode, continuous update images (every 5 s) were obtained in the same location. Subsequently, 10–15 ml diluted gadopentetate dimeglumine (4 mmol/l) (Magnevist; Schering, Berlin, Germany) was instilled through the needle via a short connecting tube. The inflow of contrast medium into the shoulder joint was monitored in a near-real-time fashion (5 s per image) on the LCD screen (Fig. 2). The exact volume of injected gadopentate depended both on the MR images and on the increasing resistance during injection. The needle was removed and arthroscopic imaging was performed using the following sequences: axial and coronal FMPSPGR (TR/TE 200/4.9 ms, flip angle 60 °, slice thickness 5 mm with 1 mm interslice grap), standard T2-weighted coronal spin echo and standard T1-weighted oblique sagittal spin echo. The whole procedure was completed within 50 min. while puncture of the shoulder and instillation of the contrast agent required no more than 5 min.

Results

Puncture of the shoulder joint with the active guidance system was possible in all three patients. The subsequent intra-articular contrast injection could be monitored with high temporal resolution (1 image per 5 s). While advancing the needle, important structures such as the axillary artery and vein were easily visualized and determination of the needle position relative to such structures was always possible. The needle tip was visible at all times and the intra-articular position was accurately confirmed in all cases. MR imaging provided sufficient temporal and contrast resolution during the injection of the paramagnetic contrast agent to assess the inflow of contrast during scanning in a single axial plane. One patient had para-articular deposition of contrast following removing of the needle that was not appreciated during injection. MR arthrography was diagnostic in all three patients as determined by visualization of a tear of the rotator cuff in two patients (Fig. 3) and a tear of the anterior labrum in the third patient. All pathologies were arthroscopically confirmed.

Discussion

MR arthrography is increasingly used in the evaluation of abnormalities affecting the glenohumeral joint [1, 2, 10]. Largely owing to the distance separating the fluoroscopy and MR suites, which makes the procedure time-consuming and cumbersome, the clinical implementation of MR arthrography has been slow at our institution. This study illustrates that all stages of MR arthrographic imaging can be accomplished in an open-configuration 0.5-T scanner.

The development of open-configuration MR imaging systems allows direct and permanent access to the patient [8]. Unimpaired patient access must be considered the prerequisite for interactive guidance of articular puncture. The superconducting open-configuration scanner used for MR arthrography operates at 0.5-T. While most studies assessing the utility of MR arthrography were based on imaging performed on 1.5-T systems [10, 11], image quality for assessing the shoulder has been shown to be sufficient with low-field systems [12]. Analysis of the arthrographic images obtained following the injection of paramagnetic contrast supports this contention (Fig. 3).

In many respects, MR imaging is ideally suited to provide imaging guidance for minimally invasive procedures. Puncture of the shoulder joint from an anterolateral approach under active MR guidance as described here was safe and easy to accomplish. The combination of a computer-generated icon and instrument artifact presentation within the Signa SP system allows the interventionalist first to predict the path of the needle as it is held outside the body for approach planning, and subsequently to confirm its actual location with real-time imaging whilst the needle is being advanced. The trajectory computation is, however, based on the assumption that the device is introduced in a straight line and remains rigid during the procedure. Any aberration from the straight course will thus inevitably result in a discrepancy between the calculated and true positions of the device, especially if thin instruments such as 22 gauge needle are used. It is therefore important to confirm the true needle position based on the susceptibility-induced signal void associated with the body of the needle.

Confirmation of the intracapsular position of the needle tip was accomplished by scanning in three planes relative to the long axis of the needle. Real-time MR imaging of contrast inflow into the joint cavity was possible by fixing the imaging plane to traverse the needle tip in the axial plane. Confirmation with a test bolus was not necessary with this protocol. In principle, this technique can also be employed in MR arthrography of other joints such as knee, hip or ankle. At this time, performing a joint puncture under MR guidance remains more cumbersome and time-consuming than using fluoroscopic control, Clearly further improvement of the technique will need to occur.

In conclusion, MR-guided arthrography of the shoulder joint is easily and safely performed in an open-configuration MR system in conjunction with an interactive guidance system. Visualization of needle passage into the articular space and subsequent depiction of the contrast inflow are comparable to that seen with fluoroscopy.

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Book reviews

European Radiology

Lee J. K. T., Sagel S. S., Stanley R. J., Heiken J. P. (Editors): Computed body tomography with MRI correlation, 3rd edition. Two volumes. Philadelphia, New York: Lippincott-Raven, 1998, 1664 pages, 3725 illustrations, £ 258.75, ISBN 0-7817-0291-7

This work is the third edition of the well-known and classic textbook written by the diagnostic radiology staff of three leading academic departments in radiology in the USA: the university of North Carolina, Mallinckrodt Institute of Radiology and the University of Alabama at Birmingham. The book is intended to provide a comprehensive overview of the application of CT and MRI to the extracranial organs of the body.

In comparison with the second edition all the chapters have been extensively revised in order to cover adequately the significant technical advances in both modalities, such as spiral and high-resolution CT, MRI fast imaging sequences and MR contrast agents, which have occurred since the publication of the second edition in 1989. Consequently the number of pages and illustrations has increased by approximately one third while most of the imaging material has been renewed in order to reflect appropriately the technical progress achieved during the last decade in CT and MRI applications. Because of the increased amount of information available this third edition is now published in two volumes instead of one.

The book is divided into 24 chapters. The first two chapters are devoted to the physical principles, image quality considerations and technique of CT and MRI respectively. These chapters are very comprehensive, well written and presented in such a way that the radiologist can acquire a good understanding of the technical matters involved. One chapter is devoted to interventional CT. It covers this topic very thoroughly and provides the interventionally active radiologist with an excellent update and a wealth of practical information.

Twenty-one chapters are devoted to the different extracranial anatomical areas and to paediatric applications of CT and MRI. For each of these areas, as in the first two editions, the chapter starts with a discussion of normal anatomy, followed by a description of organ- and compartment-specific scanning techniques, clinical applications and pathology. Each chapter is followed by a astutely selected number of key references from the literature. The lists of references also include a remarkable number of recent publications of special importance.

Of particular note are the cogent and logical discussions on how CT and MRI are properly integrated with each other as well as with clinical and other radiological procedures. Special efforts are made to define the most appropriate or optimal imaging approach for a given disease or pathological condition. The proposed and recommended sequencing of imaging procedures reflects the practice adopted over the last two decades by the staff radiologists at the three academic centres mentioned above. Where needed, however, appropriate reference and discussion is devoted to experience accumulated in other centres throughout the world as available in the radiological literature.

The reader is impressed by the remarkable degree of homogeneity and the minimal or virtually non-existent overlap in a work of such broad scope and with more than 40 collaborating authors. The authors and editors are to be specially complimented on this important aspect of the handbook. The printing quality of the text and the photographic quality of the illustrations are superb.

This work can be recommended unreservedly to all practising radiologists as the state-of-the-art textbook on CT and MRI at this end of the century. It achieves the same very high standards of quality as the two previous outstanding editions and deserves even more praise. It should be within handreach of every radiologist performing body CT. Albert L. Baert, Leuven

Eichstädt H., Felix R., Zeitler E.: Herz Grosse Gefässe: Diagnostik mit bildgebenden Verfahren. Berlin, Heidelberg, New York: Springer, 1996, 448 pages, 389 figures, 51 tables, DM 318.00, ISBN 3-540-52618-8

The newly restructured book series ‘Klinische Radiologie’, whose aim is to address all medical specialties in matters related to diagnostic and therapeutic problems from an interdisciplinary point of view, now includes a volume devoted to the heart and great vessels. The book comprises 14 chapters covering all aspects of heart diseases and written by various authors or teams of authors.

Notwithstanding the numerous contributors the uniform character of this complex book is well preserved. In each chapter enough space is devoted to pathophysiology and clinical aspects of heart diseases. The different chapters are logically structured and highly informative.

Of course, because of the growing importance of magnetic resonance imaging (MRI) in diagnostic radiology of the heart and blood vessels, some chapters are conceived in a different format. In those clinical areas where MRI already has an established role appropriate attention is devoted to the possibilities of cardio MRI and of MR angiography. However, due to the very rapid progress in MRI of the heart and the vessels and the necessary time deadlines needed to prepare such a complex book, it is understandable that it was not always possible to include the latest developments in cardio MRI and MR angiography. This refers primarily to MRI of the coronary vessels and aorto-coronary bypasses – both areas where MRI has acquired increasing importance during the last year. This shortcoming does not significantly decrease the scientific or educational value of the book, which is mainly based on the integration of pathophysiological and clinical information and its relation with the standards of innovative diagnostic imaging.

I hope that this new volume in the ‘Klinische Radiologie’ series will find numerous readers. As mentioned above it has the advantage of offering extensive basic information with relation to diagnostic imaging modalities, focused not on physical content but primarily on clinical features and pathophysiology of this interesting organ area and system. M. Thelen, Mainz