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Clinical experience of osteoarticular MRI using a dedicated system

Carlo Masciocchi,[1] Antonio Barile,[1,*] Francesco Navarra,[1] Marco Mastantuono,[2] Sergio De Bac,[2] Luigi Satragno,[3] Luciano Lupattelli[1] and Roberto Passariello[2]

[1]*Department of Radiology, University of L'Aquila, Italy*
[2]*Department of Radiology II, University "La Sapienza," Rome, Italy*
[3]*MR Research Center, Esaote Biomedica, Genua, Italy*

Magnetic resonance imaging (MRI) has a significative impact on diagnosis of musculoskeletal diseases. At present, joint diseases are evaluated with total-body systems, this fact representing an obstacle to MR diffusion in the osteoarticular field. The last technological advances have allowed the development of a cost-effective, compact and easy-to-install MR system. The system is constituted by a 0.2-T permanent unit, weighing 800 kg. The unit is used only for limb examination. To verify the diagnostic accuracy of the new system a study based on 1902 lower limb examinations was carried out between October 1992 and February 1994. Of these patients, 301 underwent surgery during which the MR findings were verified. Quite satisfying overall results were obtained, particularly in case of knee trauma, comparable to those provided by total body units with higher magnetic field. It must be noted, however, that in 3% of the investigated knee diseases, the examinations could not be performed due to technical limitations related to the magnet size. The authors believe that the limited field of view (11 cm) does not allows accurate staging of the malignant lesions concerning soft tissue and bone, which require a wider loco-regional staging. They also believe that the particular structure of the magnet allows for a comfortable management of pediatric, elderly, and acute patients.

Keywords: MRI, techniques, joints (disease), extremities.

INTRODUCTION

Imaging of the head, spine, and extremities has consistently accounted for the great majority of magnetic resonance (MR) imaging diagnostic procedures. Unfortunately, a powerful discouragement to the application of magnetic resonance in the field of joints diseases is represented by the high cost of purchasing and installing total-body systems which are also overloaded by socially relevant pathological conditions, such as neoplastic disease.

It was thought to fit the measures of a MR unit to the extremity size (1-2-3-4-5-6-7). This unit was engineered to have a high diagnostic value, despite its unusual small size, at a significantly lower cost of purchase and installation. This report examines characteristics, diagnostic possibilities, and operational limitations of the unit. The departments of Radiology of the Universities of Rome and L'Aquila (Italy) and the MR Research Center of the Esaote Biomedica, Genua were involved in the program.

MATERIALS AND METHODS

Two similar permanent magnets (Artoscan; Esaote Biomedica, Genova, Italy) were used for MR imaging in the departments of Radiology of the University of Rome and L'Aquila (Fig. 1). The dimension and shape of the unit are original. In fact, during examination, only the affected limb is in the MR unit while the patient is sitting in a comfortable armchair (Fig. 2). The system is constituted by a 0.2-T permanent unit, weighing 800 kg, with built-in radio-frequency shield and 10-mT m^{-1} gradients. A solenoidal coil was used;

* *Address for correspondence: Cattedra di Radiologia, Dipartimento di Medicina Sperimentale, Ospedale S. Maria di Collemaggio, Viale Collemaggio, 67100 L'Aquila (AQ), Italy.*

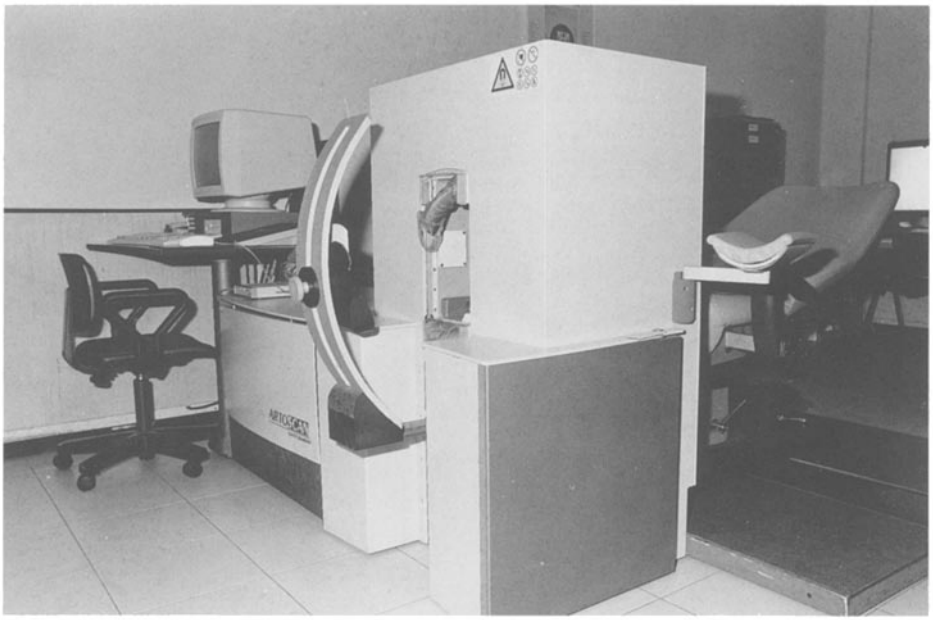

Fig. 1. MRI dedicated unit: operator side.

the gradient coil is not shielded. Postprocessing techniques are not employed with this system.

The field of view of the dedicated system ranges between 100 and 200 mm. The field of view generally employed for the study of the knee is 160 mm. The largest diameter of the magnetic field air gap, diameter of the volume having homogeneous field, is 19 cm. The homogeneity of the field is 50 ppm over 9 cm DSV. B_0 inhomogeneity artifacts are not observed in gradient-echo images. The spatial resolution is inferior to 1 mm. The pixel width is 0.625 mm, resulting from the ratio between field of view (160 mm) and the number of pixels (256).

For the examination of the knee, we used spin-echo sagittal (TR 630 ms; TE 24 ms) and transverse (TR 500 ms; TE 24 ms) scan planes. Gradient-echo T_2^*-weighted sequences (TR 500 ms; TE 18 ms; flip angle 70°) were performed on coronal scan planes. A slice thickness of

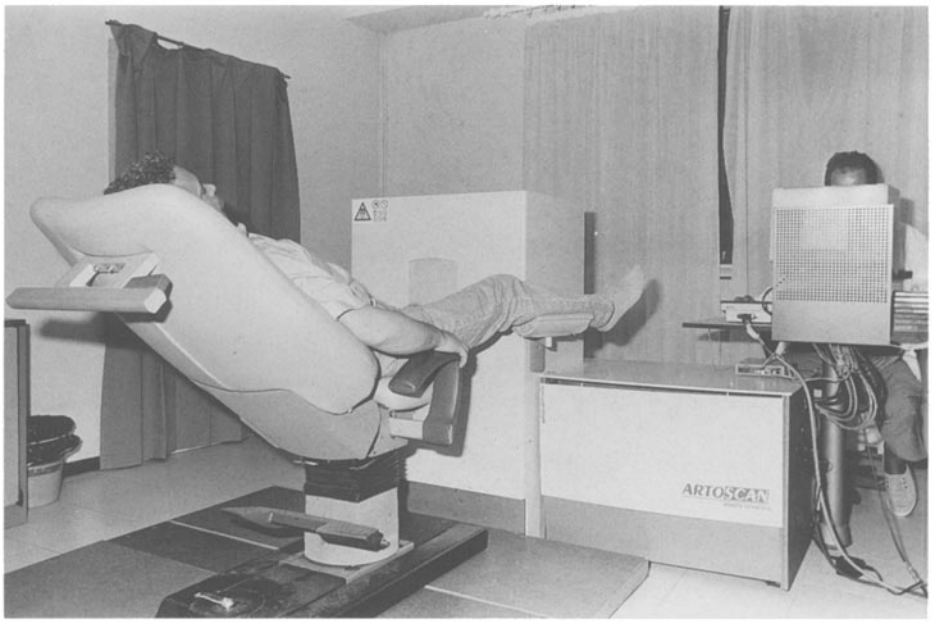

Fig. 2. MRI dedicated unit: positioning for knee study.

4 or 5 mm, two to four averages (generally three), and a 192 × 256 matrix were used. The examination time is 15 min, including positioning (2 min), scout (2 min), and three scans on sagittal, coronal, and axial planes (respectively 4, 4, and 3 min) were performed. The number of averages used is three.

The study is based on 1902 consecutive patients referred between October 1992 and February 1994 to the departments of Radiology of Rome and L'Aquila for a MR examination of lower limb. Both departments carried out the same protocol. The first 3 months were dedicated to optimization of the technique and standardization of parameters. The optimal orientation of the slices and their thickness and the acquisition parameters for different sequences were standardized according to the different clinical needs and anatomical districts to investigate.

Of the 1902 patients, 58% (n = 1103) were males; the mean age was 36 years (range, 5–83 years). Of 1902 examinations, 1488 were related to the knee joint; 405 to foot and ankle; in 9 cases, an extraarticular lesion was investigated. After MR examinations, 301 patients underwent surgery: on the knee, 233 patients; on the ankle and foot 59 patients; and on all 9 patients presenting extra-articular diseases.

In 532 patients, the MR examinations were performed to investigate acute trauma, mostly knee sprains, and more than 70% of these patients presented hemarthrosis and severe functional impairment. Moreover, 128 controls were performed in patients submitted to surgical replacement of the anterior cruciate ligament of the knee. Metallic staples or interference screws positioned at arthroscopy were present.

RESULTS

A complete and diagnostically accurate examination was possible in 1844 cases (97%). All patients with acute trauma, mostly sportsmen and athletes, were correctly examinated. In particular cases (e.g., patients in acute phase), faster sequences were used lasting 90 s. Although the signal-to-noise ratio (S/N) was not optimal, these sequences proved to be highly accurate for diagnosis. The S/N was acceptable, even when employing a 2-mm slice thickness. The overall image quality was quite satisfactory, with good contrast resolution and excellent spatial resolution (0.625 mm).

The 301 patients who underwent surgery after MR examination enabled us to verify the diagnostic accuracy of the system. In the knee, surgery was performed on 233 patients using arthroscopic or with combined arthroscopic–arthrotomic technique in cases treated with surgical replacement of the anterior cruciate ligament. When using surgical results to determine the true lesion of the knee, sensitivity, specificity, and accuracy in detecting meniscal lesions were 95%, 97%, and 92% respectively (Fig. 3). In ligamentous lesions, sensitivity was 97%, specificity 99%, and accuracy 95% (Fig. 4), whereas in osteochondral injuries they were 82%, 97%, and 80%, respectively.

Arthroscopy of the tibiotalar joint was performed in 11 cases, whereas in 48 cases, tendinous diseases, entrapment neuropathies, and skeletal dysplastic conditions were approached by arthrotomy (Fig. 5).

In nine patients operated on for extraarticular disease, muscular lesions were observed in seven cases (four lesions of the medial gastrocnemious muscle, one tear of the anterior tibial muscle, one lesion of the soleus, and one lesion of the tenomuscular junction of the Achilles tendon), whereas in the other two patients, a synovial cyst in an extra-articular site and a mixoma of the popliteal fossa were found. MR diagnosis was confirmed at surgery in all cases for both side and extension of the lesion.

Diagnostic images were not obtained in 57 cases (3%). In these cases, particular somatotypes or clinical conditions of the patients did not allow a correct positioning of the limb. These limitations concerned only the knee. Three types of limitations were encountured: a too thick limb (48 cases) due to circumference exceeding 42 cm at the level of the knee or 66 cm at the level of the thigh, a short thigh (8 cases) due to particular somatotype or in cases of pediatric patients, and, finally, the presence of tubercular coxitis outcomes (1 case) that did not allow a correct divarication of the limbs.

DISCUSSION AND CONCLUSION

Broadening of knowledge in every field of medicine forwards a progressive subdivision of radiology into more subspecialities. This trend, confirmed by many studies, stimulates MR research toward a more and more specialistic field of application. The MR Research Center of the Esaote Biomedica, Genua chose to develop a MR system engineered for one specific field of application, that is, the musculoskeletal disease of the limbs. The introduction of this or other dedicated systems will probably increase the tendency to a segmentation of radiology.

Our experience was aimed at optimization of the MR system at the clinical level. This concerned every step, from installation to evaluation of diagnostic possibilities. The installation of the MR unit was easy,

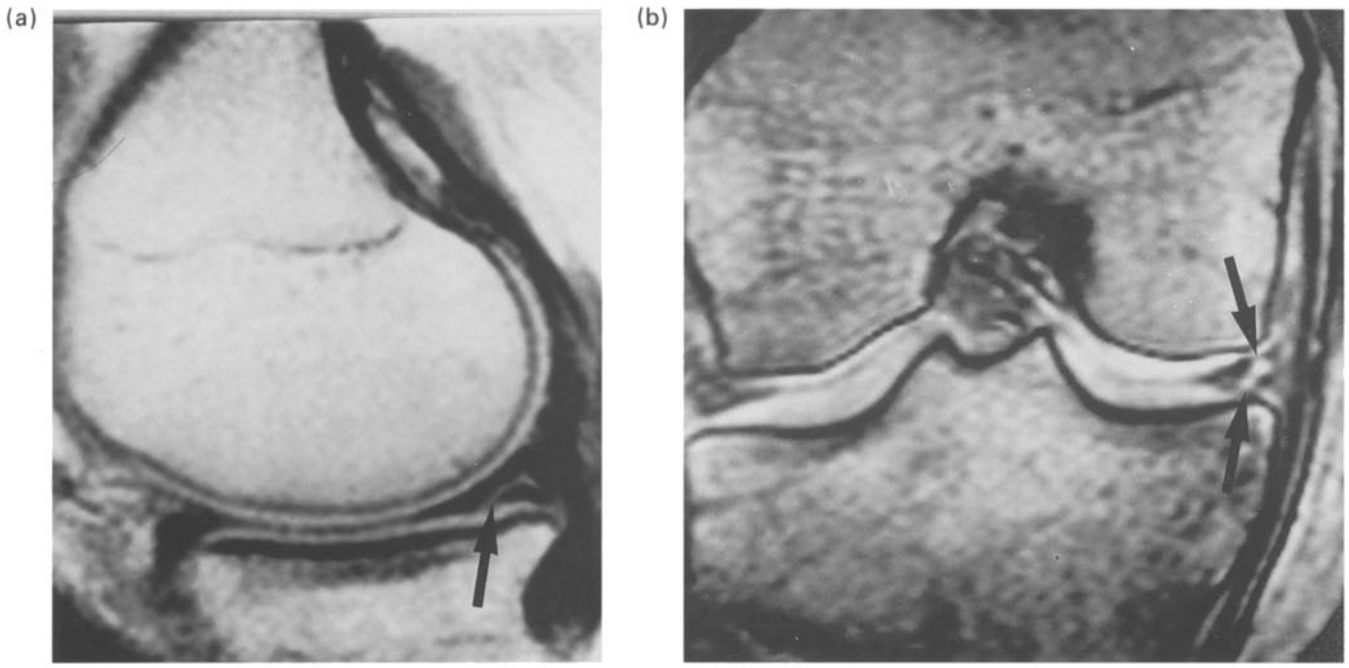

Fig. 3. Lesion of medial meniscus (black arrows), evident on sagittal spin-echo T_1-weighted sequence (a) and on coronal gradient-echo image (b).

thanks to its weight (800 kg). The system did not even have to be bolted to the floor. The normally expensive room preparation was avoided by the presence of a built-in radio-frequency shield, which prevents environmental high-frequency signals from disturbing signal acquisition. The gantry, with a 16 × 34-cm diameter, is closed around the limb with a curtain-like structures coming into contact with the patient's skin. These closing devices protect the internal magnetic field from external influences. Different closing devices are available for a proper adjustment to the sizes of the examined areas.

The shape and dimension of the unit meet ergonomic parameters that allow easy and comfortable

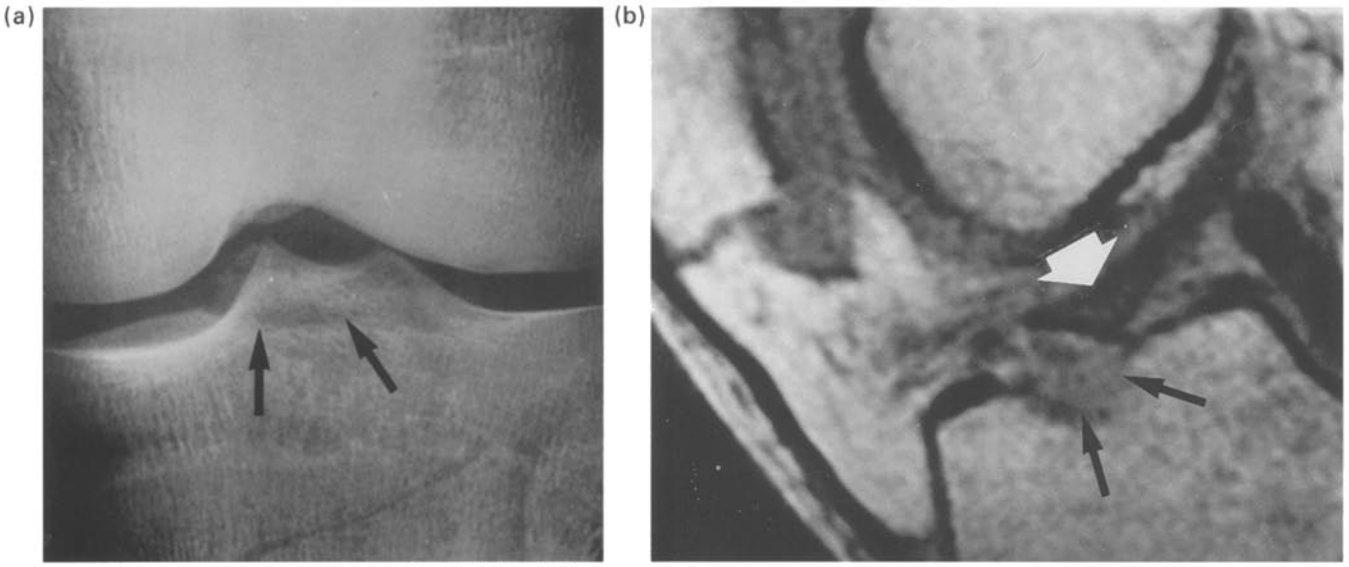

Fig. 4. Plain film (a) shows a fracture of the anterior tibial plateau (black arrows). On sagittal T_1-weighted spin-echo sequence (b), an enlargement of the distal portion of the anterior cruciate ligament (white arrow) induced by the traumatic event is shown.

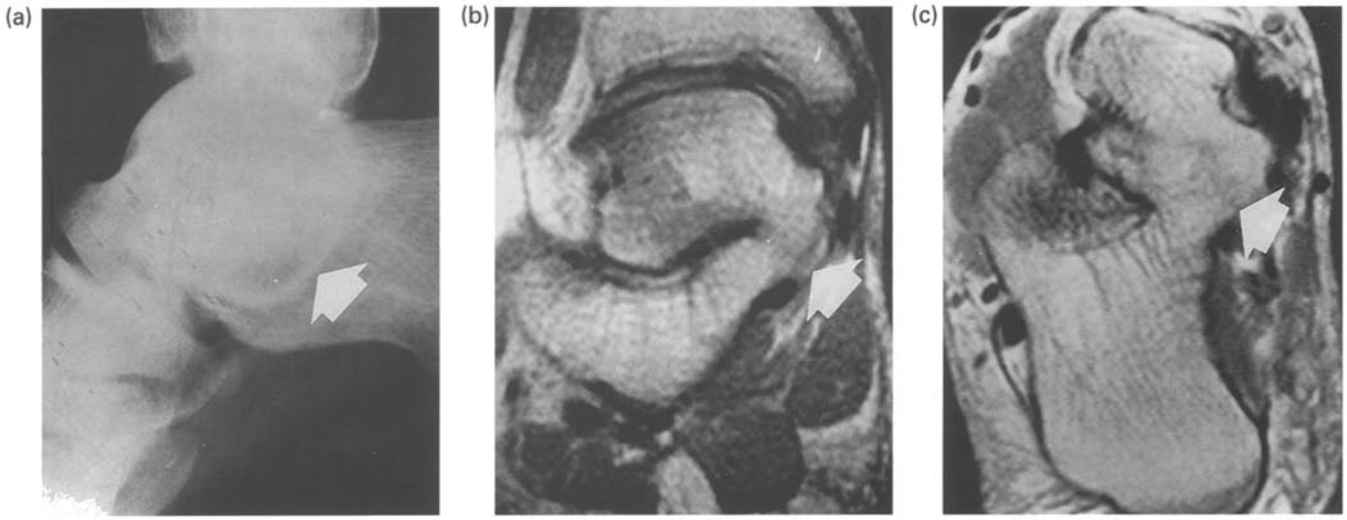

Fig. 5. Talocalcaneal coalition (white arrows): plain film (a) shows the "C sign." On coronal (b) and transverse scans, the complete osseous talocalcaneal coalition is well defined.

positioning of the patients. The patients lies half-seated or supine on the reclinable, mobile armchair with divaricate legs. Only the limb to be examinated is introduced into the gantry; the other is laid on a support provided for the purpose. The limb can be in moderate extension or flexion. Once made, the patient gets closer to the gantry aperture in the described position and the region of interest is positioned within the coil that is subsequently put on grooves and pushed inside the MR unit. The coil is provided with containment pads to prevent unvoluntary movements of the patients. Imaging of the knee is performed with a solenoidal standard coil (13.1 × 14.5 cm of internal diameters) which, in our experience, allowed evaluation of 97% of patients. An oval solenoidal coil (14.5 × 19.0 cm internal diameters) is employed for oversized joints.

Claustrophobic patients are usually unable to carry out MR examination in a whole-body unit. With the new MR unit, no claustrophobic reactions were observed on 1902 examinations. Our experience stresses the psychological relevance for the patient to introduce only one limb into the magnet. This unit is also silent. The comfortable position and the low level of noise allowed the examination of claustrophobic patients who had previously refused to carry out the examination with a whole-body unit. For the same reasons, this new unit is particularly helpful in the study of the pediatric population.

The last technological advances make the diagnostic reliability of this unit comparable to that of traditional whole-body magnets, avoiding many disadvantages. Some technical notes will help explain this good performance. Although operating at low magnetic fields (0.2 T), the unit is provided with 10-mT m^{-1} gradients. Until some time ago, this value was typically obtained with high field units. A typical aspect of a dedicate MR system is its architecture, which is studied to fit for the body district to be examined. This enables one to obtain a high correspondence between the usable homogenity field volume and the needed one. The unit tested in our program delivers only 10-A current in the coil; conversely, a nondedicated system delivers over 300 A to generate the same gradients. Moreover, the excitation radio-frequency power is 50 W in contrast to the 2000 W of the commercially available units. This new MR unit offers many advantages from the environmental and protectional points of view. In fact, the small dimension of the magnet and the shrinking of the area exposed to a variable field result in a drastic reduction of the fringe field. The dispersion of power to the body of the patients is very small and concentrated on the investigated areas.

Our experience shows that the unit is suitable for a clinical routine. Many parameters confirm this statement. The examination time is 15 min. Good spatial resolution makes it possible to image critical areas of the body, such as the subtalar region or the forefoot, to evidentiate small lesion, like Morton's neuromas or tear of the sinus tarsi ligaments. It is worth noting how technical accuracy in imaging the knee pathologies is comparable to that reported in literature by authors employing units with different technical potentialities. The employed field of view (11 cm) allows for a complete and detailed evaluation of every articular joint; conversely, it is not sufficient when a panoramic view is needed, as in case of neoplastic disease. In our experience, this represents the only limitation to the

clinical application of the dedicated MR system. Conversely, we believe that the MR system developed for the study of the articular joints and peripheral limbs can be widely applied, with possible use in emergency cases or acute trauma also.

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