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High-resolution MR imaging of the elbow using a microscopy surface coil and a clinical 1.5 T MR machine: preliminary results

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Abstract *Objective:* To obtain high-resolution MR images of the elbow using a microscopy surface coil with a 1.5 T clinical machine and to evaluate the feasibility of its use for elbow injuries. *Design and patients:* Five asymptomatic normal volunteers and 13 patients with elbow pain were prospectively studied with MR imaging using a microscopy surface coil 47 mm in diameter. High-resolution MR images using a microscopy coil were obtained with fast spin echo (FSE) proton density-weighted sequence, gradient recalled echo (GRE) T2*-weighted sequence, and short tau inversion recovery (STIR) sequence, with a 1–2 mm slice thickness, a 50–70 mm field of view, an imaging matrix of 140–224×512 using zero fill interpolation, and 2–6 excitations. *Results:* High-resolution MR images of normal volunteers using a microscopy coil clearly showed each structure of the medial and lateral collateral ligaments on GRE T2*-weighted images and FSE proton-density weighted images. Partial medial collateral ligament injury, a small avulsion of the medial epicondyle, and osteochondritis dissecans

were well demonstrated on high-resolution MR images. *Conclusion:* High-resolution MR imaging of the elbow using a microscopy surface coil with a 1.5 T clinical machine is a promising method for accurately characterizing the normal anatomy of the elbow and depicting its lesions in detail.

Keywords High-resolution MRI · Elbow · Microscopy coil

Introduction

Magnetic resonance (MR) imaging is an excellent method for evaluating a variety of injuries of the elbow [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]. However, compared with MR imaging of the knee and the shoulder, routine MR im-

aging of the elbow is not frequently performed. Limitations of the elbow MR imaging include difficulties in positioning the patient in a whole-body magnet, magnetic inhomogeneity and lower signal-to-noise ratio at the off-center magnet, the scarcity of dedicated elbow coils, and the high cost of the MR procedure itself [13]. To obtain

high-resolution and high-quality images, it is essential to use a higher-field magnet and dedicated surface coils. Recent studies examined the effects on image quality of using a small field of view (FOV) (10–15 cm) and thin sections (2–5 mm) [2, 14]. Previous studies had shown that three-dimensional gradient recalled-echo (GRE) MR imaging provides section images as thin as 1–1.7 mm [6, 7, 8, 9]. However, their FOVs were limited to 11–15 cm. If image quality is preserved, higher-resolution (smaller FOV) images are preferable for their usefulness in revealing more details and detecting subtle lesions.

Recently, microscopy coils have become commercially available and can provide high-resolution MR imaging of the wrist at 1.5 T [15]. It has been reported that MR images of each triangular fibrocartilage complex (TFCC) structure of the wrist showed significantly better delineation with microscopy coils than with a conventional small surface coil. In addition, high-resolution MR images of the TFCC, the cartilage, and the bone marrow showed significantly higher signal-to-noise ratios and contrast-to-noise ratios with microscopy coils than with a conventional surface coil. It was concluded that high-resolution MR images of the wrist using microscopy coils were both qualitatively and quantitatively superior to those using a conventional surface coil [15].

Accordingly, the purpose of this study was to obtain high-resolution MR images of the elbow using a microscopy surface coil on a 1.5 T clinical machine and to evaluate the feasibility of the use of such a coil for elbow injuries.

Materials and methods

Five asymptomatic normal volunteers and 13 patients with elbow pain were prospectively studied with MR imaging using a 47 mm microscopy surface coil (Philips Medical Systems, Best, The Netherlands). The microscopy coil is intended for a range of applications requiring a small FOV while maintaining a high signal-to-noise ratio and is well suited to examination of small anatomical regions close to the body surface such as skin or superficial vessels. The microscopy coil had a two-winding solenoid flux element, designed to pick up the MR signal. The volunteers were five women, with ages ranging from 20 to 24 years (mean age 23.0 years). The patient group was comprised of 11 male and two female patients, with ages ranging from 12 to 44 years (mean age 22.0 years). Each volunteer and patient gave written informed consent.

All MR images were obtained with a 1.5 T system (Gyroscan NT Intera, Philips Medical Systems, Best, The Netherlands). Each subject was placed in the supine position with the arm at the side in the anatomical position with the face directed anteriorly and with the upper limbs at the sides and the palms turned anteriorly. A commercially available dedicated microscopy surface coil and a 14 cm × 17 cm synergy flexible coil (Flex-M-coil) were positioned simultaneously over the elbow (Fig. 1). The microscopy coil was fixed with elastic bands, and the synergy flexible coil was wrapped around the elbow. A synergy flexible coil was used to obtain routine images prior to high-resolution MR imaging. The synergy flexible coil allows use of the new sensitive encoding (SENSE) technique, a parallel imaging technique that provides as much as a



Fig. 1 Combined coil setting of a microscopy coil and a synergy flexible coil

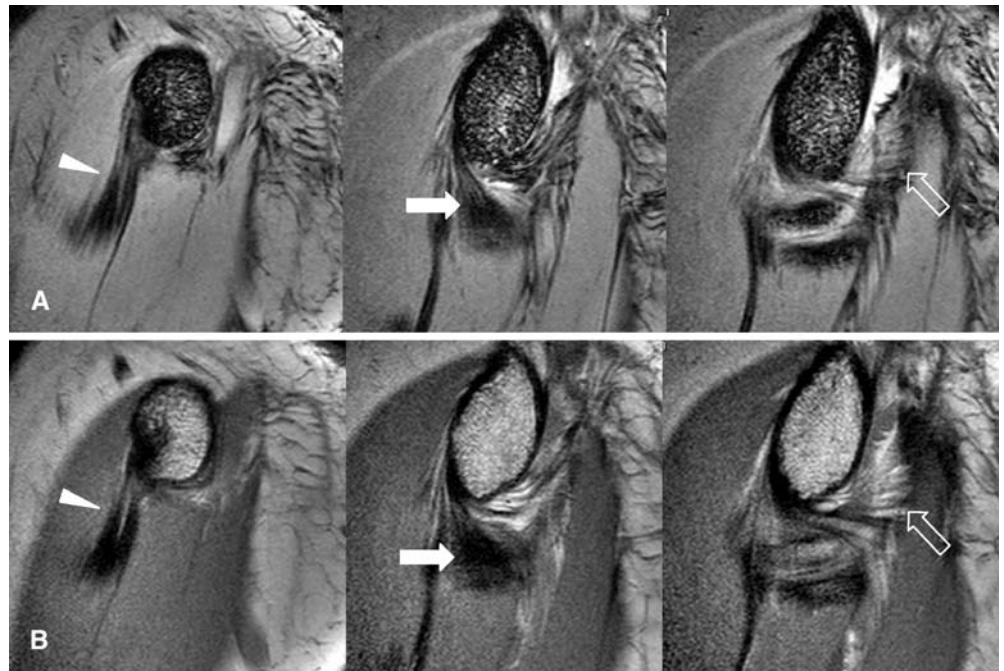
twofold reduction in scan time over standard Fourier imaging using a clinical 1.5 T system [16]. The SENSE method is based on the use of multiple radiofrequency coils and receivers. Multiple coil elements allow fewer phase encoding steps to measure the same FOV with the same resolution. This can reduce the acquisition time by the amount of coil elements.

In the patient group, coronal and axial, or coronal and sagittal images were firstly obtained with a Flex-M-coil to observe both the medial and the lateral components of the elbow. Fast spin echo (FSE) T1-weighted images (repetition time (TR) ms / echo time (TE) ms=486–500/14–16), FSE proton density-weighted images (TR/TE=2,000/17–20), and GRE T2*-weighted images (TR/TE/flip angle=332–520/14–18/30–40) were used with a 3 mm slice thickness, a 0.3 mm interslice gap, a 150–160 mm FOV, an imaging matrix of 154–256×512 using zero fill interpolation (ZIP), and 2–6 excitations. Then high-resolution MR images using a microscopy surface coil were obtained with a FSE proton density-weighted sequence (TR/TE=1,500–2,008/15), GRE T2*-weighted sequence (TR/TE/flip angle=400–538/9.2–18/30–40), and short tau inversion recovery (STIR) sequence (TR/TE/inversion time (IR) ms=3,293–3,365/90/150), with a 1–2 mm slice thickness, a 50–70 mm FOV, an imaging matrix of 140–224×512 using ZIP, and 2–6 excitations. Axial FSE T2-weighted images (TR/TE=1,872–4,991/90–110) were used to evaluate the ulnar nerve with a 1–2 mm slice thickness, a 50–70 mm FOV, an imaging matrix of 150–165×512 using ZIP, and 4–6 excitations. In volunteers, sagittal, coronal, and axial GRE T2*-weighted images (TR/TE/flip angle=477–499/15/40) were obtained with a 1–1.5 mm slice thickness, a 50 mm FOV, a 165–167×512 matrix using ZIP, and 4 excitations. Sagittal FSE

Table 1 Patients' profile (*LCL* lateral collateral ligament, *MCL* medial collateral ligament, *OCD* osteochondritis dissecans)

Patient no.	Age (years)	Sex	Clinical diagnosis	MR imaging diagnosis	Operation
1	19	M	MCL injury	MCL injury	+
2	14	M	OCD	OCD + LCL injury	+
3	42	F	Medial epicondylitis	Common flexor tendon injury	-
4	15	M	MCL injury	MCL injury	-
5	16	M	OCD	OCD + LCL injury	+
6	22	M	Ulnar nerve injury	Post-operation of ulnar nerve injury	-
7	22	F	MCL injury	MCL injury	-
8	12	M	OCD suspected	Medial epicondylitis	-
9	44	M	Cubital tunnel syndrome	No abnormal finding	-
10	24	M	MCL injury	MCL injury	-
11	17	M	MCL injury	MCL injury	-
12	18	M	MCL injury	MCL injury	-
13	18	M	MCL injury	MCL injury	-

Fig. 2 Normal medial collateral ligament on **A** sagittal T2*-weighted imaging, and **B** sagittal proton density-weighted imaging. These images clearly show the common flexor tendon (*arrowheads*), the anterior bundle (*arrows*), and the posterior bundle (*open arrows*) of the medial collateral ligament



proton density-weighted images (TR/TE=1,700/15) were also obtained with a 1 mm slice thickness, a 50 mm FOV, and a 185×512 matrix using ZIP, and 2 excitations.

Table 1 shows clinical and MR diagnoses of the patients in this study. Two patients with osteochondritis dissecans and one patient with medial collateral injury underwent surgery, and their diagnoses were confirmed. In one patient, postoperative images after ulnar nerve injury were examined. Six patients had clinically diagnosed medial collateral ligament injury without surgical confirmation.

Results

High-resolution MR images of normal volunteers using a microscopy coil clearly showed each structure of the

medial and lateral collateral ligaments in GRE T2*-weighted images and FSE proton-density weighted images. In the medial collateral ligament, the anterior bundle was seen as a triangular area of uniform low signal intensity in the sagittal plane that extended from the anteroinferior aspect of the medial epicondyle to the medial coronoid margin (Fig. 2). In addition, in the sagittal plane, the posterior bundle of the medial collateral ligament showed striated and mixed signal intensity containing fat, extending from the posteroinferior aspect of the medial epicondyle to the medial olecranon margin. The transverse bundle of the medial collateral ligament was not clearly delineated in either volunteers or patients. Regarding the lateral collateral ligament, the radial collateral ligament proper showed striated band-like low signal in-

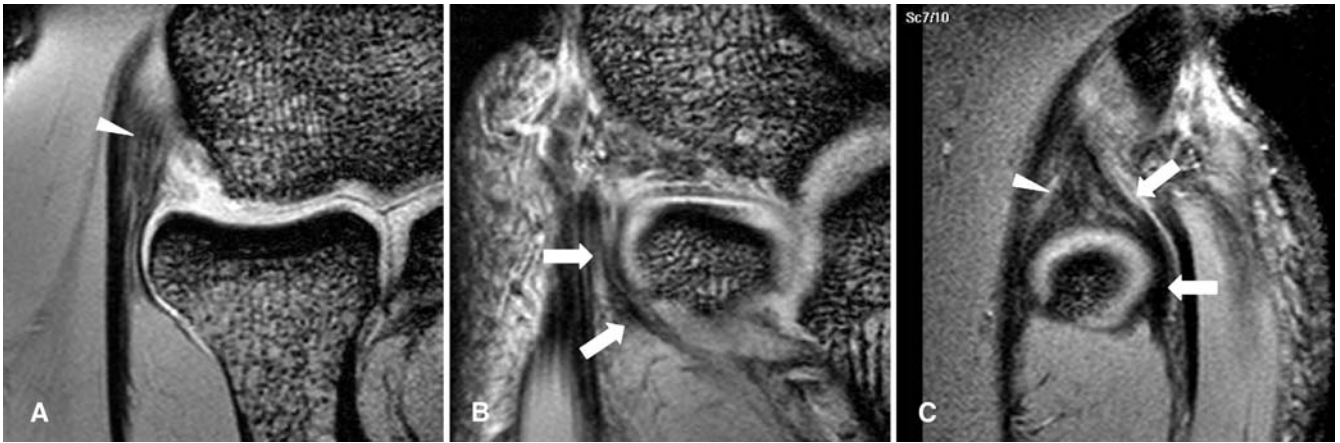


Fig. 3 Normal **A** radial collateral ligament proper (*arrowheads*) and **B** lateral ulnar collateral ligament (*arrows*) on coronal T2*-weighted imaging, and both ligaments **C** on sagittal T2*-weighted imaging

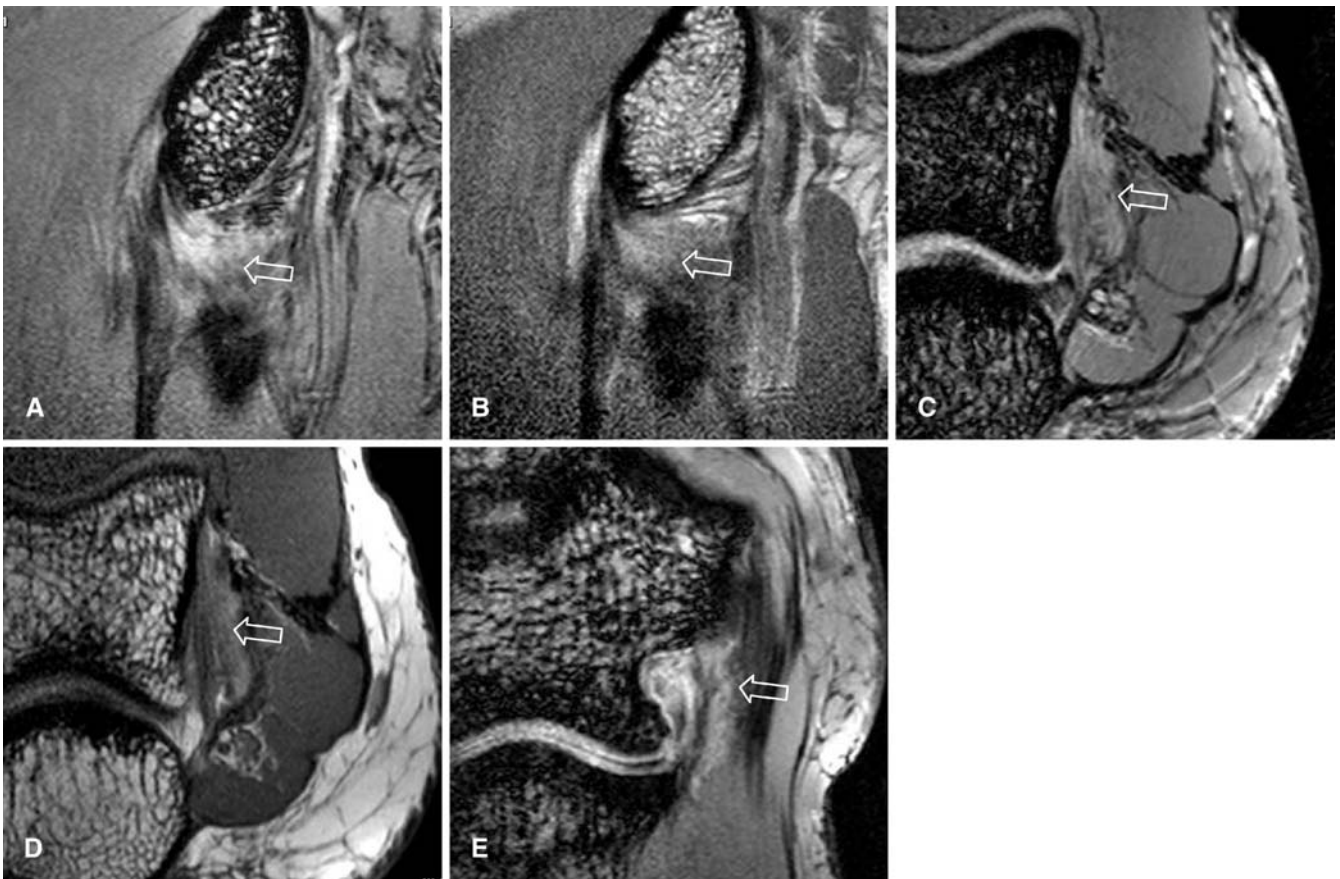


Fig. 4 Medial collateral ligament injury (*open arrows*) on **A** sagittal T2*-weighted imaging, **B** sagittal proton density-weighted imaging, **C** axial T2*-weighted imaging, **D** axial proton density-weighted imaging, and **E** coronal T2*-weighted imaging

tensity on coronal T2*-weighted images. The lateral ulnar collateral ligament curved around the radial head on the coronal plane. In sagittal T2*-weighted images and proton density-weighted images, the two ligaments formed a

triangular shape of low signal intensity above the lateral edge of the radial head (Fig. 3).

The partial medial collateral ligament injury showed abnormal high signal intensity without discontinuity of

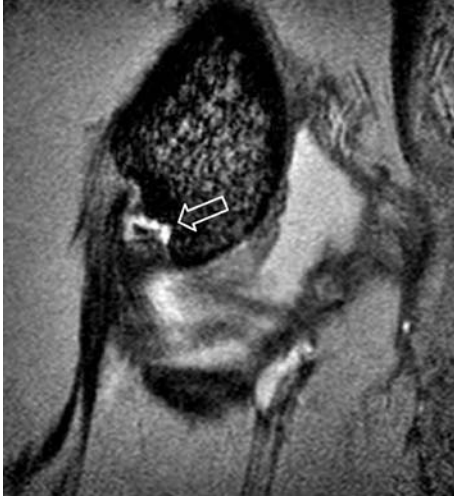


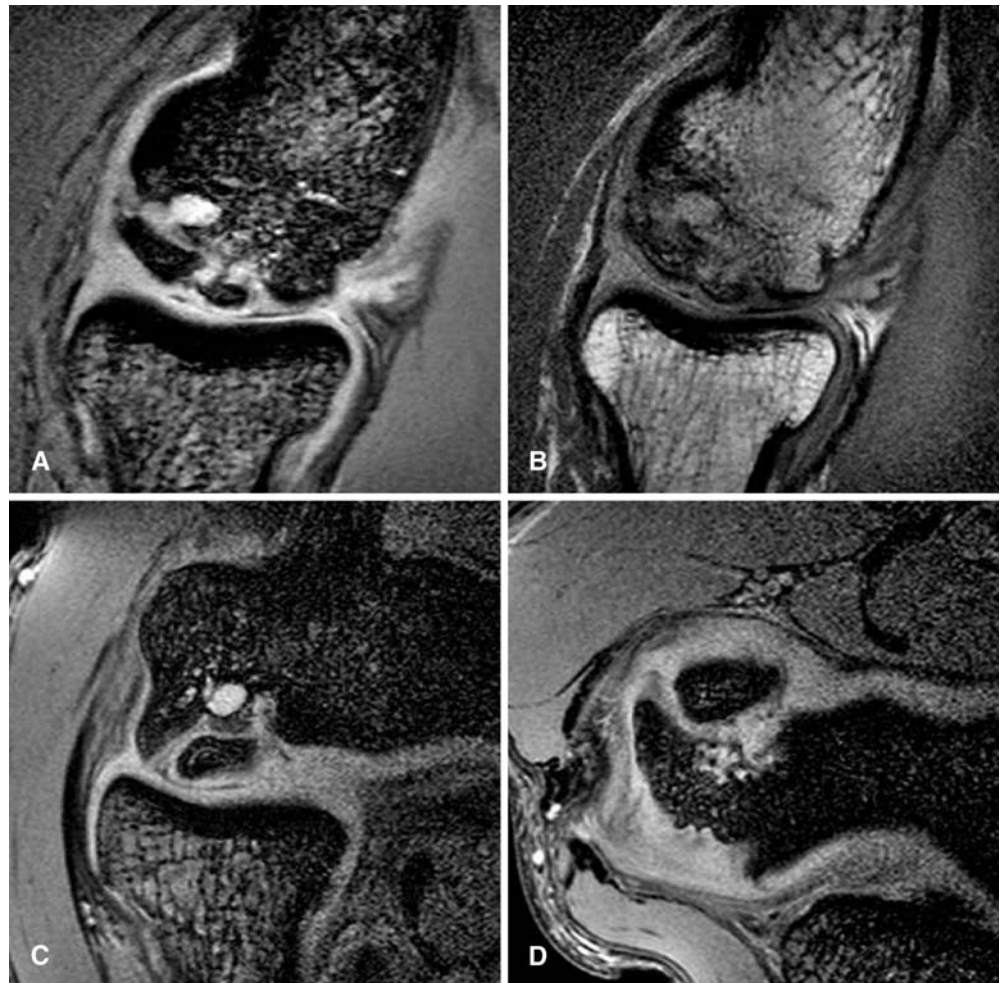
Fig. 5 Medial collateral injury with a small avulsion fracture of the medial epicondyle (*open arrow*) on sagittal T2*-weighted imaging. Joint effusion is also seen

the ligament on both the proton density-weighted sequence and T2*-weighted sequence (Fig. 4). A small avulsion of the medial epicondyle at the attachment of the anterior bundle was discernible only in high-resolution sagittal MR images in one patient (Fig. 5).

High-resolution MR imaging with a microscopy coil appreciated normal articular cartilage of the humerus, radius, and ulna in three planes. In two patients with osteochondritis dissecans, the articular surface irregularity and the fragmentation of the capitellum were demonstrated in detail in high-resolution MR images (Fig. 6). The high signal intensity of T2*-weighted images intervened in the radial ulnar collateral ligament in both cases, suggesting minor ligament injuries.

After microsurgical reconstruction, the ulnar nerve swelled and showed high signal intensity on fat-suppressed T2-weighted images and STIR images with surrounding soft tissue edema (Fig. 7). High-resolution MR imaging with a microscopy coil revealed the linear and follicular internal structure of the ulnar nerve.

Fig. 6 Osteochondritis dissecans of the capitellum on **A** sagittal T2*-weighted imaging, **B** sagittal proton density-weighted imaging, **C** coronal T2*-weighted imaging, and **D** axial T2*-weighted imaging. High-resolution MR imaging can accurately assess the overlying articular cartilage, the relation between the fragment and the parent bone, and the accompanying cystic lesions



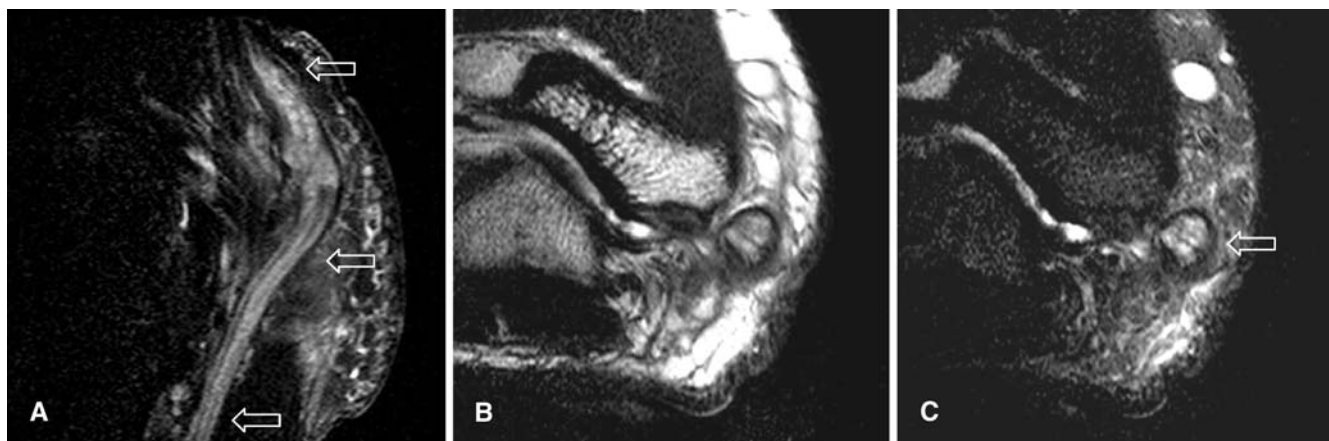


Fig. 7 Ulnar nerve repaired by microsurgical technique on **A** coronal STIR, **B** axial T2-weighted imaging, and **C** STIR. The swollen ulnar nerve is dislocated medially (*open arrows*) and shows

diffuse high intensity on T2-weighted imaging and STIR. The surrounding muscle and subcutaneous fat is edematous

Discussion

In this study, high-resolution MR images were obtained with a 1 mm section thickness and a 5 cm FOV, which was a thinner section and smaller FOV than in previous studies [17]. To our knowledge, the clinical use of high-resolution MR images using small-diameter surface coils (less than 5 cm) has been reported only for the evaluation of the carpal tunnel and the wrist [18]. High-resolution MR images with a microscopy coil allowed both the medial and lateral collateral ligaments to be well visualized with proton-density weighted and T2*-weighted sequences. The sagittal plane was especially useful for detecting both normal conditions and injuries to each anterior and posterior bundle of the medial collateral ligament, as well as each radial collateral ligament proper and lateral ulnar collateral ligament of the lateral collateral ligament. Previous studies have rarely addressed the importance of the sagittal plane because of thicker sections on two-dimensional MR imaging and limited contrast on three-dimensional MR imaging.

The technical innovation evaluated in this study was the combined use of a microscopy coil and a synergy flexible coil (SENSE technique) in the same examination. One major limitation of the microscopy coil is its reduced sensitivity due to its small size. MRI examination of both sides of the elbow is essential for elbow injuries. For example, valgus stress results in strain on the medial collateral ligament and impaction forces on the lateral aspect of the elbow, i.e., the radiocapitellar joint. We were able to examine the whole elbow and the focused lesion using the combination of a synergy flexible coil and a microscopy coil. Although this combination increased the total examination time, application of the SENSE technique with a synergy coil reduced the time necessary for each scan.

High-resolution MR imaging with a microscopy coil seems to have the potential for clinical use for lesion detection while retaining detail. This method also holds some promise for the clear delineation of ligament injuries. The collateral ligaments of the elbow were found to be best shown in coronal or oblique coronal MR images in previous literature [17, 19, 20]. However, Cotten et al. reported that the lateral ulnar collateral ligament could be difficult to differentiate from the radial collateral ligament proper on coronal oblique images, and it was reported to be poorly depicted on the routine coronal oblique sections commonly used [17]. To our knowledge, there are no reports on the usefulness of sagittal images of the elbow, perhaps because of the limited section thickness and FOV with conventional coils.

Our study had several limitations. First, we used only two-dimensional MR imaging. Carrino et al. reported that one pitfall of two-dimensional imaging is artifactual ligament discontinuity, which may result either from an inappropriate imaging plane or may be secondary to volume averaging, leading to false-positive diagnoses with nonenhanced pulse sequences [21]. Three-dimensional GRE MR imaging has been shown to provide section images as thin as 1–1.7 mm [6, 7, 8, 9], although those studies used larger FOVs (11–15 cm) than we did. However, Sonin et al. reported that the two-dimensional (2D) GRE sequence offers superior contrast compared with the three-dimensional sequence [2]. In this study, section thickness on 2D MR images was only 1 mm or 1.5 mm, which was comparable with 3D MRI. In addition, unlike 3D images, 2D MRI using microscopy coils allowed various pulse sequences such as T1-weighted images, T2-weighted images, and even STIR images, which were useful in visualizing the pathology of elbow disorders. A second limitation of our study was the relatively small number of both patients and surgical confir-

mations. Finally, the MR parameters such as TR, TE, matrix size, and number of excitations were not uniform. Therefore, our future investigations should include more MR images with optimal pulse sequences and surgical correlation to confirm the usefulness of high-resolution MRI with a microscopy coil.

In conclusion, high-resolution MR imaging of the elbow using a microscopy surface coil in a 1.5 T clinical machine is a promising method for characterizing the normal anatomy of the elbow and depicting its lesions in detail. The combination of a microscopy coil and a synergy surface coil (SENSE technique) represents a useful option for MR examination of the elbow.

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