Musculoskeletal Imaging at 3T with Simultaneous Use of Multipurpose Loop Coils

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Introduction
The goal of this paper is to show how the simultaneous use of multipurpose Loop Coils in magnetic resonance imaging (MRI) enables high-resolution musculoskeletal (MSK) studies with an increased level of contrast and specificity for assessing muscles, tendons, ligaments, joints, cartilage, etc and how this imaging procedure helps to obtain accurate clinical diagnoses.

In the following sections we present six different daily patient routine examinations carried out at Clínica Creu Blanca, a leading Spanish institution in Sports Medicine MRI (Fig. 1).

Material and methods
All MRI exams shown in this article were performed at 3 Tesla open bore system with TrueForm technology (MAGNETOM Verio, Siemens Healthcare, Germany), equipped with 32-channel (Tim [102 × 32] configuration) in combination with multipurpose Loop Coils and Flex Coil interfaces.

Loop Coils come in three sizes (Fig. 2), Large (11 cm diameter), Medium (7 cm diameter) and Small (4 cm diameter). They are iPAT-compatible (integrated Parallel Acquisition Technique) in combination with other coils and can be combined with any coil and the lower part of the 32-channel Head Coil (Table 1). The Flex Coil Interface is not permanently mounted and therefore allows flexible coil positioning.

The imaging protocols include axial, coronal and sagittal Proton Density-weighted (PD) Turbo Spin Echo (TSE) sequences with and without Fat Saturation (Fat Sat) and T1-weighted TSE.

Patient and coil positioning
Correct patient positioning and the selection of right loop coils for the region-of-interest have a huge influence on image quality (e.g. to avoid coil filling-factor). In addition, we have to make sure that the patient is positioned comfortably to make the scan bearable and to reduce the risk of patient movements. The following six examinations – as performed at Clínica Creu Blanca’s daily routine – explain how we do it and the results that can be achieved.
### Table 1: Flex Coil Interface and Loop Coils: main characteristics

<table>
<thead>
<tr>
<th>Flex Coil Interface</th>
<th>Loop Coils</th>
<th>Loop Coil, large</th>
<th>Loop Coil, medium</th>
<th>Loop Coil, small</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>General</td>
<td>• No coil tuning</td>
<td>• No coil tuning</td>
<td>• No coil tuning</td>
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<td></td>
<td>iPAT-compatible in combination with other coils</td>
<td>iPAT-compatible in combination with other coils</td>
<td>iPAT-compatible in combination with other coils</td>
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<tr>
<td>Applications</td>
<td>Applications</td>
<td>Examination of upper or lower extremities (e.g. shoulder, axilla)</td>
<td>Examination of inner ear, wrist and fingers, pediatric examinations(^*)</td>
<td>Examination of small structures near the surface (e.g. joints of fingers and toes, wrist, skin, temporomandibular joints (TMJ))</td>
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<tr>
<td>Can be combined with</td>
<td>Can be combined with</td>
<td>Any coil and the lower part of the 32-channel Head Coil</td>
<td>Any coil and the lower part of the 32-channel Head Coil</td>
<td>Any coil and the lower part of the 32-channel Head Coil</td>
</tr>
<tr>
<td>Cannot be combined with</td>
<td>Cannot be combined with</td>
<td>The complete 32-channel Head Coil and the complete 32-channel Body Coil</td>
<td>The complete 32-channel Head Coil and the complete 32-channel Body Coil</td>
<td>The complete 32-channel Head Coil and the complete 32-channel Body Coil</td>
</tr>
<tr>
<td>Weight</td>
<td>Weight</td>
<td>225 g</td>
<td>175 g</td>
<td>200 g</td>
</tr>
<tr>
<td>Diameter</td>
<td>Diameter</td>
<td>110 mm</td>
<td>70 mm</td>
<td>40 mm</td>
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\(^*\) MR scanning has not been established as safe for imaging fetuses and infants under two years of age. The responsible physician must evaluate the benefit of the MRI examination in comparison to other imaging procedures.
Carpals examination

This examination was performed using three Flex Coil Interfaces and three 7 cm Loop Coils (Fig. 3). The obtained images are depicted in Figure 4.

Cables should not be crossed otherwise there will be a signal error when a three plane localizer is launched.
(4A) Coronal PD Turbo Spin Echo (TSE) Fat Sat, TR 3500 ms, TE 44 ms, Slice thickness (SL) 1.7 mm, in-plane resolution 0.4 × 0.4 mm², matrix 192 × 192 px².

(4B) Coronal T1w TSE, TR 1290 ms, TE 12 ms, SL 1.7 mm, in-plane resolution 0.3 × 0.3 mm², matrix 320 × 320.

(4C) Axial PD TSE Fat Sat, TR 4400 ms, TE 47 ms, SL 2 mm, in-plane resolution 0.3 × 0.3 mm², matrix 256 × 256 px².

(4D) Axial PD TSE, TR 2400 ms, TE 34 ms, SL 2 mm, in-plane resolution 0.3 × 0.3 mm², matrix 256 × 256 px².

(4E) Sagittal PD TSE Fat Sat, TR 4100 ms, TE 44 ms, SL 1.8 mm in-plane resolution 0.4 × 0.4 mm², matrix 192 × 192 px².

(4F) Sagittal T1w TSE, TR 1000 ms, TE 12 ms, SL 1.8 mm, in-plane resolution 0.3 × 0.3 mm², matrix 320 × 320 px².
Thumb metacarpals examination

This examination was performed using two Flex Coil Interfaces and two 4 cm Loop Coils (Fig. 5). The obtained images are depicted in Figure 6.
**6A** Axial PD TSE Fat Sat, TR 5200 ms, TE 47 ms, SL 2 mm, in-plane resolution 0.3 x 0.3 mm², matrix 256 x 256 px².

**6B** PD TSE, TR 3000 ms, TE 35 ms, SL 2 mm, in-plane resolution 0.3 x 0.3 mm², matrix 256 x 256 px².

**6C** Sagittal PD TSE Fat Sat, TR 4100 ms, TE 44 ms, SL 1 mm, in-plane resolution 0.4 x 0.4 mm², matrix 192 x 192 px².

**6D** Sagittal T1w TSE, TR 810 ms, TE 12 ms, SL 1 mm, in-plane resolution 0.3 x 0.3 mm², matrix 256 x 256 px².

**6E** Coronal PD TSE Fat Sat, TR 3500 ms, TE 44 ms, SL 1.2 mm, in-plane resolution 0.4 x 0.4 mm², matrix 192 x 192 px².

**6F** Coronal T1w TSE, TR 650 ms, TE 12 ms, SL 1.2 mm, in-plane resolution 0.3 x 0.3 mm², matrix 256 x 256 px².
Ankle examination

This examination was performed using three Flex Coil Interfaces and three 7 cm Loop Coils (Fig. 7). The obtained images are depicted in Figure 8.

Flex Interface Coils are separated by flat pads and a couple of straps are used to immobilize the ankle.

U-shape cushion to place the feet and fix the ankle with a strap.

The triangular leg pad should be placed to increase patient comfort and to avoid lumbar lordosis.

Patient and coil positioning for ankle examinations.
(8A) Sagittal PD TSE Fat Sat, TR 5200 ms, TE 52 ms, SL 2.5 mm, in-plane resolution 0.4 x 0.4 mm², matrix 320 x 320 px².

(8B) Sagittal T1w TSE, TR 719 ms, TE 10 ms, SL 2.5 mm, in-plane resolution 0.4 x 0.4 mm², matrix 320 x 320 px².

(8C) Axial PD TSE, TR 4140 ms, TE 44 ms, SL 1.8 mm, in-plane resolution 0.3 x 0.3 mm², matrix 384 x 384 px².

(8D) Axial PD TSE Fat Sat, TR 8710 ms, TE 40 ms, SL 1.8 mm, in-plane resolution 0.4 x 0.4 mm², matrix 320 x 320 px².

(8E) Coronal T1w TSE, TR 719 ms, TE 12 ms, SL 2 mm, in-plane resolution 0.3 x 0.3 mm², matrix 320 x 320 px².

(8F) Coronal PD TSE Fat Sat, TR 5400 ms, TE 50 ms, SL 2 mm, in-plane resolution 0.3 x 0.3 mm², matrix 320 x 320 px².
**Metacarpals or fingers examination**

This examination was performed using two Flex Coil Interfaces and two 7 cm Loop Coils (Fig. 9). The obtained images are depicted in Figure 10.

![Patient and coil positioning for metacarpals or fingers examination.](image)
(10A) Sagittal PD TSE Fat Sat, TR 4100 ms, TE 44 ms, SL 1.3 mm, in-plane resolution 0.5 × 0.5 mm², matrix 192 × 192 px².

(10B) Sagittal T1w TSE, TR 1000 ms, TE 12 ms, SL 1.3 mm, in-plane resolution 0.3 × 0.3 mm², matrix 320 × 320 px².

(10C) Axial PD TSE Fat Sat, TR 5600 ms, TE 52 ms, SL 2.5 mm, in-plane resolution 0.3 × 0.3 mm², matrix 256 × 256 px².

(10D) Axial PD TSE, TR 3000 ms, TE 34 ms, SL 2.5 mm, in-plane resolution 0.3 × 0.3 mm², matrix 256 × 256 px².
Distal inter-phalangeal examination

This examination was performed using two Flex Coil Interfaces and two 4 cm Loop Coils (Fig. 11). The obtained images are depicted in Figure 12.
12A Axial PD TSE Fat Sat, TR 5200 ms, TE 47 ms, SL 2 mm, in-plane resolution 0.3 × 0.3 mm², matrix 256 × 256 px².

12B Axial PD TSE, TR 3000 ms, TE 35 ms, SL 2 mm, in-plane resolution 0.3 × 0.3 mm², matrix 256 × 256 px².

12C Sagittal PD TSE Fat Sat, TR 4100 ms, TE 44 ms, SL 1 mm, in-plane resolution 0.4 × 0.4 mm², matrix 192 × 192 px².

12D Sagittal T1w TSE, TR 810 ms, TE 12 ms, SL 1 mm, in-plane resolution 0.3 × 0.3 mm², matrix 256 × 256 px².

12E Coronal PD TSE Fat Sat, TR 3500 ms, TE 44 ms, SL 1.2 mm, in-plane resolution 0.4 × 0.4 mm², matrix 192 × 192 px².

12F Coronal T1w TSE, TR 650 ms, TE 12 ms, SL 1.2 mm, in-plane resolution 0.3 × 0.3 mm², matrix 192 × 192 px².

12G This figure shows an angiography of a finger whose third phalange was amputated: coronal FLASH 3D post contrast, TR 1.5 ms, TE 3.82 ms, SL 0.7 mm, in-plane resolution 0.7 × 0.7 mm, matrix 192 × 174 px².
Elbow examination

This examination was performed using three Flex Coil Interfaces and three 7 cm Loop Coils (Fig. 13). The obtained images are depicted in Figure 14.

References
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Conclusion

High-resolution MSK imaging can be acquired using a 3T magnetic field (MAGNETOM Verio) and a combination of multipurpose Loop Coils. It does not claim to replace dedicated MSK coils (e.g. knee coil, hand coil) but it might represent an alternative method for institutions whose number of MSK studies is scarce and/or that are not concerned about reducing MSK examination times and/or increasing patient throughput but that want to achieve similar levels of diagnostic accuracy as dedicated coils [1–6].

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(14A) Axial PD TSE Fat Sat, TR 4400 ms, TE 47 ms, SL 2 mm, in-plane resolution 0.5 × 0.5 mm², matrix 256 × 256 px².
(14B) Axial PD TSE, TR 2700 ms, TE 41 ms, SL 2 mm, in-plane resolution 0.4 × 0.4 mm², matrix 320 × 320 px².
(14C) Coronal PD TSE Fat Sat, TR 5000 ms, TE 44 ms, SL 1.8 mm, in-plane resolution 0.5 × 0.5 mm², matrix 192 × 192 px².
(14D) Coronal T1w TSE, TR 1000 ms, TE 12 ms, SL 1.8 mm, in-plane resolution 0.3 × 0.3 mm², matrix 320 × 320 px².
(14E) Sagittal PD TSE Fat Sat, TR 4800 ms, TE 41 ms, SL 2 mm, in-plane resolution 0.5 × 0.5 mm², matrix 192 × 192 px².
(14F) Sagittal T1w TSE, TR 1000 ms, TE 12 ms, SL 2 mm, in-plane resolution 0.3 × 0.3 mm², matrix 320 × 320 px².