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Advanced MR imaging with AI from peripheral nerves to knee cartilage and trauma

As one of the leading musculoskeletal (MSK) and sports medicine providers in Europe, Clínica CEMTRO specializes in trauma and orthopedic surgery. It is a reference hospital for elite athletes and is accredited as a FIFA Medical Center of Excellence – one of 32 institutions worldwide with this designation. More than 42,000 MSK MR examinations were performed in 2022, supporting approximately 14,000 surgeries, 40,000 emergency room visits and 200,000 outpatient visits that occur each year.

The hospital is equipped with some of the latest MR technologies from GE HealthCare, including two SIGNA™ Artist 1.5T, one SIGNA™ Voyager 1.5T, one SIGNA™ Pioneer 3.0T and one SIGNA™ Architect 3.0T, all running MR 30 for SIGNA™. In MR 30 for SIGNA™, AIR™ Recon DL has been extended to 3D and PROPELLER acquisitions. The center also has AIR x™ for knee exams and several AIR™ Coils – the 16-channel and 30-channel AIR™ Anterior Array (AA) Coils and the 20-channel and 21-channel AIR™ Multi-Purpose (MP) Coils.

Clínica CEMTRO utilizes its MR technologies for complex exams, such as MR neurography and knee cartilage imaging, as well as trauma imaging and total joint replacement surgeries. According to Mario Padrón, MD, Head of the Imaging Service, Clínica CEMTRO, SIGNA™ Architect is typically employed for cases where high-resolution imaging and conspicuity of a lesion or injury are critical, such as cartilage assessment and small joint studies. SIGNA™ Voyager is preferred in patients who have MR-Conditional implants, prostheses or hardware due to the reduced susceptibility artifacts at 1.5T that can otherwise negatively impact image quality.

According to Dr. Padrón, the AIR™ Coils are used for all exams due to their excellent image quality and adaptability to the patient's position and size, including the ability to use on emergency room patients who have been fitted with an orthopedic cast. And, because patients are more comfortable with the AIR™ Coils – they are softer, lighter, more flexible and easier to position on the patient than conventional rigid coils – patients better tolerate the exam, which reduces the probability they will move and degrade image quality.

AIR™ Recon DL is also used on all exams, especially now that it is available on 3D and PROPELLER sequences. In particular, AIR™ Recon DL PROPELLER has made a significant impact in motion-prone anatomies, such as the shoulder, where it is essential for reducing magnetic susceptibility artifacts with a boost in image sharpness and SNR. As a result of this improvement, Dr. Padrón has seen reduced patient callbacks and higher image quality for post-contrast and shoulder instability examinations.

“AIR™ Recon DL is key to achieving high-quality scans every time,” Dr. Padrón says. “We have implemented two approaches without sacrificing SNR: faster exams with conventional resolution or high-resolution exams in conventional scan times. We select the strategy depending on the specific patient requirements.”

By optimizing the total scan time, Dr. Padrón and colleagues can introduce sequences that provide additional clinical value to the diagnosis, such as oZTEo, quantitative MR and nerve tractography, without impacting patient throughput.

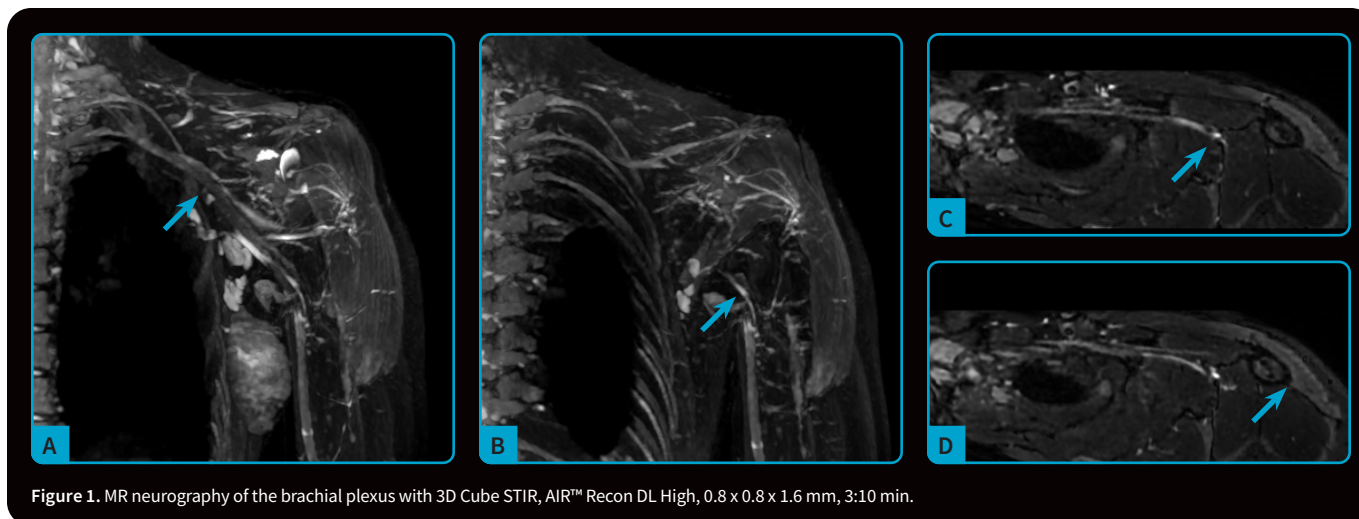


Figure 1. MR neurography of the brachial plexus with 3D Cube STIR, AIR™ Recon DL High, 0.8 x 0.8 x 1.6 mm, 3:10 min.

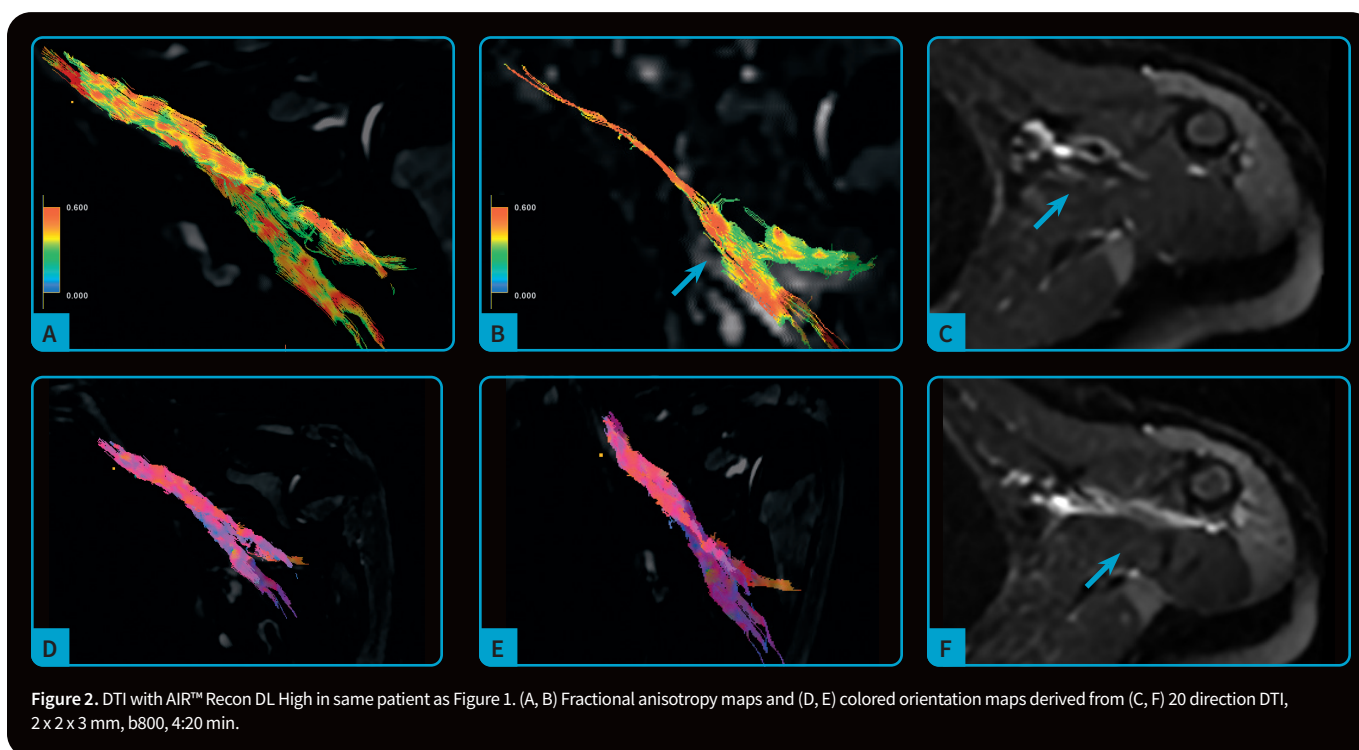


Figure 2. DTI with AIR™ Recon DL High in same patient as Figure 1. (A, B) Fractional anisotropy maps and (D, E) colored orientation maps derived from (C, F) 20 direction DTI, 2 x 2 x 3 mm, b800, 4:20 min.

MR neurography exams

The radiology unit is collaborating with the neurophysiology unit at Clínica CEMTRO in the diagnosis and treatment of peripheral nerve diseases. The neurophysiology unit performs conduction velocity tests clinically on a daily basis, recruiting and referring patients with diagnosed neuropathy. Currently, the radiology unit performs 10 MR neurography cases per month, mainly in the upper extremities and brachial plexus as referred from the emergency room.

According to Dr. Padrón, peripheral nerve imaging poses unique challenges

related to spatial resolution (given their small diameter), poor contrast resolution (relative to neighboring veins and muscle) and imaging off-isocenter of the main magnet bore. Complicating the exam are field inhomogeneities around the neck and lungs when imaging the brachial plexus or within the abdomen when imaging the lumbar plexus, with many overlapping structures and artifacts. In post-surgical patients, these exams are further challenged by artifacts caused by MR-Conditional implants or other hardware.

While the full routine protocol depends on the anatomy being imaged, Clínica CEMTRO typically acquires different Proton Density, T1- and T2-weighting, with and without FatSat, in different planes with PROPELLER (e.g., wrist or elbow) or FSE. With AIR™ Recon DL available with Flex in MR 30 for SIGNA™, the center is using it for fat/water contrast, all in the same scan. Because these routine sequences are faster with AIR™ Recon DL, Dr. Padrón and his colleagues can often include more advanced sequences to further interrogate the patient's condition.

In addition to the routine MR protocol, Clínica CEMTRO will often perform a 3D Cube STIR with AIR™ Recon DL or MENSA NERVE to best locate the lesion. MENSA NERVE is preferred in extremity imaging, and Dr. Padrón anticipates a further increase in image quality in this sequence once the center can apply AIR™ Recon DL to it with the MR 30.1 upgrade. Diffusion tensor imaging (DTI) with AIR™ Recon DL is also performed for tractography and to assess all the quantitative diffusivity measurements, including fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD) and radial diffusivity (RD). oZTEo is then utilized to overlay the bone anatomy on the fiber tractography.

“Peripheral nerve DTI imaging often requires clinically impractical scan times to ensure good SNR. One of the major pitfalls of low SNR is overestimation of FA, while low spatial resolution may lead to incorrect fiber tractography,” Dr. Padrón explains.

“AIR™ Recon DL is a game changer in MR neurography. Having the ability to increase SNR without impacting scan time allows us to perform high-quality studies in patients who are often in pain,” he adds. “The ability to achieve optimal image quality results in a higher diagnostic confidence that facilitates correlation with clinical findings.”

Trauma imaging

Nearly 400 patients present to Clínica CEMTRO’s emergency department each week with bone injuries or fractures. While X-ray is often the first imaging modality of

choice, approximately 150 patients also receive a CT exam and an estimated 50-100 patients are referred to MR to complete the bone study with soft tissue imaging.

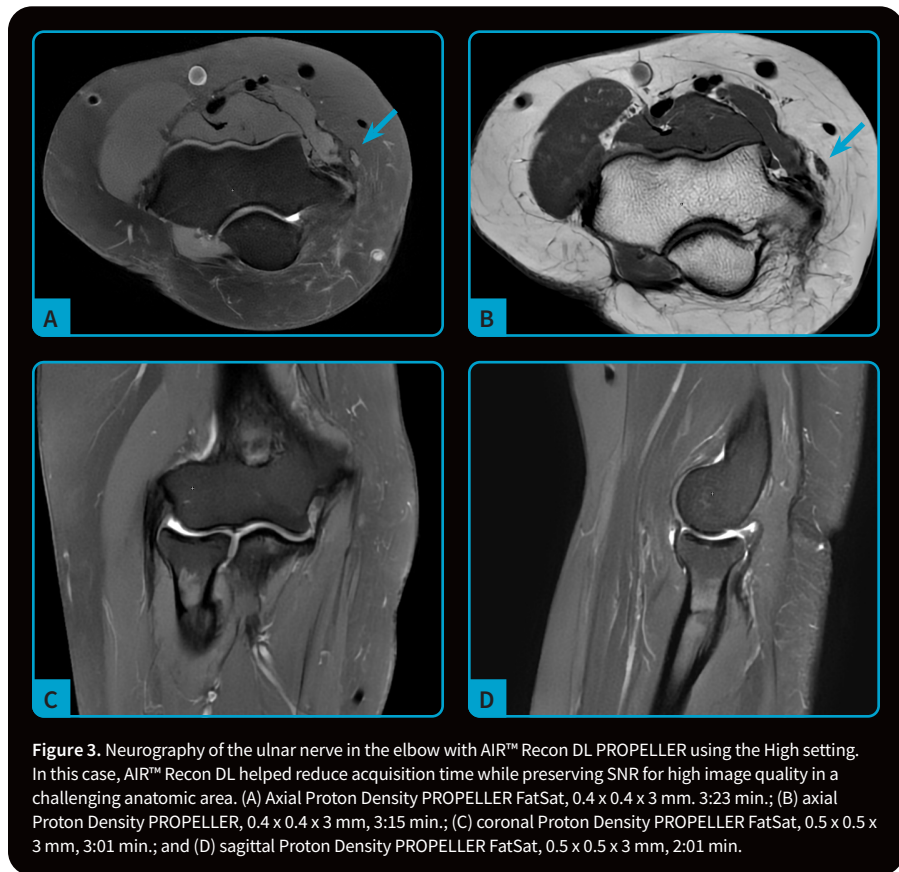


Figure 3. Neurography of the ulnar nerve in the elbow with AIR™ Recon DL PROPELLER using the High setting. In this case, AIR™ Recon DL helped reduce acquisition time while preserving SNR for high image quality in a challenging anatomic area. (A) Axial Proton Density PROPELLER FatSat, 0.4 x 0.4 x 3 mm, 3:23 min.; (B) axial Proton Density PROPELLER, 0.4 x 0.4 x 3 mm, 3:15 min.; (C) coronal Proton Density PROPELLER FatSat, 0.5 x 0.5 x 3 mm, 3:01 min.; and (D) sagittal Proton Density PROPELLER FatSat, 0.5 x 0.5 x 3 mm, 2:01 min.

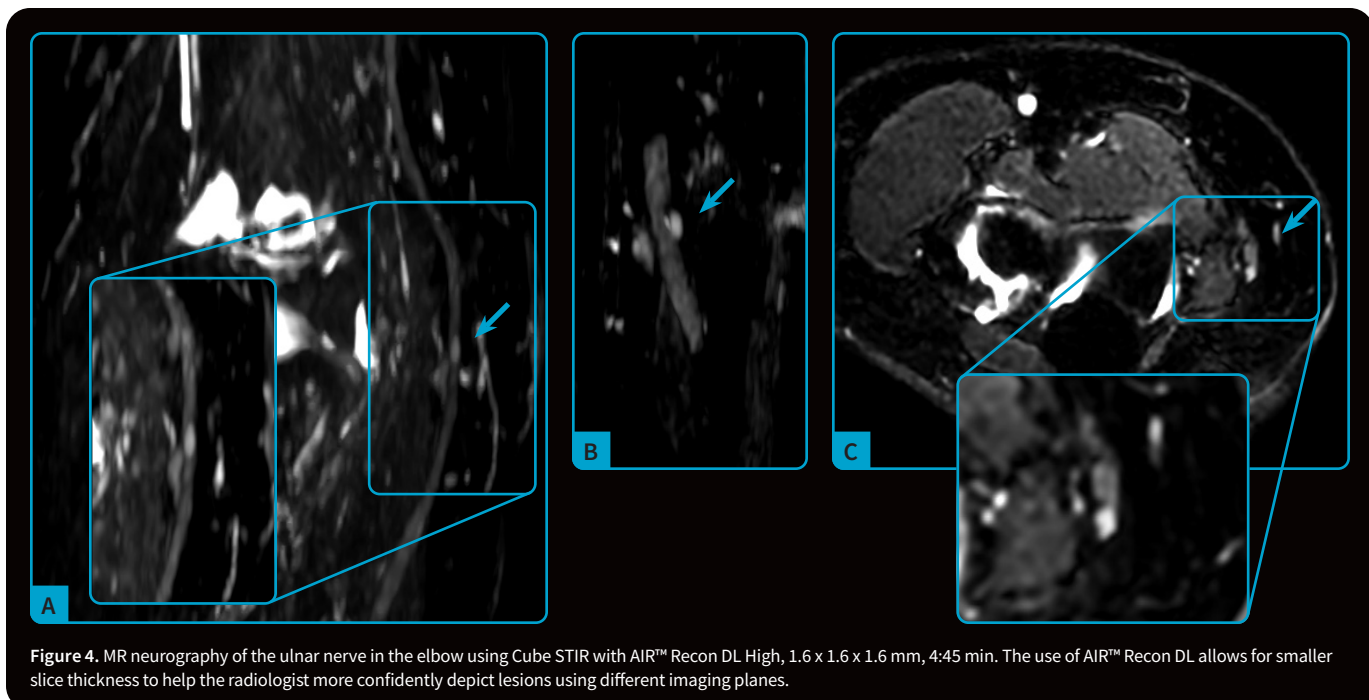


Figure 4. MR neurography of the ulnar nerve in the elbow using Cube STIR with AIR™ Recon DL High, 1.6 x 1.6 x 1.6 mm, 4:45 min. The use of AIR™ Recon DL allows for smaller slice thickness to help the radiologist more confidently depict lesions using different imaging planes.

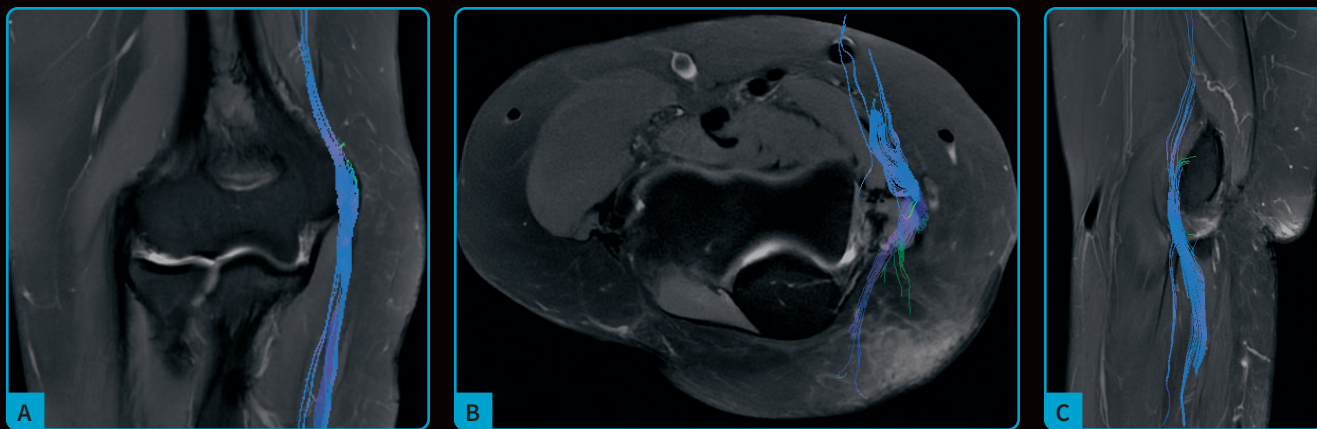


Figure 5. Same patient as Figure 4, axial DTI with AIR™ Recon DL High, 3.2 x 3.2 x 3 mm, 14 directions, 3:18 min. Combining AIR™ Recon DL with DTI delivers a useful tool to increase spatial resolution and SNR, which is essential for fiber tracking.

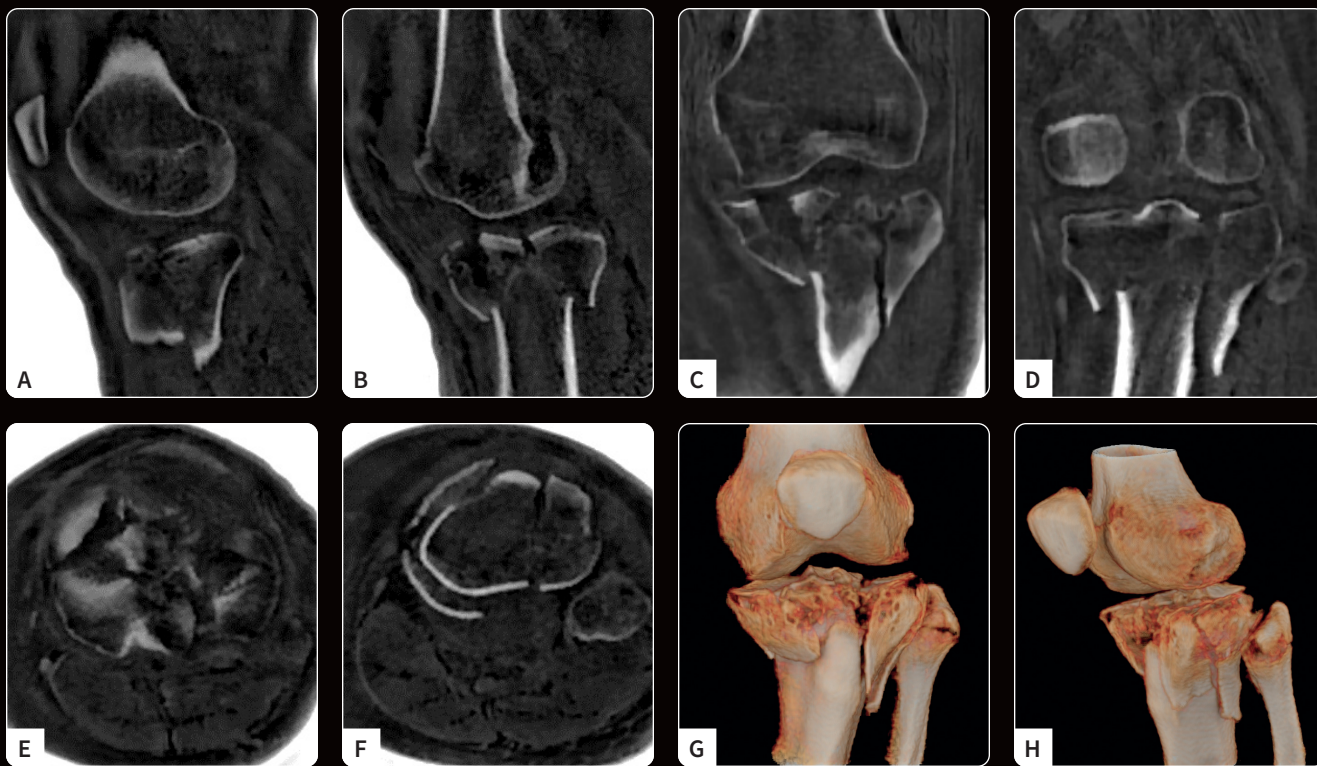


Figure 6. Patient presented to MR two days after suffering trauma to the leg with significant pain, difficulty in mobilization and in an immobilization cast. A 21-ch AIR™ MP Large Coil was used to wrap around the cast, providing comfort for the patient and optimal signal for the MR exam. Patient was diagnosed with an intra-articular comminuted fracture of the proximal tibia with non-displaced fibular head fracture and was scheduled for surgery. (A, B) Sagittal oZTEo, 0.8 x 0.8 x 1 mm, 4:27 min., (C, D) coronal oZTEo MPR, (E, F) axial oZTEo MPR and (G, H) sagittal oZTEo Volume Illumination post-processed.

In cases where a bone lesion is suspected in patients referred to MR, oZTEo is added to the examination. oZTEo is also useful for evaluating occult fractures.

“Since we have protocols optimized for speed, we can invest time in running this sequence whenever it’s needed in the clinical routine,” explains Dr. Padrón. “Our

goal is to avoid a CT exam so that we can improve the patient’s experience, delivering a one-stop shop MSK exam with MR.”

Knee cartilage imaging

Clínica CEMTRO is also one of the leading institutions in Europe for autologous chondrocyte implantation. This procedure involves harvesting a

small piece of articular cartilage from the patient, isolating and extracting the chondrocytes (the cartilage-producing cells) and then growing/expanding them in a laboratory, and then implanting the chondrocytes back into the patient at the site of the cartilage defect. Although the knee is the most common anatomy, Clínica CEMTRO has also performed

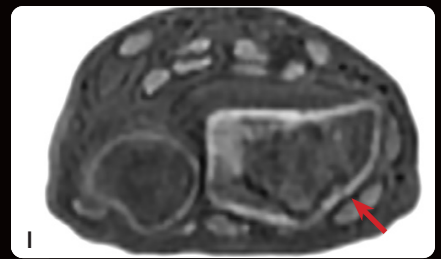
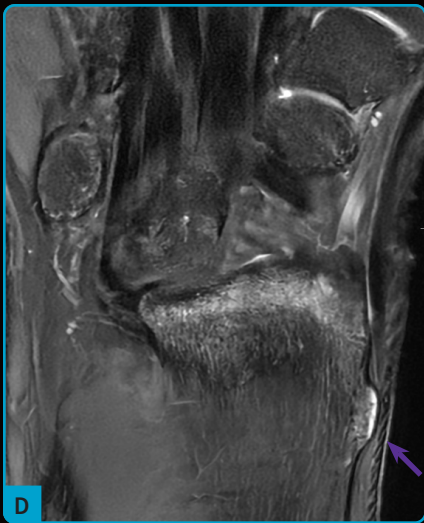


Figure 7. A 17-year-old patient presented with wrist trauma. Based on X-ray exam, patient was diagnosed with type I distal the radius epiphyseolysis and a cortical lesion in the distal diaphysis of the right wrist radius. MR confirms fracture without displacement of the distal radius with residual bone edema (red arrows) and osteochondroma in the distal radius metaphysis (purple arrows). The use of oZTEo and AIR™ Recon DL provided very high image quality, enabling assessment of both cortical bone and soft tissue in an good scan time. (A, B) Coronal T1 FSE with AIR™ Recon DL High 0.2 x 0.3 x 2.5 mm, 2:19 min.; (C, D) coronal Proton Density FatSat with AIR™ Recon DL High, 0.2 x 0.3 x 2.5 mm, 3:14 min.; (E-H) coronal oZTEo, 0.8 x 0.8 x 0.8 mm, 4:34 min.; and (I) axial oZTEo 0.8 x 0.8 x 0.8 mm, 4:34 min.

cartilage implantations in the hip, ankle and wrist.

MR imaging helps the surgeon assess the patient's knee cartilage after the procedure. Approximately 10-15 of these examinations are performed each month. AIR x™ is routinely used for automatic exam prescription in the knee, which enables greater reproducibility and similarity of the MR slices across studies, further facilitating reliable results in follow-up examinations.

The examination consists of: a routine MR imaging protocol optimized for fast scanning in under 10 minutes; Cube with AIR™ Recon DL to assess morphology in all the reformatted planes; CartiGram T2 mapping with AIR™ Recon DL; and several works-in-progress research protocols from GE HealthCare, such as radial UTE T2*† to assess the cartilage layers and T1rho mapping‡ to provide information on the proteoglycan component.

“With this study, we can access the morphological and functional information, comparing the quantitative T2 values, and when available the T2*/T1rho values at the repair site versus the patient's native or healthy cartilage,” Dr. Padrón says.

Dr. Padrón explains that this is a challenging examination with long acquisition times and time-consuming post-processing tasks to access the quantitative values at the regions of interest on the T2 maps. Artifacts from stitches and MR-Conditional hardware, such as screws used to repair ankle cartilage, can diminish image quality. Plus, there is a lack of standardized acquisition parameters and quantitative measurements for this type of case.

CartiGram with AIR™ Recon DL in MR30 for SIGNA™ allows for fast and robust T2 mapping, enabling a non-invasive quantitative assessment of cartilage. This is very useful to identify subtle changes in cartilage composition before they become visible with structural MR, as well as to monitor cartilage maturation after implantation.

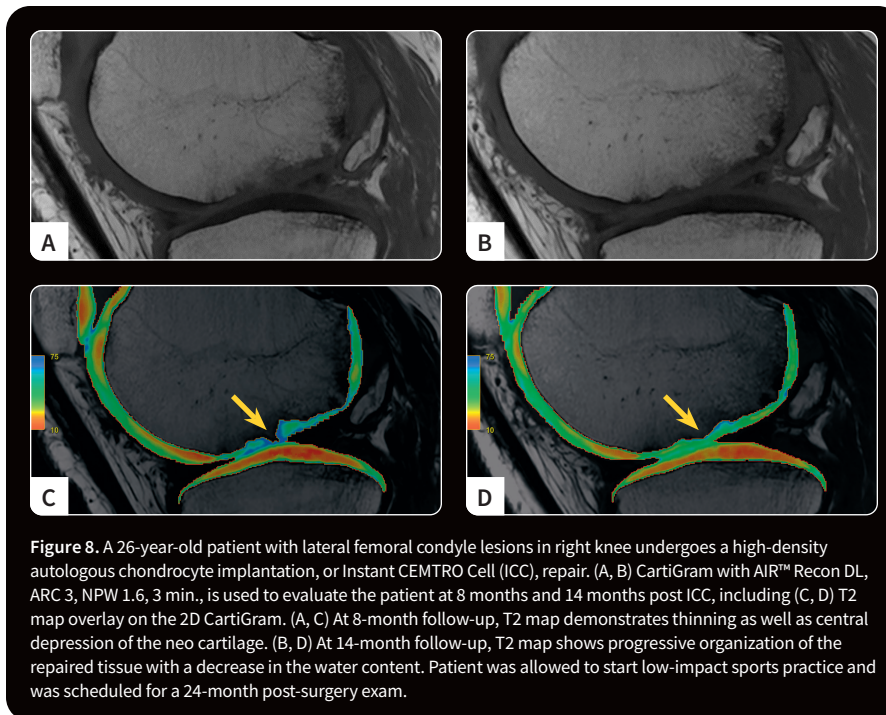


Figure 8. A 26-year-old patient with lateral femoral condyle lesions in right knee undergoes a high-density autologous chondrocyte implantation, or Instant CEMTRO Cell (ICC), repair. (A, B) CartiGram with AIR™ Recon DL, ARC 3, NPW 1.6, 3 min., is used to evaluate the patient at 8 months and 14 months post ICC, including (C, D) T2 map overlay on the 2D CartiGram. (A, C) At 8-month follow-up, T2 map demonstrates thinning as well as central depression of the neo cartilage. (B, D) At 14-month follow-up, T2 map shows progressive organization of the repaired tissue with a decrease in the water content. Patient was allowed to start low-impact sports practice and was scheduled for a 24-month post-surgery exam.

“AI is crucial to overcome these challenges,” Dr. Padrón adds. “Having AIR™ Recon DL enabled for CartiGram has made a very positive impact. In T2 mapping, AIR™ Recon DL allows for accelerated scans with increased consistency in quantitative measurements. We envision that other AI-based post-processing tools will help to overcome the tedious manual tasks to access T2 values from the maps.”

The upgrade to MR 30 for SIGNA™ has brought more advanced MR imaging capabilities to Clínica CEMTRO, supporting the center's excellence in orthopedic and sports medicine.

“We have truly optimized our patients' experience thanks to the MR 30 for SIGNA™ software. We can now offer a great variety of high-quality and reliable MSK exams in scan times that we could have never imagined before,” he adds. **S**

†Technology in development that represents ongoing research and development efforts. These technologies are not products and may never become products. Not for sale. Not cleared or approved by the US FDA or any other global regulator for commercial availability.