Cartilage Repair

Carl S. Winalski, MD; Imaging Institute, Cleveland Clinic, Cleveland Ohio, USA

The clinical goal of surgical repair of articular cartilage is to relieve pain and improve function with the hope of preventing development of osteoarthritis [1, 2]. Many surgical techniques for the repair of articular cartilage damage have been introduced; they can be broadly categorized into: marrow stimulation (microfracture, drilling, *etc.*), autologous osteochondral transplantation (OATS, *etc.*), allogeneic transplantation (osteochondral allografts, particulated cartilage grafts, *etc.*), cell techniques (ACI, MACI, *etc.*), and acellular scaffolds. Some of the techniques have FDA approval, others are approved only outside of the USA, while others are undergoing clinical or pre-clinical trials. Surgical planning and patient selection for clinical trials are often based on the characteristics of the damaged articular cartilage site and the status of the joint as a whole.

MR imaging can play a critical role in both the pre- and post-operative treatment of these patients [3]. Cartilage lesion specific factors that influence treatment decisions include defect size (width x length), depth grade (*e.g.* >50% cartilage thickness), location, the depth of bone involvement, and size of any attached bone fragment. For morphological cartilage imaging, fast spin echo (FSE or TSE) have proved most useful because they are sensitive for both cartilage assessment and evaluation of the ligaments, knee menisci, and bone marrow [4]. However, MR imaging is not fool-proof and a recent study found the area of cartilage damage that may need to be treated at surgery is often underestimated by standard MR imaging [5]. Many of the difficulties with accuracy are due to partial volume averaging artifacts and limitations of spatial resolution. Cartilage on curved surfaces such as the inferior trochlea and posterior weight-bearing regions of the femoral condyles may be particularly difficult to assess. Additionally, non-displaced cartilage delamination, *i.e.* separation of cartilage from bone, and defects filled with damaged cartilage may present diagnostic challenges. Damage to other joint structures (meniscus, ligaments, *etc.*), limb alignment, and multiplicity of cartilage defects may determine whether cartilage repair should be performed or whether concomitant procedures are necessary.

Following surgical cartilage repair, MR imaging, whether performed for clinical symptoms, research, or as part of a clinical trial, is the best non-invasive method for repair site evaluation, [3, 6]. Morphological imaging can assess the status of the repair site; quantitative volume and thickness techniques can assess defect fill, and compositional imaging, *e.g.* T2, dGEMRIC, T1-rho, may offer insights into the repair tissue type and microstructure. The morphological aspects of the repair site that should be reported include: defect fill (repair tissue thickness, volume, surface contour), integration of the repair tissue (status of bone-repair tissue and cartilage-repair tissue interfaces), and the subchondral bone response. For osteochondral grafts, CT-arthrography may offer complimentary information about the trabecular integration of the graft. An understanding of the surgical procedure performed and interval between the procedure and imaging is very important for proper interpretation, since most repairs evolve with time. For example, an autologous chondrocyte implantation (ACI) performed with a periosteal or collagen scaffold cover most often appears completely filled, or even overfilled, in the early postoperative period, however, an ACI performed with a cell-seeded matrix (matrix-assisted ACI or MACI) may normally demonstrate initial under filling with subsequent growth of tissue over the next years. Visual grading

analysis systems have been devised, MOCART being the most commonly employed [7], to semi-quantitatively score cartilage repair sites. These are most useful for clinical trials, but can serve as a basis for clinical reports. Of interest, the comparison of these grading systems and with clinical outcomes has found limited correlation other than for defect fill; even comparison of compositional MR results and clinical outcome have shown only weak to moderate correlations [8].

MR imaging is also useful in the evaluation of non-repair site complications following surgery. On clinical exam a patient's symptoms may be non-specific, and the surgeon may not know if there is a problem with the repair site or other joint structures. MR images may show damage to the ligaments or meniscus without any abnormalities at the repair site. Complications related to surgery, such as joint adhesions or fibrosis, may or may not directly affect the repair site. Finally, the patient may develop cartilage defects at new sites, either from an injury or progression toward osteoarthritis.

The role of MR imaging following surgical cartilage repair is evolving. Currently, the technique is the mainstay of clinical evaluation. Careful assessment of the images may provide valuable information for patient care. Further work is required to improve the diagnosis of repair site complications, to correlate imaging findings with prognosis, and to determine the clinical utility of compositional MR imaging techniques.

1. Minas T. A primer in cartilage repair. J Bone Joint Surg Br. 2012; 94(11 Suppl A):141-146.

2. Gomoll AH, Farr J, Gillogly SD, Kercher J, Minas T. Surgical management of articular cartilage defects of the knee. J Bone Joint Surg Am. 2010; 92(14):2470-2490.

3. Forney MC, Gupta A, Minas T, Winalski CS. Magnetic resonance imaging of cartilage repair procedures. Magn Reson Imaging Clin N Am. 2014; 22(4):671-701.

4. Potter HG, Linklater JM, Allen AA, Hannafin JA, Haas SB. Magnetic resonance imaging of articular cartilage in the knee. An evaluation with use of fast-spin-echo imaging. J Bone Joint Surg Am. 1998; 80(9):1276-1284.

5. Gomoll AH, Yoshioka H, Watanabe A, Dunn JC, Minas T. Preoperative Measurement of Cartilage Defects by MRI Underestimates Lesion Size. Cartilage. 2011; 2(4):389-393.

6. Trattnig S, Winalski CS, Marlovits S, Jurvelin JS, Welsch GH, Potter HG. Magnetic Resonance Imaging of Cartilage Repair: A Review. Cartilage. 2011; 2(1):5-26.

7. Welsch GH, Zak L, Mamisch TC, Resinger C, Marlovits S, Trattnig S. Three-dimensional magnetic resonance observation of cartilage repair tissue (MOCART) score assessed with an isotropic three-dimensional true fast imaging with steady-state precession sequence at 3.0 Tesla. Invest Radiol. 2009; 44(9):603-612.

8. de Windt TS, Welsch GH, Brittberg M, Vonk LA, Marlovits S, Trattnig S, et al. Is magnetic resonance imaging reliable in predicting clinical outcome after articular cartilage repair of the knee? A systematic review and meta-analysis. Am J Sports Med. 2013; 41(7):1695-1702.