Magnetic Resonance Imaging of the Postoperative Meniscus

Resection, Repair, and Replacement

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KEYWORDS

• Knee MR imaging • Knee arthroscopy • Meniscus tear • Meniscus repair • Postoperative imaging • Meniscectomy

KEY POINTS

- To correctly interpret magnetic resonance (MR) imaging findings in the postoperative meniscus, physicians must understand the surgical techniques applied to the meniscus: the "3 Rs," namely resection, repair, and replacement, each resulting in a different MR imaging appearance of the postoperative meniscus.
- Resection (most often partial meniscectomy) is by far the most common procedure, but there is an increasing body of literature questioning its clinical efficacy. Consequently, meniscus preservation is increasingly emphasized, and repair techniques may become more common in the coming years.
- Repair techniques generally are subdivided into 3 types: inside-out, outside-in, and all-inside. After surgical repair, the meniscus can be categorized as healed (ie, no fluid signal in the repair), partially healed (ie, fluid signal extending into <50% of the repair site), or not healed (ie, fluid signal extending into >50% of the repair site).
- Meniscus replacement can be performed for postmeniscectomy syndrome in appropriate young to middle-aged patients. In the United States, this usually takes the form of a cadaveric meniscus allograft. In Europe and elsewhere, there is increasing experience with synthetic meniscus implants.

INTRODUCTION

Meniscus surgery is one of the most commonly performed orthopedic procedures, with an estimated 1 million meniscus surgeries[1] and US$4 billion in direct medical expenditures each year.[2]

Magnetic resonance (MR) imaging of the knee commonly is indicated to investigate the cause of unresolved or recurrent pain that can occur in patients after meniscus surgery.

The objectives of this article are to review selected highlights of (1) basic science (normal anatomy and emerging MR imaging techniques), (2) meniscus surgery (indications and techniques), (3) MR imaging protocols (with vs without arthrography), and (4) postoperative MR imaging interpretation (clinical outcomes and diagnostic criteria).

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BASIC SCIENCE: IMPLICATIONS FOR KNEE MR IMAGING

Like articular (hyaline) cartilage, the fibrocartilaginous meniscus plays several roles, including load bearing, load distribution, joint stability, and joint lubrication. Compared with articular cartilage, the meniscus has a higher collagen content (15%–25% vs 10%–20%), lower proteoglycan content (1%–2% vs 5%–10%), and lower water content (60%–70% vs 68%–85%).[3]

Although the most important principles of meniscus anatomy are covered elsewhere in this issue by Rosas and colleagues, a few basic science concepts regarding the meniscus deserve to be highlighted here to emphasize our evolving understanding of this surprisingly heterogeneous tissue. Indeed, the meniscus structure varies both radially (peripheral to central) and also with depth (superficial to deep). Current research is providing insights into the various constituents within the meniscus, including cells, collagen, vascularity, and innervation.

Meniscus Cells: Do Meniscus Cells Die?

Meniscus cell degeneration and death (apoptosis) is significantly associated with meniscus tears and prognosis for successful meniscus repair.[4]

Meniscus cell (fibrochondrocyte) subpopulations show marked regional variation, with concomitant zonal variation in the surrounding matrix (pericellular and extracellular) that they produce.[5] Indeed, rather than being a homogeneous tissue, recent work indicates that this wedge-shaped tissue varies consistently from the thin, cartilage-like free edge, where compressive forces predominate and proteoglycan content is high, to the thicker, more peripheral region, where circumferential tensile loads predominate and proteoglycan content is low.

In addition to zonal variation in the proteoglycan matrix produced by the cells, there is also a zonal variation in the density of meniscus cells and their phenotypes (chondrocytic inner zone versus fibroblastic outer zone).[6]

MR imaging with T1rho mapping[7,8] and delayed gadolinium enhancement,[9] known to be sensitive to changes in proteoglycan loss in cartilage, recently has been used to show differences between normal and degenerated menisci.

Given that the anatomy and mechanisms that drive meniscus degeneration may be zonally dependent, future treatments such as gene therapy may use a targeted therapeutic approach for inner versus outer zones of the meniscus.

Collagen: Can MR Imaging Evaluate Collagen?

Collagen fibers are primarily responsible for tensile strength. In the classic description, collagen fibers are arranged for transferring vertical (compressive) loads into circumferential hoop stresses. In particular, the hoop stresses are contained via a belt of peripheral circumferential fibers, and these circumferentially oriented fascicles are secured together by radially oriented tie fibers. With aging, there tends to be an increase in connective tissue stiffness related to processes such as elastin degradation and collagen rigidification.[10]

Although the collagen architecture is often presented in a stylized fashion in diagrams, recent work indicates that the highly ordered microstructure is even more complex, and exquisite, than appreciated previously (**Fig. 1**).

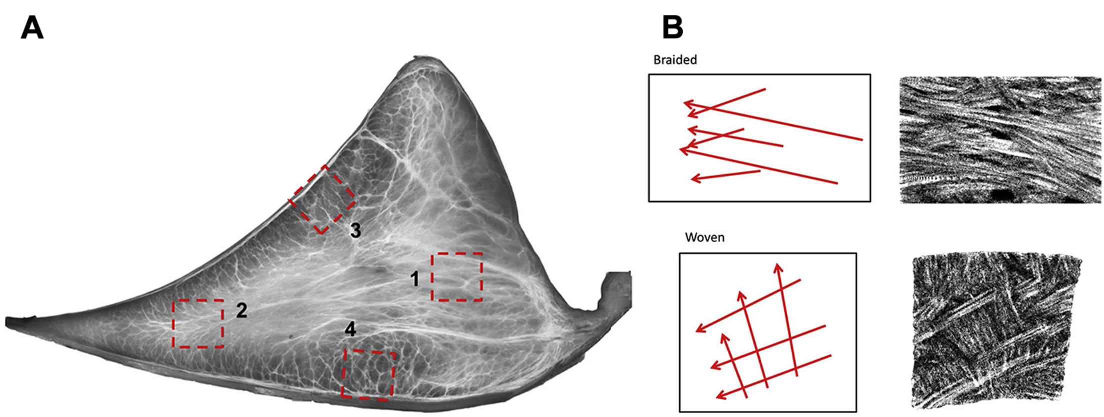

Fig. 1. Meniscus collagen structure. (*A*) Site-specific variation in the structure of the meniscus at 4 sample areas in the body segment: (1) outer third, (2) inner third, (3) femoral surface, and (4) tibial surface. (*B*) Schematic of braided and woven fascicle organizations (*left*) with associated sections from meniscus samples illustrating these arrangements using optical projection tomography (*right*) (scale, 1 mm.). (*From* Andrews SH, Ronsky JL, Rattner JB, et al. An evaluation of meniscal collagenous structure using optical projection tomography. BMC Med Imaging 2013;13(1):21.)