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Meniscal Deficiency
Repair and Transplantation

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Current Procedural Terminology Codes	
29882	Arthroscopy, knee, surgical; with meniscus repair (medial OR lateral)
29883	Arthroscopy, knee, surgical; with meniscus repair (medial AND lateral)
29868	Arthroscopy, knee, surgical; meniscal transplantation (includes arthrotomy), medial or lateral

Injury to the meniscus may result in substantially altered knee biomechanics and functionality in a young and otherwise healthy patient population.[1,2] Even small meniscal defects can increase joint contact pressures by greater than 300%, which can result in articular cartilage damage.[3-7] As a result, surgical treatment options for meniscal injuries have moved from resection toward preservation.

Clinical Evaluation

A thorough history investigating the patient's symptoms is essential for diagnosis. Patients presenting with meniscal injuries most frequently report an acute injury via a noncontact twisting mechanism, with immediate pain and swelling. Mechanical symptoms, such as locking, catching, and loss of extension, can occur. Feelings of instability may also be reported; in these cases, the surgeon must evaluate for concomitant ligamentous pathology.

Physical examination should include assessment for alignment, effusion, localized swelling (ie, meniscal cyst), and range of motion. Provocative tests for a meniscal tear include joint line tenderness, the Apley grind test, the McMurray test, the Thessaly test, and pain with maximal flexion or forced hyperextension.[8-10] When the tests are positive, it is important to inquire as to how well the subjective complaints elicited on physical examination mirror the patient's complaints that occur with or without activities, to improve the clinical specificity of the provocative tests.

Radiographic imaging should include weight-bearing extension anteroposterior, posteroanterior in 45-degree flexion, lateral views, and patellofemoral (Merchant or sunrise) views. Magnetic resonance imaging can also be used to evaluate the meniscus and the cruciate and collateral ligaments.

Cole BJ, Harris JD, eds.
Biologic Knee Reconstruction: A Surgeon's Guide (pp 199-209).

Preoperative Patient Education Material for Meniscal Repair and Transplantation

Background

Each year, nearly 1 million Americans injure their meniscus. The meniscus is a crescent-shaped cartilage that protects the cartilage of the knee through load sharing. The meniscus can be damaged by sudden knee twisting or become symptomatic over time when it is degenerative in nature. Injury to the meniscus can result in pain and swelling or "giving way." The loss of articular cartilage protection can lead to secondary osteoarthritis.

Anatomy and Function

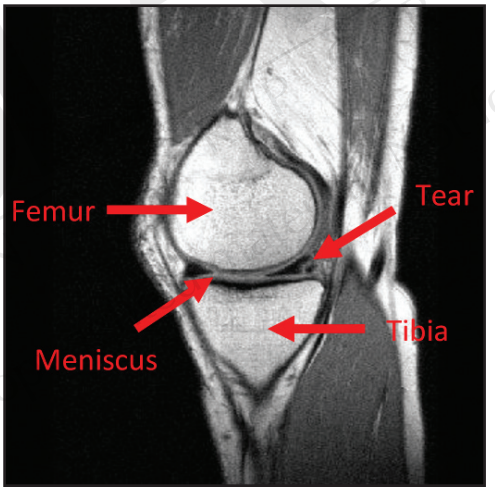
The meniscus cartilage of the knee is separated into 2 compartments: the medial (inside) and the lateral (outside). The wedge-shaped menisci line the surface of the knee in a semicircular fashion, which allows for improved shock-absorption from the femur (thigh bone) to the tibia (shin bone).

Preserving the Meniscus

In the past, the first line of treatment for a meniscal tear was removal of the involved meniscus. Today, to preserve knee function after injury, surgeons repair the meniscus whenever possible, removing only the portions that are considered irreparable.

Restoring the Meniscus

For select patients who have had a critical portion of the meniscus removed and continue to have knee pain or develop subsequent pain, meniscus transplantation may be an option. Surgeons can transplant donated meniscus cartilage that has been tested to ensure that it is free of any transmittable disease. This procedure does not require patients to be on life-long "antirejection" medications. Once transplanted into the knee, the meniscus can heal and function much like the patient's own meniscus.



Indications and Contraindications for Meniscal Repair

The vascular anatomy of the meniscus largely determines indications for repair. Only the peripheral 10% to 30% of the meniscus is vascularized; thus tears in the peripheral 3 mm (red-red zone) are more amenable to primary repair than tears more than 5 mm from the meniscocapsular junction (white-white zone).[11-13] Tears of the transitional area (red-white zone) are managed on a case-by-case basis, taking into consideration host factors, concomitant anterior cruciate ligament (ACL) reconstruction, chronicity, meniscal tear pattern, location, and tear size. Successful repairs in the avascular zone in young patients have been reported.[14,15] Ultimately, the decision

INSTRUMENTATION	
MENISCAL REPAIR	**MENISCAL ALLOGRAFT TRANSPLANTATION**
Standard Arthroscopy • 30-degree arthroscope • Probe • Basket forceps • Graspers • Scissors • Motorized shavers • Electrocautery *Other* • Henning retractor • Zone-specific cannulae • Dissecting tools • Meniscal needles and sutures • Needle passers/holders • ± All-inside repair system	*Tools Required* • Depth gauge • Drill guide • 3.2-mm pin • 7- to 8-mm drill • 7- to 8-mm drill sleeve • 7- to 8-mm box cutter • 7- to 8-mm rasp • Curved osteotomes • Pituitary rongeur • Graft sizer • Tamp, 7 to 8 mm

to repair a torn meniscus is multifactorial and also should consider patient-specific factors such as activity level, timing of surgery, timing for return to sport, and patient expectations.

Acute, longitudinal/vertical tears and bucket-handle tears are most amenable to repair. Degenerative tears (ie, those with oblique flaps or multiple horizontal cleavage planes) are indicated for partial meniscectomy.[11,12,16] Oblique undersurface tears often extend into the avascular zone and are less likely to heal. Untreated ACL deficiency can also lead to repair failure.[17]

SURGICAL TECHNIQUE

Patient Positioning

Position the patient supine with a thigh tourniquet. Depending on surgeon preference, a leg holder or lateral post at the level of the tourniquet is applied. Ensure that positioning allows full knee flexion and access to the posterolateral or posteromedial approaches.

The type of anesthesia (general, regional, or spinal) is a matter of patient, anesthesiologist, and surgeon preference. Examination under anesthesia should routinely be performed to evaluate range of motion and ligamentous stability.

Diagnostic Arthroscopy

Diagnostic arthroscopy is performed to characterize the pathology. An anterolateral viewing portal may be made adjacent to the patellar tendon. An anteromedial portal is made via the outside-in technique, using the spinal needle to confirm that instruments inserted through this portal will be able to access the pathologic portions of the meniscus.

Arthroscopic Meniscal Repair

Meniscal Preparation

Using a rasp or mechanical shaver, debride the capsular side of the tear to stimulate the healing process. Trephination may also be performed by using an 18-gauge needle to create vascular access channels connecting an avascular lesion to the peripheral blood supply. Perform trephination without violating the meniscal surface with the needle. Place the tip of a switching stick at the tip of the tear to assist with localization during the approach.

Step-by-Step Technique for Meniscus Repair

INSIDE-OUT TECHNIQUE: "THE GOLD STANDARD" (FIGURE 24-1)

Indication: Middle or posterior meniscal tears

Posteromedial Exposure

1. Flex the knee to 90 degrees, moving the infrapatellar branch of saphenous nerve away from the incision.
2. Longitudinal 3- to 4-cm incision behind superficial medial collateral ligament, one-third above and two-thirds below joint line.
3. Expose sartorius fascia. Avoid crossing infrapatellar branch of the saphenous nerve.
4. Incise fascia and retract pes tendons posteriorly.
5. Bluntly develop interval between posteromedial capsule and medial head of gastrocnemius. Dorsiflex and plantarflex the ankle with a finger in the interval to help to confirm correct plane.
6. Place a Henning retractor or sterile spoon to protect the neurovascular structures.

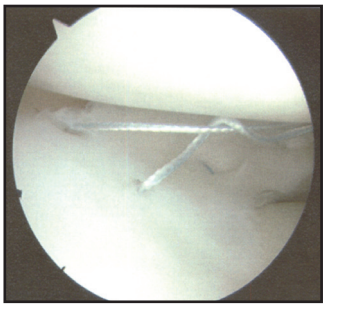
Posterolateral Exposure

1. Flex the knee to 90 degrees. Longitudinal 3- to 4-cm incision behind lateral collateral ligament, one-third above and two-thirds below joint line.
2. Develop iliotibial band and biceps femoris interval.
3. Retract biceps tendon posteriorly to protect the common peroneal nerve.
4. Bluntly develop interval between posterolateral capsule and lateral head of gastrocnemius. Start distally as there may be fewer adhesions between the tendon and lateral capsule.
5. Place a Henning retractor or sterile spoon to protect the neurovascular structures.

Sutures

1. A variety of manufacturers provide zone-specific cannulae and repair systems.
2. Utilize ipsilateral viewing portal and contralateral instrumentation portal.
3. Directly observe cannula placement to avoid iatrogenic chondral injury.
4. Begin placing sutures at the posterior aspect of the tear and proceed anteriorly.
5. To create a vertical mattress, one limb of each double-arm suture is passed above the tear and the other limb is passed below the tear.
6. Retrieve the needles from the popliteal retractor using a probe/hemostat.
7. Do not blindly push suture through capsule if not visualized directly on the retractor.
8. Clamp the suture arms for suture management.
9. Place sutures at 3- to 5-mm intervals on the dorsal and ventral surface of the meniscus.
10. Tie from posterior to anterior with the knee in extension to avoid tethering the iliotibial band or sartorius fascia to the capsule.
11. Once the repair is complete, inspect for gap formation while ranging the knee.

Figure 24-1. Left knee, medial meniscus repair. View through anterior-inferior medial portal. Begin placement of vertical mattress sutures posteriorly, working anteriorly in 3- to 5-mm increments until the tear is approximated.



(continued)

Step-by-Step Technique for Meniscus Repair (continued)

OUTSIDE-IN TECHNIQUE

Indication: Anterior horn tears

Exposure

1. Protect saphenous nerve along medial joint line.
2. View from contralateral portal.
3. Place 18-gauge spinal needle superior to the tear, using a probe against the capsule for counterpressure.
4. Incise the skin at needle, dissect to capsule.
5. Using same incision, introduce a second spinal needle into adjacent part of tear, with vertical mattress configuration.

Sutures

1. Place #1 polydioxanone (PDS) suture down one spinal needle. Pass cable loop down other spinal needle. Manipulate suture end into the loop. A spinal needle with a 30-degree bend is helpful. Be careful not to cut suture on needle.
2. Withdraw the cable loop and tie the suture over the capsule.

ALL-INSIDE TECHNIQUE

The operative steps described are for a device with two 5-mm absorbable anchors joined by suture.

1. Introduce delivery needle via cannula or skid.
2. Guide the needle to the superior suture position.
3. Deploy implant via the handle mechanism.
4. Pull the needle back and reinsert the needle in position of the inferior suture.
5. Slide the trigger forward until resistance is felt, seating the second anchor into position.
6. Remove delivery device from joint.
7. Pull the free suture end to advance the pre-tied sliding knot onto the meniscal surface.
8. Cut the suture.

Pearls and Pitfalls for Meniscal Repair

PEARLS	PITFALLS
• Avoid the saphenous and peroneal nerves medially and laterally, respectively • Dorsiflex and plantarflex the foot to confirm that dissection is proceeding in the correct plane • Use zone-specific cannulae to improve access • Place sutures from posterior to anterior	• Neurovascular injury can occur without meticulous technique • Do not violate the meniscal surface during trephination • Anterior tears best approached with outside-in technique • Tie sutures with knee in extension beneath layer 1

Bridge-in-Slot Technique for Meniscal Allograft Transplantation (Figure 24-2)

Indications

Ideal candidates for meniscal allograft transplantation (MAT):

1. Under age 50 years
2. Persistent pain in meniscectomized compartment
3. Neutral or corrected alignment
4. Ligamentous stability
5. Intact chondral surface, or concurrent articular cartilage repair technique

Contraindications

1. Osteoarthritis
2. Inflammatory arthritis
3. Infection
4. Morbid obesity

Meniscal Sizing

1. Allografts are size and compartment specific.
2. Within 5% of native meniscus, which can be radiographically or demographically estimated.[18]

Exposure

1. Debride residual meniscus to 1 to 2 mm peripheral rim, creating punctate bleeding.
2. Preserve meniscal horn insertion sites, which help guide slot preparation.
3. Enhance visualization and passage with ipsilateral posterior-inferior notchplasty.
4. Create a mini transpatellar or peripatellar arthrotomy at meniscal insertion.
5. Perform an ipsilateral posteromedial or posterolateral approach.
6. Elevate the iliotibial band or sartorius fascia anteriorly to allow suture tying.

Slot Preparation

1. Orient slots to normal anatomy of meniscal insertion sites.
2. Using electrocautery, draw a line connecting meniscal insertion sites for reference.
3. Use 4-mm burr to make a reference slot of the dimensions of the burr.
4. Confirm slot height, width, and length measurements with a depth gauge.
5. Using a drill guide, introduce a guide pin 2 mm deep and parallel to the slot.
6. Overdrill with 7- to 8-mm cannulated drill bit. Do not violate the posterior cortex.
7. Finish slot with 7- to 8-mm by 10-mm box cutter and rasp.

Allograft Preparation

1. Identify the attachment sites of the meniscus on bone block.
2. Fashion bone bridge to height and width of 7 mm by 10 mm, respectively. Undersize by 1 mm to minimize risk of bridge fracture and facilitate easier graft passage.
3. Remove bone posterior to the posterior attachment, preserve all anterior bone.
4. If anterior bridge is wider than the slot, widen the anterior slot accordingly—keep the posterior bridge and slot to a 7 mm width.
5. Place #0 PDS for traction at posterior/middle one-third junction.

(continued)

Bridge-in-Slot Technique for Meniscal Allograft Transplantation (continued)

Allograft Insertion and Fixation

1. Place zone-specific cannula through contralateral portal.
2. Place nitinol suture-passing pin through the cannula, through posterior/middle one-third junction on capsule out posterior incision.
3. Use nitinol suture passer to deliver allograft traction sutures out posterior incision.
4. Gently advance meniscal allograft into joint using the suture, while carefully positioning bone bridge into slot.
5. Manually reduce the meniscus. Valgus or varus stress to open ipsilateral compartment aids in graft introduction and reduction.
6. Once the allograft is in position, cycle the knee to ensure proper placement.
7. Secure bone bridge via interference screw placed on intercondylar notch side of bridge.
8. Perform meniscal repair using inside-out vertical mattress sutures supplemented with all-inside fixation devices and outside-in sutures as necessary anteriorly.
9. Close arthrotomy and portals.

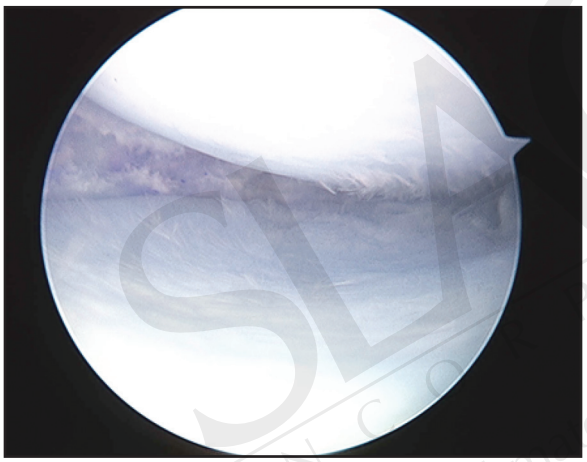


Figure 24-2A. Left knee: view through anterior-inferior medial portal. Trimming of medial meniscus to peripheral rim for MAT host preparation.

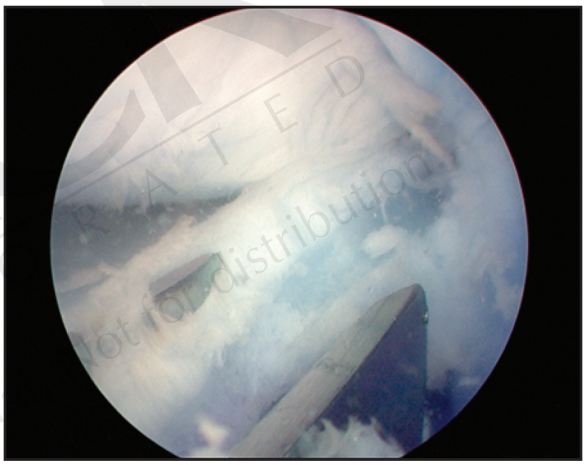


Figure 24-2B. Left knee: view through anterior-inferior medial portal. Use of a bone cutter to customize the bone trough.

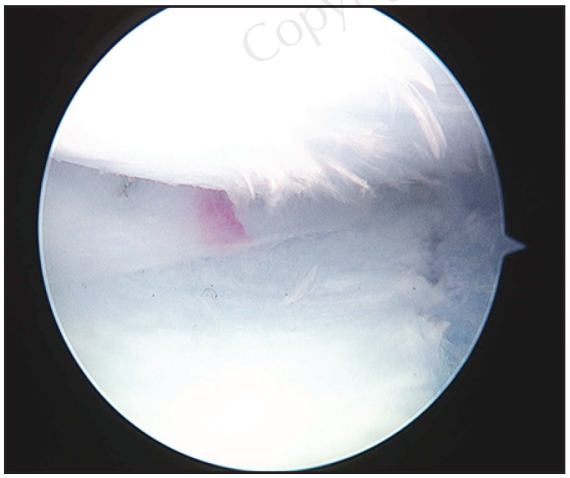


Figure 24-2C. Left knee, medial meniscus transplantation. View through anterior-inferior medial portal. Initial insertion of the meniscal allograft marked at the junction of the middle and posterior one-third.

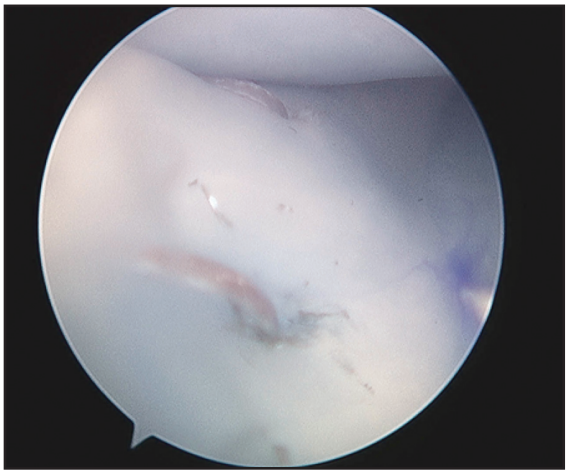


Figure 24-2D. Left knee, medial meniscus transplantation. Arthroscopic close-up of vertical mattress suture placement for final fixation.

Pearls and Pitfalls for Meniscal Allograft Transplantation

PEARLS	PITFALLS
• Arthrotomy: in-line with meniscal insertion sites • Undersize bone bridge by 1 mm • Widen the bone bridge anteriorly as necessary • Use a finger to manually reduce the meniscus	• Indicate patients appropriately • Do not violate capsule during meniscectomy • Do not remove bone anterior to attachment • Do not fracture bone bridge during insertion

Postoperative Rehabilitation for Meniscal Repair

WEEKS	WEIGHT BEARING	BRACE	RANGE OF MOTION	EXERCISES
0 to 2	WBAT with crutches	Lock in extension	Full ROM, no WB at flexion > 90 degrees	Heel slides, quad strength, mobilize patella, ankle ROM
2 to 4		Unlock brace		
4 to 6		Discontinued brace	Full ROM + PROM as tolerated > 90 degrees flexion	Partial wall sits w/ flexion angle < 90 degrees
6 to 8	Wean crutches			
8 to 12	WB without crutches		Full active ROM	Closed-chain, stationary bike, lunges/leg press 0 to 90 degrees
12+				Single-leg exercises, run/jog, sports drills, plyometrics, squat and hyperflex at 6 months

PROM, passive range of motion; ROM, range of motion; WB, weight bearing; WBAT, weight bearing as tolerated.

Postoperative Rehabilitation for Meniscal Allograft Transplantation

WEEKS	WEIGHT BEARING	BRACE	RANGE OF MOTION	EXERCISES
0 to 1	Partial WB with crutches	Lock in extension	Non-WB 0 to 90 degrees	Heel slides, quad strength, mobilize patella, ankle ROM
1 to 2		Extension with WB		
2 to 4	WBAT with crutches	Locked at 0 to 90 degrees	Non-WB ROM as tolerated	No WB with flexion Heel raises, closed-chain exercises, knee extensions
4 to 6				
6 to 8	Wean crutches	Discontinued brace		
8 to 12	WB without crutches		Full active ROM	Closed-chain, stationary bike, lunges/leg press 0 to 90 degrees
12+				Single-leg exercises, run/jog, sports drills, plyometrics, squat and hyperflex at 6 months

ROM, range of motion; WB, weight bearing; WBAT, weight bearing as tolerated.

Clinical Outcomes of Individuals Undergoing Meniscal Repair

AUTHORS	REPAIR TECHNIQUE	SAMPLE SIZE	FOLLOW-UP		ACL STATUS	SUCCESS RATE	COMMENTS
			YEARS	RATE			
Eggli et al[19] (1995)	Inside-Out	54	7.5	96%	100% Intact	73%	64% of failures in first 6 months
Johnson et al[20] (1999)	Inside-Out	50	10.75	71%	100% Intact	76%	100% patients satisfied with results
Logan et al[21] (2009)	Inside-Out	45	8.5	100%	17% Intact	73%	Athletes with complex tears
Noyes et al[22] (2011)	Inside-Out	33	16.8	88%	21% Intact	62%	< 20 years with red-white region tears
Kotsovolos et al[23] (12006)	All-Inside	61	1.5	96%	38% Intact	90%	88% good-excellent clinical outcomes
Barber et al[24] (2008)	All-Inside	41	2.5	100%	30% Intact	83%	Technical problems in several cases
Kalliakmanis et al[25] (2008)	All-Inside	280	2	-	0% Intact	89%	3 devices used
Morgan et al[26] (1991)	Outside-In	74	6	100%	38% Intact	84%	19% incompletely healed, but stable
van Trommel et al[27] (1998)	Outside-In	51	1.25	100%	32% Intact	76%	31% partial healing on MRI or scope
Totals			4.6	94%		83%	

ACL, anterior cruciate ligament; MRI, magnetic resonance imaging.

Clinical Outcomes

Meniscal Repair

Long-term follow-up of meniscal repair has shown excellent clinical outcomes in appropriately selected patients for all techniques.[28,29] Positive prognostic factors included simple tears, male sex, age < 40 years, and associated anterior/posterior cruciate ligament injuries.[30] Small reported complication rates of 2.4%.[31] Complications specific to meniscal repair include: re-tear, arthrofibrosis, neurovascular injury chondral injury, and implant breakage.

Meniscal Allograft Transplantation

MAT has excellent clinical results, alleviating pain and improving knee function in appropriate patients. Patient satisfaction ranges from 63% to 100% and return to normal or near-normal activity levels ranges from 68% to 89%.[32] Nearly 80% of high-level athletes are able to return to their desired level of play following MAT.[33] Complications include re-tear, arthrofibrosis, neurovascular injury, chondral injury, and implant breakage. To date, no instance of HIV infection has been reported following MAT.[34] The risk of graft failure appears greatest with irradiated grafts, grade III or IV osteoarthritic changes, and uncorrected malalignment or instability.

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Clinical Outcomes of Individuals Undergoing Meniscal Allograft Transplantation

AUTHORS	AVERAGE AGE (YEARS)	SAMPLE SIZE	MEAN FOLLOW-UP	SUCCESS RATE*	COMMENTS
Verdonk et al[35] (2005)	35	101	7.2 years	78%	Many patients with concomitant procedures
Cole et al[36] (2006)	31	39	2.8 years	81%	MAT with concomitant procedures
van der Wal et al[37] (2009)	39.4	63	13.8 years	71%	21% of patients received total knee arthroplasty
Vundelinckx et al[38] (2010)	33	47	8.8 years	87%	12% of patients received total knee arthroplasty
Kim et al[39] (2012)	33.1	110	2.9 years	82%	MRI and/or second-look arthroscopy
Totals	34.5		6.8 years	80%	

*Success was defined as either good or excellent results defined by the individual study authors, second-look arthroscopy, and/or MRI evaluation. Clinical parameters such as overall patient satisfaction, pain reduction, and overall knee function were taken into account.

MAT, meniscal allograft transplantation; MRI, magnetic resonance imaging.

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