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ORIGINAL ARTICLE

MRI Shows Biologic Restoration of Posterior Soft Tissue Repairs after THA

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Abstract Although posterior capsule repair reduces the incidence of dislocation after THA, radiographic imaging studies suggest a high failure rate of the repair. Using MRI, we prospectively followed patients to evaluate the integrity of the posterior soft tissue repair after primary THA. Thirty-six patients (21 men, 15 women) underwent arthroplasty using a standard posterior approach. The posterior capsule and external rotators were repaired as separate layers using nonabsorbable sutures through two drill holes in the greater trochanter. Patients observed postoperative hip precautions for 6 weeks after surgery. All patients underwent initial MRI between postoperative Days 2 and 4. Thirty patients returned for followup MRI 3 months after surgery. At 3 months followup, the posterior capsule remained intact in 27 of 30 patients (90%) and the quadratus femoris repair remained intact in 29 of 30 patients (97%). Thirteen of 30 piriformis tendon repairs (43%) and 17 conjoined tendon repairs (57%) showed a gap between the hypointense tendon end and the greater trochanter greater than 25 mm. Our data show repaired posterior soft tissues provide a biologic scaffold allowing formation of a posterior pseudocapsule.

Introduction

Primary THA using a posterior approach without reconstruction of the posterior capsule and external rotators has a higher dislocation rate than THA using the direct lateral or anterolateral approach (4.5% versus 0.4% versus 0.7%) [7]. In 1998, the senior author (PMP) reported a reduction of his overall dislocation rate from 4% to 0% after using a posterior capsule and external rotator repair [8]. In a recent meta-analysis, Kwon et al. [7] reported on that study and four additional studies directly comparing the posterior approach with and without soft tissue repair [2, 3, 8, 14, 15]. Implementation of a posterior soft tissue repair resulted in a reduction in the postoperative dislocation rate from 4.5% without repair to 0.5% with a soft tissue repair. The posterior soft tissue repair also has led to a reduction in postoperative dislocation in elderly patients and is the most important predictive factor for dislocation in this high-risk population [10]. Similar results have been reported for patients with femoral neck fractures—a subgroup of patients historically known to have a high risk of postoperative dislocations [6].

Although the majority of clinical outcome studies support posterior soft tissue repair, studies focusing on the integrity of the repair have been less encouraging. In the absence of dislocation, failure rates of posterior repair are between 11% and 80%. In the literature, failure is defined as increasing gap size between the tendon and its bony insertion using radiographic or ultrasound markers [5, 11–13]. Based on these failure rates, some authors do not recommend routine repair of the posterior capsule and external rotators. Kao and

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Woolson and Stählin et al. noted repair of the short external rotator muscles after hip arthroplasty contributes little to prevention of dislocation [5, 12].

The current literature only uses the distance between radiographic markers and the greater trochanter to define failure. It provides no information regarding whether the space between the tendon and the greater trochanter is filled with scar tissue or remains a fluid-filled dead space. Nor does it provide measurements between the tendon stump and the greater trochanter, because often the marker typically is placed somewhere in the tendon, not at the end of the tendon. Finally, there are no observations regarding muscle atrophy which would reflect failure of the muscle tendon unit.

We used MRI to determine (1) what percentage of patients would have an increase in distance between the tendon stump/capsule and greater trochanter greater than 25 mm, suggesting failure of the external rotator or capsular repair; (2) what percentage of patients had muscle atrophy of the external rotator muscles develop as a result of failure of the functioning muscle tendon unit; (3) whether increased gap size is equivalent to a fluid-filled dead space or whether scar tissue forms in the defect; and (4) whether increased range of motion during early followup is correlated to an increased gap size of the capsular and external rotator repair.

Materials and Methods

Between February and May 2005, the senior author (PMP) operated on approximately 80 patients undergoing primary uncemented THA. Of those patients, 40 were approached and 36 agreed to participate in this prospective MRI study to investigate the integrity of the posterior capsule and external rotator tendon repair; MR images were obtained during the first few days after surgery and again at approximately 3 months. Thirty-six patients, including 21 men and 15 women, agreed to participate. Their mean age at the time of surgery was 63 years (range, 37–75 years). Their mean body mass index was 26.8 kg/m^2 (range, 16.5–41.6 kg/m^2). Thirty-five patients underwent hip arthroplasties for osteoarthritis of the hip and one patient for osteonecrosis of the hip. There were 23 right and 13 left THAs in the study group. The study received Institutional Review Board approval at the authors' institution.

All patients were operated on by the senior author. The capsule and external rotators were released close to their insertion using electrocautery with the technique described previously [1]. We used the same implants in all patients: Synergy Stem (titanium), Reflection Shell (titanium), and Oxinium Head (Smith and Nephew, Memphis, TN). We closed the posterior soft tissues in two separate layers using Number 2 Ethibond sutures (Ethicon Endo Surgery, Inc, Cincinnati, OH) through 2.3-mm drill holes in the greater trochanter. Two sutures were placed in the posterior capsule and one suture was placed each in the piriformis tendon and the conjoined tendon (common insertion of inferior gemellus, superior gemellus, and obturator internus muscle), respectively. The quadratus muscle was repaired using Number 0 Vicryl (Ethibond; Ethicon Endo Surgery, Inc).

All patients were mobilized weightbearing as tolerated on postoperative Day 1. Hip precautions were enforced during the first 6 weeks after surgery. Patients were asked to avoid flexion past 90° and any internal rotation of the surgically treated hip.

All patients underwent initial MRI an average of 3.6 days after surgery (range, 2–4 days). Thirty patients (83%) returned for followup MRI an average of 107 days after surgery (range, 91–138 days). MRI was performed using an established protocol that reduces the frequency shift generated by the metallic components [9]. All examinations were performed on a clinical superconducting 1.5-Tesla unit (Horizon HDx; General Electric Health Care, Milwaukee, WI) using a receive-only phased array shoulder coil (shoulder phased array; MedRad, Indianola, PA). We obtained coronal and axial fast spin echo images with a repetition time of 4000 to 6000 ms and echo time (effective) of 34 ms, receiver bandwidth of 62.5 to 100 kHz (over the entire frequency range) with a maximum in-plane resolution of 352 μm × 562 μm, and slice resolution of 2.5 to 3 mm at three to four excitations.

All MRI studies were interpreted by one experienced radiologist (HGP). The posterior capsule repair was considered intact when there was contact of the proximal and distal posterior capsule with the greater trochanter, partially intact when there was contact of either the proximal or distal part of the posterior capsule, or failed when there was no contact of the posterior capsule with the greater trochanter. We assessed integrity of the external rotator repair by measuring the distance (gap) between the tendon (end of the hypointense tendon signal on the sequence) and the greater trochanter in millimeters. A gap was interpreted as discontinuity of the hypointense tendon signal but the space is filled with more hyperintense scar tissue instead of fluid. A gap distance greater than 25 mm was considered failure of the repair based on the current literature [10, 11]. Piriformis and obturator internus muscle quality was rated as no atrophy, mild atrophy, moderate atrophy, or severe atrophy based on subjective fatty infiltration in the cross-section of the muscle bellies, between the two MRI examinations.

We documented the postoperative range of motion of the surgically treated hip 6 weeks after surgery. The postoperative changes in leg length and offset were measured on standard preoperative and postoperative radiographs.

We used bivariate Pearson correlation (two-tailed) to analyze correlations between the postoperative range of motion and failure of the repair (Version 17.0; SPSS, Chicago, IL).

Results

At the 3-month followup, 27 patients (90%) had at least partial contact of the posterior capsule with the greater trochanter. In 20 patients (67%), the proximal and distal capsules showed continuity of the signal toward the bone and in seven patients, at least one of the two attachment sides remained intact (Fig. 1). Overall, eight proximal and five distal posterior capsule repairs had an interruption of the capsule on MRI.

The average distance between the hypointense piriformis tendon signal and the greater trochanter was 25.5 mm (range, 11.7–37.4 mm) (Fig. 2). Thirteen of 30 patients (43%) had interruption of the hypointense tendon signal over more than 25 mm. At the 3-month followup, seven of the 13 patients had no piriformis muscle atrophy, 12 patients had mild muscle atrophy, 11 patients had moderate muscle atrophy, and no patient had severe muscle atrophy.

The average distance between the hypointense conjoined tendon MRI signal and the greater trochanter was 27.5 mm (range, 11.7–43.0 mm). Seventeen of 30 patients (53%) had interruption of the signal over more than 25 mm. At the 3-month followup, six of these 17 patients had no muscle atrophy of the obturator internus muscle, 12 patients had mild muscle atrophy, 12 patients had moderate muscle atrophy, but no patient had severe muscle atrophy (Fig. 3). We observed no correlation ($p > 0.35$) between gap size (mm) and the muscle atrophy.

Range of motion at the 6-week followup was documented (Table 1). There was a correlation between an increased gap of the external rotator tendons and an increased amount of postoperative flexion and internal rotation 6 weeks after surgery. We observed a correlation ($p = 0.012$) between the gap of the external rotator tendons and postoperative flexion and internal rotation 6 weeks after surgery.

We observed no correlation between changes in leg length or offset and gap formation of the posterior soft tissue repair. The average changes in leg length and offset between preoperative and postoperative radiographs were 0.27 cm (range, –0.5 to 1.5 cm) and −0.21 cm (range, −1.4 to 0.5 cm), respectively. The postoperative leg-length discrepancy was 0 cm (range, −0.8 to 0.8 cm).

Discussion

Although several studies have shown posterior capsular repair reduces the risk of posterior dislocation after THA [2, 3, 7, 8, 14, 15], some authors [5, 12] do not recommend routine repair based on studies showing an increased gap between tendon and bone as observed radiographically or by ultrasound [5, 11–15]. These latter studies appear discrepant from reduction in dislocation rates. We therefore used MRI to address four questions: (1) what percentage of patients would have an increase in distance between the tendon stump/capsule and greater trochanter greater than 25 mm, suggesting failure of the external rotator or capsular repair; (2) what percentage of patients had muscle atrophy of the external rotator muscles develop as a result of failure of the functioning muscle tendon unit; (3) whether increased gap size is equivalent to a fluid-filled dead space or whether scar tissue forms in the defect; and (4) whether increased range of motion during early followup is correlated to an increased gap size of the capsular and external rotator repair.

Our study has some limitations, including an assumption that if the repair stays intact for 3 months after surgery, it will remain intact long-term. Based on the number of subjects in the study and the study design, we are unable to answer whether patients with an interruption of the posterior soft tissue signal on MRI are more likely to

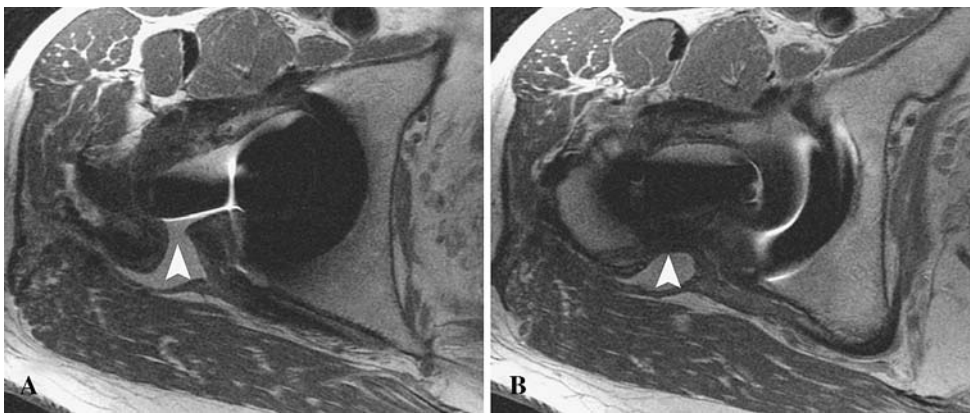

Fig. 1A–B Axial MR images obtained 3 months after THA show (**A**) dehiscence of the proximal posterior capsular repair (arrowhead) and (**B**) an intact distal repair (arrowhead).

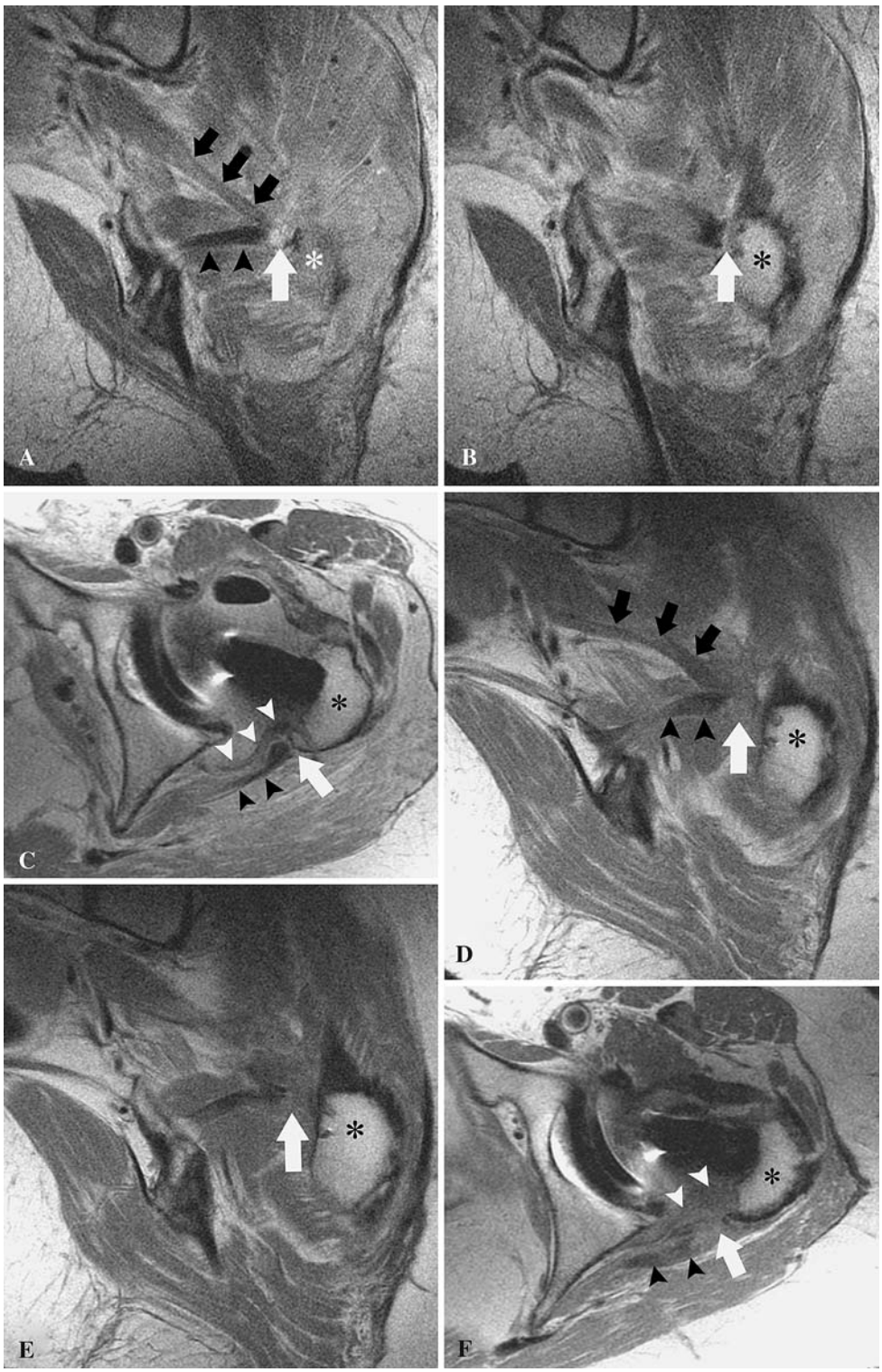

Fig. 2A–F (**A–C**): MR images 3 days following total hip arthroplasty. Coronal image through the posterior soft tissue repair (**A**) demonstrates the piriformis tendon (black arrows) and the obturator internus tendon (black arrowheads) converging towards the greater trochanter (asterisk). Adjacent coronal image (**B**) demonstrates the distal margins of the tendons apposing the greater trochanter (asterisk) to form an intact posterior soft tissue repair (white arrow). Axial image (**C**) demonstrates an intact posterior capsule (white arrowheads) attached to the greater trochanter (asterisk). The intact obturator internus tendon repair (black arrowheads and white arrow) is once again noted. (**D–F**): MR images 3 months following surgery. Coronal image through the posterior soft tissue repair (**D**) demonstrates mildly thickened and scarred piriformis tendon (black arrows) and the obturator internus tendon (black arrowheads) converging towards the greater trochanter (asterisk). The adjacent coronal image (**E**) demonstrates the distal margins of the tendons apposing the greater trochanter (asterisk) where there is progressive soft tissue scarring at the site of an intact posterior soft tissue repair (white arrow). Axial image (**F**) demonstrates an intact and scarred posterior capsule (white arrowheads) attached to the greater trochanter (asterisk). The intact obturator internus tendon repair (black arrowheads and white arrow) is once again noted.

experience postoperative dislocation. Failure of the external rotator muscle repair is defined as a gap formation greater than 25 mm based on a literature review [5, 11]. Compared with radiographic studies that usually use metal clips or wires to mark the distal tendon stump, an interruption in the hypointense tendon signal is more difficult to interpret [5, 11]. Although assessment of postoperative changes using traditional MRI protocols can make the gap measurement less accurate, the modified protocol was designed specifically to reduce the susceptibility artifact generated by the arthroplasty and the nonabsorbable suture used in the repair. MRI offers a detailed evaluation of the

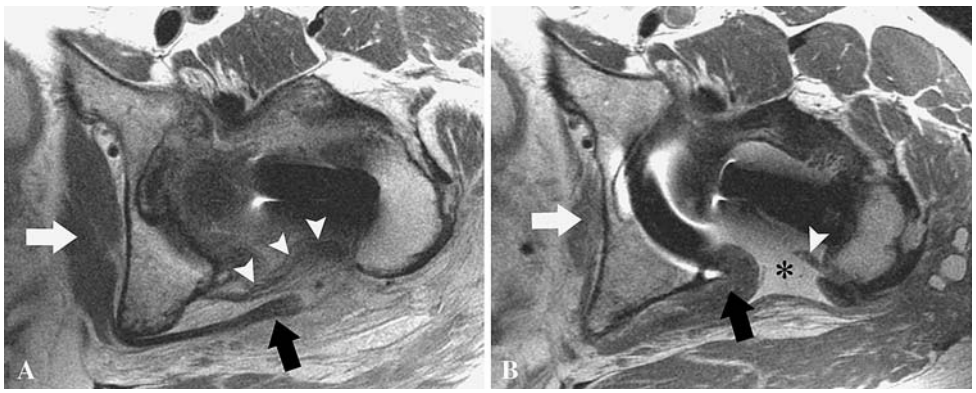

Fig. 3A–B (**A**) An axial MR image obtained 3 days after THA shows an intact posterior capsular (arrowheads) and obturator internus tendon (black arrow) repair without atrophy of the obturator internus muscle (white arrow). (**B**) A corresponding MR image obtained 3 months after surgery shows interval dehiscence of the posterior soft tissue repair (asterisk) with scarring of the posterior capsule and obturator internus tendon to the posterior acetabular rim (black arrow) and corresponding marked muscle atrophy of the obturator internus (white arrow). Only a small remnant of the repaired posterior capsule remains attached to the greater trochanter (arrowhead).

Table 1. Range of motion at 6-week followup

Direction	Average (degrees)	Standard deviation (degrees)	Minimum (degrees)	Maximum (degrees)
Flexion	101.5	19.5	40.0	140.0
Extension	1.9	5.4	0.0	20.0
Internal rotation	3.6	5.0	0.0	20.0
External rotation	18.0	10.8	0.0	40.0
Abduction	28.6	8.4	15.0	45.0
Adduction	15.9	6.5	0.0	25.0

tissue filling the gap between discernable tendon and the drill holes in the trochanter, noting any fluid-filled dead space. When the data in the current study are compared with published data, it should be considered that a reduction in the gap size to less than 20 mm would increase the failure rate in the external rotator repair to 77% in the current study. A control group would provide additional information regarding the posterior soft tissues if no repair was attempted; however, considering the substantial increase in the rate of postoperative dislocation, we did not consider it ethical to have a control group.

Kao and Woolson first reported the integrity of the posterior repair [5]. In a small cohort of 10 patients undergoing THA through a posterior approach, they performed an isolated piriformis tendon repair [5]. The anteroposterior capsule was excised completely and the conjoined tendon was left detached. At the time of surgery, a metallic clip was inserted into the cut end of the piriformis tendon, and another clip was implanted into the greater trochanter as close as possible to the first clip; the distance between both clips was measured on postoperative radiographs. Failure was determined as doubling of the initial distance between the clips (greater than 25 mm). In their study, only two (20%) of the repairs remained intact and one patient with an intact repair sustained a postoperative dislocation. Based on their poor results, they suggested repair of the piriformis tendon is of no major benefit to the stability of a THA.

Stähli et al. repaired the posterior soft tissues using three sutures, all of them looping through the posterior capsule and the external rotators [11]. The piriformis and conjoined tendons were marked using thin wires and a tantalum marker was inserted into the greater trochanter close to the insertion site. Similar to the study by Kao and Woolson, a distance greater than 25 mm was considered failure of the repair. The repair failed in 15 of 20 hips and Stähli et al. concluded the capsular-enhanced short external rotator muscle repair after arthroplasty was insufficient to withstand the forces that occur.

In contrast, most clinical followup studies confirm a considerable reduction in the incidence of postoperative dislocations in patients with a posterior soft tissue repair after THA through a posterior approach [2, 3, 7, 8, 14, 15]. Based on these studies, an enhanced soft tissue repair incorporating the posterior capsule and the external rotators is more effective than an external rotator tendon repair alone [4].

Our MRI study confirms that although numerous patients show gap formation between the hypointense external rotator tendon/capsule and the greater trochanter, dead space formation did not occur and the defect was filled with hyperintense scar tissue in all patients in the current study. We therefore suggest the posterior repair functions as a biologic scaffold for restoration of the posterior soft tissue envelope. This likely explains the difference between the high failure rate in some radiographic followup studies and the considerable reduction in the incidence of

postoperative dislocations in most clinical followup studies. This is further supported by the low incidence in piriformis and obturator internus muscle atrophy in our patients. As opposed to radiographs that simply measure the gap detected by the osseous structures and radioopaque markers, the superior soft tissue contrast of MRI affords observation of the tissue remodeling that occurs in the operative bed. Muscle atrophy is probably a sign for a nonfunctioning muscle tendon unit and suggests the repair is not working. Muscle atrophy should be an early phenomenon after hip arthroplasty. It is unlikely it will occur at a later time when the patient resumes more strenuous activities. Therefore, we believe an early followup at 3 months has advantages over a later followup.

Additional studies are needed to investigate the long-term remodeling potential of the posterior pseudocapsule and its ability to withstand loads over a longer postoperative interval. Based on our study, we advise separate repair of the capsule and external rotators to assure disruption of one structure will not automatically lead to failure of the other. We believe the capsule, when released off its insertion at the neck, has more play to be reattached to the greater trochanter than the external rotators. The insertion of the external rotator lies more anterior on the greater trochanter and therefore posterior release can shorten the tendon length available for reconstruction. In addition, muscle contractures in an arthritic hip increase the tendon stiffness and might contribute to the increased failure rate of the external rotator repair.

Our observations suggest a correlation between postoperative range of motion and integrity of the posterior repair; however, we were unable to show whether increased range of motion results in gap formation or whether the increase in motion is a result of plastic deformation of the posterior soft tissue envelope.

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