Arthroscopic Superior Capsule Reconstruction Can Eliminate Pseudoparalysis in Patients With Irreparable Rotator Cuff Tears

Teruhisa Mihata,*†‡§‖ MD, PhD, Thay Q. Lee,‡§ PhD, Akihiko Hasegawa,† MD, PhD, Takeshi Kawakami,† MD, PhD, Kunimoto Fukunishi,† MD, Yukitaka Fujisawa,† MD, PhD, Yasuo Itami,† MD, Mutsumi Ohue,‖ MD, and Masashi Neo,† MD, PhD
Investigation performed at the Department of Orthopedic Surgery, Osaka Medical College, Takatsuki, Japan

Background: Patients with pseudoparalysis and irreparable rotator cuff tears have very poor function. The authors developed a superior capsule reconstruction (SCR) technique for irreparable rotator cuff tears that restores shoulder stability and muscle balance, improving shoulder function and relieving pain.

Purpose: To evaluate whether arthroscopic SCR reversed preoperative pseudoparalysis in patients with irreparable rotator cuff tears.

Study Design: Case series; Level of evidence, 4.

Methods: One hundred consecutive patients with irreparable rotator cuff tears underwent arthroscopic SCR with fascia lata autografts; 7 patients with deltoid weakness from cervical or axillary nerve palsy and 5 with severe presurgical shoulder stiffness were excluded. The remaining 88 were allocated to 3 groups according to their preoperative active shoulder elevation: no pseudoparalysis (45 patients; mean age, 66.2 years; mean tear size, 3.5 cm), moderate pseudoparalysis (28 patients, 68.3 years, 3.5 cm), and severe pseudoparalysis (15 patients, 62.3 years, 4.9 cm). Clinical outcome, active shoulder range of motion, acromiohumeral distance, and healing rate were compared between patients with and without pseudoparalysis, as well as before surgery and at final follow-up (35-110 months).

Results: American Shoulder and Elbow Surgeons score, active elevation, active external rotation, and acromiohumeral distance increased significantly after arthroscopic SCR among all patients. Graft healing rates did not differ among the groups (P = .73): 98% (44 of 45) for no pseudoparalysis, 96% (27 of 28) for moderate pseudoparalysis, and 87% (13 of 15) for severe pseudoparalysis. Pseudoparalysis was reversed in 96% (27 of 28) of patients with preoperative moderate pseudoparalysis and 93% (14 of 15) with preoperative severe pseudoparalysis. Both patients with residual pseudoparalysis postoperatively (1 of 28 with preoperative moderate pseudoparalysis, 1 of 15 with preoperative severe pseudoparalysis) had graft tears.

Conclusion: Arthroscopic SCR restored superior glenohumeral stability and improved shoulder function among patients with or without pseudoparalysis who had previously irreparable rotator cuff tears. In the absence of postoperative graft tear, arthroscopic SCR reversed preoperative pseudoparalysis. Graft healing rates after arthroscopic SCR did not differ between patients with and without pseudoparalysis.

Keywords: irreparable; pseudoparalysis; reconstruction; rotator cuff; superior capsule; tear

Rotator cuff tear is a common shoulder injury and causes pain and dysfunction in the shoulder joint. In some patients with large to massive rotator cuff tears, active shoulder elevation is reduced to <90° mainly owing to a loss of the "force couple" that stabilizes the humeral head during elevation. This situation is similar to that in nerve injuries such as cervical palsy or axillary nerve palsy and is therefore referred to as pseudoparalysis.[4,6,9,34,40] Even if patients with rotator cuff tear have pseudoparalysis of the shoulder joint, complete repair of the torn tendon can restore shoulder function and remove the pseudoparalysis (recovery rate, 95%).[9,10]

Some large to massive rotator cuff tears are irreparable and severely degenerated and atrophied, making it hard to expect functional recovery even after partial repair of the torn tendons. Reverse shoulder arthroplasty is one of the alternative treatments to improve active shoulder

The American Journal of Sports Medicine
1–10
DOI: 10.1177/0363546518786489

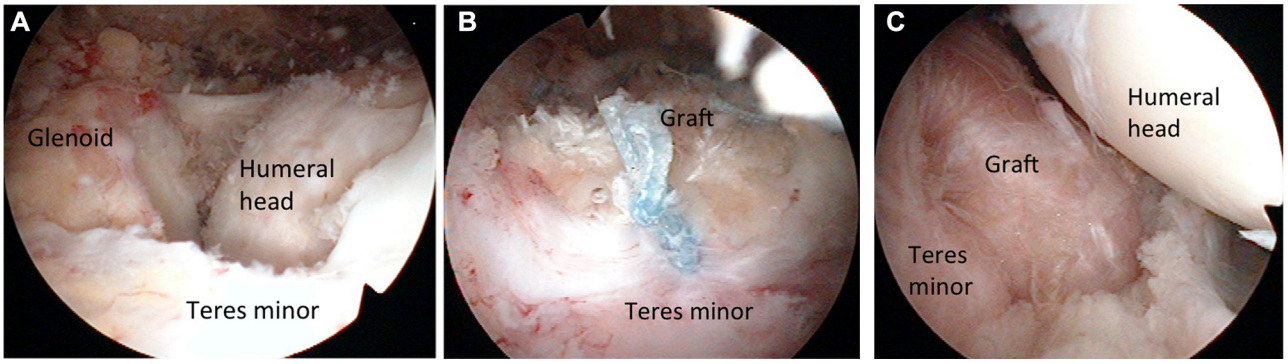

Figure 1. Arthroscopic findings before and after superior capsule reconstruction: posterior view of the (A) subacromial space before surgery, (B) subacromial space just after surgery, and (C) glenohumeral joint just after surgery.

elevation (ie, above shoulder level) with pain relief, improving daily activity[3,36,41,42] and permitting a return to low-intensity activity[13]; however, various postoperative complications have been reported, including scapular notching, dislocation, infection, nerve palsy, glenoid loosening, humeral loosening, fracture of acromion and scapular neck, and polyethylene wear.[5,12,35,36] Farshad and Gerber[12] concluded that reverse shoulder arthroplasty is associated with a high rate of complications. Furthermore, in their study, all complications requiring removal of the implant left the patient with very poor function. Reverse shoulder arthroplasty for the treatment of primary glenohumeral osteoarthritis with intact rotator cuff can result in excellent clinical outcomes.[24,33]

Superior capsule reconstruction (SCR) was more recently developed for the treatment of irreparable rotator cuff tears.[25,27-31] Restoration of superior stability by SCR is reported to improve functional outcomes.[19,27] We investigated whether arthroscopic SCR reversed preoperative pseudoparalysis among patients with irreparable rotator cuff tears. Our hypothesis was that SCR would restore shoulder function for patients with or without preoperative pseudoparalysis.

METHODS

A series of 100 consecutive patients with irreparable rotator cuff tears that had failed nonoperative treatment (for at least 3 months) underwent arthroscopic SCR with fascia lata autografts (Figure 1) by a single surgeon between 2007 and 2014. Seven patients with deltoid weakness attributed to cervical or axillary nerve palsy and 5 patients with severe shoulder stiffness (passive shoulder elevation <90°) before surgery were excluded from the study population. The remaining 88 patients were allocated to 3 groups according to their preoperative active shoulder elevation (Table 1):

- *No pseudoparalysis*: ≥90° of active shoulder elevation (45 patients, all primary cases)
- *Moderate pseudoparalysis*: no shoulder stiffness, <90° of active shoulder elevation; patients maintained >90° elevation once the shoulder was elevated passively (28 patients: 26 primary cases and 2 revision cases after a failed rotator cuff repair)
- *Severe pseudoparalysis*: no shoulder stiffness, <90° of active shoulder elevation; patients had a positive drop-arm sign (15 patients: 13 primary cases and 2 revision cases after a failed rotator cuff repair)

While pain and some muscle weakness cause limited elevation in moderate pseudoparalysis, severe muscle weakness is the main cause of limited elevation in severe pseudoparalysis. Patients without pseudoparalysis were the control group of this study. There was no significant difference in age among the 3 groups. Tear size in the severe pseudoparalysis group was significantly greater than that in the other 2 groups ($P < .05$) (Table 1). Each patient signed an informed consent form approved by the Institutional Review Board of our university (Osaka Medical College, No. 1854). The current study included updated data from the previous study.[27] Irreparable rotator cuff tear was evaluated during shoulder arthroscopy. When the torn tendon could not reach the original footprint, the rotator cuff tear was defined as an irreparable tear.

The stage of osteoarthritis before surgery is classified by the Hamada grade.[17] In this system, grade 1 is associated with minimal radiographic changes; grade 2, narrowing of the subacromial space to <6 mm; grade 3, erosion and so-called acetabulization of the acromion caused by superior migration of the humeral head; grade 4, glenohumeral

*Address correspondence to Teruhisa Mihata, MD, PhD, Department of Orthopedic Surgery, Osaka Medical College, 2-7 Daigaku-machi, Takatsuki, Osaka 569-8686, Japan (emails: tmihata@yahoo.co.jp, tmihata@osaka-med.ac.jp).
†Department of Orthopedic Surgery, Osaka Medical College, Takatsuki, Japan.
‡Orthopaedic Biomechanics Laboratory, VA Healthcare System, Long Beach, California, USA.
§Department of Orthopaedic Surgery, University of California, Irvine, California, USA.
‖Katsuragi Hospital, Kishiwada, Japan.
Presented at the interim meeting of the AOSSM, San Diego, California, USA, March 2017.
The authors declared that they have no conflicts of interest in the authorship and publication of this contribution.

TABLE 1
Patient Age and Severity of Rotator Cuff Tear[a]

	Pseudoparalysis, Mean (Range) or n		
	No (n = 45)	Moderate (n = 28)	Severe (n = 15)
Age, y	66.2 (43-78)	68.3 (45-82)	62.3 (45-80)
Tear size in anterior-posterior direction, cm	3.5 (2-7)	3.5 (2-6)	4.9[b] (3-7)
Acromiohumeral distance, mm			
Before surgery	4.4 (0.6-8.7)	4.7 (1.2-9.0)	4.1 (1.7-6.8)
At the final follow-up after SCR	9.7 (2.3-13.8)	9.8 (3.5-15.9)	8.1 (2.4-12.5)
Torn tendons			
2: supraspinatus and infraspinatus	25	19	7
3: supraspinatus, infraspinatus, subscapularis	18	8	8
3: supraspinatus, infraspinatus, teres minor	2	0	0
4	0	1	0
Hamada grade			
1	7	7	3
2	26	17	10
3	11	3	2
4a	0	1	0
4b	1	0	0
5	0	0	0
Goutallier stage			
0/1	0	0	0
2	3	1	1
3	19	11	4
4	23	16	10

[a]SCR, superior capsule reconstruction.
[b]Tear size in the severe pseudoparalysis group was significantly greater than that in the no pseudoparalysis group and the moderate pseudoparalysis group ($P < .05$).

arthritis; and grade 5, the presence of humeral head osteonecrosis.

We also evaluated fatty degeneration of the supraspinatus muscle with preoperative magnetic resonance imaging (MRI) using the grading system of Goutallier et al.[16] The grading classifies fatty degeneration into 5 stages: stage 0, completely normal muscle without any fatty streak; stage 1, muscle with some fatty streaks; stage 2, increased fatty infiltration but still more muscle than fat; stage 3, as much fat as muscle; and stage 4, more fat than muscle.

Patient Assessment

The patients provided a standard history. Shoulder elevation, external rotation at side, and internal rotation were measured actively with a goniometer by the primary surgeon before surgery and at the final follow-up. Internal rotation was measured as the highest vertebral body that the patient was able to reach with the thumb of the affected arm. We evaluated muscle strength by manual muscle testing (MMT) on a scale of 0 to 5: 5, normal amount of resistance to applied force; 4, resistance between 5 and 3; 3, ability to move the segment (the arm) through its range of motion against gravity; 2, ability to move the segment through its range of motion but not against gravity; 1, presence of contraction in the muscle without joint motion; 0, no muscle contraction.[8] Grades 3 and 4 were further divided into 3 grades (3–, 3, and 3+ and 4–, 4, and 4+), and grade 5 was divided into 2 grades (5– and 5).[21] We recorded the muscle strength of shoulder abduction with the thumb up, which is known as the full can position.[22,23] External rotation strength was measured with the arm at the side.[8] We assessed strength in lifting the hand off the back to assess the internal rotation strength.[14] The hornblower sign[38] and external and internal rotation lag signs[18] were assessed before surgery and at final follow-up after surgery. All patients were assessed preoperatively with the scoring systems of the shoulder index of the American Shoulder and Elbow Surgeons (ASES; a 100-point scoring system) and the Japanese Orthopaedic Association (JOA; a 100-point scoring system) and were reassessed at the time of the final follow-up. The postoperative complication rate was also recorded. MRI was performed with a 1.5-T closed-type scanner (MRT-2000/V2; Toshiba) before surgery and at final follow-up after surgery. Oblique coronal, oblique sagittal, and axial T2-weighted MRI scans were acquired for structural and qualitative assessment of the rotator cuff and repair integrity after surgery (Figure 2). The mean time to final follow-up was 60 months (range, 35-110 months).

Surgical Technique

Preparation. All procedures were performed with the patient under general anesthesia in the lateral decubitus position. Normal arthroscopic pump pressure was set

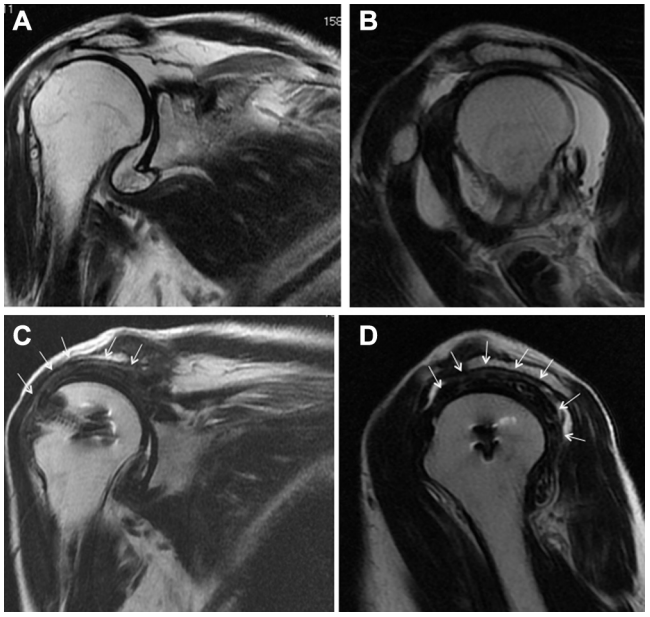

Figure 2. Magnetic resonance image findings before and after arthroscopic superior capsule reconstruction. (A) Coronal view before surgery. The torn supraspinatus tendon is severely retracted, and the supraspinatus muscle is severely atrophied and infiltrated with fat. (B) Sagittal view before surgery. The supraspinatus, infraspinatus, and teres minor are torn. (C) Coronal view 2 years after surgery. The graft has healed. White arrows represent the healed graft. (D) Sagittal view 2 years after surgery. The graft has connected with subscapularis anteriorly and teres minor posteriorly, suggesting that force coupling in the anteroposterior direction has been restored. White arrows represent the healed graft.

between 30 and 50 mm Hg. Shoulder range of motion and laxity were examined under general anesthesia. Three portals were typically required for arthroscopic SCR. A posterior portal was established for initial assessment of the glenohumeral joint. An anterior portal through the rotator interval was established as the working portal for the treatment of intra-articular lesions (eg, labral tear and biceps tear) or subluxation. The arthroscope was then removed from the glenohumeral joint and redirected into the subacromial space. A lateral portal was also established. Any pathological bursal tissue that impeded clearance of the space was removed. Arthroscopic subacromial decompression was performed to create a flat acromial undersurface. Bony spurs in the inferior part of the acromioclavicular joint and at the distal end of the clavicle were removed.[29] The superior glenoid and rotator cuff footprint of the greater tuberosity were debrided to expose cortical bone. If the subscapularis tendon tear was reparable, it was completely repaired with fully threaded titanium suture anchors (diameter, 5 mm; Corkscrew II Suture Anchor, Arthrex). The size of the superior capsular defect was evaluated with a measuring probe in the anteroposterior and mediolateral directions at 30° to 45° of shoulder abduction.

Measurement of Defect Size. The defect size was measured in 2 directions: mediolateral (from the superior edge of the glenoid to the lateral edge of the greater tuberosity: no pseudoparalysis, mean = 3.9 cm; moderate, 3.8 cm; severe, 4.1 cm) and anteroposterior (from the anterior edge to the posterior edge of the torn tendon: no pseudoparalysis, mean = 3.5 cm; moderate, 3.5 cm; severe, 4.9 cm). Length in the anteroposterior direction was measured without partial repair of the infraspinatus tendon.

Choosing the Graft Size and Harvesting the Fascia Lata. Appropriate graft size was the most important point in this surgery. If the graft was torn after surgery, the clinical results were likely to be poor[27]: partial graft tear might be acceptable, but complete graft tear gave poor results. We found that the optimal graft length in the anteroposterior direction was exactly the same as the length of the defect without partial repair of the torn infraspinatus tendon. The graft length in the mediolateral direction (no pseudoparalysis, mean = 5.4 cm; moderate, 5.3 cm; severe, 5.6 cm) was 15 mm longer than the distance from the superior edge of the glenoid to the lateral edge of the greater tuberosity to give a 10-mm footprint on the superior glenoid and a leeway of 5 mm to regulate graft size.

A vertical skin incision was made over the lateral thigh, beginning 1 to 2 cm distal to the greater trochanter of the femur, with care to include the posterior thicker tissue (Figure 3, A-C). The average thickness of a single layer of autologous fascia lata was 2 to 4 mm. Therefore, a graft thickness of 6 to 8 mm[28] was achieved by folding the fascia lata 2 or 3 times. Also, the fascia lata includes an intermuscular septum that consists of the tissues of 2 tendons and connects the fascia lata to the femur (Figure 3C). To make a thicker graft, this intermuscular septum should be included in it (Figure 3, D and E). The fascia lata was mostly thinner at its anterior aspect than posteriorly; therefore, to make a flat graft of even thickness, the intermuscular septum was usually sutured to the anterior surface of the fascia lata after being completely detached from it (Figure 3F). All fatty tissue should be removed from the graft. Finally, the layers of fascia lata were united very closely with nonabsorbable sutures to prevent delamination after surgery (Figure 3G).

Graft Attachment. All soft tissues were removed on the superior glenoid and greater tuberosity to expose cortical bone. The graft was inserted into the subacromial space via the lateral portal. We usually use a 10-mL syringe as a cannula. The medial side of the fascia lata was then attached to the superior glenoid with 2 fully threaded titanium suture anchors (diameter, 5 mm; Corkscrew II Suture Anchor, Arthrex), each with 2 No. 2 FiberWire nonabsorbable sutures (Arthrex), which were inserted into the superior glenoid at the 10- to 11-o'clock and 11- to 12-o'clock positions on the glenoid of the right shoulder (or the 1- to 2-o'clock and 12- to 1-o'clock positions of the left shoulder). FiberWires from the superior glenoid were placed through the fascia lata in a mattress fashion outside the body before the graft was inserted.

The lateral side of the fascia lata was attached to the rotator cuff footprint on the greater tuberosity with the compression double-row technique, which is a combination of the conventional double-row technique and the suture bridge,[26,32] or the SpeedBridge technique with FiberTape

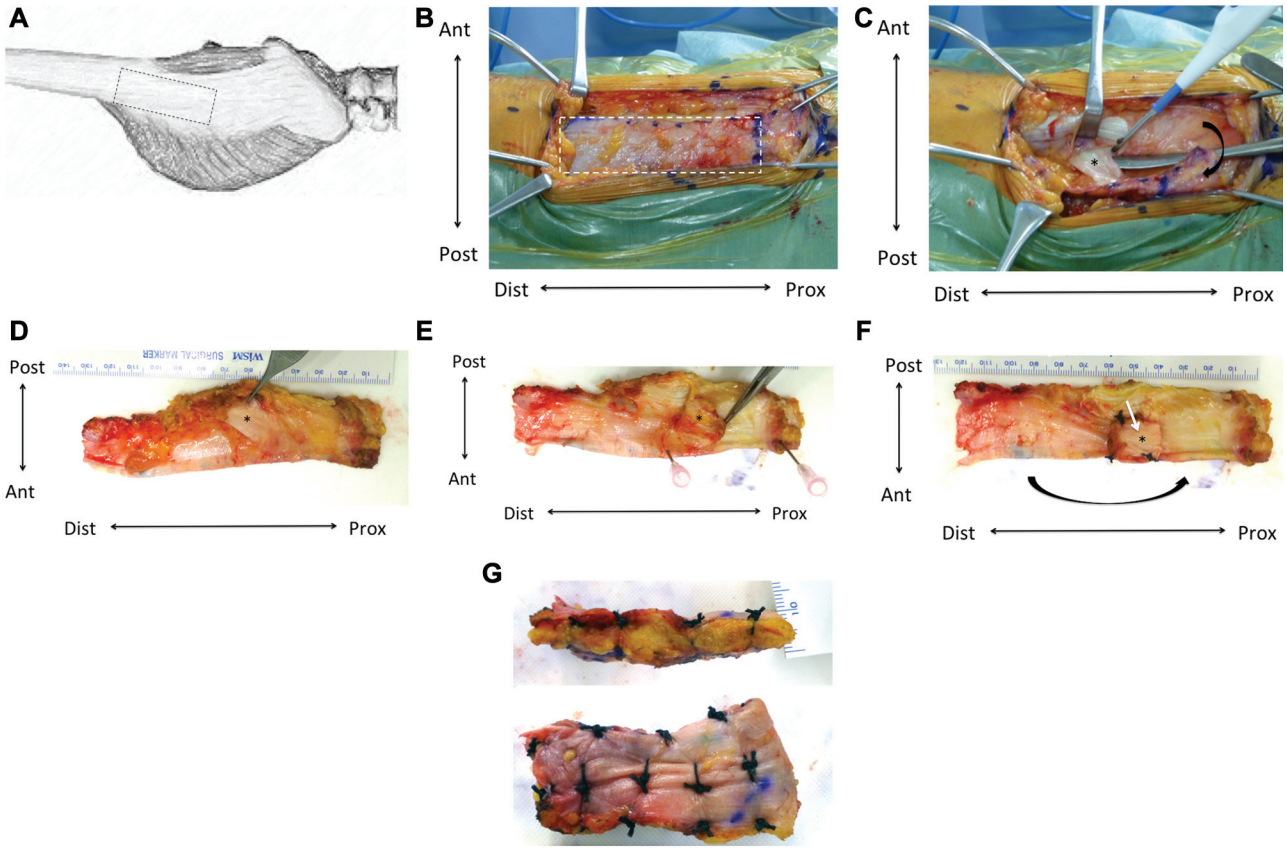

Figure 3. Harvesting the fascia lata and making the graft. (A, B) Location of fascia lata harvest in the proximal thigh (A, black dotted line; B, white dotted line). (C) The fascia lata is flipped over after incision along 3 sides of the dotted rectangle (from ''ant'' to ''prox'' to ''dist''). The fascia lata includes an intermuscular septum (asterisk) that consists of the tissues of 2 tendons and connects the fascia lata and the femur. To make the graft thicker, this intermuscular septum should be included. (D) Reverse side of the harvested fascia lata. (E) The intermuscular septum is completely detached from the fascia lata. (F) The fascia lata tends to be thinner anteriorly. Therefore, to make a flat graft of even thickness, the intermuscular septum is usually sutured to the anterior surface of the fascia lata, and the fascia lata is then folded. (G) Finally, the layers of fascia lata are united with nonabsorbable sutures. The upper and lower pictures show the lateral and inferior views of the graft, respectively. ant, anterior; dist, distal; post, posterior; prox, proximal.

(Arthrex), at 30° to 45° of shoulder abduction. Corkscrew II suture anchors or SwiveLocks (Arthrex) were placed medially at the edge of the articular cartilage and laterally 5 to 10 mm inferior to the highest point of the greater tuberosity to minimize the possibility of the anchors pulling out. The sutures were placed through the fascia lata with either a suture shuttle (Suture Lasso; Arthrex) or a suture-passing device (Scorpion Suture Passer; Arthrex). Finally, side-to-side sutures with No. 2 FiberWire nonabsorbable sutures (Arthrex) were added between the graft and the infraspinatus tendon or teres minor tendon and between the graft and the residual anterior supraspinatus tendon or subscapularis tendon to improve force coupling in the shoulder joint. Careful attention should be paid to ensure that the side-to-side suture at the anterior side was not overtightened, to avoid shoulder contracture after surgery. When the graft was attached securely at the medial, lateral, and posterior sides, an anterior suture might be unnecessary.

Postoperative Protocol

We recommended the use of an abduction sling (Block Shoulder Abduction Sling; Nagano Prosthetics & Orthotics Co Ltd) for 4 weeks after reconstruction. After the immobilization period, passive and active-assisted exercises were initiated to promote scaption. Eight weeks after the surgery, patients began to perform exercises to strengthen the rotator cuff and the scapula stabilizers. Full activities were allowed at 6 months if patients had sufficient range of motion and muscle strength. Physical therapists assisted all patients.

Statistical Analysis

A 1-way analysis of variance followed by a Tukey post hoc test was performed to compare age, tear size, acromiohumeral distance, ASES score, JOA score, and active shoulder

TABLE 2
Concomitant Injuries and Surgery

	Pseudoparalysis, n		
	No (n = 45)	Moderate (n = 28)	Severe (n = 15)
Subscapularis			
Intact or partial tear (no treatment)	34	24	9
Repair for complete tear	11	4	6
Biceps			
Intact (no treatment)	12	10	5
Partial tear (no treatment)	18	9	2
Complete tear (no treatment)	11	6	7
Tenodesis for dislocated biceps	4	3	0
Tenotomy for dislocated biceps	0	0	1
Acromioplasty	45	28	15

range of motion among the 3 groups (no, moderate, and severe pseudoparalysis). To calculate the mean MMT grade, we converted each grade to a scale of 0 to 10, where MMT 5 = 10, 5– = 9, 4+ = 8, 4 = 7, 4– = 6, 3+ = 5, 3 = 4, 3– = 3, 2 = 2, 1 = 1, and 0 = 0. All data were compared with the *t* test (before surgery vs final follow-up). The number of torn tendons, Hamada grade, Goutallier grade, the number of subscapularis repairs, biceps pathology/treatment, and graft healing rates were compared among the 3 groups with a chi-square test. Data are shown as mean ± SD. A significant difference was defined as $P < .05$.

RESULTS

Tear size in the anteroposterior direction in the severe pseudoparalysis group (mean, 4.9 cm; range, 3-7 cm) was significantly greater than in the no pseudoparalysis group (mean, 3.5 cm; range, 2-7 cm; $P = .003$) and moderate pseudoparalysis group (mean, 3.5 cm; range, 2-6 cm; $P = .004$) (Table 1). There was no significant difference in age ($P = .11$), number of torn tendons ($P = .32$), acromiohumeral distance ($P = .74$), Hamada grade ($P = .64$), Goutallier grade of supraspinatus muscle ($P = .82$), number of subscapularis repairs ($P = .17$), and biceps injury and treatment ($P = .16$) among the 3 groups (Tables 1 and 2). Acromioplasty was performed in all patients. Acromiohumeral distance significantly increased after SCR in all group ($P < .001$) (Table 1).

Pseudoparalysis was reversed in 96.4% of patients with moderate preoperative pseudoparalysis (27 of 28; increased active elevation, 60°-150°) and in 93.3% with severe preoperative pseudoparalysis (14 of 15; increased active elevation, 70°-170°). Both patients with residual pseudoparalysis postoperatively had graft tears (Table 3). The graft healing rate without retear was 98% (44 of 45) among patients with no preoperative pseudoparalysis, 96% (27 of 28) for those with moderate pseudoparalysis, and 87% (13 of 15) in the severe pseudoparalysis group. Graft healing rates did not differ among the 3 groups ($P = .73$).

Preoperative scores were 43.6 ± 17.2 (ASES) and 61.2 ± 8.7 (JOA) in the no pseudoparalysis group, 29.2 ± 18.3 and 46.6 ± 9.3 points in the moderate pseudoparalysis group, and 20.3 ± 13.6 and 40.6 ± 10.8 points in the severe pseudoparalysis group, respectively. The moderate and severe pseudoparalysis groups had significantly lower preoperative ASES and JOA scores than the no pseudoparalysis group ($P < .001$). Clinical outcome scores after arthroscopic SCR were significantly improved at final follow-up ($P < .001$) among all 3 groups, and there were no significant differences in postoperative scores (Table 4): ASES (no pseudoparalysis, 96.5 ± 5.9 points; moderate, 92.2 ± 13.9; severe, 91.8 ± 11.8; $P = .32$-$.99$) and JOA (no pseudoparalysis, 95.2 ± 5.5 points; moderate, 90.6 ± 12.9; severe, 92.3 ± 8.9; $P = .19$-$.81$).

Preoperative active shoulder elevation was 142.7° ± 23.4° in the no pseudoparalysis group, 54.3° ± 24.4° in moderate pseudoparalysis group, and 36.7° ± 19.1° in severe pseudoparalysis group. Active preoperative elevation was significantly less in the severe pseudoparalysis group than in the no pseudoparalysis ($P < .001$) and moderate pseudoparalysis ($P = .03$) groups. Active preoperative elevation was significantly less in the moderate pseudoparalysis group than in the no pseudoparalysis group ($P < .001$). Shoulder active elevation improved significantly after arthroscopic SCR at final follow-up for all 3 groups (no pseudoparalysis, 163.6° ± 15.4°; moderate, 146.8° ± 33.0°; severe, 150.0° ± 36.8°; $P < .001$); there were no significant differences in this improvement among the 3 groups ($P = .12$-$.93$) (Table 5). The severe pseudoparalysis group had significantly less active shoulder external rotation before surgery than the no pseudoparalysis group ($P = .02$). Active shoulder external and internal rotation improved significantly after arthroscopic SCR in all 3 groups ($P < .001$), and there were no significant differences in the improvement among the 3 groups ($P = .21$-$.99$) (Table 5). Shoulder muscle strength improved significantly after arthroscopic SCR in all 3 groups ($P < .001$) (Table 6). All patients in the moderate and severe pseudoparalysis groups had a positive hornblower sign before surgery. External rotation lag sign was positive for 3 of 45 patients with no pseudoparalysis, 7 of 28 with moderate pseudoparalysis, and 5 of 15 with severe pseudoparalysis before surgery. At the final follow-up after arthroscopic SCR, the hornblower and external rotation lag signs became negative for all patients if the graft was healed. Two patients with graft tear (1 with preoperative moderate pseudoparalysis and 1 with preoperative severe pseudoparalysis) had positive external rotation lag and hornblower signs at the final follow-up. For all patients with positive internal rotation lag sign (0 of 45 with no pseudoparalysis, 3 of 28 with moderate pseudoparalysis, and 3 of 15 with severe pseudoparalysis), the lag sign became negative at the final follow-up after arthroscopic SCR.

Some postoperative complications were experienced. Three patients had suture anchor pullout. Three patients had severe shoulder stiffness, which was treated with arthroscopic release of rotator interval and inferior capsule. Two patients had postoperative infection (*Propionibacterium acnes*). Both patients were treated by arthroscopic debridement and removal of some sutures and anchors, without removal of the graft because we found that the graft had already started to heal to the bone. One patient had

TABLE 3
Functional Outcomes of Patients With Postoperative Graft Tear[a]

	Pseudoparalysis Grade		ASES Score		JOA Score		Active Elevation	
Patient	PRE	POST	PRE	POST	PRE	POST	PRE	POST
1	No	No	28.3	91.7	54.5	86	140	110
2	Moderate	Severe	60	38.3	43	44	20	20
3	Severe	Severe	20	65	54.5	72.5	40	50
4	Severe	No	63.3	86.7	66.5	82	80	170

[a]ASES, American Shoulder and Elbow Surgeons; JOA, Japanese Orthopaedic Association; POST, postoperative; PRE, preoperative.

TABLE 4
Pre- and Postoperative Shoulder Scores[a]

	ASES Score		JOA Score	
Pseudoparalysis	Preoperative	Postoperative	Preoperative	Postoperative
No				
Total	43.6 (18.3-78.3)	96.5 (70-100)	61.2 (33-76)	95.2 (76.5-100)
Healed graft	44.0 (18.3-78.3)	96.6 (70-100)	61.4 (33-76)	95.4 (76.5-100)
Moderate				
Total	29.2[b] (3.3-68.3)	92.2 (38.3-100)	46.6[b] (30-74)	90.6 (44-100)
Healed graft	28.0[b] (3.3-68.3)	94.2 (61.7-100)	46.8[b] (30-74)	92.3 (59.5-100)
Severe				
Total	20.3[b] (6.7-63.3)	91.8 (65-100)	40.6[b] (26.5-66.5)	92.3 (72.5-100)
Healed graft	17.1[b] (6.7-28.3)	94.2 (70-100)	37.5[b] (26.5-51.5)	94.6 (79.5-100)

[a]Data are expressed as mean (range). Postoperative data were recorded at the final follow-up. All pre- vs postoperative values per score were significant at $P < .001$.
[b]Score was significantly lower than that in the no pseudoparalysis group ($P < .05$).

discomfort in the gluteal muscle, although she could play badminton at the competitive level without any pain. No patients had pain with the harvest site at the final follow-up.

DISCUSSION

Whereas rotator cuff repair reverses preoperative pseudoparalysis in most patients with reparable rotator cuff tears,[9,34] pseudoparalysis attributed to irreparable rotator cuff tear is considered a difficult situation in which to restore shoulder function, even surgically. Reverse total shoulder arthroplasty (TSA) is an alternative treatment for irreparable rotator cuff tears and was reported to improve shoulder function, even though it is not completely restorative[6,40,41]; however, relatively high rates of complications[5,35,37] and severe limitation of shoulder external or internal rotation, or both,[6] were reported, even after reverse TSA. Otto et al[35] documented a total complication rate of 22.4% after reverse shoulder arthroplasty among patients aged <55 years. Wall et al[39] indicated that the risk of complication associated with revision surgery (36.7%, 18 of 49) was significantly higher than that with primary surgery (13.3%, 20 of 150). When patients have severe glenohumeral osteoarthritis, reverse TSA is thought to be a good surgical option.[24,33] SCR was recently developed and reported to restore shoulder function for patients with irreparable rotator cuff tear.[2,19,27-31] We found here that 96.4% (27 of 28) of patients with moderate preoperative pseudoparalysis and 93.3% (14 of 15) with severe preoperative pseudoparalysis had no pseudoparalysis (>90° of active elevation) at final follow-up after SCR. Also, both patients with residual pseudoparalysis had graft tears postoperatively. Furthermore, complication after SCR (anchor pullout, infection, and shoulder stiffness) was not so severe, and the rate of complication was relatively low. Thus, SCR completely eliminated pseudoparalysis in patients with irreparable rotator cuff tears, with a low rate of complications if the graft healed very well.

Our previous clinical study showed that postoperative clinical outcome scores were significantly better among healed patients (ASES, 96.0; JOA, 94.9) than unhealed patients who had graft tears or retears of the repaired rotator cuff tendon (ASES, 77.1 [$P < .0001$]; JOA, 81.1 [$P < .001$]).[27] Similarly, our results showed that preoperative pseudoparalysis was not eliminated after SCR in 2 of 4 cases with graft tears (Table 3). These results suggest that graft healing is the key to improved shoulder function after SCR, especially for patients with pseudoparalysis.

The common symptoms and signs of irreparable rotator cuff tear—including pain from subacromial impingement, muscle weakness, and limitation of active shoulder range

TABLE 5
Pre- and Postoperative Active Shoulder Range of Motion[a]

	Active Elevation		Active External Rotation		Active Internal Rotation	
Pseudoparalysis	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
None						
Total	142.7 (90 to 170)	163.6 (110 to 180)	33.4 (–60 to 80)	45.4 (0 to 70)	L4 (S to T12)	L1 (S to T7)
Healed graft	142.8 (90 to 170)	164.8 (120 to 180)	33.3 (–60 to 80)	46.0 (0 to 70)	L4 (S to T12)	L1 (S to T7)
Moderate						
Total	54.3[b] (20 to 80)	146.8 (20 to 180)	22.9 (0 to 50)	37.9 (10 to 60)	L5 (S to T7)	L2 (S to T7)
Healed graft	55.6[b] (20 to 80)	151.5 (90 to 180)	23.3 (0 to 50)	38.9 (10 to 60)	L5 (S to T7)	L2 (S to T7)
Severe						
Total	36.7[b,c] (10 to 80)	150.0 (50 to 180)	16.7[b] (–20 to 60)	44.0 (20 to 90)	L5 (S to T12)	L1 (S to T10)
Healed graft	33.1[b,c] (10 to 60)	156.2 (100 to 180)	14.6[b] (–20 to 60)	46.2 (20 to 90)	L5 (S to T12)	L1 (L3 to T12)

[a]Data are expressed in degrees, mean (range). Postoperative data were recorded at the final follow-up. All pre- vs postoperative values per range of motion category were significant at $P < .001$.
[b]Range of motion was significantly less than that in the no pseudoparalysis group ($P < .05$).
[c]Range of motion was significantly less than that in the moderate pseudoparalysis group ($P < .05$).

TABLE 6
Pre- and Postoperative Muscle Strength Grades[a]

	Abduction				External Rotation				Internal Rotation			
	Preoperative		Postoperative		Preoperative		Postoperative		Preoperative		Postoperative	
Pseudoparalysis	MMT	10 Scale	MMT	10 Scale	MMT	10 Scale	MMT	10 Scale	MMT	10 Scale	MMT	10 Scale
None												
Total	4 (3 to 5–)	7.0 (4 to 9)	5– (4– to 5)	9.3 (6 to 10)	4 (1 to 5)	7.0 (1 to 10)	5– (3 to 5)	9.0 (4 to 10)	4+ (3– to 5)	8.4 (3 to 10)	5 (4 to 5)	9.6 (7 to 10)
Healed graft	4 (3 to 5–)	7.0 (4 to 9)	5– (4 to 5)	9.3 (7 to 10)	4 (1 to 5)	7.0 (1 to 10)	5– (3 to 5)	9.1 (4 to 10)	4+ (3– to 5)	8.4 (3 to 10)	5 (4 to 5)	9.6 (7 to 10)
Moderate												
Total	3– (2 to 3–)	2.8 (2 to 3)	4+ (1 to 5)	8.4 (1 to 10)	3+ (1 to 4)	4.5 (1 to 7)	5– (3 to 5)	8.6 (4 to 10)	4 (1 to 5)	7.2 (1 to 10)	5– (3 to 5)	9.2 (4 to 10)
Healed graft	3– (2 to 3–)	2.8 (2 to 3)	5– (3 to 5)	8.7 (4 to 10)	3+ (1 to 4)	4.6 (1 to 7)	5– (3 to 5)	8.8 (4 to 10)	4 (1 to 5)	7.2 (1 to 10)	5– (3 to 5)	9.3 (4 to 10)
Severe												
Total	3–[b,c] (1 to 3–)	2.5 (1 to 3)	4+ (2 to 5)	7.9 (2 to 10)	3–[b,c] (1 to 4)	2.9 (1 to 7)	4[b] (2 to 5)	7.4 (2 to 10)	4[b] (1 to 5)	6.7 (1 to 10)	5– (4 to 5)	9.3 (7 to 10)
Healed graft	3–[b,c] (1 to 3–)	2.6 (1 to 3)	5– (3 to 5)	8.5 (3 to 10)	3–[b,c] (1 to 4)	3.2 (1 to 7)	4+ (3– to 5)	8.2 (3 to 10)	4+ (1 to 5)	7.5 (1 to 10)	5 (4 to 5)	9.5 (7 to 10)

[a]Data are expressed in degrees, mean (range). Postoperative data were recorded at the final follow-up. All strength grades were significantly different between preoperative and postoperative ($P < .05$). MMT, manual muscle testing.
[b]Muscle strength was significantly less than that in the no pseudoparalysis group ($P < .05$).
[c]Muscle strength was significantly less than that in the moderate pseudoparalysis group ($P < .05$).

of motion—result mainly from loss of superior stability of the glenohumeral joint.[11,15] This loss of superior stability is due to defects in the superior capsule and the supraspinatus and infraspinatus tendons.[1,20] Reduced glenohumeral stability may cause more severe symptoms,[7] such as pseudoparalysis. Therefore, a stiffer graft is needed to improve glenohumeral stability among patients with pseudoparalysis.[28] Here, we found relatively high rates of graft healing (95%, 84 of 88 patients) with MRI after arthroscopic SCR using fascia lata autografts. Furthermore, graft healing rates after arthroscopic SCR did not differ between patients with and without pseudoparalysis. These results suggest that a fascia lata graft 6 to 8 mm thick in our current technique has the appropriate stiffness for SCR, even for patients with pseudoparalysis.

In this study, all external and internal rotation lag signs became negative when the graft was healed. However, for 2 patients with postoperative graft tear, external rotation lag signs did not resolve. Therefore, graft healing is necessary to improve external and internal rotation lag signs. When the graft is healed, the capsular continuity in the anterior-posterior direction is recovered, and the residual external rotators (infraspinatus and teres minor) and subscapularis work well because (1) the side-to-side suture is utilized between the graft and the residual rotator cuff tendons and (2) subscapularis tendon repair is performed. These biomechanical improvements make the external and internal rotation lag signs recover. Even though all patients with graft healing can hold an externally or internally rotated position after SCR, the muscle strength of external and internal rotation was still weaker than the other side in some cases.

According to the current study, arthroscopic SCR is recommended for irreparable medium, large, and massive tears of posterior-superior rotator cuff tendons with Hamada grades 1 to 3 and Goutallier grades 3 and 4. Age is not a limiting factor for arthroscopic SCR. A contraindication is deltoid weakness attributed to cervical or axillary

nerve palsy because postoperative functional improvement mainly results from deltoid muscle strength with stabilized glenohumeral joint by SCR. Also severe glenohumeral osteoarthritis is not a good indication for arthroscopic SCR.

In this study, we could repair the subscapularis tendon tear in all cases. Therefore, subscapularis tendon tear cannot be a contraindication for SCR, and we can expect good clinical outcomes after SCR when the torn subscapularis tendon is repaired. Even in 4 tendon tears (1 patient in the moderate pseudoparalysis group), we could obtain good clinical outcome after SCR (active elevation and ASES score: 50° and 38.3 preoperatively, 140° and 88.3 points postoperatively). Regarding irreparable subscapularis tendon tear, we will conduct a study to examine if it can be an indication of SCR.

Our study had some limitations. First, we did not compare the clinical outcome of SCR with any other treatment, such as debridement alone, partial cuff repair, repair with a patch, or reverse TSA. Second, we investigated clinical outcomes only after fascia lata SCR. Different grafts, such as allografts or synthetic grafts, may not have given similar clinical results after SCR. Third, we presented only retrospective results after arthroscopic SCR. Fourth, all the procedures in this study were performed by a single experienced shoulder surgeon, which could have biased the results, as it may not be easy for less-experienced surgeons to obtain the same outcomes. Fifth, we did not include patients with deltoid weakness attributed to cervical or axillary nerve palsy or with severe shoulder stiffness (passive shoulder elevation <90°) to investigate the effect of pseudoparalysis on postoperative outcomes. If we investigate the postoperative outcomes of all patients, including those with deltoid weakness or severe shoulder stiffness, postoperative ASES and JOA scores should be worse than those of the current study.

CONCLUSION

Arthroscopic SCR restored superior glenohumeral stability and improved shoulder function in patients with or without pseudoparalysis who had previously irreparable rotator cuff tears. If the graft did not tear postoperatively, arthroscopic SCR reversed preoperative pseudoparalysis. Graft healing rates after arthroscopic SCR did not differ between patients with and without pseudoparalysis.

REFERENCES

1. Adams CR, DeMartino AM, Rego G, Denard PJ, Burkhart SS. The rotator cuff and the superior capsule: why we need both. *Arthroscopy*. 2016;32:2628-2637.
2. Adams CR, Denard PJ, Brady PC, Hartzler RU, Burkhart SS. The arthroscopic superior capsular reconstruction. *Am J Orthop (Belle Mead NJ)*. 2016;45:320-324.
3. Bacle G, Nove-Josserand L, Garaud P, Walch G. Long-term outcomes of reverse total shoulder arthroplasty: a follow-up of a previous study. *J Bone Joint Surg Am*. 2017;99:454-461.
4. Berhouet J, Collin P, Benkalfate T, et al; Société d'Orthopédie de l'Ouest. Massive rotator cuff tears in patients younger than 65 years: epidemiology and characteristics. *Orthop Traumatol Surg Res*. 2009;95:S13-S18.
5. Boileau P. Complications and revision of reverse total shoulder arthroplasty. *Orthop Traumatol Surg Res*. 2016;102:S33-S43.
6. Boileau P, Chuinard C, Roussanne Y, Bicknell RT, Rochet N, Trojani C. Reverse shoulder arthroplasty combined with a modified latissimus dorsi and teres major tendon transfer for shoulder pseudoparalysis associated with dropping arm. *Clin Orthop Relat Res*. 2008;466:584-593.
7. Chung SW, Kim JY, Kim MH, Kim SH, Oh JH. Arthroscopic repair of massive rotator cuff tears: outcome and analysis of factors associated with healing failure or poor postoperative function. *Am J Sports Med*. 2013;41:1674-1683.
8. Daniels L, Worthingham C. *Muscle Testing*. Philadelphia, PA: WB Saunders; 1980.
9. Denard PJ, Koo SS, Murena L, Burkhart SS. Pseudoparalysis: the importance of rotator cable integrity. *Orthopedics*. 2012;35:e1353-e1357.
10. Denard PJ, Ladermann A, Brady PC, et al. Pseudoparalysis from a massive rotator cuff tear is reliably reversed with an arthroscopic rotator cuff repair in patients without preoperative glenohumeral arthritis. *Am J Sports Med*. 2015;43:2373-2378.
11. Duralde XA, Bair B. Massive rotator cuff tears: the result of partial rotator cuff repair. *J Shoulder Elbow Surg*. 2005;14:121-127.
12. Farshad M, Gerber C. Reverse total shoulder arthroplasty—from the most to the least common complication. *Int Orthop*. 2010;34:1075-1082.
13. Fink Barnes LA, Grantham WJ, Meadows MC, Bigliani LU, Levine WN, Ahmad CS. Sports activity after reverse total shoulder arthroplasty with minimum 2-year follow-up. *Am J Orthop (Belle Mead NJ)*. 2015;44:68-72.
14. Gerber C, Krushell RJ. Isolated rupture of the tendon of the subscapularis muscle: clinical features in 16 cases. *J Bone Joint Surg Br*. 1991;73:389-394.
15. Gerber C, Maquieira G, Espinosa N. Latissimus dorsi transfer for the treatment of irreparable rotator cuff tears. *J Bone Joint Surg Am*. 2006;88:113-120.
16. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures: pre- and postoperative evaluation by CT scan. *Clin Orthop Relat Res*. 1994;304:78-83.
17. Hamada K, Fukuda H, Mikasa M, Kobayashi Y. Roentgenographic findings in massive rotator cuff tears: a long-term observation. *Clin Orthop Relat Res*. 1990;254:92-96.
18. Hertel R, Ballmer FT, Lombert SM, Gerber C. Lag signs in the diagnosis of rotator cuff rupture. *J Shoulder Elbow Surg*. 1996;5:307-313.
19. Hirahara AM, Adams CR. Arthroscopic superior capsular reconstruction for treatment of massive irreparable rotator cuff tears. *Arthrosc Tech*. 2015;4:e637-e641.
20. Ishihara Y, Mihata T, Tamboli M, et al. Role of the superior shoulder capsule in passive stability of the glenohumeral joint. *J Shoulder Elbow Surg*. 2014;23:642-648.
21. Itoi E, Minagawa H, Yamamoto N, Seki N, Abe H. Are pain location and physical examinations useful in locating a tear site of the rotator cuff? *Am J Sports Med*. 2006;34:256-264.
22. Kelly BT, Kadrmas WR, Speer KP. The manual muscle examination for rotator cuff strength: an electromyographic investigation. *Am J Sports Med*. 1996;24:581-588.
23. McFarland EG. Strength testing. In: McFarland EG, ed. *Examination of the Shoulder*. New York, NY: Thieme Medical Publishers Inc; 2005:88-125.
24. McFarland EG, Huri G, Hyun YS, Petersen SA, Srikumaran U. Reverse total shoulder arthroplasty without bone-grafting for severe glenoid bone loss in patients with osteoarthritis and intact rotator cuff. *J Bone Joint Surg Am*. 2016;98:1801-1807.
25. Mihata T. Superior capsule reconstruction for irreparable rotator cuff tears. In: Tamai K, Itoi E, Takagishi K, eds. *Advances in Shoulder Surgery*. Tokyo, Japan: Springer; 2015:173-183.
26. Mihata T, Fukuhara T, Jun BJ, Watanabe C, Kinoshita M. Effect of shoulder abduction angle on biomechanical properties of the repaired rotator cuff tendons with 3 types of double-row technique. *Am J Sports Med*. 2011;39:551-556.

27. Mihata T, Lee TQ, Watanabe C, et al. Clinical results of arthroscopic superior capsule reconstruction for irreparable rotator cuff tears. *Arthroscopy*. 2013;29:459-470.
28. Mihata T, McGarry MH, Kahn T, Goldberg I, Neo M, Lee TQ. Biomechanical effect of thickness and tension of fascia lata graft on glenohumeral stability for superior capsule reconstruction in irreparable supraspinatus tears. *Arthroscopy*. 2016;32:418-426.
29. Mihata T, McGarry MH, Kahn T, Goldberg I, Neo M, Lee TQ. Biomechanical effects of acromioplasty on superior capsule reconstruction for irreparable supraspinatus tendon tears. *Am J Sports Med*. 2016;44:191-197.
30. Mihata T, McGarry MH, Kahn T, Goldberg I, Neo M, Lee TQ. Biomechanical role of capsular continuity in superior capsule reconstruction for irreparable tears of the supraspinatus tendon. *Am J Sports Med*. 2016;44:1423-1430.
31. Mihata T, McGarry MH, Pirolo JM, Kinoshita M, Lee TQ. Superior capsule reconstruction to restore superior stability in irreparable rotator cuff tears: a biomechanical cadaveric study. *Am J Sports Med*. 2012;40:2248-2255.
32. Mihata T, Watanabe C, Fukinishi K, et al. Functional and structural outcomes of single-row vs double-row vs combined double-row and suture-bridge repair for rotator cuff tears. *Am J Sports Med*. 2011;39(10):2091-2098.
33. Mizuno N, Denard PJ, Raiss P, Walch G. Reverse total shoulder arthroplasty for primary glenohumeral osteoarthritis in patients with a biconcave glenoid. *J Bone Joint Surg Am*. 2013;95:1297-1304.
34. Oh JH, Kim SH, Shin SH, et al. Outcome of rotator cuff repair in large-to-massive tear with pseudoparalysis: a comparative study with propensity score matching. *Am J Sports Med*. 2011;39:1413-1420.
35. Otto RJ, Clark RE, Frankle MA. Reverse shoulder arthroplasty in patients younger than 55 years: 2- to 12-year follow-up. *J Shoulder Elbow Surg*. 2017;26(5):792-797.
36. Rhee YG, Cho NS, Moon SC. Effects of humeral component retroversion on functional outcomes in reverse total shoulder arthroplasty for cuff tear arthropathy. *J Shoulder Elbow Surg*. 2015;24:1574-1581.
37. Riley C, Idoine J, Shishani Y, Gobezie R, Edwards B. Early outcomes following metal-on-metal reverse total shoulder arthroplasty in patients younger than 50 years. *Orthopedics*. 2016;39:e957-e961.
38. Walch G, Boulahia A, Calderone S, Robinson AH. The ''dropping'' and ''hornblower's'' signs in evaluation of rotator-cuff tears. *J Bone Joint Surg Br*. 1998;80:624-628.
39. Wall B, Nove-Josserand L, O'Connor DP, Edwards TB, Walch G. Reverse total shoulder arthroplasty: a review of results according to etiology. *J Bone Joint Surg Am*. 2007;89:1476-1485.
40. Werner BS, Boehm D, Gohlke F. Revision to reverse shoulder arthroplasty with retention of the humeral component. *Acta Orthop*. 2013;84:473-478.
41. Werner CM, Steinmann PA, Gilbart M, Gerber C. Treatment of painful pseudoparesis due to irreparable rotator cuff dysfunction with the Delta III reverse-ball-and-socket total shoulder prosthesis. *J Bone Joint Surg Am*. 2005;87:1476-1486.
42. Wiater JM, Fabing MH. Shoulder arthroplasty: prosthetic options and indications. *J Am Acad Orthop Surg*. 2009;17:415-425.