

Subscapularis Failure after Anatomic Total Shoulder Arthroplasty: A Review of Diagnosis and Management

Nadhaporn Saengpetch, MD¹, Pinkawas Kongmalai, MD²

¹ Department of Orthopaedics, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok Thailand

² Department of Orthopaedics, Faculty of Medicine, Srinakharinwirot University, Nakhon Nayok, Thailand

Background: The volume of anatomic total shoulder arthroplasty has been increasing in recent years. The deltopectoral approach necessitates detaching and subsequent repairing of the subscapularis tendon. Failure of the tendon to heal can lead to pain, compromised function, and patient dissatisfaction. Our aim is to present a review article regarding current thinking on the problem of a diagnostic algorithm and therapeutic guidelines for subscapularis failure following anatomic TSA.

Materials and Methods: Searches were completed in July 2018 using a series of NOT phrases to match certain exclusion criteria in PubMed.

Results: A total of 23 relevant studies were included in the analysis. Only three of the seven studies linked physical examination results to evidence of post-operative subscapularis rupture. Eleven of the eighteen patients with subscapularis tears obtained ultrasonography confirmation, whereas the remaining patients had revision surgery confirmation. The decrease in internal rotation strength and the lift-off test were the most regularly performed tests. The former was shown to be positive in all fourteen patients from two trials, whereas the latter was found to be positive in eight of fourteen. Five studies on therapy in different situations were proposed, but there was no head-to-head comparison of treatment outcomes.

Conclusion: The most common cause of anterior instability in prosthetic shoulder is subscapularis insufficiency. Physical examination and radiological studies may not provide a conclusive diagnosis. Patients who present with pain, weakness, or instability require surgical treatment, which varies based on their age, tendon reparability, and component position.

Keywords: Subscapularis tear; Subscapularis dysfunction; Subscapularis tenotomy; Lesser tuberosity osteotomy; Total shoulder replacement

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A volume of anatomic total shoulder arthroplasty (TSA) has been increasing with durable and successful outcomes⁽¹⁻³⁾. Anterior approach to the glenohumeral joint can be performed by subscapularis tenotomy (ST), subscapularis peeling-off the bone (SP), or lesser tuberosity osteotomy (LTO). Although the concept of using subscapularis-sparing TSA has been discussed recently, this approach is a technically difficult procedure and cannot be used in all patients⁽⁴⁾.

Dysfunction of subscapularis tendon can compromise the surgical outcome or lead to anterior instability of the prosthesis⁽⁵⁻⁸⁾. Although prior studies reported that

rupture of the tendon after TSA was relatively rare, their findings were based on case series of patients who had been presented with instability and required revision surgery^(6,7). Based on physical examination testing⁽⁹⁾ or sonographic findings⁽¹⁰⁾, failure to heal the subscapularis is more common than has previously been reported. The goal of this review article is to provide an overview of current thinking on the topic of a diagnostic algorithm and therapeutic guidelines for subscapularis failure after anatomic TSA.

Materials and Methods

Searches were completed in July 2018 using the PubMed Medline database. Two fellowship-trained shoulder surgeons independently performed the search and assessed eligibility of all relevant studies based on predetermined inclusion criteria. Disagreements between reviewers were resolved by discussion. An electronic search algorithm with key words and a series of NOT phrases to match certain exclusion criteria was the following:

((((((((((((((((((((((total[Title]) AND shoulder [Title]) AND arthroplasty[Title]) NOT reverse[Title]) NOT hemiarthroplasty[Title]) NOT nonoperative[Title]) NOT nonsurgical[Title]) NOT elbow[Title/Abstract]) NOT wrist[Title/Abstract]) NOT hip[Title/Abstract]) NOT knee[Title/Abstract]) NOT ankle[Title/Abstract]) NOT

Correspondence to:

Kongmalai P.

Department of Orthopaedics, Faculty of Medicine, Srinakharinwirot University, 62 Moo 7 Ongkharak, Nakhon Nayok 26120, Thailand.

Phone: +66-81-5703867

Email: pinkawass@hotmail.com

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interphalangeal[Title/Abstract]) NOT carpometacarpal[Title/Abstract]) NOT biomechanics[Title/Abstract]) NOT biomechanics[Title/Abstract]) NOT biomechanical[Title/Abstract]) NOT revision[Title/Abstract]) NOT cadaveric [Title/Abstract]) NOT histology[Title/Abstract]) NOT histological[Title/Abstract]) NOT kinematic[Title/Abstract]))).

All scientific papers with reference to the total shoulder arthroplasty were included in the study. Study exclusion criteria consisted of review articles and basic science studies. In addition, studies were excluded if they did not report any clinical or radiographic outcomes. The search was then narrowed to include only studies with functional loss of subscapularis tendon and written in English language. Relevant articles' bibliographies were also reviewed to expand the search.

Results

Twenty-three studies were included in the analysis^(5-9,11-28) (Figure 1). Four studies focused on the occurrence of anterior instability due to subscapularis failure following TSA^(7,8,16,23). Seven studies were related to clinical examinations or investigations, but only three of them^(6,19,9) compared physical examination results to evidence of post-

operative subscapularis rupture (Table 1). There were eighteen patients who had subscapularis tears. Eleven were confirmed by ultrasound, while the remaining patients were confirmed by revision surgery. Internal rotation strength was found to be decreased in fourteen patients, while the inability to tuck the shirt in the back was found in three of the remaining four patients. The lift-off test was positive in eight of fourteen patients from two trials, while the other study did not publish the lift-off test result. Five studies explored the use of various investigations such as ultrasonography, EMG, and MRI^(9,19,21). There has been no head-to-head comparison of any strategy in this condition for management, however five studies have recommended acceptable treatment in various situations⁽²⁴⁻²⁸⁾.

Discussion

Evidence suggests that subscapularis tendon tear has been the most common rotator cuff tear after TSA. According to Sanchez-Sotelo et al, the incidence of subscapularis tear after TSA was roughly 2.3 percent based on case series of anterior instability patients who underwent revision surgery⁽⁸⁾. However, our review found that incidence of this complication probably was more common than previous reported. Moeckel et al retrospectively reviewed

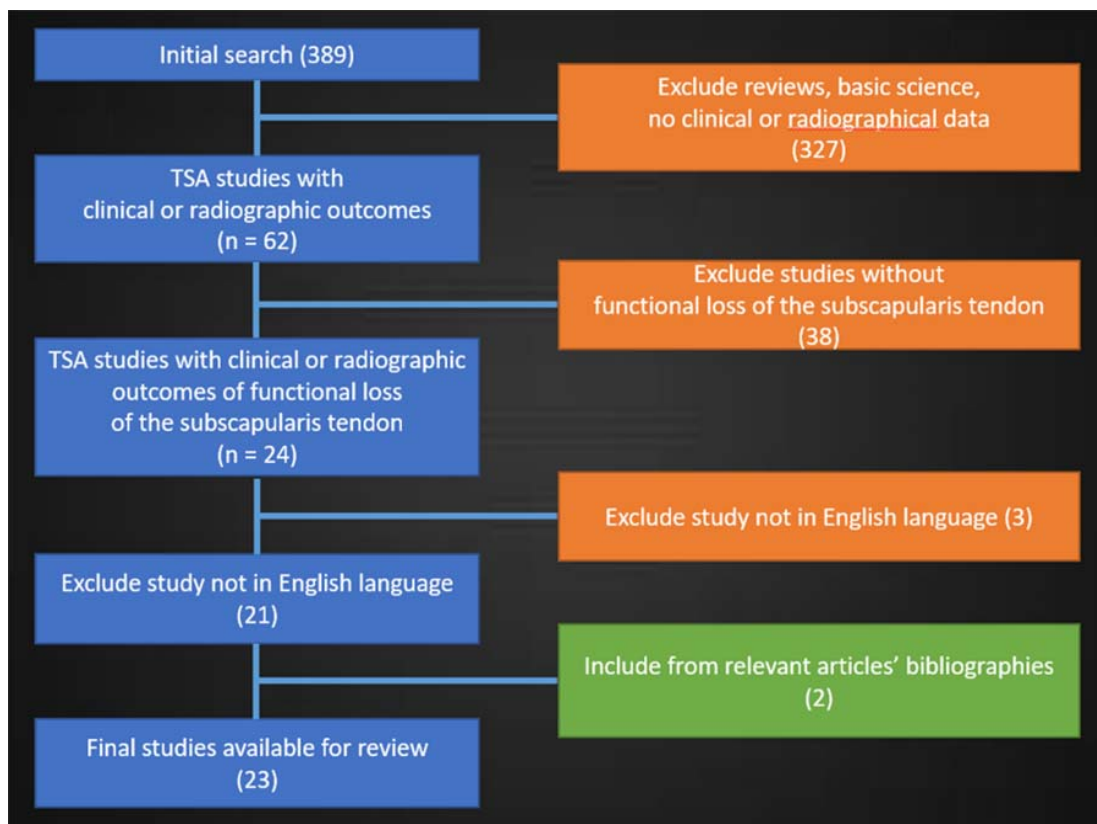


Figure 1. Flow chart of search strategy.

Table 1. Compare the findings of the physical examination to the evidence of post-operative subscapularis rupture

Study	Number of patients with evidence of subscapularis tear	Confirmed by	Lift off test positive	Belly press test	Other significant findings
Miller, 2005 ⁽⁶⁾	7	Revision surgery	5/7	-	- Decreased internal rotation strength 7/7 - Increase passive external rotation 5/7 - Inability to tuck the shirt in to the back 3/4
Armstrong, 2006 ⁽¹⁹⁾	4	Ultrasound	-	Sensitivity 25%, Specificity 73%	
Jackson, 2010 ⁽⁹⁾	7	Ultrasound	3/7	4 false negative 3 false positive	- Decreased internal rotation strength 7/7 - Bear hug dynamometry test

seven cases of anterior instability in a study of 236 shoulders⁽⁷⁾. All of them demonstrated tear of the subscapularis tendon at the time of revision. More recently, Kany et al reported seven cases of isolated subscapularis tears in 19 patients who experienced postoperative instability after TSA. Four of them were found anterior instability. Jackson et al. further revealed that employing patients with instability likely underestimated the true incidence of subscapularis tear following TSA because the rate of post-operative subscapularis rupture can be as high as 47 percent (seven of 15 shoulders), as found on ultrasonography⁽⁹⁾.

Multiple operations, overstuffing of the joint, aggressive activity or physical therapy during the early postoperative period, and compromise of the tendon repair as a result of various subscapularis lengthening techniques have all been proposed as risk factors for postoperative subscapularis rupture⁽⁶⁻⁸⁾.

The diagnostic algorithm was summarized in Figure 2. Patients with a subscapularis failure after TSA may be present with pain, weakness, or instability. When physical examination is performed by an experienced physician, the presence of subscapularis tendon tear can be reliably predicted in native shoulder⁽²⁹⁾. However, results using physical examination to assess subscapularis integrity in post arthroplasty patients have been inconsistent. Miller discovered that all seven patients with subscapularis tear after TSA which was confirmed by revision surgery had weak internal rotation strength, whereas five of them had a positive lift-off sign and increased passive external rotation. Using ultrasound as a gold standard, Armstrong discovered that the lift-off and belly press tests may be ineffective for detecting a subscapularis tear following TSA⁽¹⁹⁾. A retrospective review by Qureshi et al also supported this theory. They found that several patients (40%) still had abnormal belly-press test despite 100% of radiographic union of the lesser tuberosity osteotomy⁽²²⁾. However, Jackson et al found that the decreased internal rotation strength and bear hug dynamometry were statistically related to the ultrasound finding⁽⁹⁾. The dynamometer was used to measure the force created by holding the hand up against the shoulder as the examiner resisted internal rotation during the bear hug dynamometry test. This test could be performed without the need for the arm to be placed behind the back, which is typically challenging in post-arthroplasty patients.

Imaging for subscapularis tears after TSA should begin with conventional radiographs. If there was the disruption of the repaired subscapularis tendon attributed to anterior shoulder prosthetic instability, an axillary lateral view may demonstrate anterior subluxation of the humeral component (Figure 3). However, if there was no associated anterior instability, routine plain x-rays might not be helpful. None of the seven patients in Jackson et al. study who had a complete tear of the repaired subscapularis tendon based on ultrasound testing exhibited radiographic results that showed instability⁽⁹⁾.

The ultrasound is an investigation of choice to assess the structural integrity of subscapularis tendon after TSA

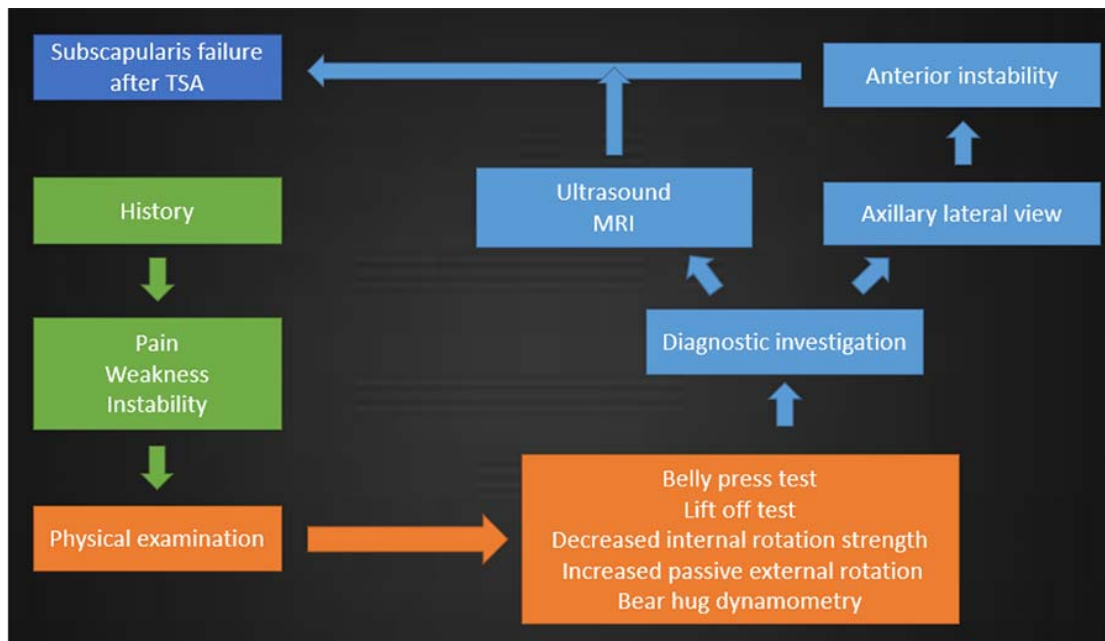


Figure 2. Diagnostic algorithm for the subscapularis failure after total shoulder arthroplasty.

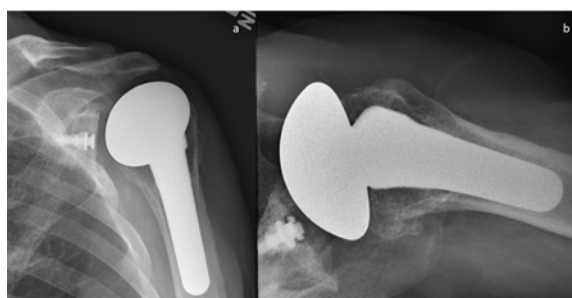


Figure 3. Anteroposterior (a) and axillary (b) radiographs of left shoulder showing anterior subluxation of the humeral head due to subscapularis dysfunction after total shoulder arthroplasty.

because it is simple, inexpensive and can be done with the presence of a prosthesis^(9,19). However, it does not provide information on the subscapularis's functional state. Armstrong et al studied the rate of nonfunctional but structurally intact subscapularis healing using electromyography (EMG). However, they found that the EMG could not be suggested as a diagnostic tool in this cohort.

Although there is some concern about signal loss next to metallic components in an MRI, Sperling et al suggested that the MRI with modified fast spin-echo sequencing was effective in the management of painful shoulder arthroplasty. In their study, 11 rotator cuff tears

were identified, eight patients involved subscapularis tendon tear. The sensitivity and specificity of MRI for detecting a full thickness rotator cuff tear was 91% (10/11) and 80% (8/10) respectively. MRI can also be used to assess fatty infiltration of the subscapularis tendon, which must be addressed if open repair is planned. The benefits and drawbacks of each investigation were summarized in a Table 2.

Management of subscapularis failure after TSA is very challenging. In Figure 4, the authors provided a treatment algorithm for a patient with subscapularis failure. The most important factor determining treatment is whether or not the tear is associated with anterior instability. If the patient has a stable component, an asymptomatic subscapularis tear with no pain or weakness may not require surgery. A multicenter study from Young et al reported that from thirteen cases of subscapularis rupture, eleven of them did not undergo surgical repair because they were doing well⁽²³⁾. Table 3 highlights the advantages, disadvantages, and best-case scenario for each surgical operation.

Revision surgery should be undertaken if symptoms such as discomfort, weakness, or instability are present. The absolute condition for primary repair is an acute injury causing tendon disruption with sufficient tendon quality. The better outcomes could be expected when the repair is performed early after traumatic rupture⁽³⁰⁾. Miller et al treated seven patients with surgical repair of the ruptured tendon⁽⁶⁾. Four of them required repair augmentation with a pectoralis major tendon transfer. They found that two patients who had instability as a result of subscapularis insufficiency still suffered from anterior instability and

Table 2. The advantages and disadvantages of the investigation for subscapularis tear following TSA

	Advantages	Disadvantages	Notes
Plain films	<ul style="list-style-type: none"> - Low radiation dose - Inexpensive - Readily available 	<ul style="list-style-type: none"> - Inability to assess integrity and quality of the subscapularis tendon 	<ul style="list-style-type: none"> - Only useful in cases of anterior instability.
Ultrasonography	<ul style="list-style-type: none"> - No radiation exposure - Widely available - Real-time dynamic assessment of the subscapularis tendon's integrity 	<ul style="list-style-type: none"> - Operator-dependent - More expensive than radiography 	<ul style="list-style-type: none"> - It can be used to assess the integrity of the subscapularis tendon; however, it cannot identify non-functional but structurally intact tendon like EMG does.
MRI	<ul style="list-style-type: none"> - No radiation exposure - Assessment of the subscapularis tendon's integrity, retraction, and muscle fatty infiltration 	<ul style="list-style-type: none"> - A specialized technique was required to reduce metal artifacts. - More expensive than radiography and ultrasound 	<ul style="list-style-type: none"> - Useful in cases where there is a suspicion of tendon quality and an intention to open repair the tendon.

required additional operations. Another augmentation procedure such as anterior capsule reconstruction with autograft or allograft might be considered if the soft tissue has uncertain quality, but the results in post-arthroplasty patients are still unknown⁽³¹⁾. If there is any abnormal humeral or glenoid prosthesis rotation or version, they must also be addressed in revision surgery.

Pectoralis tendon transfer is still questionable, and it might be reserved in the irreparable tear with the stable component. The rationales of pectoralis major tendon transfer are to improve internal rotation strength, serve an additional anterior buttress and dynamic transfer to restore balance to the anterior-posterior force couple⁽³²⁾. A previous report by Wirth et al showed a satisfactory result of pectoralis major transfer to reconstruct irreparable tears of subscapularis associated with anterior shoulder instability in native shoulders⁽³³⁾. However in patients with subscapularis insufficiency associated with shoulder replacement, Elhassan et al demonstrated that the pectoralis tendon transfer failed in six of the eight patients. Five of them had pre-operative anterior subluxation of the humeral component. They concluded that this procedure did not re-center the humeral head once it was subluxated as a result of an irreparable subscapularis tear after replacement⁽²⁴⁾.

In three of seven anterior instability after TSA patients treated by Moeckel et al⁽⁷⁾ surgical repair of the subscapularis tendon failed. A second revision procedure which secured using a bone block-Achilles tendon allograft to the glenoid neck and humeral head was performed with successful result. The downside of this procedure was post-operative loss of range of motion. The mean forward elevation was 85 degrees, and the mean external rotation was 5 degrees at 18 to 36 months follow-up. Chou et al modified the technique using bone block-Achilles tendon allograft⁽²⁸⁾. They carefully prepared the contour of the graft to match the concavity of the host glenoid in order to maximize the tenodesis effect. Elhassan et al also recommended Bristow and other techniques involved bone block for patients with irreparable subscapularis failure after TSA which pre-operatively axillary x-ray demonstrated anterior subluxation of humeral component⁽²⁴⁾. Case series by Endres et al supported that Latarjet procedure was a reasonable method of salvage when anterior shoulder instability occurred in a symptomatic patient that has a static anterior subluxation of TSA⁽²⁷⁾.

Due to the semi-constrained nature of the reverse total shoulder arthroplasty (RTSA), it is an option to correct the instability (Figure 5). Retrospective case series of 19 patients from Walker et al⁽³⁴⁾ reported RTSA can be an effective treatment for instability after TSA by decreasing pain and improving shoulder function. Abdel et al also found good short-term results after revision of an unstable hemiarthroplasty or anatomical TSA using RTSA. More recently, Hernandez et al also reported the survival free from the revision at 2 and 5 years was 85% and 78% respectively⁽²⁵⁾. Although the absence of subscapularis may raise the concern that RTSA would be continually unstable. The needs

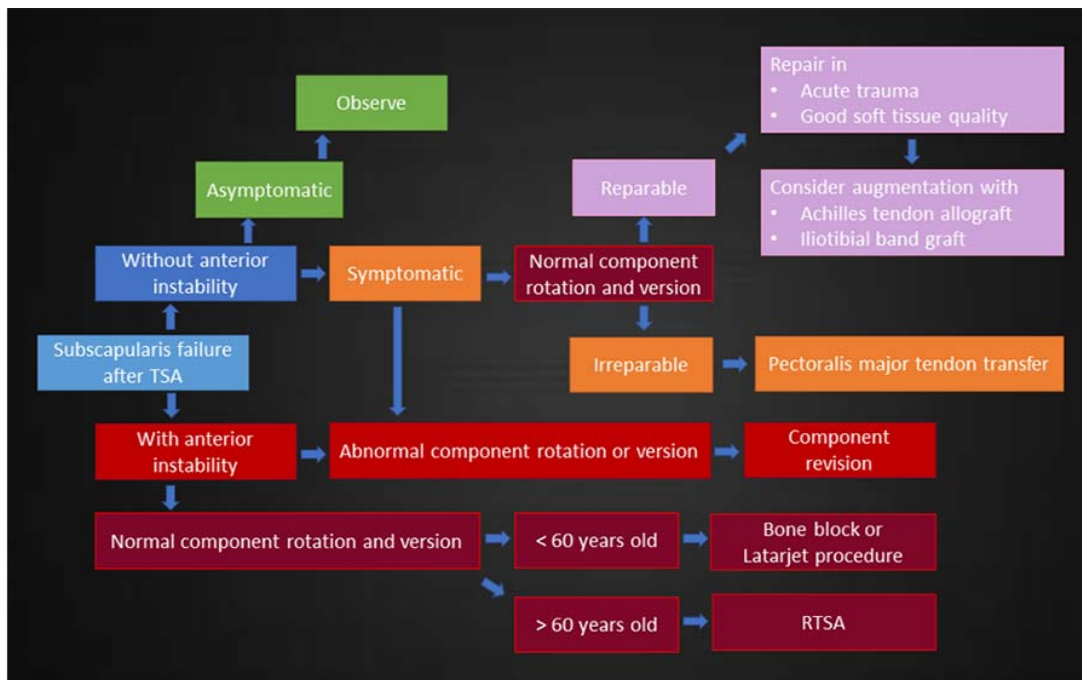


Figure 4. Algorithm of treatment in patients with subscapularis failure after total shoulder arthroplasty.

for repair of subscapularis in RTSA has been still controversial^(35,36). Consideration of using larger glenosphere or increasing the lateral offset may minimize the risk of instability for RTSA⁽²⁵⁾. However, care should be taken when offering RTSA to patients 60 years old or younger⁽³⁷⁾ because the longevity of the implant and subsequent need for revision surgery remained a significant concern.

One of the most common reasons of subscapularis failure after TSA is vigorous passive external rotation rehabilitation⁽³⁸⁾. After revision surgery, a more conservative rehabilitation program should be established. The immobilizing position is controversial either neutral rotation or abduction and external rotation. But the operative shoulder was generally immobilized at least six weeks to let the repair heal and prevent subsequent anterior instability from excessive motion.

Conclusion

After TSA, no single test could consistently diagnose subscapularis failure. A series of tests was required to increase the likelihood of identifying subscapularis tendon insufficiency. Unless the tear was associated with anterior instability, plain radiographs presented certain limitations in assessing subscapularis integrity. Ultrasound can provide precise structural information about the subscapularis. The MRI is superior in terms of tendon quality assessment and muscle fat infiltration, but it must be performed according to a specific procedure. Symptoms of instability, age, tendon repairability, and component position are all factors that

will influence treatment. To improve the patient's result, it is advisable to delay rehabilitation after revision surgery.

What is already known on this topic?

Clinically significant subscapularis tendon dysfunction after anatomic TSA requires prompt intervention. Until today, there has been no agreement on a diagnosis algorithm or management guidelines for these patients.

What this study adds?

Physical examination may not be reliable to diagnose subscapularis failure after TSA. In the instance of anterior instability, the axillary lateral film might be used to make a diagnosis. Ultrasound and MRI can reveal the structural integrity of the tendon. Patients who are experiencing symptoms require surgical intervention. In the case of an acute post-operative traumatic injury, primary repair may be performed. Revision to RSA leads in an acceptable outcome, but at the expense of a significant risk of revision surgery if the implant fails.

Potential conflicts of interest

The authors declare no conflict of interest.

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Table 3. The advantages, disadvantages, and best-case scenario for each surgical operation

	Advantages	Disadvantages	Treatment of choice in
Skillful neglected	- Non-invasive - No surgical risk	- The pathology is not addressed	Asymptomatic patient
Subscapularis repair	- Restore tendon strength and function	- Poor results in cases with anterior instability	Acute subscapularis tear with sufficient tissue quality
Bone block or Latarjet procedure	- Anterior buttress to restore balanced to the anterior-posterior force couple - Salvage treatment for static anterior TSA subluxation when RTSA is not an option	- Risk of post-operative motion loss	Irreparable subscapularis tear with normal component version and rotation
Reverse shoulder arthroplasty	- Predictable outcome regardless of tendon quality	- The longevity of the implant increases the risk of revision surgery in patients less than 60 years old	Elderly patient (more than 60 years old) with irreparable subscapularis tear

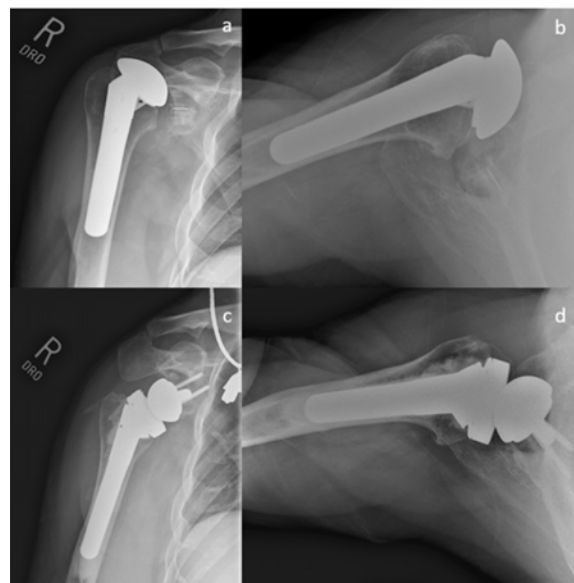


Figure 5. Pre-operative anteroposterior (a) and axillary (b) radiographs of right shoulder demonstrate decentered humeral head. Post-operative anteroposterior (c) and axillary (d) radiographs were demonstrated after conversion to reverse total shoulder arthroplasty.

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