Perioperative Rotator Cuff Injury and Disease With Anatomic Total Shoulder Arthroplasty

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Summary: Rotator cuff disease is a relatively uncommon but important complication in total shoulder arthroplasty (TSA). Posterior superior cuff injury is not commonly encountered in the setting of glenohumeral osteoarthritis, but has been reported in 5% to 10% of standard anatomic shoulder replacements. In these cases, cuff lesions that are small or moderate are usually amenable to direct repair during the time of standard arthroplasty implantation. Glenoid component implantation is typically avoided in patients with massive tears due to concerns for eccentric wear of the component from abnormal humeral shear forces. Rotator cuff disease in the postoperative setting after standard TSA may occur either traumatically or chronically. Traumatic rupture of the subscapularis is a challenging problem that typically requires surgical repair of the tendon or consideration for capsular reconstruction with allograft and pectoralis major transfer if the tendon is irreparable. Chronic secondary cuff dysfunction affects the posterior superior rotator cuff and has been reported in up to 55% of the patients with retained implants over 15 years. For these patients, conversion to a reverse TSA has demonstrated adequate clinical outcomes.

Key Words: rotator cuff—total shoulder arthroplasty—injury—rocking horse—repair—subscapularis—eccentric—anatomic.

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Rotator cuff disease is an uncommon condition in patients with primary glenohumeral osteoarthritis. As opposed to rotator cuff tear arthropathy, wherein advanced articular destruction occurs as a result of major cuff deficiency, the presence of primary osteoarthritis may actually be protective for the integrity of the rotator cuff. This idea has been quantified scientifically by Moor and colleagues, who formulated a critical shoulder angle that appears to preclude patients to either primary glenohumeral osteoarthritis (with significantly smaller incidence of degenerative cuff disease) or rotator cuff lesions with minimal associated joint degenerative disease. This shoulder angle is determined by the native inclination of the glenoid and the lateral extension of the acromion.[1]

Although infrequent, rotator cuff injury or disease can occur in conjunction with advanced glenohumeral osteoarthritis.[2–4] In the setting of total shoulder arthroplasty (TSA) for the treatment of glenohumeral degenerative joint disease, the finding of associated rotator cuff disease in the perisurgical setting can be associated with worse outcomes.[5–7] This is especially important in the postoperative setting in which a traumatic event can lead to acute cuff rupture, most notably with the vulnerable subscapularis, which can place the prosthesis at risk.[6,7] The purpose of this review article is to examine the incidence and parameters of rotator cuff dysfunction in the perioperative setting of anatomic TSA and to provide insight on the management of associated cuff disease and injury.

PERIOPERATIVE INJURY TO THE POSTERIOR SUPERIOR ROTATOR CUFF

The rotator cuff functions to position the humeral head in the center of the glenoid providing a fulcrum for the larger muscles of the shoulder girdle to position the arm in space. Without this centering function, the humeral head shifts within the socket during motion and rides superiorly on the face of the glenoid with deltoid firing during attempted arm elevation. If this superior displacement of the humeral head occurs after the placement of a TSA, it can cause eccentrically applied compressive forces along the superior aspect of the glenoid component. This phenomenon has been named the "rocking horse" glenoid, in which off-center rocking movements stress and ultimately loosen the anchorage of the glenoid component.[5]

PREOPERATIVE ROTATOR CUFF TEAR

In 1988, Franklin and colleagues published a study on 7 cases of TSA that exhibited major glenoid loosening within 30 months of surgery, and found that 6 of these patients had massive, irreparable preoperative rotator cuff tears. The authors reported that the amount of superior migration of the humeral component was closely correlated with the degree of glenoid loosening. They then correlated this group of 16 consecutive arthroplasties with intact rotator cuff tendons at the time of surgery, none of which developed glenoid loosening in the 5 years after the surgery. The authors concluded that the upward riding of the prosthetic humeral head that occurs in patients with massive rotator cuff deficiencies likely contributes to the loosening of the glenoid component after TSA.[5] Since this landmark article was published, TSA has commonly been avoided in patients with rotator cuff lesions, especially massive and irreparable tears.

Despite the concerning outcomes reported by Franklin and colleagues on shoulder replacements with massive cuff tears, small posterosuperior rotator cuff (supraspinatous or infraspinatous) lesions that are amenable to primary repair may be an acceptable indication for anatomic arthroplasty in conjunction with cuff repair. As mentioned, the incidence of small to moderate cuff lesions with end-stage glenohumeral osteoarthrosis is low. Edwards et al[2] reported finding that 42 out of 514 (8.2%) total shoulder replacement patients also had preoperative rotator cuff tearing that involved only the supraspinatus. Norris and Iannotti[3] reported that 13 out of 128 (10.2%) patients had tears, also involving only the supraspinatus. Finally, Simone et al[4] recently reported that 45 out of 932 (4.8%) patients from the Mayo Clinic database undergoing

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anatomic shoulder arthroplasty also underwent concomitant rotator cuff repair.

Despite the relative infrequency of small cuff lesions in the setting of primary osteoarthritis, it is important to identify and treat these tears as the results of TSA with repair of small full-thickness tears appear favorable. In the investigations by Edwards et al[2] and by Norris and Iannotti,[3] perioperative repair of small cuff lesions did not affect outcomes negatively. In the study with the largest patient population, Simone and colleagues reported that 85% of the patients with repairable preoperative cuff lesions had excellent or satisfactory outcomes with improved clinical markers after TSA. In this study, 6 shoulders (13%) appeared to have a postoperative retear, with all of these patients developing postoperative superior instability, glenoid component loosening, and poor clinical outcomes. Notably, of the 6 patients who developed retears, all had medium or large preoperative cuff tears. The authors concluded that small full-thickness cuff tears are amenable to repair at the time of standard TSA; however, a reverse total shoulder should be considered for patients with medium-sized to large-sized cuff lesions.[4]

INTRAOPERATIVE POSTERIOR SUPERIOR ROTATOR CUFF TEARS

The preoperative evaluation of patients with end-stage glenohumeral osteoarthritis typically consists of plain radiographs along with 3-dimensional imaging (CT scan or MRI) to evaluate the characteristics of the glenoid vault. A preoperative CT scan is appropriate for most patients to help plan optimal positioning of the glenoid component; however, for patients who present with any concerning clinical characteristics of cuff disease such as pain with resisted forward elevation, weakness with external rotation, or a lag sign, an evaluation of the shoulder with an MRI is recommended to both assess the rotator cuff integrity and provide 3D imaging of the glenoid.

If a small-sized or medium-sized rotator cuff lesion is apparent at the time of surgery, it can typically be directly repaired safely with 1-mm Dacron tapes placed through bone tunnels in the greater tuberosity. After the final implant is placed, the tuberosity is prepared with light decortication using a burr and microfractured with a drill to induce a healing response. Bone tunnels are then positioned just lateral to the humeral head and brought through the proximal lateral humerus with large needles providing a transosseous repair (Figs. 1A–C).

For standard anatomic arthroplasty, component insertion and positioning are critical to maintain long-term cuff viability and to minimize the risk of postoperative cuff disease. The posterior cuff is placed directly at risk during the humeral head osteotomy as a result of difficult visualization of the tendon during this step. Running the saw blade along the posterior cortical rim or an overassertive push with the saw can injure the tendon. To help protect the cuff, the head cut should begin along the anterior superior margin of the anatomic neck where the cuff can be visualized and protected. The saw blade can then be directed along the anatomic neck inferiorly away from the cuff, and then using this plane as a cutting block, the saw can be carefully directed posteriorly (Fig. 2). Stopping the saw just anterior to the posterior cortical margin and completing the cut with an osteotome can also help ensure cuff protection. Meticulous protection of the cuff during the placement of retractors should also be carried out throughout the procedure.

The positioning of the humeral head prosthesis is important for postoperative shoulder function and the preservation of cuff integrity. Goals of standard total shoulder replacement include reconstructing the native shoulder anatomy including restoring individual humeral retroversion and head height. The highest point of the average humeral head lies 5 to 8 mm superior to the level of the greater tuberosity and then tapers distally and laterally to the greater tuberosity. This allows for the superior cuff to drape over the head and insert with little tension along the greater tuberosity just lateral to the margin of the head articular cartilage.[8] Long-term failure of the posterior superior rotator cuff tendon as a result of tension overload is a potential consequence of humeral head prosthetic positioning proximal to the anatomic position. Nyffeler and colleagues evaluated the effect that the humeral prosthesis height had on the range of motion and rotator cuff motion arms during shoulder abduction. They compared anatomically placed humeral head prostheses to those placed either 5 or 10 mm too high. Both the 5 and 10-mm malpositioned heads caused the center of rotation to be displaced upward, which resulted in significant reduction in the abduction moment arms of the superior cuff and the subscapularis and increased the tension on the cuff insertion.[9] Ultimately, correct positioning of the humeral head contributes to postoperative function and cuff integrity.

In addition to the positioning of the humeral head component, alterations in the inclination angle of the glenoid component can alter stress forces on the superior cuff. Implantation of the glenoid component with a superior tilt has been found to be a clinical prognostic factor in secondary cuff dysfunction after shoulder arthroplasty.[10] Oosterom and colleagues cemented glenoid components into bone substitute models with variable inclination angles and cyclically loaded the models. They found that a more downward-facing glenoid component allowed for higher superior subluxation forces relative to the joint compression force and increased superior shoulder stability. These authors concluded that a more downward-facing glenoid component provided the most optimal balance in terms of glenoid prosthesis structural deformation and superior humeral head subluxation forces.[11] In another investigation, Terrier and colleagues showed, using a CT model, that a downward inclination of the glenoid component helped to recenter the eccentric contact pattern of the superior cuff-deficient shoulder. However, these authors also noted that an increased eccentric reaming to position a downward-facing glenoid component did take some subchondral bone, leading to increased cement deformation and stress.[12] Ultimately, the positioning of the glenoid component in a slightly downward-facing position may improve the protection of the cuff from superior humeral joint forces; however, this positioning should not come at the expense of the integrity of the glenoid subchondral bone.

POSTOPERATIVE ROTATOR CUFF TEAR

Secondary rotator cuff dysfunction is a known complication after standard TSA (Fig. 3). In a multicenter study, Young and colleagues reported on clinical and radiographic follow-up of >5 years in 518 shoulders after anatomic replacement. Shoulders were diagnosed with cuff dysfunction if severe superior subluxation of the humeral head was present on postoperative radiographs. The authors found that the overall rate of rotator cuff dysfunction was 16.8%. Interestingly, in this study, they found no secondary cuff dysfunction at the 5-year follow-up, but 55% of the patients demonstrated secondary cuff dysfunction with retained implants over 15 years. Risk factors that demonstrated significance included

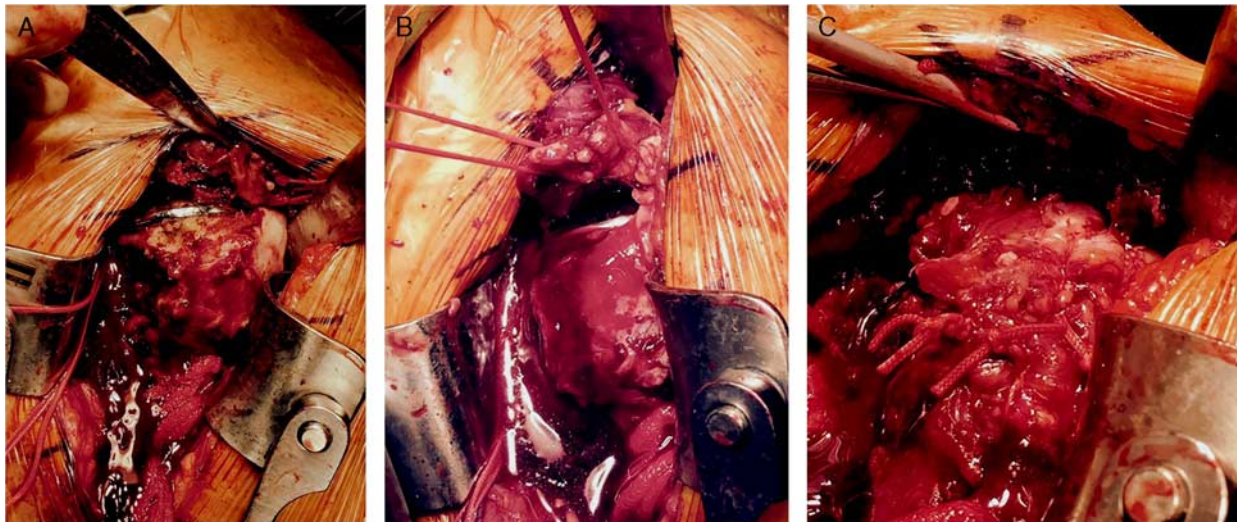

FIGURE 1. A, A rotator cuff tear involving the entire supraspinatous tendon that was not identified until the time of total shoulder arthroplasty. There was minimal retraction and excellent reparability of the tendon. In this image, the rotator cuff tendon tear is held by forceps in the superior portion of the image. The humeral head component has already been implanted (Courtesy: Peter Johnston, MD). B, Mobilization of the torn supraspinatous tendon utilizing 1-mm Dacron tapes (Courtesy: Peter Johnston, MD). C, Final repair of the supraspinatous tendon tear (Courtesy: Peter Johnston, MD). full color online

patients with glenoid components implanted with a superior tilt and patients with preoperative fatty infiltration of the infraspinatous muscle belly on MRI.[10] Ultimately, adequate component positioning can help protect the cuff, but rotator cuff tendon dysfunction may be inevitable in a number of aging postsurgical patients.

For patients with symptomatic secondary cuff dysfunction or loose anatomic implants, conversion of the failed anatomic total shoulder to reverse TSA appears to be an acceptable salvage option. Melis and colleagues reported 37 anatomic TSA that were revised to reverse TSA for aseptic glenoid loosening. Of these patients, 24 (65%) were found to have associated rotator cuff tears at the time of revision. About 86% of these patients were satisfied or very satisfied with the conversion to reverse TSA, although 8 patients (21%) required another procedure due to new or recurrent complications.[13] Historically, the conversion to reverse from standard shoulder arthroplasty required the removal of the humeral component, which can be exceptionally difficult if removing a well-cemented or on-growth stem with distal texturing. However, current platform humeral component designs will now allow for the conversion of a TSA into a reverse shoulder arthroplasty without humeral component removal.[14] Although platform stem designs tend to be more expensive, the option for future conversion to reverse without the potential morbidity of stem removal has become exponentially more popular during

FIGURE 2. When making the humeral head osteotomy, the saw blade should start at the superior anterior anatomic neck and be directed inferiorly away from the posterior superior rotator cuff insertion. This image demonstrates the humeral head of a patient undergoing total shoulder arthroplasty for avascular necrosis. A saw blade is positioned (right aspect of image) along the superior anterior aspect of the head and directed away from the cuff. The surrounding retractors are positioned to protect the surrounding soft tissue optimally. full color online

FIGURE 3. A radiograph demonstrating superior migration after total shoulder arthroplasty, indicating posterior superior rotator cuff dysfunction in the postoperative setting.

implant placement for routine standard TSA. Ultimately, secondary cuff dysfunction increases as the duration from the primary procedure increases; however, for patients who are symptomatic, conversion to reverse TSA appears to be a viable option for unsalvageable anatomic TSA.

SUBSCAPULARIS CUFF TEAR

Mobilization of the subscapularis rotator cuff tendon is required for most TSA to allow access to the glenohumeral articulation. There are a number of methods for this including direct peel of the tendon from its insertion on the lesser tuberosity, tenotomy, and lesser tuberosity ostetomy (LTO). All require repair of the tendon and may weaken the tendon integrity in the postoperative period by direct muscle denervation,[15] repair attenuation, or gross failure of repair. A number of studies have examined the most optimal subscapularis method with mixed results. Despite this, LTO may be the most optimal for limiting postsurgical dysfunction compared with the other methods. Buckley and colleagues compared patients undergoing either LTO or subscapularis peel during TSA with subjective measures and ultrasonography. These authors reported that abnormal subscapularis tendons confirmed by ultrasonography occurred only in the peel group (12.5%), which also correlated with clinically significant inferior functional outcome scores.[16] Despite this, Lapner et al[17] reported no significant differences in healing rates or subscapularis fatty infiltration grades on postoperative CT scans between subscapularis peel and the LTO in their investigation. Jandhyala et al[18] reported that patients who underwent LTO had a better postoperative functional outcome (graded belly-press test) when compared with those who had a subscapularis tenotomy. Scalise et al[19] also reported that LTO resulted in higher clinical outcome scores, a lower rate of subscapularis tendon tears, and universal healing of the osteotomy when compared with tenotomy. Ultimately, violation of the subscapularis can have deleterious postoperative effects; however, the LTO technique may be the most protective when compared with subscapularis peel or tenotomy.

Despite this, postoperative rupture of the subscapularis tendon after TSA is a relatively infrequent complication. Most commonly, disruption occurs in conjunction with a postoperative traumatic incident such as a fall or early aggressive internal rotation strengthening.[6,7] Complete disruption of the subscapularis can lead to anterior instability of the glenohumeral articulation, pain, loss of function, and the potential for abnormal glenoid rim loading and loosening.

Clinical suspicion for subscapularis rupture should occur for any patient who sustains a traumatic incident after TSA, for patients reporting a pop with external rotation, or for those with anterior-based pain, weakness in internal rotation, or anteriorly translated humeral head on axillary radiographs. The physical examination can be challenging as many of these patients have internal rotation deficits that make the belly-press test or the lift-off test unreliable. Up to 68% of the patients have been reported to have reduced subscapularis function and abnormal physical tests after TSA,[6,20] and 30% of the postoperative patients have been shown to have some partial deficit of the repaired tendon,[21] making diagnostic determination of true full-thickness tears difficult. An ultrasound evaluation or a CT arthrogram of the glenohumeral articulation may help with the diagnosis.

Surgical repair of the subscapularis is typically recommended for patients found to have complete tendon disruption. Unfortunately, however, functional and subjective patient outcomes after revision repair have been reported to be marginal. Miller and colleagues reported 7 patients who underwent reoperation for symptomatic rupture of the subscapularis repair, which occurred in 5.8% of their total TSA cases during their study collection period. Factors associated with tendon rupture included subscapularis-lengthening techniques to address internal rotation contracture and previous surgery that violated the subscapularis tendon (eg, the Putti-Platt procedure). In this study, direct tendon repair was possible in only 3 patients, and pectoralis tendon transfer was required in 4 patients. All 7 patients reported residual weakness and 2

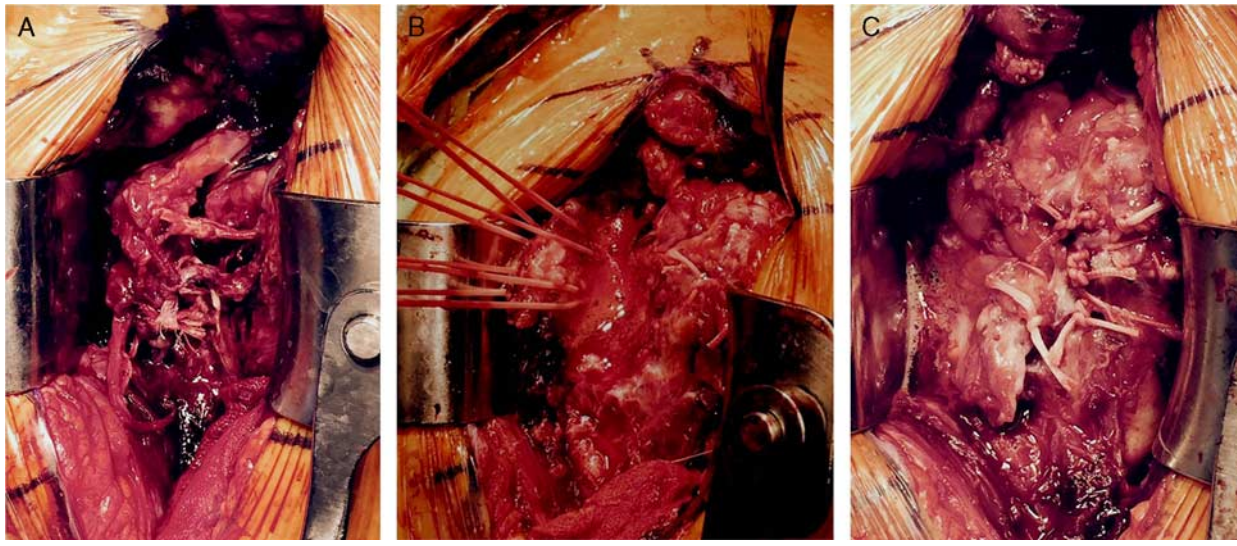

FIGURE 4. A, Patient with a subscapularis tear after total shoulder arthroplasty due to a fall. This image shows disruption of the integrity of the repair with minimal retraction of the tendon (Courtesy: Peter Johnston, MD). B, The torn subscapularis has been mobilized and tagged with 1-mm Dacron tapes for repair to the lesser tuberosity (Courtesy: Peter Johnston, MD). C, Direct subscapularis repair to the lesser tuberosity with 1-mm Dacron tapes (Courtesy: Peter Johnston, MD). full color online

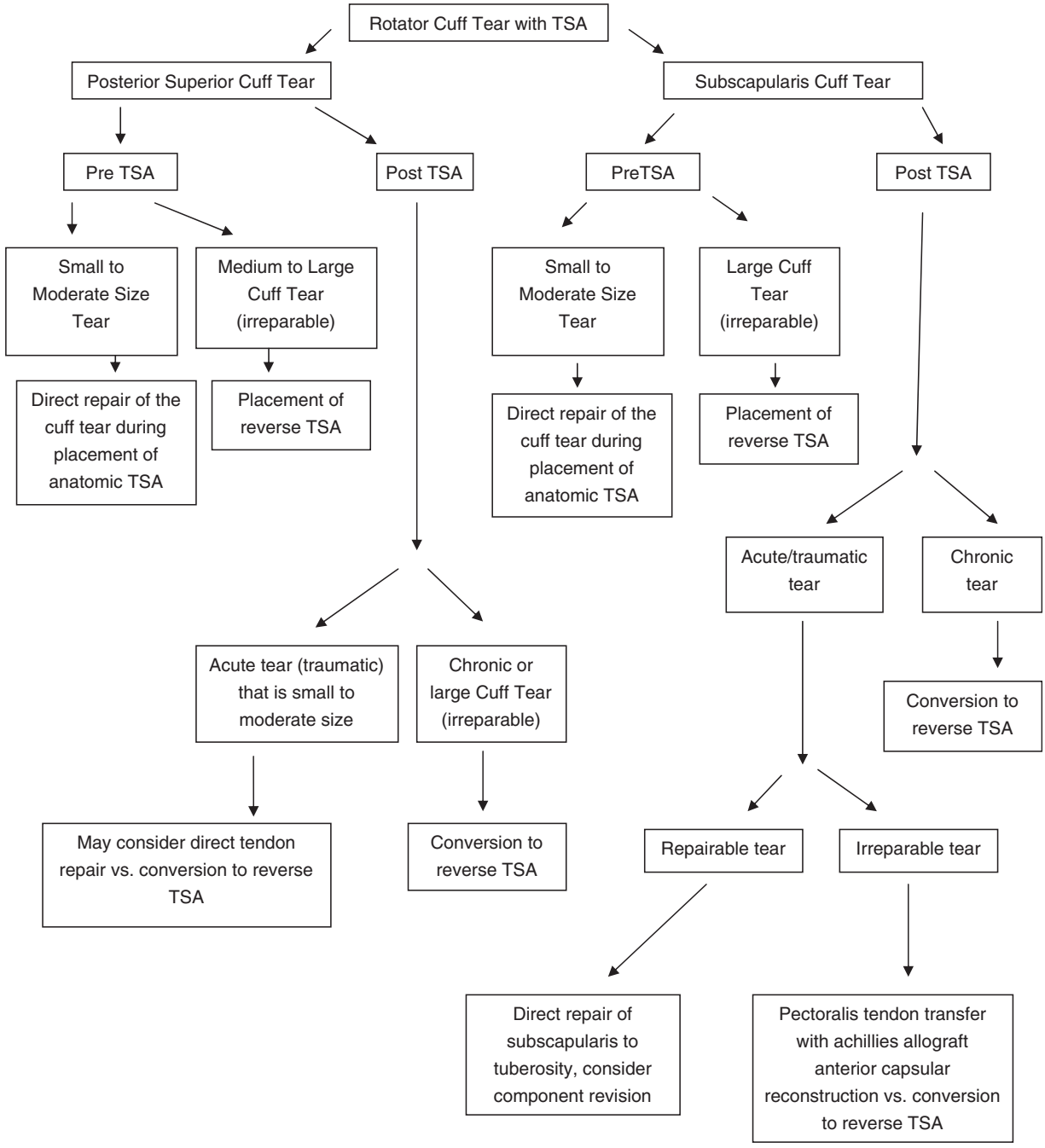

FIGURE 5. Rotator cuff disease in total shoulder arthroplasty (TSA): treatment algorithm.

patients continued to have anterior instability after revision surgery.[6] In another series, Moeckel and colleagues reported on 10 patients with shoulder instability after arthroplasty. Seven of these patients had anterior instability that occurred after the failure of the subscapularis repair. All patients underwent direct surgical repair of the ruptured tendon; however, anterior instability remained in 30% of the cases after revision subscapularis fixation. These patients ultimately required capsular reconstruction with Achilles allograft.[7]

For patients with postsurgical disruption of the subscapularis tendon, attempted direct repair of the detached tendon is ideal during revision repair (Figs. 4A–C). However, a delayed diagnosis of even 4 to 6 weeks may make direct tendon repair impossible. In addition, malpositioning of the arthroplasty itself may preclude effective repair. In these cases, revision of the humeral head prosthesis to alter the eccentric position of the head and reduce tension on the repair can improve the viability of the repair, and therefore revision implants should be available at the time of surgery. For patients with poor integrity of the subscapularis or an irreparable cuff tendon, pectoralis major tendon transfer may be required. Mobilization of the pectoralis tendon underneath the

conjoined tendon can improve tendon vector and function of the transferred muscle.[22] Most of these patients will have an associated anterior capsular deficiency that contributes to the anterior instability. Reconstruction of this capsule deficiency can be completed with the Achilles allograft secured to the anterior inferior glenoid rim and the medial aspect of the lesser tuberosity with either transosseous suture tunnels or suture anchors.[7]

CONCLUSIONS

Rotator cuff disease is a relatively uncommon, but potentially devastating complication in TSA (Fig. 5). Posterior superior cuff disease is not commonly encountered in the preoperative setting, but has been reported to occur in about 5% to 10% of the standard TSA cases. In these cases, if the cuff lesion is small or moderate, cuff direct repair can safely take place during standard arthroplasty implantation. Rotator cuff disease in the postoperative setting after standard TSA may occur either traumatically or chronically. Traumatic rupture of the subscapularis after TSA is a challenging problem that typically requires surgical repair of the tendon or consideration for capsular reconstruction with allograft and pectoralis major transfer if the subscapularis is irreparable. Chronic secondary cuff dysfunction affects the posterior superior rotator cuff and has been reported in up to 55% of the patients with retained implants over 15 years. For these patients, conversion to a reverse TSA has demonstrated adequate clinical outcomes.

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