JSES International 8 (2024) 528–534

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

The subcoracoid distance is correlated with pain and internal rotation after reverse shoulder arthroplasty

Emma L. Klosterman, MD[a], Adam J. Tagliero, MD[b], Timothy R. Lenters, MD[c], Patrick J. Denard, MD[d], Evan Lederman, MD[e], Reuben Gobezie, MD[f], Benjamin Sears, MD[g], Brian C. Werner, MD[h,*], Shoulder Arthroplasty Research Committee (ShARC)

[a]Department of Orthopaedic Surgery, Michigan Medicine, Ann Arbor, MI, USA
[b]Department of Orthopaedic Surgery, Mayo Clinic, Rochester, MN, USA
[c]Department of Orthopaedic Surgery, Trinity Health, IHA Medical Group, Byron Center, MI, USA
[d]Department of Orthopaedic Surgery, Oregon Shoulder Institute, Medford, OR, USA
[e]Department of Orthopaedic Surgery, Banner Health, Scottsdale, AZ, USA
[f]Department of Orthopaedic Surgery, The Cleveland Shoulder Institute, Beachwood, OH, USA
[g]Department of Orthopaedic Surgery, Western Orthopaedics, Denver, CO, USA
[h]Department of Orthopaedic Surgery, University of Virginia, Charlottesville, VA, USA

A R T I C L E I N F O

Keywords:
Coracoid impingement
Subcoracoid impingement
Reverse shoulder replacement
Reverse shoulder arthroplasty
Subcoracoid distance
Internal rotation

Level of evidence: Level IV; Case Series; Prognosis Study

Background: A proposed etiology of anterior shoulder pain and limited internal rotation after reverse shoulder arthroplasty (RSA) is impingement of the humeral component on the coracoid or conjoint tendon. The primary goal of this study was to investigate radiographic surrogates for potential coracoid or conjoint tendon impingement and their relationship to postoperative pain and internal rotation after RSA.

Methods: A retrospective review of a clinical registry was performed to identify patients with (1) primary RSA, (2) minimum 2-year clinical follow-up, and (3) satisfactory postoperative axillary lateral radiographs. The primary radiographic measurement of interest was the subcoracoid distance (SCD), defined as the distance between the posterior aspect of the coracoid and the anterior glenosphere. Additional measurements were as follows: anterior glenosphere overhang, posterior glenosphere overhang, native glenoid width, lateralization of glenosphere relative to the coracoid tip, lateralization shoulder angle, and distalization shoulder angle. The primary clinical outcome of interest was the 2-year postoperative Visual Analog Scale score. Secondary outcomes were (1) internal rotation (IR) defined by spinal level (IRspine), (2) IR at 90 degrees of abduction, (3) American Shoulder and Elbow Surgeons score, (4) forward flexion, and (5) external rotation at 0 degrees of abduction. Linear regression analyses were used to evaluate the relationship of the various radiographic measures on the clinical outcomes of interest.

Results: Two hundred seventeen patients were included. There was a statistically significant relationship between the SCD and Visual Analog Scale scores: B = −0.497, $P = .047$. There was a statistically significant relationship between the SCD and IRspine: B = −1.667, $P < .001$. Metallic lateralization was also positively associated with improving IRspine; increasing body mass index was negatively associated. There was a statistically significant relationship between the SCD and IR at 90 degrees of abduction: B = 5.844, $P = .034$.

Conclusion: For RSA with a 135° neck shaft angle and lateralized glenoid, the postoperative SCD has a significant association with pain and IR. Decreasing SCD was associated with increased pain and decreased IR, indicating that coracoid or conjoint tendon impingement may be an important and potentially under-recognized etiology of pain and decreased IR following RSA. Further investigations aimed toward identifying a critical SCD to improve pain and IR may allow surgeons to preoperatively plan component position to improve clinical outcomes after RSA.

This work was performed at the University of Virginia.
This study was approved by the Southern Oregon Institutional Review Board – Protocol # 15-001.
Shoulder Arthroplasty Research Committee (ShARC) authorship. Anup Shah, MD, Asheesh Bedi, MD, Bradford Parsons, MD, Brandon Erickson, MD, Bruce Miller, MD, Christopher O'Grady, MD, Daniel Davis, MD, David Lutton, MD, Jorn Steinbeck, MD, John Tokish, MD, Julia Lee, MD, Kevin Farmer, MD, Matthew Provencher, MD, Michael Bercik, MD, Michael Kissenberth, MD, Patric Raiss, MD, Peter Habermeyer, MD, Philipp Moroder, MD, Russell Huffman, MD, Samuel Harmsen, MD, Tyrrell Burrus, MD, Tyler Brolin, MD, Anthony Romeo, MD, R. Alexander Creighton, MD, Justin W. Griffin, MD, Albert Lin, MD, Dirk Petre, MD.
*Corresponding author: Brian C. Werner, MD, Department of Orthopaedic Surgery, University of Virginia, 2280 Ivy Road, Charlottesville, VA 22903, USA.
E-mail address: bcw4x@uvahealth.org (B.C. Werner).

https://doi.org/10.1016/j.jseint.2024.01.010

Reverse shoulder arthroplasty (RSA) is accepted as a predicable surgery to decrease pain and improve function for a variety of indications. Implant survival rates have been quoted from 81%-93% at 10 years in recent data with the evolution of indications, implant design, and techniques.[4,8,10] Despite the fact that the complication rate has been downtrending, it remains significant at 16.1%. The most common complication after RSA is reported to be instability followed by periprosthetic fracture, infection, and component loosening.[5] In long-term follow-up studies, the majority (82%) of patients were very satisfied or satisfied with their outcome, and 94% of patients would choose to have the procedure again.[20] Postoperative pain is not captured by published complication literature but may adversely affect overall satisfaction rates. There remains a subset of dissatisfied patients with persistent shoulder pain or limited motion after RSA.

Multiple studies have elaborated on potential etiologies of pain specific to RSA, which include instability, scapular notching, acromial/scapular spine fractures, and anterior shoulder pain/subcoracoid pain.[7,9,11] Anterior shoulder pain after RSA is not well defined. It has been postulated to be secondary to coracoid fracture,[2] subcoracoid adhesions in the setting of multiple surgeries causing stiffness, excessive distalization of the humerus leading to tendinitis of the biceps brachii and coracobrachialis tendon,[24] and subcoracoid impingement due to the abutment of the humeral prosthesis.

In the native shoulder, subcoracoid impingement is a recognized diagnosis. Stenosis of the coracohumeral interval between the lesser tuberosity of the humerus and coracoid process < 6 mm can be associated with anterior shoulder pain, rotator cuff pathology, and biceps pathology. It can be secondary to bony or soft tissue morphology. Treatment is largely nonoperative, but can include arthroscopic subcoracoid decompression (coracoplasty) for patients who have failed conservative measures.[17]

After RSA, there is potential for a similar mechanism where the humeral component impinges on the coracoid or conjoint tendon anteriorly during adduction or internal rotation (IR). There are limited clinical data supporting this potential etiology of postoperative pain or limited IR. The primary goal of this study therefore was to investigate postoperative radiographic measurements for coracoid impingement and their relationship to postoperative pain and IR deficit after RSA. We hypothesized that postoperative radiographic measures of decreasing distance between the coracoid and glenosphere would correlate with increased levels of postoperative pain and limited IR after RSA.

Materials and methods

Database and study patients

A retrospective review of a multicenter clinical registry of RSAs was performed to identify patients with (1) primary RSA, (2) minimum 2-year clinical follow-up, and (3) appropriate postoperative axillary and anteroposterior radiographs. Institutional review board approval was obtained. Demographic variables were collected for each patient, including age, sex, body mass index (BMI), and whether surgery was performed on the dominant arm. Surgical variables were also recorded, including glenosphere diameter and metallic lateralization, defined as combined glenoid baseplate and glenosphere lateralization.

Surgical technique

Eleven surgeons contributed to the clinical registry with minimal variation in their surgical techniques. Each preformed a standard deltopectoral approach for exposure. The biceps tendon was either tenodesed or tenotomized. The 3 sisters were electrocauterized. The subscapularis was managed per surgeon preference: peel (N = 178, 82%), tenotomy (N = 4, 2%), or lesser tubeosity osteotomy (N = 35, 16%). A 135° humeral head cut allowed for en face glenoid exposure. The glenoid was prepared using a sequential reaming technique as per the manufacturer's recommendation. The baseplate was implanted (Universal Baseplate or Modular Glenoid System; Arthrex, Inc., Naples, FL, USA) and secured with appropriate central fixation. No augmented baseplates were included. Decisions of baseplate lateralization, as well as glenosphere diameter, and glenosphere lateralization were patient-specific and based on coverage, bone quality, age, sex, preoperative planning, and intraoperative soft-tissue tension. A 135° neck shaft angle (NSA), inlay, stemmed, humeral component (Univers Revers or Revers Apex System; Arthrex Inc., Naples, FL, USA) was then press-fit before subsequently trialing of the polyethylene humeral liners and metallic humeral spacers as needed. Sizing was again patient-specific, based on range of motion (ROM) and intraoperative stability. During closure, the subscapularis was repaired based on surgeon preference, tendon mobility, and tissue quality (repaired in 173 of 217 cases, 80%).

Postoperative rehabilitation

Postoperatively, patients followed similar rehabilitation protocols, although there was some variability between sites. In general, immediately postoperatively until 6 weeks, patients wore a sling at all times except to complete their home exercise program and physical therapy. ROM was limited to pendulums, passive supine forward rotation, and passive supine external rotation until 2 weeks. From 2 weeks to 6 weeks, passive ROM was advanced as tolerated in the forward flexion (FF), abduction, and external rotation planes, while internal rotation was still restricted. From 6 weeks to 12 weeks, internal rotation and cross body motion was incorporated as passive ROM transitioned from supine to vertical positioning and active ROM was started. After 12 weeks, gradual strengthening and restoration to normal activities was expected.

Radiographic evaluation

All radiographs were obtained according to a strict protocol which is frequently queried for quality control to assure appropriate views are being obtained. The primary radiographic measurement of interest was the subcoracoid distance (SCD), defined as the distance between the posterior aspect of the coracoid and the anterior glenosphere on the axillary radiograph (Fig. 1*A*). The center of rotation to the posterior edge of the coracoid and the center of rotation to the edge of the sphere were also measured (Fig. 1*B* and *C*). Anterior glenosphere overhang and posterior glenosphere overhang were measured on the axillary radiographs as the distance from the most anterior or posterior edge of the native glenoid to the furthest extent of the glenosphere (Fig. 2*A*). Native glenoid width was measured from the furthest cortical extent (Fig. 2*B*). Metallic lateralization was measured in relation to the coracoid tip by the distance between parallel lines to the native glenoid placed

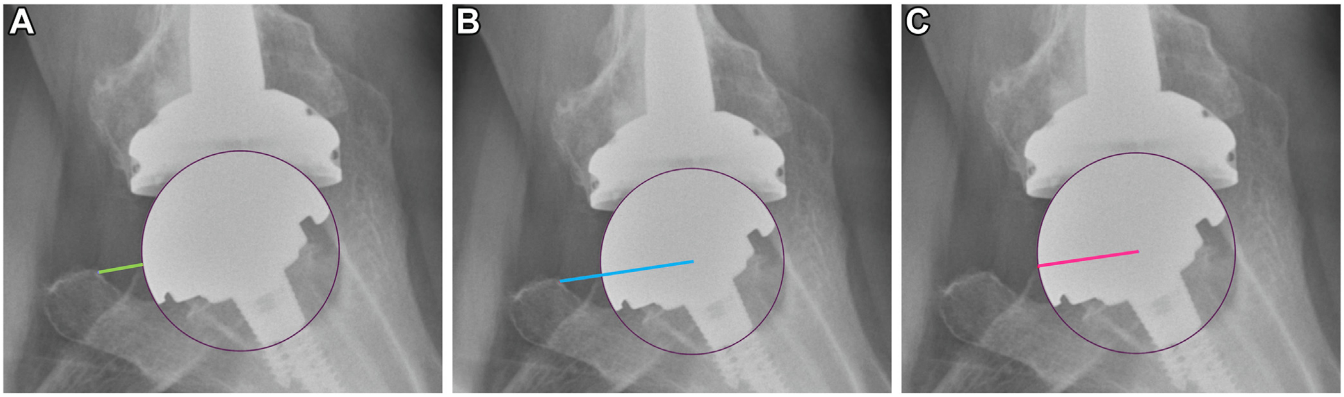

Figure 1 Subcoracoid space (SCS), center of rotation to the tip of the coracoid (COR-C), and the center of rotation to the edge of the sphere (COR-S). (**A**) The purple sphere outlines the glenosphere. The subcoracoid space (SCS; *green*) is defined as the distance (mm) between the posterior aspect of the coracoid and the anterior glenosphere on the axillary radiograph. (**B**) The center of rotation to the tip of the coracoid (COR-C; *blue*) is defined by the distance (mm) from the center of the rotation to the posterior aspect of the coracoid on the axillary radiograph. (**C**) The center of rotation to the edge of the sphere (COR-S; *pink*) is defined as the distance (mm) from the center of rotation to the boundary of the glenosphere, or the radius of the glenosphere (*purple*).

at the edge of the glenosphere and coracoid tip (Fig. 2C). If the glenosphere extended lateral to the coracoid tip, it was recorded as a positive number. If medial to the coracoid tip, this was recorded as a negative number. The glenosphere diameter was measured on each axillary radiograph and, along with the known implanted glenosphere diameter, used to normalize all measurement in millimeters and control for magnification differences. For patients with multiple sets of postoperative radiographs, the best axillary radiograph was used at the closest time point to surgery to avoid reactive bone changes.

Given their previously established clinical relevance, the lateralization shoulder angle (LSA) and distalization shoulder angle were also measured on anteroposterior radiographs (Fig. 3).[6] All radiographic measurements were completed by 4 surgeons (E.L.K., A.J.T., T.R.L., and B.C.W.). As these were angular measurements, no normalization for magnification was required.

Clinical outcomes

The primary outcome of interest was the 2-year postoperative Visual Analog Scale (VAS) score. Secondary outcomes were (1) IR defined by spinal level (IRspine), (2) IR at 90 degrees of abduction (IR90), (3) 2-year American Shoulder and Elbow Surgeons (ASES) score, (4) FF, and (5) external rotation at 0 degrees of abduction (ER0).

Statistical analyses

A reliability analysis was performed on 20 cases prior to proceeding with the complete study. All proposed radiographic measurements had a high degree of interobserver reliability between the 4 surgeons (alpha = 0.790-0.940). Linear regression analyses were used to evaluate the relationship of the various radiographic measures on the clinical outcomes of interest. For each 2-year clinical outcome including ROM, the preoperative baseline of that measure was included in the regression to control for variability at presentation. For all analyses, $P < .05$ was considered statistically significant.

Results

Two hundred and seventeen patients met appropriate criteria and were included in the study. The mean age at time of surgery was 69.7 ± 8.4 years with 59.9% male patients and involvement of the dominant arm in 61.3% of patients. The mean BMI of our patient cohort was 29.8 ± 5.5 kg/m^2. A 33-mm, 36-mm, 39-mm, or 42-mm diameter glenosphere were used 11%, 39%, 31%, and 19% of the cases, respectively. Glenoid lateralization was 0 mm, 2 mm, 4 mm, 6 mm, or 8 mm in 8%, 3%, 44%, 24%, and 21% of the cases, respectively.

VAS

There was a statistically significant relationship between the SCD and VAS scores: B = −0.497, P = .047, indicating that for every 1 mm increase in the SCD, the 2-year VAS decreased by 0.5 points. No other demographic, surgical, or radiographic measures were significantly associated with the postoperative VAS.

IRspine

There was a statistically significant relationship between the SCD and IRspine: B = −1.667, $P < .001$, indicating that for every 1 mm increase in the SCD, there were 1.5 levels of improvement in IRspine. Metallic lateralization was also positively associated with improving IRspine (B = −0.193, P = .012). Increasing BMI was negatively associated with improving IRspine (B = 0.082, P = .040).

IR90

There was a statistically significant relationship between the SCD and IR90: B = 5.844, P = .034, indicating that for every 1 mm increase in the SCD, there was nearly 6° of improvement in IR90. Metallic glenoid lateralization was also positively associated with improving IR90 (B = 1.410, P = .042). No other demographic, surgical, or radiographic measures were significantly associated with IR90.

Other

There was no association between the SCD with the 2-year ASES, FF, or ER0. Of the remaining radiographic measurements, the LSA was associated with 2-year ASES scores (B = −0.356, P = .10). Anterior overhang was associated with ER0 (B = 17.35, P = .029). There were no other significant associations found.

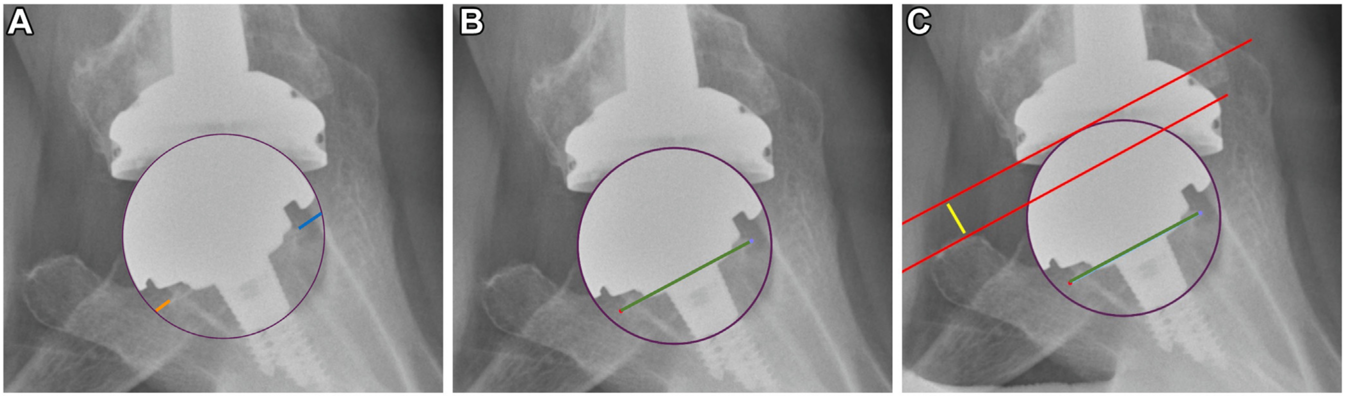

Figure 2 Glenosphere overhand, native glenoid width, and glenoid lateralization. (**A**) Anterior glenosphere overhang (*orange*) and posterior glenosphere overhang (*blue*) were measured on the axillary radiographs as the distance from the most anterior or posterior edge of the native glenoid to the furthest extent of the glenosphere (*purple*). (**B**) Native glenoid width (*dark green*) was measured from the furthest cortical extent but not to include any reactive bone. (**C**) Glenoid lateralization (*yellow*) was measured in relation to the coracoid tip by the distance between parallel lines to the native glenoid (*dark green*) placed at the edge of the glenosphere (*red*) and coracoid tip (*red*).

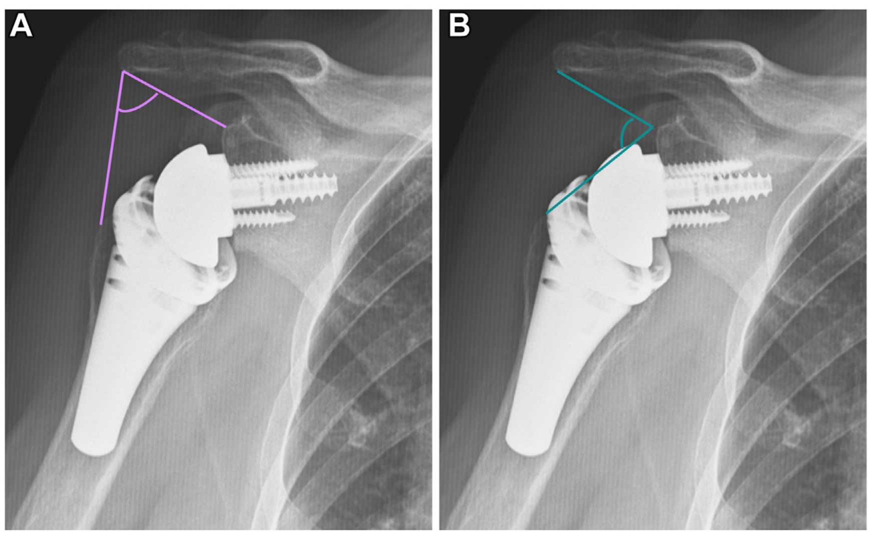

Figure 3 Lateralization shoulder angle (LSA) and distalization shoulder angle (DSA). (**A**) The lateralization shoulder angle (LSA; *lavender*) is formed by a line connecting the superior glenoid tubercle and the most lateral border of the acromion and a line connecting the most lateral border of the acromion and the most lateral border of the greater tuberosity. (**B**) The distalization shoulder angle (DSA; *teal*) is formed by a line connecting the most lateral border of the acromion and the superior glenoid tubercle and a line connecting the superior glenoid tubercle and the most superior border of the greater tuberosity.

Discussion

The postoperative SCD, measured as the distance between the posterior coracoid and anterior glenosphere, has a significant association with pain and active internal rotation after RSA. For every 1 mm increase in the SCD, the 2-year VAS decreased by 0.5 points, the IRspine improved by 1.5 levels, and there was nearly 6° of improvement in IR90. This demonstrates the potential for decreased pain and increased IR with an increasing SCD. These findings support that coracoid or conjoint tendon impingement may be a significant and under-reported etiology of pain and decreased IR following RSA.

Despite generally high levels of pain reduction following RSA, persistent postoperative pain remains a concern for patients.[4,7,14,20] As many as 33% to 45% of patients failed to achieve a patient acceptable symptom state (PASS) after RSA in a multicenter study retrospective review. Pain, rather than ROM, was the predominant driver of this failure with reported mean VAS scores in patients not achieving PASS as high as 3.1 depending on the anchor for determining PASS.[26] Patients undergoing RSA necessitate an improvement of 1.4 points in the VAS score to reflect a minimal clinically important difference.[23] There are a variety of causes of persistent pain after RSA. Some are less predictable or modifiable such as infection, neurologic syndromes, polyethylene wear, aseptic loosening, or metal allergies.[7] Other pain factors can be addressed at the time of surgery such as instability and scapular notching. While pain after RSA is likely multifactorial in etiology and is unlikely completely ameliorated with implant positioning adjustments, planning for an increased SCD could allow for diminished postoperative pain from coracoid or conjoint tendon impingement and is worthy of further study.

The cause of anterior shoulder pain, or subcoracoid pain itself, can be difficult to determine; it has been postulated to be secondary to adhesions, impingement, tendonitis, or coracoid fracture.[7] Persistent anterior shoulder pain secondary to adhesions or impingement has been reported by Ardebol et al.[3] A stepwise coracoplasty with removal of any posterior projection of the coracoid, débridement of the lesser tuberosity, vs. metallosis indicative of component abutment was described for treatment of anterior shoulder pain. Conjoint tendinitis as a cause of anterior shoulder pain after RSA has been described by Tashjian et al. They proposed the tensioning of the biceps brachii and coracobrachialis tendons in conjunction with the functional deltoid tensioning necessitated by a RSA or excessive distalization of humerus as a plausible etiology. In their study, 11 patients were followed after an open, isolated conjoint tendon release. Fifty-five percent of patients had complete resolution of symptoms and 82% had VAS score improvement greater than the minimal clinically important difference.[24] Similarly, Gomez et al reported an open z-lengthening of the conjoint tendon for anterior shoulder pain after RSA for 7 patients with complete symptom resolution by 3 months.[12] They have continued to perform this lengthening prospectively at time of RSA implantation for taut conjoint tendons.[28]

Coracoid fracture as a cause of anterior shoulder pain after RSA has been described in 4 cases in the literature.[2,18,22] These authors postulate tensioning of the conjoint tendon in small stature patients with poor bone quality vs. mechanical abutment as fracture etiology. These fractures were managed nonoperatively in a sling from 3-6 weeks with resolution of symptoms. Each of these studies aligns with the present study's findings of increasing anterior shoulder pain after RSA attributed to impingement on the coracoid or conjoint tendon, or conjoint tendonitis. However, prior studies have not been able to provide a radiographic parameter to allow widespread assessment of the issue.

Functional IR after RSA remains a less predictable postoperative outcome. Additionally, many of the current outcome measures have floor effects such that they do not capture the loss of function experienced by patients despite their difficulty with IR.[16,21] Aleem et al have developed a functional IR scale to assess patient's ability to perform tasks dependent on IR, for example, toileting, bathing, tucking in a shirt, putting an arm into a jacket, or looping a belt through pants, as these are tasks that are important and not currently regularly assessed.[1] Lower humeral NSAs, lateralization of the glenoid, decreasing humeral retroversion, and increasing glenosphere diameter are associated with increased IR.[13] Even with these clinical associations, radiographic correlates have been limited. Kim et al found increased peg-glenoid rim distance was associated with increased IR for patients with rotator cuff arthropathy.[15] Similarly, the SCD represents a novel radiographic parameter that has a significant association with 1.5 level improvements of IRspine and nearly 6° of improvement of IR90 for every 1 mm increase. This parameter may have future value in 3-dimensional preoperative planning to allow optimization of impingement-free ROM. Further study would be needed to qualify how impactful this could be for functional improvements in IR tasks. The present study implies that in the primary setting it may be a consideration to use a smaller glenosphere when in between sizes and maximize lateralization to improve internal rotation and to decrease postoperative pain.

The present study is not without limitations. The study is limited by the retrospective cohort design, which includes 11 surgeons with varying surgical techniques. The present study used only one implant system which allowed for improved internal comparisons and validity of the data but may impact the ability to generalize these data to other available commercial systems. However, using a radiographic parameter as a primary outcome may mitigate this and allow for a more generalizable dataset. The study included multiple high-volume shoulder arthroplasty surgeons; however, this also introduces heterogeneity within techniques and intraoperative decision-making. The present study design did not allow control of certain patient or technical factors that affect internal rotation after RSA, such as preoperative rotator cuff status, scapular neck length, subscapularis repair, and inferior glenosphere placement of the glenosphere, among others.[19,25,27] We were able to control for some of this by including preoperative ROM measurements in the regression, as well as including the LSA and distalization shoulder angle, which have been previously validated clinically. While we have presented SCD as a measurable radiographic parameter to allow for comparison across implants, it is notable that the present study design cannot differentiate impingement on the coracoid as a source of pain/dysfunction from contact with the conjoint tendon.

Conclusion

For RSA with a 135° NSA and lateralized glenoid, the postoperative SCD has a significant association with pain and IR after RSA. Decreasing SCD was associated with increased pain and decreased IR, indicating that coracoid or conjoint tendon impingement may be an important and potentially underrecognized etiology of pain and decreased IR following RSA. Further investigations aimed toward identifying a critical SCD to improve pain and IR may allow surgeons to preoperatively plan component position to improve clinical outcomes after RSA.

Disclaimers:

Funding: Arthrex, Inc.
Conflicts of interest: Dr. Tim Lenters reports Paid consultant: Arthrex, Inc; Research support: Irispet; AAOS: social media committee. Patrick Denard, MD reports Consultant, Royalties, and Research grants from Arthrex, Inc.; Stock ownership in PT Genie and Kaliber Labs. Evan Lederman, MD reports Arthrex, Inc.: Consultant, Royalties, and Research support. Reuben Gobezie, MD reports consultant for and receive royalties from Arthrex, Inc. Dr. Benjamin W. Sears reports Consultant and Royalties from United Orthopaedic Corporation (UOC), Aeuvumed, Shoulder Innovations, BioPoly; Research funding/support from Arthrex, Inc., Exactech, Stryker, and FX Solutions. Brian Werner, MD reports Arthrex, Inc.: Consultant, research support; Lifenet: Consultant; Biomet: Research support; Pacira: Research support. Dr. Anup Shah reports Arthrex, Inc.: Education/research consultant; Medacta: Royalties. Dr. Asheesh Bedi reports Arthrex, Inc.: Consultant and royalties. Dr. Bradford Parsons reports Arthrex, Inc.: Consultant and royalties; Editor JBJS reviews. Dr. Brandon Erickson reports AAOS: Board or committee member; American Orthopaedic Society for Sports Medicine: Board or committee member; American Shoulder and Elbow Surgeons: Board or committee member; Arthrex, Inc.: Paid consultant; Research support; DePuy, A Johnson & Johnson Company: Research support; Linvatec: Research support; PLOS One: Editorial or governing board; Smith & Nephew: Research support; Stryker: Research support. Dr. Bruce Miller reports AJSM: Editorial or governing board; Arthrex, Inc.: Paid consultant; FH Orthopedics: Royalties. Dr. Christopher O'Grady reports Education consultant/Speaker for: Arthrex, Inc., Stryker, Smith and Nephew, Mitek. Dr. Daniel Davis reports Arthrex, Inc.: Paid consultant, paid presenter/speaker; Catalyst OrthoScience: Stock or stock options; Board Member: Pennsylvania Orthopaedic Society; Board Member: Philadelphia Orthopaedic Society. Dr. David Lutton reports Arthrex, Inc.: Paid consultant, Paid speaker or presenter; Avanos: Paid speaker or presenter; CORE: Reviewer (not Editor). Dr. Jorn Steinbeck reports Reviewer: JSES, JBJS; Arthrex, Inc.: Consultant. Dr. John Tokish reports Arthrex, Inc.: IP royalties; Paid consultant; Paid presenter or speaker; Arthroscopy Association of North America: Board or committee member; Journal of Shoulder and Elbow Surgery:

Editorial or governing board, financial or material support; Orthopedics Today: Editorial or governing board. Dr. Julia Lee reports Arthrex, Inc.: Consulting and medical education; American Shoulder Elbow Society – Committee member. Dr. Kevin Farmer reports American Orthopaedic Society for Sports Medicine Florida Orthopaedic Society: Board or committee member; Arthrex, Inc. Paid consultant, paid presenter or speaker; Exactech, Inc.: Paid consultant. Dr. Mathew Provencher reports Royalties from Arthrex, Inc. Arthrosurface, Responsive Arthroscopy (2020), and Anika Therapeutics, Inc.; Consulting fees from Arthrex, Inc., Joint Restoration Foundation (JRF), Zimmer Biomet Holdings, and Arthrosurface; received grants from the Department of Defense (DoD), the National Institute of Health (NIH), and the DJO (2020); Honoria from Flexion Therapeutics; Editorial board or governing board member for SLACK, Inc.; Board or committee member for AANA, AAOS, AOSSM, ASES, SDSI, and SOMOs; serves on the medical board of trustees for the Musculoskeletal Transplant Foundation (through 2018). Dr. Michael Bercik reports American Shoulder and Elbow Surgeons: Board or committee member; Arthrex, Inc.: Paid consultant; WRS Specialists: Paid consultant. Dr. Michael Kissenberth reports Paid consultant for a company or supplier: Arthrex, Inc.; Financial or material support from a company or supplier: Hawkins Foundation; Board Member: Hawkins Foundation. Dr. Patric Raiss reports Paid consultant for Arthrex, Inc.; Shareholder Zurimed Technologies AG.Dr. Peter Habermeyer reports Royalties Arthrex, Inc. Dr. Philipp Moroder reports Consultant for Alyve Medical, Arthrex, and Medacta; Receives royalties from Alyve Medical, Arthrex, and Medacta. Dr. G. Russell Huffman reports Speakers bureau/paid presentations for a company or supplier: Arthrex, Inc., LIMA; Paid consultant for a company or supplier: Arthrex, Inc., LIMA; Stock or stock options in a company or supplier: Catalyst; Research support from a company or supplier as a PI: LIMA IDE. Dr. Samuel Harmsen reports Arthrex, Inc.: Royalties; Paid consultant; Paid presenter or speaker; Research support; Embody, Inc.: Royalties; Paid consultant; Enovis, Inc.: Paid consultant; paid presenter; Genesis Software Innovations, LLC: Royalties; Stock or stock options; Shoulder Innovations, Inc.: Royalties, Paid consultant; Paid presenter or speaker; Zimmer US Inc.; Paid consultant; Paid presenter or speaker; Stock or stock options. Dr. Matthew Tyrrell Burrus reports Arthrex, Inc.: Paid consultant; Paid presenter or speaker; Research support; Arthroscopy: Editorial or governing board. Dr. Tyler Brolin reports AAOS: Board or committee member; American Shoulder and Elbow Surgeons: Board or committee member; Arthrex, Inc.: IP royalties; Paid consultant; Research support; Elsevier: Publishing royalties, financial or material support; Orthofix, Inc.: Research support; Orthopedic Clinics of North America: Editorial or governing board; Zimmer: Research support. Dr. Anthony Romeo reports that from Arthrex Inc. he receives royalties, research support and is a paid consultant; from Saunders/Mosby-Elsevier and SLAC Inc.; he receives publishing royalties and financial or material support; from AANA and MLB he receives other financial or material support; from Paragen Technologies research support and stock or stock options. Dr. Alexander Creighton is a consultant for Arthrex and receives research support from Arthrex Breg and Smith & Nephew. Dr. Justin Griffin reports that from Arthrex Inc.; he receives research support, royalties, and is a paid consultant and that from Springer he receives publishing royalties. Dr. Albert Lin reports that he is a paid consultant for Arthrex and Tornier. He is a Board or committee member of AAOS, AOA, AOSSM, ASES, and ISAKOS. Dr. Dirk Petre reports Arthrex, Inc.: Paid consultant, paid presenter/speaker, research support.

References

1. Aleem AW, Chamberlain AM, Keener JD. The functional internal rotation scale: a novel shoulder arthroplasty outcome measure. JSES Int 2020;4:202-6. https://doi.org/10.1016/j.jses.2019.10.002.
2. Anakwenze OA, Kancherla VK, Carolan GF, Abboud J. Coracoid fracture after reverse total shoulder arthroplasty: a report of 2 cases. Am J Orthop (Belle Mead NJ) 2015;44:E469-72.
3. Ardebol J, Pasqualini I, Hartzler RU, Griffin JW, Lederman E, Denard PJ. Arthroscopic management of stiffness and anterior shoulder pain following reverse shoulder arthroplasty. Arthrosc Tech 2022;11:e1763-8. https://doi.org/10.1016/j.eats.2022.06.012.
4. 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;99:454-61. https://doi.org/10.2106/JBJS.16.00223.
5. Bohsali KI, Bois AJ, Wirth MA. Complications of shoulder arthroplasty. J Bone Joint Surg Am 2017;99:256-69. https://doi.org/10.2106/JBJS.16.00935.
6. Boutsiadis A, Lenoir H, Denard PJ, Panisset JC, Brossard P, Delsol P, et al. The lateralization and distalization shoulder angles are important determinants of clinical outcomes in reverse shoulder arthroplasty. J Shoulder Elbow Surg 2018;27:1226-34. https://doi.org/10.1016/j.jse.2018.02.036.
7. Burrus MT, Werner BC, Menendez ME, Denard PJ. Evaluation of the painful total shoulder arthroplasty. J Am Acad Orthop Surg 2023;31:440-9. https://doi.org/10.5435/JAAOS-D-22-01006.
8. Cuff DJ, Pupello DR, Santoni BG, Clark RE, Frankle MA. Reverse shoulder arthroplasty for the treatment of rotator cuff deficiency a concise follow-up, at a minimum of 10 years, of previous reports. J Bone Joint Surg Am 2017;99:1895-9. https://doi.org/10.2106/JBJS.17.00175.
9. Ekelund AL. Management of painful reverse shoulder arthroplasty. Shoulder Elbow 2017;9:212-22. https://doi.org/10.1177/1758573217702333.
10. Forlizzi JM, Puzzitiello RN, Hart PA, Churchill R, Jawa A, Kirsch JM. Predictors of poor and excellent outcomes after reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2022;31:294-301. https://doi.org/10.1016/j.jse.2021.07.009.
11. Fossati C, Vitale M, Forin Valvecchi T, Gualtierotti R, Randelli PS. Management of painful shoulder arthroplasty: a narrative review. Pain Ther 2020;9:427-39. https://doi.org/10.1007/s40122-020-00186-0.
12. Gomez GV, Huffman GR. Conjoint tendon lengthening for recalcitrant anterior shoulder pain after reverse shoulder arthroplasty: a technique article. JSES Rev Rep Tech 2022;2:164-7. https://doi.org/10.1016/j.xrrt.2021.12.005.
13. Gruber MD, Kirloskar KM, Werner BC, Lädermann A, Denard PJ. Factors associated with internal rotation after reverse shoulder arthroplasty: a narrative review. JSES Rev Rep Tech 2022;2:117-24. https://doi.org/10.1016/j.xrrt.2021.12.007.
14. Grubhofer F, Muniz Martinez AR, Ernstbrunner L, Haberli J, Selig ME, Yi K, et al. Speed of recovery of the most commonly performed shoulder surgeries. JSES Int 2021;5:776-81. https://doi.org/10.1016/j.jseint.2021.03.007.
15. Kim SC, Lee JE, Lee SM, Yoo JC. Factors affecting internal rotation after reverse shoulder arthroplasty. J Orthop Sci 2022;27:131-8. https://doi.org/10.1016/j.jos.2020.11.012.
16. Kirkley A, Griffin S, Dainty K. Scoring systems for the functional assessment of the shoulder. Arthroscopy 2003;19:1109-20. https://doi.org/10.1016/j.arthro.2003.10.030.
17. Mckernan MJ, Schickendantz MS, Frangiamore SJ. Diagnosis and management of subcoracoid impingement. J Am Acad Orthop Surg 2021;29:100-7. https://doi.org/10.5435/JAAOS-D-20-00008.
18. Nolan BM, Ankerson E, Wiater JM. Reverse total shoulder arthroplasty improves function in cuff tear arthropathy. Clin Orthop Relat Res 2011;469:2476-82. https://doi.org/10.1007/s11999-010-1683-z.
19. Oak SR, Kobayashi E, Gagnier J, Denard PJ, Sears BW, Gobezie R, et al. Patient reported outcomes and ranges of motion after reverse total shoulder arthroplasty with and without subscapularis repair. JSES Int 2022;6:923-8. https://doi.org/10.1016/j.jseint.2022.07.009.
20. Sheth MM, Heldt BL, Spell JH, Vidal EA, Laughlin MS, Morris BJ, et al. Patient satisfaction and clinical outcomes of reverse shoulder arthroplasty: a minimum of 10 years' follow-up. J Shoulder Elbow Surg 2022;31:875-83. https://doi.org/10.1016/j.jse.2021.09.012.
21. Smith MV, Calfee RP, Baumgarten KM, Brophy RH, Wright RW. Upper extremity-specific measures of disability and outcomes in orthopaedic surgery. J Bone Joint Surg 2012;94:277-85. https://doi.org/10.2106/JBJS.J.01744.
22. Stechel A, Fuhrmann U, Irlenbusch L, Rott O, Irlenbusch U. Reversed shoulder arthroplasty in cuff tear arthritis fracture sequelae and revision arthroplasty: outcome in 59 patients followed for 2-7 years. Acta Orthop 2010;81:367-72. https://doi.org/10.3109/17453674.2010.487242.
23. Tashjian RZ, Hung M, Keener JD, Bowen RC, McAllister J, Chen W, et al. Determining the minimal clinically important difference for the American shoulder and elbow surgeons score, simple shoulder test, and visual analog scale (VAS) measuring pain after shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:144-8. https://doi.org/10.1016/j.jse.2016.06.007.
24. Tashjian RZ, Frandsen JJ, Christensen GV, Chalmers PN. Conjoint tendon release for persistent anterior shoulder pain following reverse total shoulder arthroplasty. JSES Int 2020;4:975-8. https://doi.org/10.1016/j.jseint.2020.07.005.

25. Virani NA, Cabezas A, Gutiérrez S, Santoni BG, Otto R, Frankle M. Reverse shoulder arthroplasty components and surgical techniques that restore glenohumeral motion. J Shoulder Elbow Surg 2013;22:179-87. https://doi.org/10.1016/j.jse.2012.02.004.
26. Werner BC, Lederman E, Gobezie R, Denard PJ. Understanding the variables that are associated with failure to achieve an acceptable symptom state after reverse shoulder arthroplasty. Semin Arthroplasty JSES 2021;31:730-6. https://doi.org/10.1053/j.sart.2021.05.001.
27. Werner BC, Lederman E, Gobezie R, Denard PJ. Glenoid lateralization influences active internal rotation after reverse shoulder arthroplasty. J Shoulder Elbow Surg 2021;30:2498-505. https://doi.org/10.1016/j.jse.2021.02.021.
28. Williams R, Gomez G, Huffman GR. Conjoint tendon lengthening for alleviation or prevention of anterior shoulder pain after reverse total shoulder arthroplasty. San Diego, CA. In: AAOS orthopaedic video theater; 2021. https://www.aaos.org/videos/video-detail-page/23227__Videos. Accessed September 23, 2023.