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Conversion of anatomic total shoulder arthroplasty to reverse shoulder arthroplasty using a unique hybrid glenoid component: technique and preliminary results

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Background: Degenerative arthritis of the shoulder is a common condition that is successfully treated with anatomic total shoulder arthroplasty (TSA). Rotator cuff disease has evolved as a leading cause of failure of anatomic TSA, requiring revision to reverse shoulder arthroplasty (RSA). This revision procedure can be extremely complex, particularly if removal of a well-fixed glenoid component is necessary. This case series outlines the technique and preliminary clinical results of conversion of anatomic TSA to RSA utilizing both modular humeral and hybrid glenoid components.

Methods: From July 2017 to December 2019, the senior author (PMC) performed 84 consecutive anatomic TSA procedures utilizing a modular humeral arthroplasty system and a unique hybrid glenoid component. Three cases (3/84, or 3.6%) required conversion from anatomic TSA to RSA because of postoperative traumatic rotator cuff failure. All modular revision cases were performed without humeral stem removal and with utilization of the existing, well-fixed hybrid glenoid central titanium peg as the foundation for glenoid component revision. Preoperative and postoperative American Shoulder and Elbow Surgeons scores, visual analog scale pain scores, forward flexion, and patient satisfaction were analyzed in this modular revision group. In addition, several perioperative variables including operative time, blood loss, and length of stay were compared between this modular revision group and a nonmodular anatomic TSA to RSA revision comparative cohort.

Results: At an average follow-up of 24 months, average active forward flexion, postoperative American Shoulder and Elbow Surgeons scores, and visual analog scale pain scores improved significantly compared with preoperative scores in the modular revision group. All three patients were satisfied with their outcome. The average total operative time (109 minutes vs. 154 minutes, $P = .02$), blood loss (183 cc vs. 500 cc, $P = .08$), and length of hospital stay (26.3 hours vs. 36.6 hours $P < .05$) were lower in the modular revision group than those in a nonmodular revision cohort.

Conclusion: Revision of anatomic TSA to RSA utilizing a modular humeral system and a convertible hybrid glenoid component that does not require removal of a well-fixed central titanium peg which serves as the foundation for glenoid component revision was performed efficiently, safely, and successfully in three cases. This technique results in significantly improved clinical outcomes when revision to RSA is needed while potentially decreasing perioperative complications in the revision setting.

Degenerative arthritis of the shoulder is a common condition that is successfully treated with anatomic total shoulder arthroplasty (TSA).[2,16,39] Complications after anatomic TSA have historically been related to the glenoid component. Problems with cemented, all-polyethylene glenoid components over time have been related largely to poor initial fixation[19] and/or aseptic, mechanical glenoid loosening,[6,19] potentially leading to severe glenoid bone loss[38] and difficult revision surgery.[32]

In an attempt to address issues of glenoid fixation and mechanical loosening, metal-backed glenoid components were introduced.[11] Early experience with a metal-backed glenoid was disappointing as Cofield et al showed only 80% survivorship at 5

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years and 52% survivorship at 10 years.[40] The rationale for increased failure included poor initial fixation (potentially related to early metal-backed designs), the thickness of metal plus its polyethylene insert being greater than normal anatomy, thus overtensioning of the soft tissues and increased load on the polyethylene insert, insufficient thickness of the polyethylene insert if attempts were made to avoid overstuffing, the increased rigidity (modulus of elasticity) of the metal-backed tray which creates increased stresses in (thus increased wear of) the polyethylene insert, and unavoidable eccentric loading providing even greater asymmetric glenoid polyethylene wear.[15]

Nevertheless, metal-backed glenoid components for anatomic TSA had somewhat of a recent resurgence because of the very successful experiences surgeons had with uncemented, metal-backed glenoid baseplates as the foundation for the glenosphere in reverse shoulder arthroplasties.[3,25] In addition, there have been improvements in metal-backed glenoid design and fixation[20,25] based on metal-backed implants that have enjoyed success in other joints (hips, knees).[30,31,46] In addition, metal-backed components that are stable and ingrown can allow successful, efficient, and safe conversion of a failed anatomic TSA to reverse shoulder arthroplasty (RSA) by simple exchange of modular glenoid components. Castagna et al (2010) published excellent mid-term results using a metal-backed glenoid component in 35 consecutive anatomic TSAs; they had no instances of glenoid component loosening, no instances of polyethylene-glenoid dissociation, and no glenoid implant–related complications.[8] However, other surgeons have not endorsed this resurgence of metal-backed glenoid components for anatomic shoulder arthroplasty. Boileau et al (2015) suggested that metal-backed glenoid implants with a polyethylene insert are not a viable long-term therapeutic option in their multicenter study of 165 patients showing only a 46% survival rate at 12 years.[4] Based on their combined experiences, these authors suggested that metal-backed glenoid components with polyethylene inserts will invariably lead to high rates of complications and revisions. In addition, Page et al recently reported the Australian Orthopaedic Association National Joint Replacement Registry's findings of a statistically higher revision rate of over 10,000 primary shoulder arthroplasties at only 5 years with cementless, metal-backed glenoid components vs. cemented, all-polyethylene glenoid components (17.9% vs. 3.7%, respectively).[1] Given that metal-backed glenoid components continue to produce unpredictable results in anatomic TSA, all-polyethylene glenoid components continue to be the preferred implant design with anatomic TSA. These implants, however, continue to generate concern as aseptic glenoid loosening remains an important cause of failure in primary anatomic TSA.[6]

A new, unique, modular glenoid component design has been developed (Lima Corporate, IT) to address the challenges of glenoid component fixation as well as the anticipated challenges of revision arthroplasty. It is a hybrid glenoid prosthesis with a primary polyethylene component and a central, trabecular titanium peg. The polyethylene-bone interface is maximized, particularly in the peripheral aspects of the glenoid where glenohumeral contact and stresses are greatest.[34] The superior and inferior pegs of the polyethylene component are cemented which idealizes the modulus of elasticity differences between native bone and implant just as with traditional cemented, all-polyethylene glenoid components. The press-fit, central, trabecular titanium peg provides exceptional initial fixation and allows for bony ingrowth, which minimizes long-term glenoid loosening and associated glenoid bone loss due to a mechanical, rocking mechanism. This innovative modular hybrid glenoid component also allows efficient, safe, and successful revision by allowing maintenance of the well-fixed, trabecular titanium central peg as the foundation for the glenoid baseplate and glenosphere components of a RSA. This implant design simplifies glenoid revision when converting from an anatomic TSA to RSA, leading to shorter duration of surgery, lower intraoperative blood loss, and decreased risk of glenoid vault defects that can result from extraction of the glenoid component of a failed anatomic TSA. It is the subject of this case series to describe the surgical technique

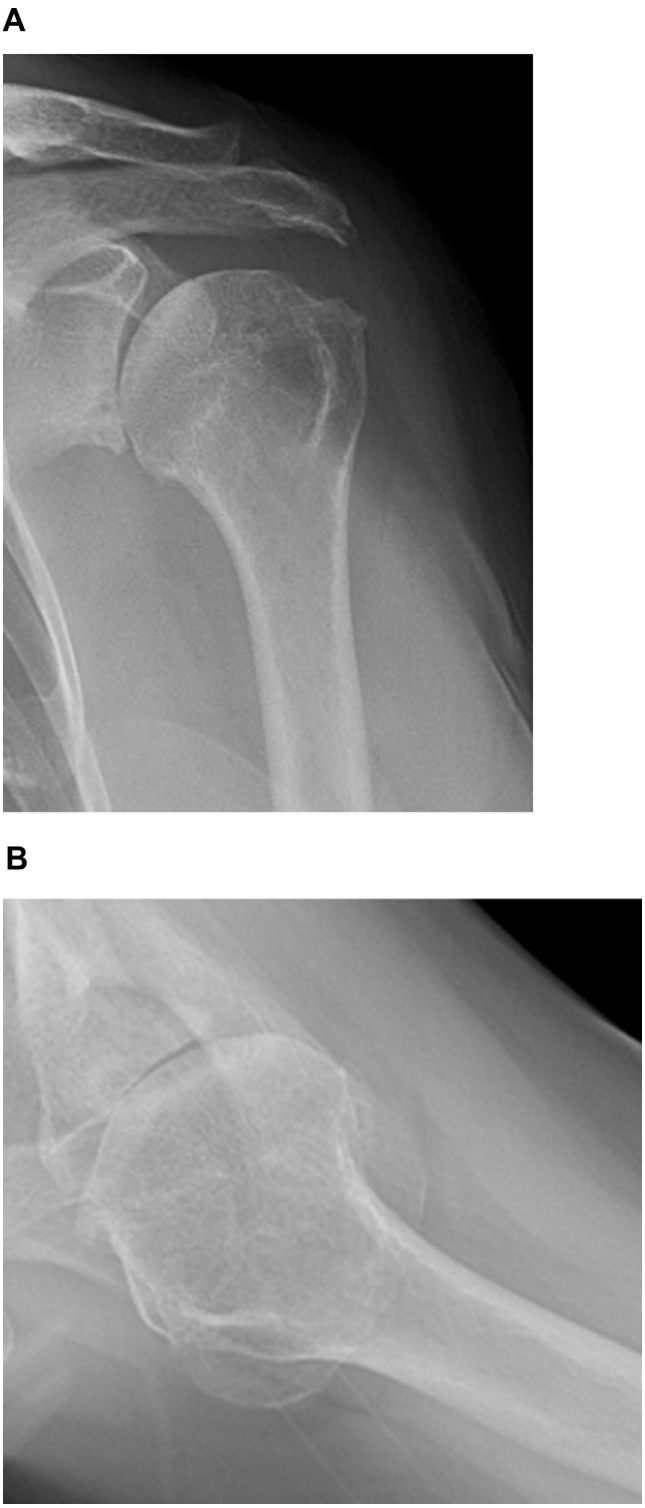

Figure 1 (**A**) Anteroposterior and (**B**) axillary radiographs of the left shoulder demonstrating degenerative changes consistent with primary osteoarthritis.

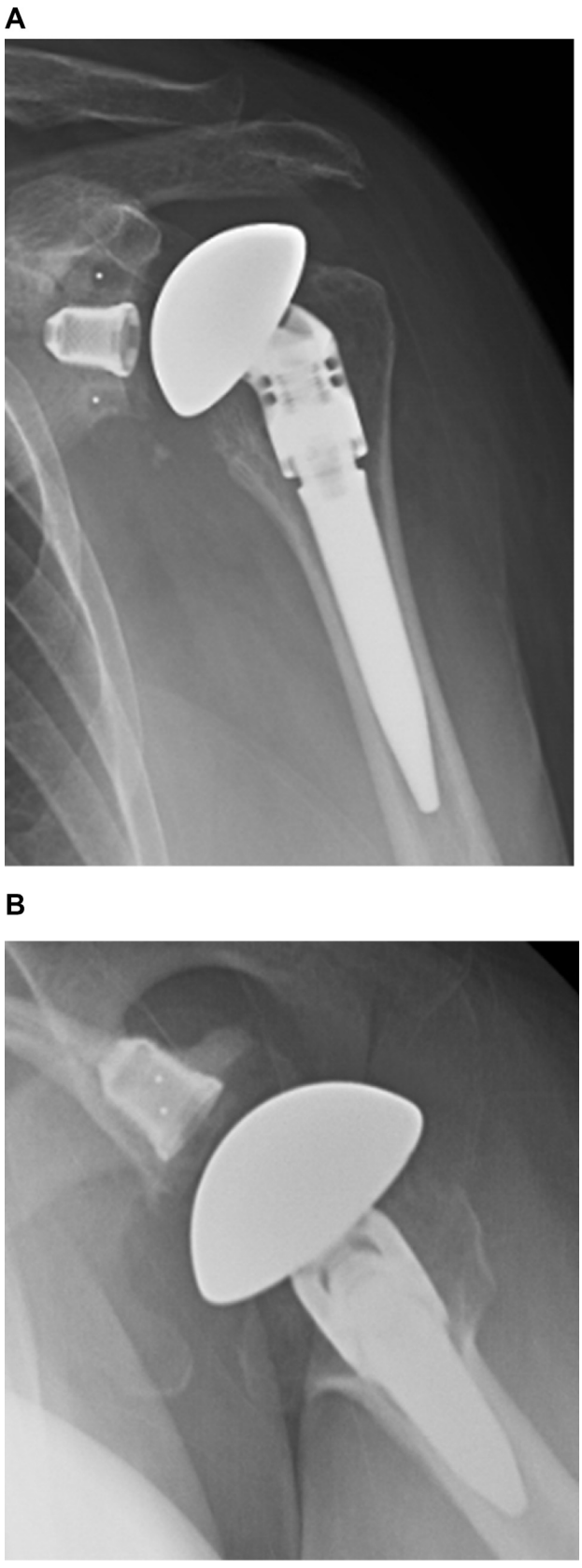

Figure 2 (**A**) Anteroposterior and (**B**) axillary postoperative radiographs of the left shoulder after anatomic total shoulder arthroplasty showing stable implants in anatomic position.

used and report preliminary clinical results of conversion of failed anatomic TSA, due to traumatic rotator cuff failure, to RSA using this modular hybrid glenoid component

Methods

From July 2017 to December 2019, 84 consecutive anatomic TSA procedures were performed for various arthritic conditions of the shoulder by the senior author utilizing a modular humeral arthroplasty system and a unique hybrid glenoid component. Three cases (3/84, or 3.6%) required conversion from anatomic TSA to RSA because of postoperative traumatic rotator cuff failure at an average of 9 months (range, 6-12 months) after the index procedure. Primary anatomic TSA failure due to postoperative rotator cuff failure was diagnosed via physical examination and postoperative radiographs showing anterior-superior escape in all three patients. All patients were noted to have intact rotator cuffs at the time of their index procedure, and all had achieved excellent clinical results thereafter before their falls and traumatic rotator cuff avulsions. Average preoperative American Shoulder and Elbow Surgeons scores, visual analog scores (VAS), and active forward flexion outcome scores were compared with postoperative outcome scores in the three modular revision patients. In addition, operative time, intraoperative blood loss, and hospital length of stay (LOS) were analyzed for all three of these modular revision procedures and compared with 16 recent revisions of anatomic TSA to RSA performed by the same senior author between 2014 and 2020 where modular components were not utilized and removal and revision of both humeral and glenoid components were required. Paired Student's *t*-test was used to compare normally distributed continuous variables with significance established as an alpha value of .05 or less using SPSS software (ver.22.; IBM, Armonk, NY, USA).

A representative case of conversion from anatomic TSA to RSA using modular humeral and hybrid glenoid components is described in the following:

A fifty-nine-year-old woman (5'3 ft., 123 lbs., 22 body mass index) with end-stage left shoulder osteoarthritis (Fig. 1 *A* and *B*) was treated with anatomic TSA using modular humeral and hybrid glenoid components (Fig. 2 *A* and *B*). Index procedure was uncomplicated; rotator cuff was noted to be a bit "thin" superiorly, but intact throughout. Primary anatomic TSA is indicated when partial tearing is limited to less than 25% of the tendon thickness on the bursal or articular side. The patient did very well postoperatively, achieving complete relief of her pain, 150 degrees of active forward flexion, 45 degrees of active external rotation, and active internal rotation to L1. Rotator cuff strength testing was intact throughout, including subscapularis testing. Eight months postoperatively, the patient fell down several steps, landing on her outstretched arm. She experienced a tearing sensation in her shoulder and was noted to have anterosuperior instability of the shoulder with attempts to elevate her arm. She had no ability to actively elevate her shoulder, was weak with external rotation, and had abnormal lift off and modified lift off tests. Radiographs showed anterosuperior subluxation of the humerus relative to the glenoid, but no changes to the implants; the position of the central peg of the glenoid was stable, and there were no radiolucencies (Fig. 3 *A* and *B*). She returned to the operating room 9 months after her index procedure where the upper two-thirds of the subscapularis and entire supraspinatus and infraspinatus tendons were noted to be avulsed. Implants were very well fixed, including the central glenoid peg, and conversion to an RSA was uncomplicated. She is now approximately 22 months out from her revision procedure; she has no shoulder pain, 140 degrees of active forward flexion, and 40 degrees

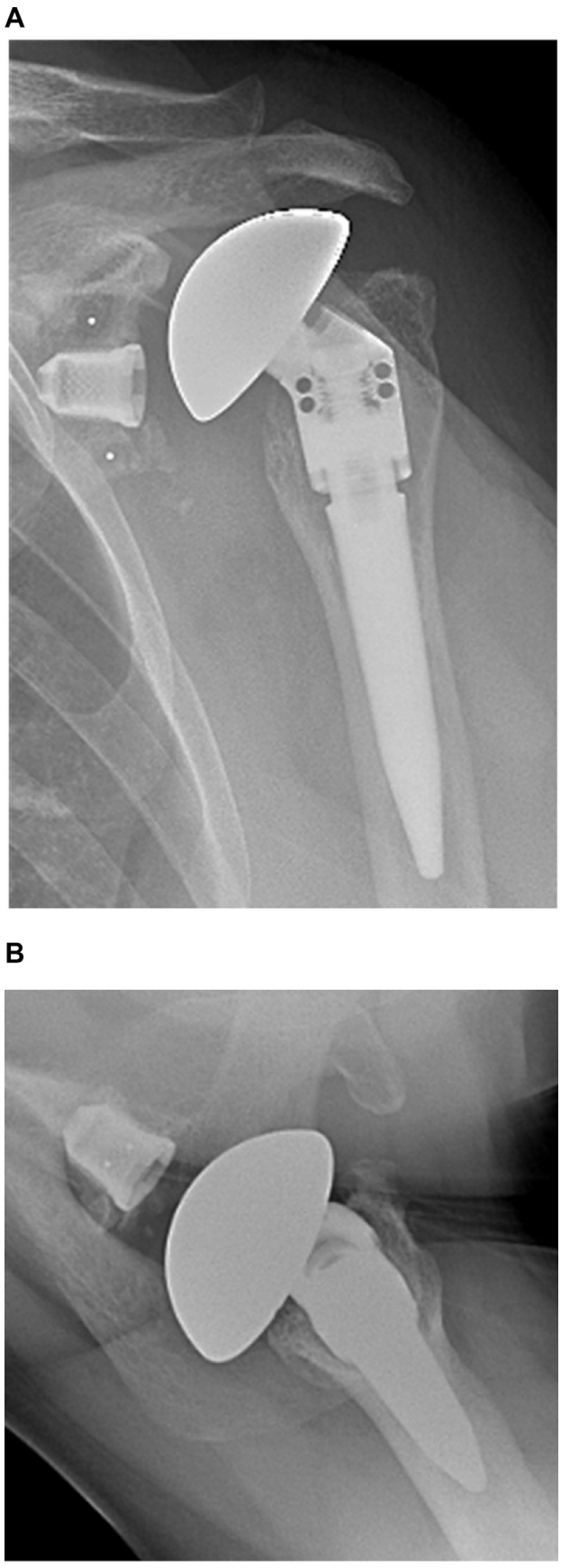

Figure 3 (**A**) Anteroposterior and (**B**) axillary radiographs of the left shoulder after a traumatic fall causing an acute injury to the rotator cuff leading to anterosuperior migration of the humeral component compared with previous imaging.

of active external rotation and active internal rotation to the side. Postoperative radiographs show no humeral or glenoid lucencies, several millimeters of the glenosphere rotated inferior to the lateral scapular neck, and benign implant-bone interfaces (Fig. 4 *A* and *B*).

Surgical technique and findings

All primary shoulder arthroplasty procedures performed by the senior author are performed through an anterior deltopectoral approach and use a subscapularis tendon "peel", circumferential subscapularis mobilization, and subsequent two-layered subscapularis repair to the lesser tuberosity at the conclusion of the procedure. All revision procedures were performed through the same deltopectoral approach as the primary procedure (Video 1). All three patients were noted to have traumatically avulsed the

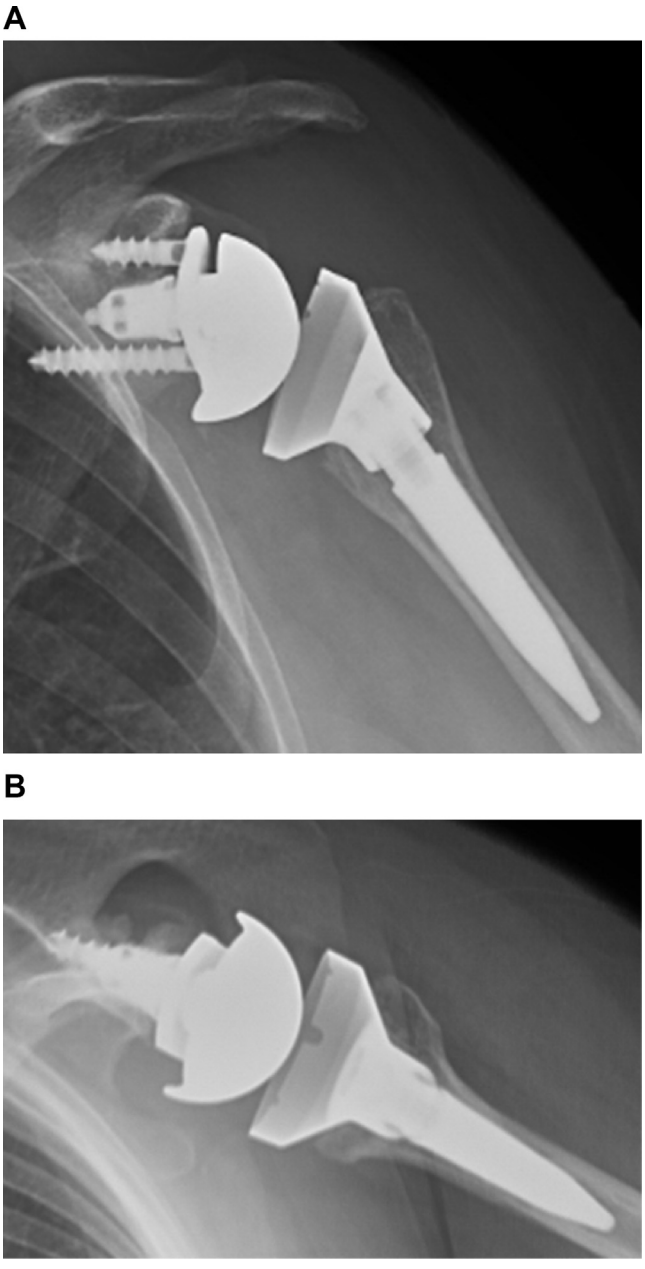

Figure 4 (**A**) Anteroposterior and (**B**) axillary postoperative radiographs after modular conversion of failed anatomic TSA to RSA. *TSA*, total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasty.

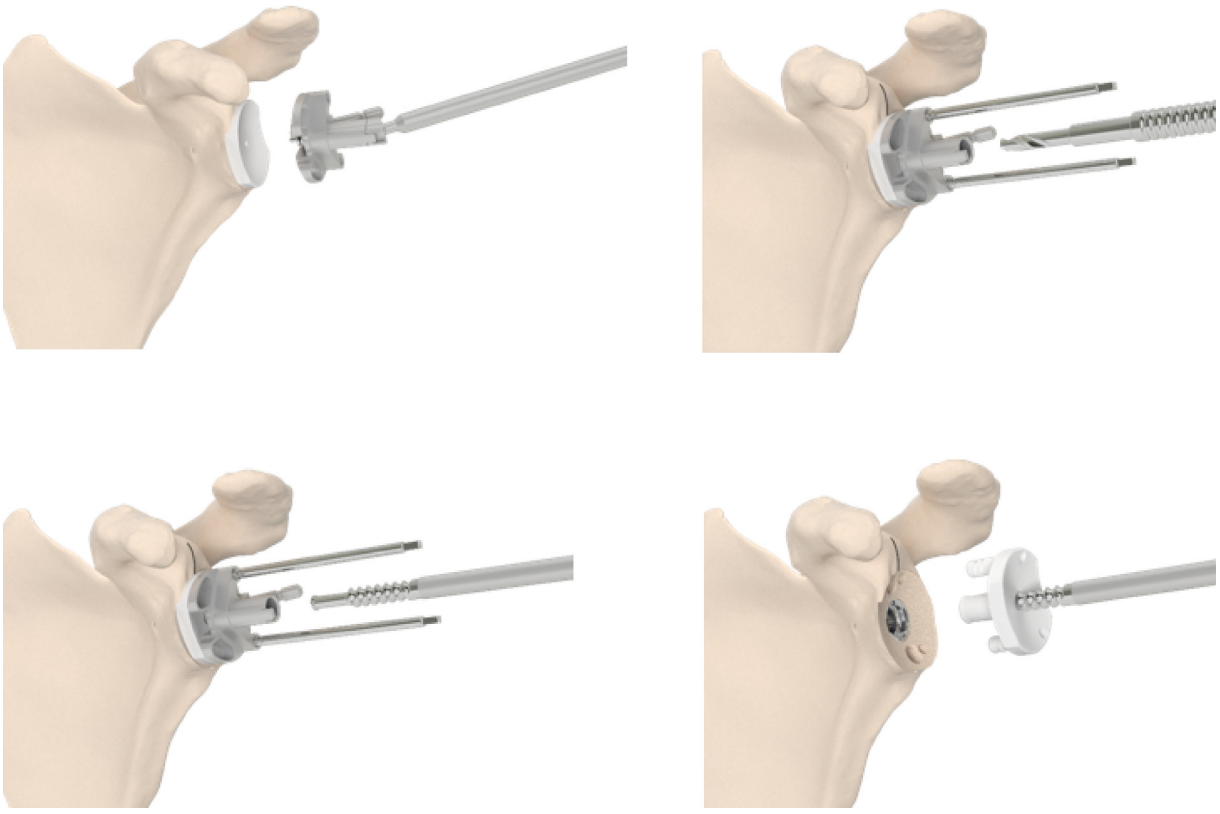

Figure 5 Surgical technique for efficient removal of the polyethylene component of the hybrid implant while leaving the central trabecular titanium peg in place within the central glenoid.

superior aspect of the subscapularis tendon insertion and the entire supraspinatus and entire infraspinatus tendons; the teres minor tendon was intact in all patients. There was no loosening or objective pathology noted to the humeral or glenoid components. After removal of the modular humeral head, the proximal body of the humeral implant was atraumatically removed from the humeral stem components with a dedicated instrument to release the taper; all humeral diaphyseal stems were well fixed and were retained.

After glenoid exposure was maximized circumferentially, the glenoid component was noted to be intact in all cases and very secure to manipulation. The polyethylene component of the hybrid glenoid was then removed from the trabecular titanium central peg using dedicated instruments: a drill guide was centered and fixed to the polyethylene with threaded pins, a drill was passed through the guide to disrupt the central polyethylene peg locking mechanism, and a reverse cork-screw extraction device atraumatically removed the polyethylene components (Fig. 5). The central, trabecular titanium peg was noted to be well fixed and ingrown to the native glenoid bone in all cases, completely stable to intraoperative stress in axial compression, distraction, and rotation. After clearing debris from the central peg, this central peg was used as the foundation for the reverse metal-backed baseplate as the baseplate was inserted into the central peg and stabilized by the Morse taper and two 6.5-mm compression screws were inserted through the superior and inferior aspects of the baseplate for additional compression and rotational stability. Excellent purchase with these screws was achieved as they traversed the portion of the glenoid that had been previously cemented. An eccentric glenosphere was then inserted into the baseplate, rotated appropriately to extend slightly inferior to the inferior neck of the scapula, and secured with gentle impaction and a locking screw.

The reverse metaphyseal portion of the humeral component was placed in approximately 10 degrees of retroversion and secured to the retained well-fixed diaphyseal humeral stem. Trial spacers and liners were tested before final spacers and polyethylene liners were chosen to ideal periprosthetic tension; they were implanted in the standard fashion, and the prosthesis was reduced. The subscapularis tendon was repaired back to the lesser tuberosity with transosseous sutures.

Table I
Summary of visual analog scale (VAS), American Shoulder and Elbow Surgeons score (ASES), and active forward flexion (FF) values in modular hybrid conversion of anatomic TSA to RSA patients before and after revision surgery.

Variable/Outcome	Average preoperative value (range)	Average postoperative value (range)	*P* value
VAS	6.3 (5-7)	1.3 (0-3)	.01*
ASES	32.2 (26.7-41.3)	76.2 (58.3-92.0)	.02*
Active FF (degrees)	73 (30-110)	152 (140-170)	.04*

TSA, total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasty.
*denotes significance.

Results

The three patients who are the subject of this review were followed for an average of 24 months (range, 22-26 months). All three revision patients experienced significant clinical improvements in pain, range of motion, and patient-reported outcome scores compared with preoperative values. VAS scores significantly improved from an average of 6.3 preoperatively (range, 5-7) to 1.3 postoperatively (range, 0-3) ($P = .01$). Average active forward flexion improved from 73 degrees preoperatively (range, 30-110) to 152 degrees postoperatively (range, 140-170) ($P = .04$). American Shoulder and Elbow Surgeons scores significantly improved from an average of 32.2 preoperatively (range, 26.7-41.3) to an average of 76.2 postoperatively (range, 58.3-92.0) ($P = .02$). These outcomes are summarized in Table I.

The average operative time from incision until the conclusion of subscapularis tendon repair in these three modular revision procedures was 77 minutes (range, 65-95 minutes). The average operative time from incision until conclusion of the entire procedure was 109 minutes (range, 92-134 minutes) in the modular conversion group compared with 154 minutes (range, 107-201 minutes) in the comparative group where modular components were not present ($P = .02$) (Fig. 6). There were no intraoperative or postoperative complications, particularly no instances of intraoperative glenoid bone destruction or loss. The average estimated blood loss was 183 cc (range, 100 cc-300 cc) in the modular revision group compared with 500 cc (range, 100 cc-2,100 cc) in the comparative nonmodular revision group ($P = .08$) (Fig. 7). The average LOS was significantly longer in the nonmodular revision group at 36.6 hours (range, 21-89 hours) than that in the modular revision group of 26.3 hours (range, 26-27 hours) ($P < .05$) (Fig. 8).

The postoperative radiographs of the three modular revisions showed appropriate implant position, stability, and continued appearance of a stable bone/central peg interface as well as the position of glenosphere relative to the lateral scapula to avoid notching.

Discussion

The early results of this small case series of revision from anatomic TSA to RSA using modular humeral and hybrid glenoid components are very promising. All revision procedures were performed very efficiently and without intraoperative complications relative to the modular revision of a well-fixed, hybrid glenoid component to a glenosphere, and there were no baseplate failures or other implant-related or clinical complications observed at a mean follow-up of 24 months.

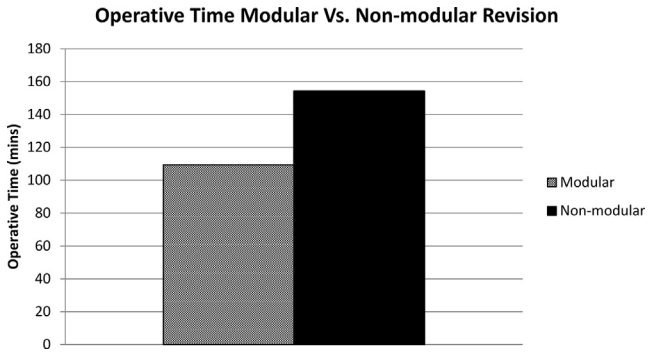

Figure 6 Difference in operative time (measured in minutes) between modular conversions of hybrid anatomic TSA to RSA vs nonmodular anatomic TSA to RSA revision. *TSA*, total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasty.

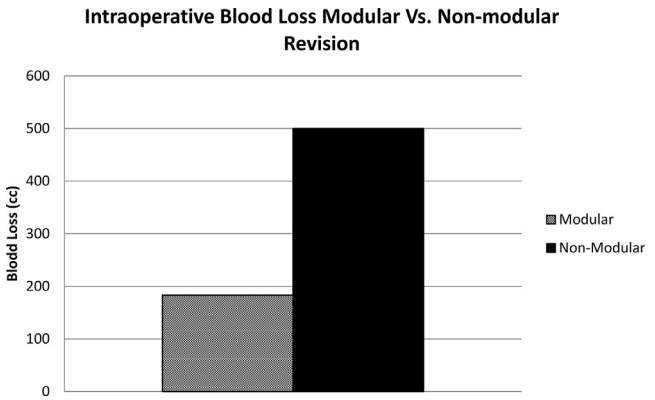

Figure 7 Difference in intraoperative blood loss (measured in cc's) between modular conversions of hybrid anatomic TSA to RSA vs nonmodular anatomic TSA to RSA revision. *TSA*, total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasty.

Rotator cuff dysfunction and failure has become an increasingly recognized cause of failure after anatomic shoulder arthroplasty, potentially replacing aseptic glenoid component loosening as the most common reason for revision after anatomic TSA.[18,45] It is our opinion that improved glenoid fixation at the implant-bone interface, as well as improvements in the material properties of newer glenoid implants, continues to decrease the overall incidence of aseptic glenoid loosening which has played an important role in the paradigm shift of rotator cuff dysfunction replacing glenoid failure as the primary cause of failure after primary anatomic TSA. Secondarily, we believe surgeons have become more aware of cuff dysfunction as a possible cause of failed primary anatomic TSA and, thus, are most astute at diagnosing this condition postoperatively. The Australian National Joint Registry reported on over 10,805 anatomic TSAs performed for primary osteoarthritis. Cuff insufficiency was the reason for revision in 28.2% of cases, constituting the main cause of failure after anatomic TSA, whereas glenoid loosening was responsible for 7.3% of all revisions. The second most common cause of revision was dislocation/instability with 24.3%. These instability cases are often related to cuff insufficiency or dysfunction.[36] Levy et al (2016) found 30% proximal humeral head migration in a systematic review on 1338 shoulders from 15 studies, with “nearly all studies” reporting indirect markers of rotator cuff dysfunction.[29] Secondary rotator cuff dysfunction after anatomic TSA leads to inferior outcomes, and attempts to repair the deficient rotator cuff after anatomic are unpredictable , and can lead to poor clinical results.[22] Thus, when rotator cuff dysfunction occurs, either via traumatic or progressive atraumatic failure to the point where pain and/or functional limitations dictate further intervention, revision to RSA is often indicated, and doing so in the setting of a cemented, all-polyethylene glenoid component presents unique surgical challenges. If the glenoid component is loose, mechanical rocking can lead to significant structural glenoid bone loss that makes revision difficult, glenoid bone grafting necessary, and surgical results inconsistent.[35] If the cemented, all-polyethylene component is well-fixed, its removal at the time of revision to RSA is also difficult and can lead to glenoid bone destruction in the process, especially in the setting of compromised glenoid bone quantity and quality.[42] Common experiences have shown this to be true as the removal of a well-fixed glenoid component is a tedious, time consuming, and difficult process. It is important to note that all three of the patients in our hybrid revision cohort required revision because of rotator cuff failure as a result of trauma.

The number of anatomic TSA procedures continues to grow, and novel implant designs have led to improved glenoid survivorship.[14]

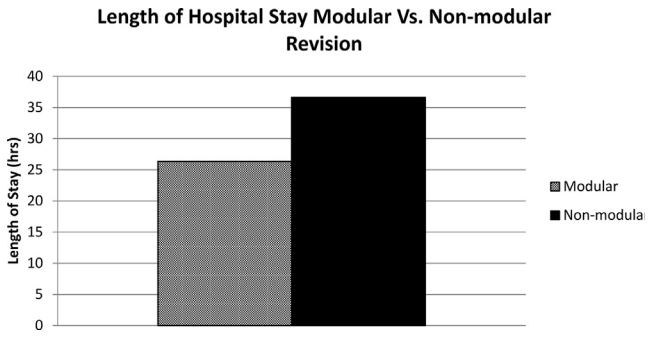

Figure 8 Difference in the length of hospital stay (measured in hours) between modular conversions of hybrid anatomic TSA to RSA versus non-modular anatomic TSA to RSA revision. *TSA*, total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasty.

Recent advances, aimed to decrease the incidence of aseptic glenoid loosening, include the development of hybrid glenoid components which are characterized by press-fit central glenoid stems with peripherally cemented pegs (Zimmer TM, Biomet Comprehensive, Tornier Aequalis Perform, Exactech Equinoxe, Depuy Anchor).[7,13,28,41] None of these designs, however, are modular; it is necessary in all of these designs to remove the entire glenoid component to change the implant configuration from anatomic to reverse in cases of cuff failure, a procedure that is cumbersome and can result in a considerable amount of glenoid bone loss during the extraction process.

Modularity on the humeral side has grown in popularity to aid with convertibility from an anatomic TSA to RSA. Humeral modularity has become a common design feature for most humeral stems in anatomic shoulder arthroplasty systems as modular humeral implants have the potential to make revision surgery easier, safer, and potentially more successful. Crosby et al (2017) showed in a consecutive series of shoulder arthroplasties requiring revision that retention of a modular humeral stem significantly reduced operative time, blood loss, and intraoperative complications as well as improved postoperative range of motion vs cases that required complete stem removal and revision.[12] Similarly, Cisneros et al evaluated 17 revision anatomic TSA to RSA cases that required glenoid revision and removal of a diaphyseal engaging humeral stem vs cases that only required revision of a metaphyseal engaging implant and found that the former group had increased operative times, blood loss, need for transfusion, glenoid bone loss, and intraoperative fractures.[9]

Revisions of anatomic TSA to RSA that require removal of both the glenoid and humeral components result in increased complications, bone loss, operative time, and blood loss.[23,33,43,44] Walker et al reported on a series of 22 patients needing such conversion; 10 were revised for instability without mechanical failure, 9 were revised for instability related to mechanical failure, which is usually secondary to deficiencies of various portions of the rotator cuff, 2 were revised because of infection, and 1 patient underwent surgery for component failure without instability.[43] Of the 22 patients, 7 glenoids were loose, whereas the other 15 required bone grafting to fill the bone defects. Structural allografts for secure baseplate insertion were required in 10 cases, and nonstructural grafts were required in 5 cases. In this series, a complication rate of 22.7% was reported at a minimum follow-up of just 2 years. This study showed a high need for glenoid bone grafting at the time of revision shoulder arthroplasty surgery, which is concerning as they[43] and others have reported a high incidence of complications and glenoid component failure when revision RSA requires glenoid bone grafting for baseplate fixation.[3]

Operative time, blood loss, and hospital LOS play important roles in patient outcomes. Clark et al found that increased operative times in shoulder arthroplasty are associated with a higher incidence of unplanned readmission within 30 days after anatomic TSA and RSA.[10] Kandil et al performed a large database study of 51,191 patients who underwent anatomic TSA and found a blood transfusion rate of 6.1%. They determined that patients who required a blood transfusion had significantly longer hospital stays and total patient encounter charges.[24] The association of revision arthroplasty with longer hospital stays and blood loss requiring perioperative blood transfusions has been described by several authors.[21,26] Both a longer hospital stay and the need for a blood transfusion are risk factors for surgical site infection after anatomic TSA.[27] Given these findings, it is important to try and minimize intraoperative blood loss, operative time, and length of hospital stay in the setting of revision shoulder arthroplasty. The technology specific to the modular, hybrid glenoid implant described in this series, along with the use of a modular humeral stem, allows for safe and efficient revision of failed anatomic TSA to RSA.

This study has several limitations including a small sample size and relatively short-term follow-up. The short-term follow-up of hybrid revisions is due to the novelty of this implant and its only recent adoption and clinical application. Another weakness of this study is the retrospective nature of the analysis performed using prospectively collected data. The inclination and relative position, superior to inferior in the coronal plane, of the RSA baseplate relative to the glenoid is predetermined by the placement of the original hybrid glenoid component. This is important as inferior tilt and placement were previously recommended when implanting the glenoid implants during RSA to better approximate the RSA angle and prevent scapular notching.[5,17] Recently, these recommendations have come into question as research has shown that increasing the size of the glenosphere adds stability and provides increased offset which decreases notching and maximizes the function of periarticular muscles. In addition, offset glenospheres allow rotation of the glenosphere inferiorly to minimize notching without influencing tilt as recent literature has shown that increasing inferior tilt may actually increase notching and adversely affect the stress distribution on the glenoid component, which may play a role in glenoid baseplate loosening.[37,47] This RSA implant system provides an eccentric glenosphere option which idealizes glenosphere offset and inferior positioning which have been shown to improve postoperative function and decrease scapular notching, respectively.[37,47] Thus, this glenoid component allows the benefits of an efficient and effective modular conversion from anatomic TSA to RSA while also idealizing glenosphere offset and inferior positioning.

Conclusion

The need to convert an anatomic TSA to RSA is often a daunting surgical challenge given this surgery's complexity and potential associated complications, especially related to glenoid component removal and revision in the setting of compromised glenoid bone quality and quantity. Our experience suggests that one is able to perform this revision surgery successfully while decreasing several perioperative complications using the described technique with a modular humeral component and a unique, convertible hybrid glenoid component design in a way that is safe, very efficient, cost-effective, and clinically successful. Furthermore, this technique significantly improves patient-reported outcomes and objective clinical measures of revision of anatomic TSA to RSA at short-term follow-up. These patients and their outcomes will need to be followed further and confirmed at mid- and long-term follow-up.

Disclaimers:

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Conflicts of interest: The senior author (PMC) was involved in the research and development of the convertible, hybrid glenoid component (Lima Corporate, IT) that is the subject of this manuscript. The other authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.xrrt.2021.11.002.

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