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Reverse total shoulder arthroplasty after iatrogenic axillary artery injury: a case report

Daniel R. O'Neill, BS[a], **Joseph J. King, MD**[b], **Kevin W. Farmer, MD**[b,*]

[a]*University of Florida College of Medicine, Gainesville, FL, USA*
[b]*Department of Orthopaedics and Rehabilitation, University of Florida, Gainesville, FL, USA*

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Reverse total shoulder arthroplasty (RTSA) comes with the risk of multiple complications, including glenoid component loosening, hematoma formation, infection, scapular notching, acromial and periprosthetic fractures, and instability.[2] Less common complications, such as neurologic complications and axillary artery thrombosis, have also been reported in the literature.[26] Despite the proximity of the axillary artery and brachial plexus to the glenohumeral joint, which places it at risk of injury, axillary artery or direct brachial plexus injury has very rarely been reported with RTSA. Even more so, if a patient had preexisting trauma to the axillary artery, there is a known risk associated with performing an RTSA as the expected arm lengthening associated with RTSA will place a longitudinal strain on the axillary vessels and brachial plexus,[27] but the magnitude of this risk is unknown. We report a unique case of a patient who sustained an axillary artery injury during shoulder arthroplasty that was aborted after an axillary stent was placed, and the subsequent successful RTSA.

Case report

A 71-year-old right-hand–dominant man with a medical history of hyperlipidemia and hypertension was scheduled for a right anatomic total shoulder arthroplasty (TSA) at an outside hospital as a result of extensive degenerative joint disease confirmed with radiographs (Fig. 1, *A*) and magnetic resonance imaging (Fig. 1, *B*). During the original planned right TSA using the deltopectoral approach, the humeral head cut was made with an oscillating saw and completed with an osteotome. Significant bleeding was noted following retractor removal after the humeral head osteotomy. After multiple unsuccessful attempts to control the bleeding, concern that the axillary artery was compromised prompted an intraoperative vascular surgery consultation that revealed an axillary artery laceration. Vascular surgery directly placed a Gore-Viabhan stent graft to repair the axillary artery measuring 50 mm, and hemostasis was obtained. After integrity of the axillary artery was achieved, both orthopedic and vascular surgery made the decision to stop the procedure, as the retraction of the humerus during glenoid reaming and the stress on the humerus during humeral broaching could further compromise the axillary artery and the newly placed stent. The incision was closed with plans to complete the procedure after vascular surgery deemed the patient at appropriate risk for shoulder arthroplasty.

Postoperatively the patient was placed on dual anticoagulation therapy of acetylsalicylic acid 81 mg and clopidogrel 75 mg daily. The patient had normal distal pulses in the right extremity postoperatively, but had new complaints of consistent lateral forearm paresthesia consistent with a musculocutaneous nerve palsy. His right shoulder pain was a consistent 4/10 in pain severity and reached a maximum 8/10 pain with aggravating factors such as

Institutional review board approval was not required for this case report. Consent was granted from the patient to use his images.

*Reprint requests: Kevin W. Farmer, MD, Division of Sports Medicine, Department of Orthopedics, University of Florida College of Medicine, 3450 Hull Road, Gainesville, FL 32607, USA.

E-mail address: farmekw@ortho.ufl.edu (K.W. Farmer).

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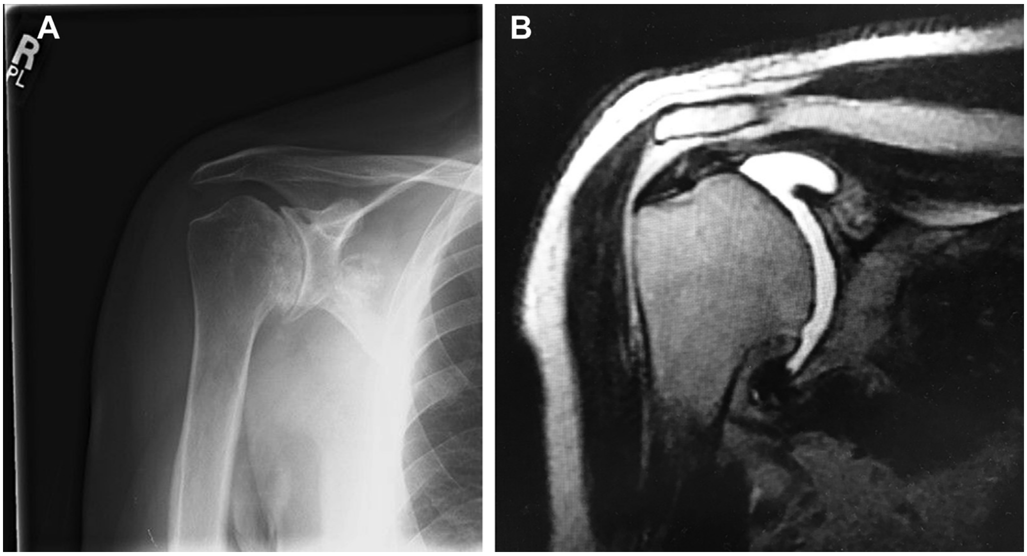

Figure 1 (**A**) Grashey radiograph of the right shoulder showing significant glenohumeral osteoarthritis. (**B**) Coronal magnetic resonance image of the right shoulder showing significant arthritis and an intact supraspinatus tendon.

lifting, reaching, pushing, and pulling. Three months after his original planned surgery, there was no change in his pain, paresthesia, and limited range of motion, but surgery was continually delayed for fear of compromise to the axillary artery stent integrity during a revision procedure.

The patient was seen at our institution for a second opinion regarding completion of the shoulder arthroplasty due to his continued pain and dysfunction. The patient had continued complaints of right shoulder pain and paresthesia in his right lateral forearm with elbow flexion weakness correlating to his musculocutaneous nerve injury.

On physical examination, his prior incision was healed without erythema. His radial pulse was present and equal bilaterally. There was radiating pain down his right medial upper arm with a decreased sensation on the right lateral forearm in the musculocutaneous nerve distribution. His range of motion showed active abduction 80°, active forward flexion 80°, and external rotation 70°; internal rotation at 90° of abduction was 60. His muscle strength was 3/5 in abduction, internal rotation, external rotation, forward flexion, and biceps flexion limited due to pain.

Right shoulder radiographs show the proximal humerus with the head previously resected, irregular medial calcar bone suggesting further progressive loss of the medial humeral calcar, a large loose body visible within the subscapularis recess, and a stent placed along the axillary artery course (Fig. 2). A computed tomographic scan appreciated these findings, showing that the axillary artery stent was in place with no evidence of collapse (Fig. 3, *A* and *B*). A 3-dimensional computed tomographic scan showed that the most medial edge of the cut humerus was 15 mm from the stented axillary artery and 15.6 mm from the anterior glenoid rim (Fig. 4, *A* and *B*).

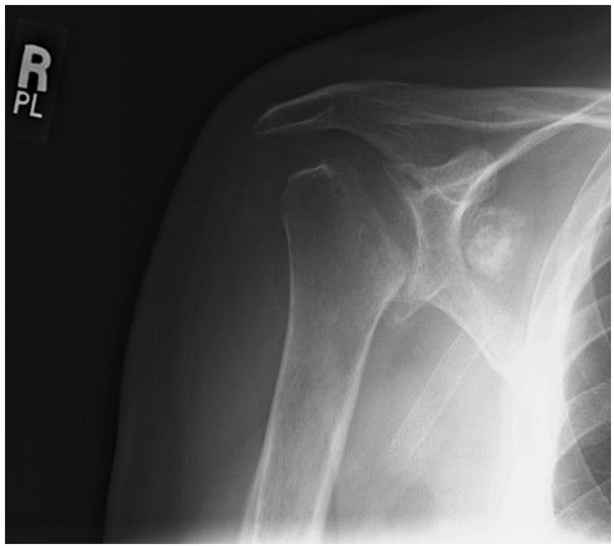

Figure 2 Grashey radiograph of the right shoulder after attempted shoulder arthroplasty with axillary artery stent.

Nonoperative and operative options were explained to the patient; after much discussion about the risks of axillary artery stent compromise from the arm lengthening as well as retraction that occurs during an RTSA, the patient elected to pursue right shoulder revision surgery. The plan was to perform an RTSA vs. hemiarthroplasty depending on the intraoperative findings.

RTSA revision was performed 6.5 months after the initial attempted shoulder arthroplasty. A cervical paravertebral catheter was placed and general anesthesia was administered. The deltopectoral approach was used via the previous incision. The rotator cuff had a full-thickness tear in the supraspinatus and infraspinatus tendons, with an

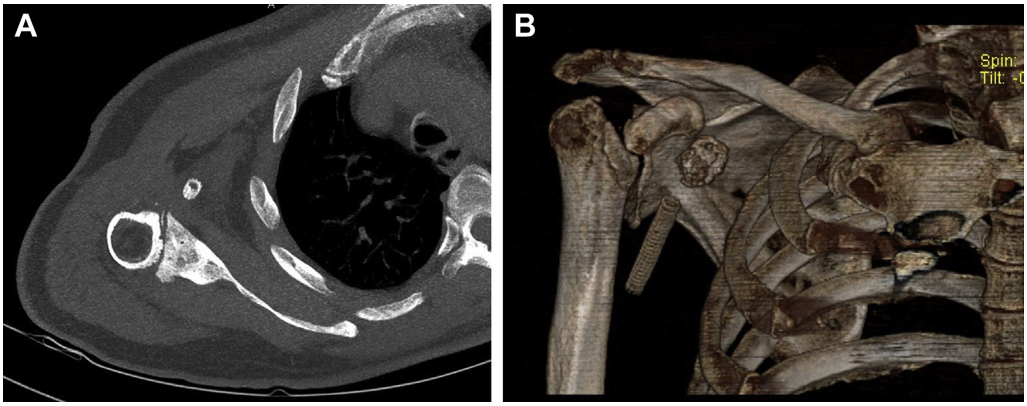

Figure 3 (**A**) Axial view of noncontrast CT of the right shoulder showing the proximity of the axillary artery stent to the glenohumeral joint. (**B**) Three-dimensional CT image of the right shoulder showing the humeral cut and axillary artery stent. *CT*, computed tomography.

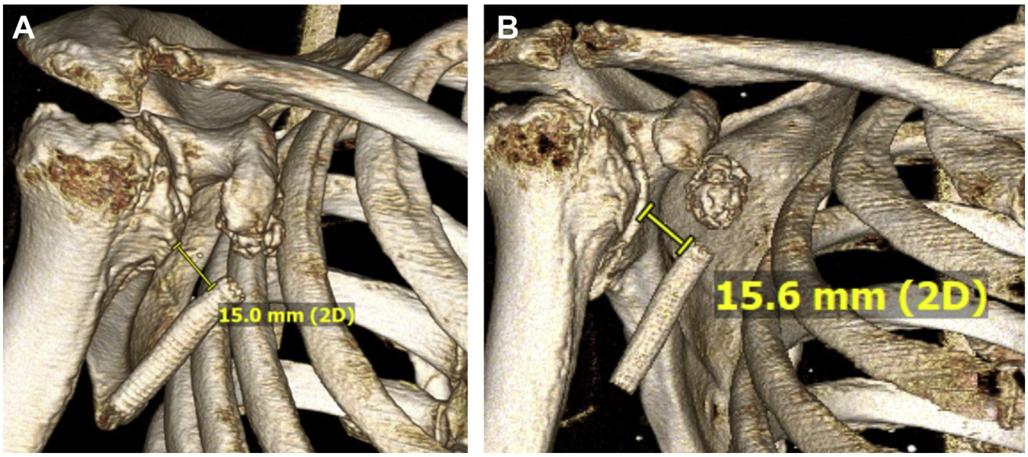

Figure 4 Three-dimensional rendered image of a computed tomographic scan before reverse total shoulder arthroplasty revision. (**A**) Distance between the humeral cut and the axillary artery stent. (**B**) Distance between the anterior glenoid rim and the axillary artery stent.

intact teres minor and subscapularis that had healed from a previous repair. Subscapularis peel was performed along with a capsular release off of the humerus with sequential external rotation and extension of the humerus to gain adequate exposure. The previous proximal humerus osteotomy was freshened with an oscillating saw after the appropriate retractors were placed protecting the anteromedial structures, to the level of the supraspinatus insertion (removing as much bone as possible to avoid overlengthening of the humerus) at approximately 25° of retroversion. An attempt to remove the loose body in the subscapularis recess was performed, but, given its proximity to the axillary artery (proximal to the zone of prior injury, see Fig. 3, *B*) and scarring from prior surgery, removal of the loose body was abandoned.

The proximal humerus was retracted in a posteroinferior direction to the glenoid, while bringing the arm into neutral flexion and external rotation after the appropriate glenoid retractors were placed. The glenoid baseplate and glenosphere were placed without difficulty. The humerus was then reamed and broached. After humeral trialing, the final component was press fit with appropriate counterpressure on the humerus. The implant used was an Exactech Equinoxe implant (Exactech, Inc., Gainesville, FL, USA) with a standard caged glenoid baseplate to allow for appropriate overhang, 38-mm glenosphere, and standard-length humeral stem. The smallest glenosphere was chosen to avoid excessive arm lengthening through the glenosphere as well as increased humeral lateralization seen with the lateralized or larger glenosphere options. Subscapularis repair was attempted in order to act as a buffer between the proximal humerus and axillary contents during range of motion, but because of poor compliance and scarring of the subscapularis tendon, repair was not possible in this case. Hemostasis was at no point compromised during the surgery, and the patient's radial pulse was palpable at the termination of the procedure.

Immediate postoperative radiographs showed the RTSA in adequate alignment and no changes to the axillary stent (Fig. 5). Pulses were monitored sequentially for the first 24 hours after surgery. On the day of discharge, the patient had a palpable radial pulse and was neurologically intact except for continued decreased sensation along his lateral forearm. The patient used a shoulder abduction sling for 6 weeks

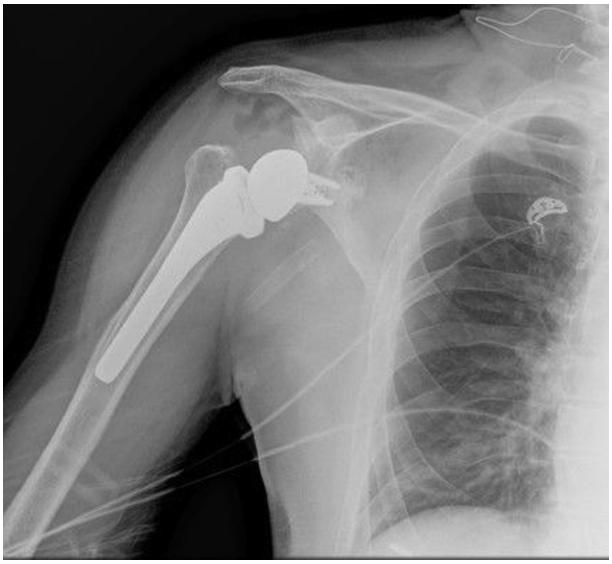

Figure 5 Immediate postoperative anteroposterior radiograph of the right shoulder after reverse total shoulder arthroplasty revision.

postoperatively and started a home-taught physical therapy exercise program beginning 2 weeks postoperatively. At his 3-month postoperative visit, the patient had followed the home exercise program appropriately and improved enough to resume recreational activities, including golf. He expressed 0/10 pain in his right shoulder with significant improvement of his right arm paresthesia. Two years postoperatively, the patient continued to have no pain, no complications with his existing axillary stent, and significant improvement in right shoulder strength and function. On physical examination, he had equal and present radial pulses on both extremities with no signs of vascular compromise. His active forward flexion was 150° and active abduction was 140°, which were only 15° less than in his contralateral shoulder (Fig. 6). His strength in the scapular plane was better in the right shoulder compared to the left shoulder (23 vs. 20 pounds) and his external rotation strength was good, but less than his left shoulder (20 vs. 24 pounds) measured with a dynamometer. His Constant score was 85 (normalized Constant score, 96). American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form score was 97 and Simple Shoulder Test score was 12. Postoperative radiographs showed no hardware complication, and the stent was present without any concerning features (Fig. 7, *A* and *B*).

Discussion

To our knowledge, no other cases have been reported in the literature on placement of an RTSA after a prior axillary artery injury with stent placement. This case demonstrates the severe and extremely rare complication of an acute

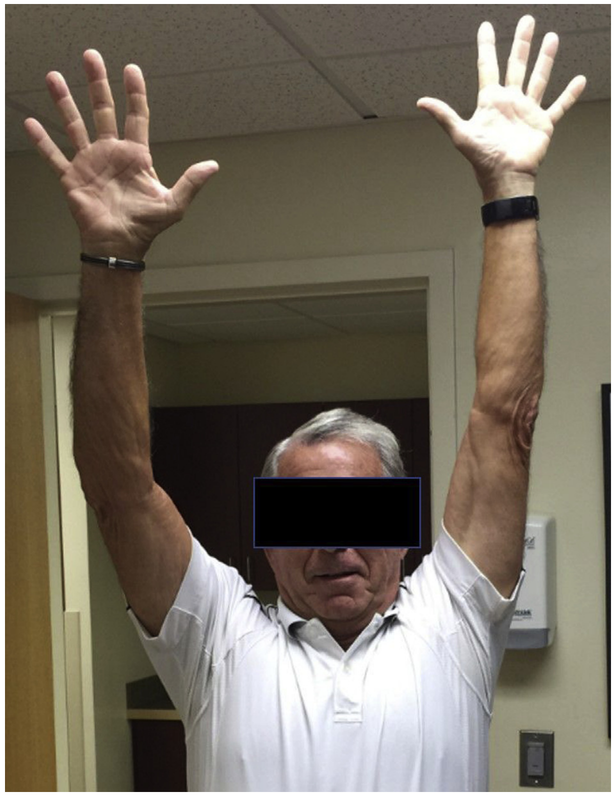

Figure 6 Patient at 2-year follow-up from reverse total shoulder arthroplasty revision.

axillary artery injury occurring intraoperatively during shoulder arthroplasty, and shows that a revision with RTSA is possible despite a prior axillary artery injury with stenting after a careful risk, benefit, and alternative analysis was performed.

The RTSA procedure is becoming more popular among physicians as it has demonstrated good outcomes in pain relief, function, and range of motion in patients with varying types of shoulder arthritis.[6,26] Notwithstanding the increase in popularity, the RTSA is not without risks, including instability, infection, hematoma, mechanical baseplate fracture, periprosthetic fracture, infection, and neurovascular injury.[7,26]

Our main concern in the decision-making process for this patient to undergo a revision to RTSA was the possibility of direct trauma to the axillary artery either with instrumentation or retraction. The axillary vasculature and the brachial plexus are in close proximity to the glenohumeral joint. Both the axillary artery and the brachial plexus originate in the posterior triangle of the neck, bound by the clavicle as well as the muscles of the trapezius and sternocleidomastoid muscles. They enter the axilla deep in the pectoralis minor muscle and run 5-20 mm medial to the anterior glenoid rim; their proximity makes them susceptible to injury from shoulder trauma as well as surgery involving the glenohumeral joint.[17,23,24] This is consistent

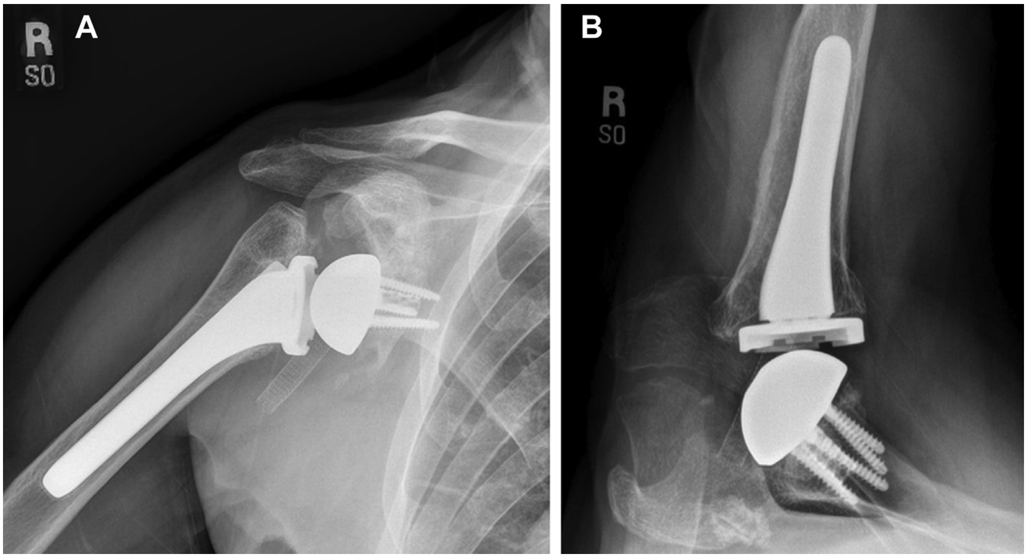

Figure 7 (**A**) Grashey and (**B**) axillary radiograph of the shoulder 2 years post-RTSA revision.

with this study, which showed that the axillary artery was 15.6 mm from the anterior glenoid rim and 15 mm from the anteromedial humerus.

The axillary artery, in general, can be injured via trauma, iatrogenically during surgery, and from complications postoperatively. Traumatic injuries of the axillary artery are comparatively infrequent and represent 15%-20% of all upper limb arterial injuries. Of the traumatic injuries, 94% are due to penetrating wounds,[22,29] with the remaining 6% due to proximal humerus fractures[4,16,18,25,28] and anterior shoulder dislocation.[10,11,20,22] Patients who are older than 50 have shown a higher disposition to axillary artery injury after trauma due to accumulated atherosclerosis and decrease in arterial elasticity.[21,26]

Apart from the aformentioned risk factors of the vasculature's proximity to the joint, arterial compromise secondary to the effects of aging, the shoulder arthroplasty procedure also puts the axillary artery at risk. With that understanding, cases of iatrogenic axillary artery injuries during RTSA or postoperatively are extremely rare. To date, there is 1 known case of direct avulsive trauma to the axillary artery intraoperatively, with 4 known cases of postoperative injury due to etiher thrombosis or occlusion.[3,8,26,27] In all case reports, it is suggested that the forces placed on the axilla from the intraoperative shoulder position or the placement of retractors were the main culprits for injury. Bents et al[3] stated that the procedure's torsional forces placed on the vasculature were similar to that of an anterior shoulder dislocation. Wingert et al[27] described a case of axillary artery avulsion during RTSA due to traction intraoperatively. Ghanem et al[8] hypothesized that the delayed axillary artery occlusion after RTSA they reported on was due to intimal injury during the procedure. Lastly, Wilkerson et al[26] proposed a similar hypothesis that the postoperative thrombosis of the axillary artery that they reported occurred from etiher a traction or intimal injury during the procedure. A summary of cases described in the literature is found in Table I**.**

Typical treatment for axillary artery compromise, like all vascular compromise, can be treated conservatively or surgically based on the presentation and associated features. Yagubyan et al[28] state that approximately 10% of patients with acute axillary artery injury are treated conservatively, and this is primarily due to the axillary artery having a robust collateral system of 5 major branches that may be able to support limb viability. When a lacerated or blocked artery is detected, conservative management is unambiguously advised against, as the lowered systolic blood pressure in the limb leads to decreased tissue perfusion pressure and perpetuates limb ischemia; surgical management is therefore recommended.[9]

Recent review of the literature shows that approximately 70% of the patients with acute axillary arterial injury underwent arterial reconstruction by using techniques including end-to-end anastomosis and interposition, bypass grafts with saphenous veins or vascular prostheses, and endovascular treatment including endovascular stent grafts.[5,19,23,28,29] Our patient initially needed a stent graft to stabilize his primary vascular insult, and all of these techniques were used in the known cases of axillary artery injury from shoulder arthroplasty in the literature (Table I).

Our second primary concern was with the prospective problems from tension placed on the vasculature associated with known humeral lengthening that occurs with RTSA. Because the axillary artery is tethered by the subscapular and humeral circumflex arteries, it can be elongated when pulled with humeral retraction during surgery.[1,26] The mean lengthening of the arm, with standard deviation, after an

Table I Review of all reported cases of shoulder arthroplasty induced axillary artery trauma

Case	Age/Sex	Procedure	Complications	Proposed mechanism of injury	Subsequent intervention	Vascular/ Neurologic outcome	Clinical outcome
Wingert 2014[27]	78-yr-old woman	RTSA due to rotator cuff tear arthropathy	Intraoperative axillary artery avulsion	As a result of intraoperative traction during procedure	Unsuccessful primary repair with pericardial patch prompted bypass graft placement	Complete motor and sensory dysfunction of radial, ulnar, and musculocutaneous nerves 6 mo postoperatively	Unknown
Bents 2011[3]	59-yr-old woman	Humeral resurfacing arthroplasty due to osteoarthritis	Axillary artery occlusion recognized immediately postoperatively	Torsional forces placed on the vasculature from arm position intraoperatively	Retrograde balloon thrombectomy, arterial thrombus removed	Normal neurovascular examination 1 yr postoperatively	Great pain relief 1 yr postoperatively
Bents 2011[3]	64-yr-old woman	Humeral resurfacing arthroplasty because of osteoarthritis	Occlusion of axillary artery recognized postoperative day 1	Torsional forces placed on the vasculature form arm position intraoperatively	Unsuccessful balloon thrombectomy necessitated a reverse saphenous vein bypass graft	Mild weakness in elbow flexion 1 yr postoperatively	No shoulder problems 1 yr postoperatively
Ghanem 2016[8]	60-yr-old man	Conversion to RTSA from failed hemiarthroplasty	Axillary artery occlusion found 2 mo postoperatively	Intimal injury intraoperatively	Balloon thrombectomy with placement of self-expanding stent	Normal angiography and patent axillary artery stent at 9 mo postoperatively	Continued pain management for postoperative complex regional pain syndrome and/or local nerve injury 9 mo postoperatively
Wilkerson 2019[26]	65-yr-old woman	RTSA due to rotator cuff arthropathy	Axillary artery dissection and thrombosis discovered immediately postoperatively	Because of either traction or an intimal injury intraoperatively	Surgical thrombectomy with artery repaired primarily	Normal neurovascular function 6 mo postoperatively	Unknown
O'Neill 2020 (present study)	71-yr-old man	Attempted shoulder arthroplasty (injury), then revision to RTSA	Axillary artery laceration (primary surgery), no injury at revision to RTSA	Direct axillary artery injury intraoperatively (possible retractors vs. saw)	Direct axillary artery repair and stent placement, no injury during revision to RSTA	Normal neurovascular function 2 yr postoperatively	No pain. Constant score 85; normalized onstant score 96; ASES score 97; SST score 12

RTSA, reverse total shoulder arthroplasty; *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; *SST*, Simple Shoulder Test.

RTSA is known to be 2.7 ± 1.8 cm (range, 0-5.9 cm) compared with the normal, contralateral side.[12] The factors that lead to postoperative arm length include position of the glenosphere (overhang), size of the glenosphere, use of an augment or bone graft, polyethylene thickness, height of the humeral cut, and humeral inlay vs. onlay design, among others.[12,14,15] Known complications associated with RTSA arm lengthening are acromial or scapular spine fractures, vascular complications, and neurologic lesions.[12,13]

All these complications point to stresses placed on the surrounding bony and soft tissue structures, especially those found within the axilla. There are no studies proving that arm lengthening places direct stress on the axillary artery itself, as the most common vascular postoperative complications associated with arm lengthening are hematomas and phlebitis.[8] In contrast, there have been studies focusing on neurologic deficits associated with arm lengthening. These neurologic lesions, although mild, are frequent and have been shown to mostly affect the nerves of the brachial plexus and axillary nerve.[13] The anatomy of the brachial plexus and the axillary artery is extensively intertwined, as they lie in a common fascial sheath[29]; given the reports of neurologic stretch injuries, it is therefore likely that stress is placed on the axillary artery as well. Ladermann et al[12] performed an extensive review of RTSA postoperative complications and found that a postoperative arm lengthening allowance of 0-2 cm was a reasonable goal to avoid postoperative neurologic impairment. In this case, the arm was lengthened 23.4 mm based on preoperative radiographs and 27.4 mm based on radiographs prior to revision to RTSA (after shoulder arthroplasty had been aborted). Despite this lengthening, no neurologic or vascular complications from the RTSA were seen.

Several techniques exist to decrease the stress on and limit injury to the axillary artery and brachial plexus intraoperatively. For humeral exposure, sequential release of the medial soft tissues on the proximal humerus during external rotation will allow for decreased rotational forces translated to the axillary artery. In addition, a proximal directed force (ie, upward force on the elbow) during external rotation will prevent excessive traction on the axillary contents during external rotation. Lastly, when cutting the proximal humerus, appropriate anteromedial retractors should be placed to avoid iatrogenic laceration of the axillary artery or brachial plexus. For glenoid exposure, adequate soft tissue release around the proximal humerus is needed to allow for proximal humeral retraction. Placing the anterior retractors directly on the anterior surface of the glenoid will help prevent any laceration of the axillary contents and will allow for retraction of the contents with the remaining subscapularis muscle as a buffer to direct pressure-related injury. In addition, when retracting the proximal humerus in a posteroinferior direction away from the glenoid, use only the amount of external rotation needed to achieve adequate glenoid exposure. Alternatively, shoulder abduction can help achieve posterior proximal humerus retraction without as much external rotation and may be preferable in this scenario to decrease stress on the axillary artery.

This case highlights that it is possible to perform RTSA on a patient with prior axillary artery injury. With care taken to avoid excessive traction on the artery intraoperatively, RTSA was possible. Arm lengthening did not cause a vascular issue postoperatively, and in fact the patient's prior musculocutaneous nerve palsy resolved after RTSA. Ultimately, this patient had a successful recovery after iatrogenic axillary artery injury and delayed RTSA.

Conclusion

A previous injury to the axillary artery poses a risk that complicates the decision to proceed with further surgery to the glenohumeral joint. Our case highlights that with careful consideration and appropriate planning, it is possible to perform a successful RTSA in the setting of a previously stented iatrogenic axillary arterial injury with a satisfactory 2-year outcome.

Disclaimer

Joseph J. King is a consultant for Exactech, Inc. Kevin W. Farmer is a consultant for Exactech, Inc. The other author, his immediate family, and any research foundations with which he is affiliated has not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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