Reverse shoulder arthroplasty: diagnostic and treatment options for the infected reverse

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Abstract: Infection in the setting of reverse total shoulder arthroplasty (RTSA) can be a devastating complication. Revision for infection in RTSA has the worst functional outcomes for any reason for revision. A consensus for the definition of a periprosthetic shoulder infection has yet to be defined, and diagnostic techniques are variable. Options for treatment include irrigation and debridement with component retention, one-stage revision, two-stage revision, and resection arthroplasty. There is no gold standard for treatment and decisions are made based on multiple factors, including bacterial species, medical comorbidities, and patient expectations.

Keywords: Reverse shoulder arthroplasty; infected arthroplasty; periprosthetic infection; septic arthritis

Introduction

Modern reverse total shoulder arthroplasty (RTSA) as initially described by Grammont, has increased in use significantly over the past years, and was approved by the United States Food and Drug Administration in 2003 (1,2). Although RTSA is a reliable treatment option for cuff tear arthropathy (CTA) and osteoarthritis, it is not without complications. Reported rates of infection for RTSA are up to 5% (3,4). Reported rates of infection in patients with rheumatoid arthritis can be up to 9.5% (5). Periprosthetic joint infections (PJI) of the shoulder are the main cause of revisions within the first 2 years following arthroplasty (6).

The definition of a periprosthetic infection of shoulder arthroplasty is unclear, and there is no consensus for infection workup. A meta-analysis by Hsu *et al.* showed significant variability in the definition of infection and culture practices (7). The current literature on infection in RTSA is generally poor and lacking definitive conclusions.

The normal flora of the shoulder makes diagnosing PJI difficult (8). With increasing knowledge of certain bacteria such as *Cutibacterium acnes* (formerly *Propionibacterium acnes)* and coagulase negative *Staphylococcus* species (i.e., papers written after 2000 showing modern diagnostic techniques), our understanding of true infection versus deep tissue inoculation versus specimen contamination continues to evolve. Though diagnostic strategies are controversial, the present study will present a general diagnostic approach and review of surgical treatment options.

Diagnosis

Diagnosis of shoulder PJI is very challenging. According to the Musculoskeletal Infection Society (MSIS) criteria a diagnosis of infection is made with 1 or more major criteria (sinus tract communicating with the prosthesis; or a pathogen isolated by culture from at least two separate tissue or fluid samples obtained from the affected prosthetic
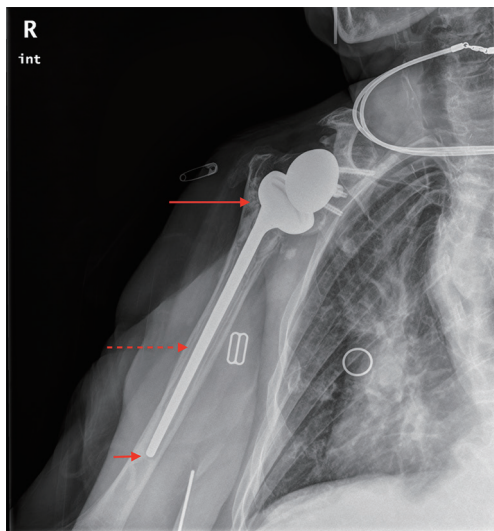
Figure 1 Infected RTSA—X-ray showing typical characteristics of a loose stem. Long arrow: stem subsidence; dashed arrow: dissociation of the cement mantle; short arrow: pedestal present with lucencies around the stem tip. RTSA, reverse total shoulder arthroplasty.

joint), or 4 or more minor criteria [elevated serum erythrocyte sedimentation rate (ESR) and serum C-reactive protein (CRP) concentration; elevated synovial leukocyte count; elevated synovial neutrophil percentage; presence of purulence in the affected joint; isolation of a microorganism in one culture of periprosthetic tissue or fluid; and greater than five neutrophils per high-power field in five high-power fields observed from histological analysis of peri-prosthetic tissue at ×400 magnification] (9,10). While PJI caused by virulent organisms (e.g., *Staphylococcus aureus*) commonly manifests with clinical signs (erythema, swelling) and elevated laboratory markers (CRP, ESR), PJI with less virulent organisms (*Cutibacterium acnes*) uncommonly presents with obvious evidence of infection (11). Other techniques that have demonstrated efficacy in hip and knee PJI, such as leukocyte esterase and IL-6, have not been shown to be a reliable test for PJI (12,13). As a result, the diagnosis of PJI is commonly made several weeks after revision surgery and is heavily reliant on culture results. Cultures are unfortunately difficult to interpret because C. acnes is the most commonly cultured bacteria in cases of both primary shoulder arthroplasty and revision arthroplasty. As a result, its role as a commensal organism, deep tissue inoculant, or infecting agent remains uncertain.

Despite the limitations, the number of cultures is a variable but important determinant of infection, as serological markers such as WBC, CRP, and ESR may be falsely normal even in the setting of infection. Mook and Garrigues described the phenomena of "failed arthroplasty with positive cultures" (FAPC) (14). In this scenario they recommend a description of the number of positive cultures over the total number of cultures taken and stating the organism (e.g., "2/5 for *P. acnes*" would indicate 2 cultures out of 5 taken were positive for *P. acnes*).

Clinical evaluation

Clinical presentation of PJI can be extremely variable in appearance. Suppurative infections present similar to hip and knee periprosthetic infection, which generally involve pain, swelling, erythema, and purulence if a wound is present. Indolent infections require a high level of suspicion, as these do not present with the hallmarks of infection as described above. Patients may complain of poor function or degradation of function over time. As described in the following section in more detail, there may be signs of radiographic loosening or fracture which could represent infection (*Figure 1*).

Risk factors for periprosthetic infection include postoperative hematoma (15), arthroplasty for trauma (16), younger age (17), and male sex. Pain is the most common complaint, followed by stiffness, erythema, effusion, fever, and night sweats (18).

A thorough examination of the entire extremity is essential. The examiner must evaluate the skin completely for signs of skin breakdown, potential sinus tracts, erythema, swelling, and muscle bulk. A neurovascular examination is also critical to perform at this stage. The shoulder active and passive motion should be assessed. Pain with passive motion is a nonspecific sign of infection but is frequently present when there is an effusion.

Imaging

Initial imaging should include 4 views of the shoulder (AP, true-AP, scapular-Y, axillary views) to rule out other potential causes of shoulder pain. X-rays should be scrutinized for nonspecific changes including effusion, bony resorption, periosteal reaction, osteolysis, and contiguous radiolucent lines (*Figure 1*). Serial radiographs may show subtle changes over time, such as increase in size of

radiolucent lines.

Computed tomography (CT) and/or magnetic resonance imaging (MRI) may be done for preoperative planning but is not necessary for diagnosis. If osteomyelitis is suspected, MRI may be beneficial for planning bony debridement and identifying pockets of purulence within the soft tissues prior to entering the operating room.

Laboratory testing

Although ESR and CRP are frequently performed in suspected cases of infection, these laboratory values have a low sensitivity, and thus are not helpful for ruling out PJI (19). One must bear in mind that normal inflammatory marker levels do not preclude deep joint infection in the shoulder as they do in the hip and knee. Though inflammatory markers have low sensitivity, specificity is relatively high (20); and so, our current practice includes obtaining ESR and CRP in cases with suspicion of infection.

Aspiration and cultures

There is no clear evidence to guide the decision to aspirate in the case of suspected infection. According the American Academy of Orthopaedic Surgeons (AAOS) clinical practice guidelines for periprosthetic hip and knee infections, aspiration should be performed if the ESR or CRP is elevated (21). No thresholds for intraarticular WBC count have been reported in shoulder PJI and attempted aspirations are commonly "dry". Dilisio et al. reported fluoroscopically guided glenohumeral aspiration yielded a sensitivity of 16.7%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 58.3% (22). Because of the high specificity and positive predictive value, we commonly obtain a preoperative aspiration in cases with suspicion of PJI.

Intraoperative cultures which grow an organism early, with multiple positive bottles may be a more reliable indication for a "true infection". One study showed positive cultures with a median of 5 days in the probable true-positive group compared to a median of 9 days in the probable contaminant group (23). Our current practice involves taking deep cultures at 5 sites at the time of revision, including the anterior and posterior capsule, behind the glenoid component, under the explanted humeral head, and from within the humeral canal, and

holding cultures for 13 days. Both aerobic and anaerobic media are utilized.

Surgical management

General approach to the infected RTSA

Once the decision has been made to perform surgical intervention for infection, several factors must be considered. The surgeon must assess the likely etiology of infection (e.g., direct inoculation from prior surgery, latent infection, osteomyelitis, systemic infection etc.), comorbidities, and patient functional level. Antibiotic suppression alone has shown high failure rates with 60% symptomatic shoulders (24). Irrigation and debridement with component retention has also shown high recurrence rates of 12–50% and is not routinely recommended (18,24). While certain clinical situations (infirm patients, acute hematogenous infections, etc.) may warrant an attempted irrigation and debridement with component retention, patients and surgeons must understand the high recurrence rate relative to alternative treatments.

Two-stage revision (25)

The traditional treatment of PJI has been a two-stage revision, consisting of removal of all components and cement, followed by a period of systemic culture-specific antibiotics and typically placement of an antibiotic cement spacer. There is no literature to support the time needed prior to definitive replantation, however a 6-week course is utilized by many clinicians.

An antibiotic-loaded cement spacer is used at the time of explant to maintain soft tissue tension and to create an envelope for later implant. The spacer also provides local antibiotic efflux. Vancomycin and an aminoglycoside antibiotic are most commonly used in combination; however, there is no clear consensus for antibiotic choice. Antibiotic spacers can be fashioned in multiple ways including stemmed and stemless designs (Figure 2). Neither design has been demonstrated to be more effective for treatment of PJI (26). Another method described by Levy et al., used a hemiarthroplasty coated with antibiotic-loaded cement (27). Nine of 14 patients in their series had satisfactory outcomes with the functional spacer and did not go on to a second stage reimplantation (27).
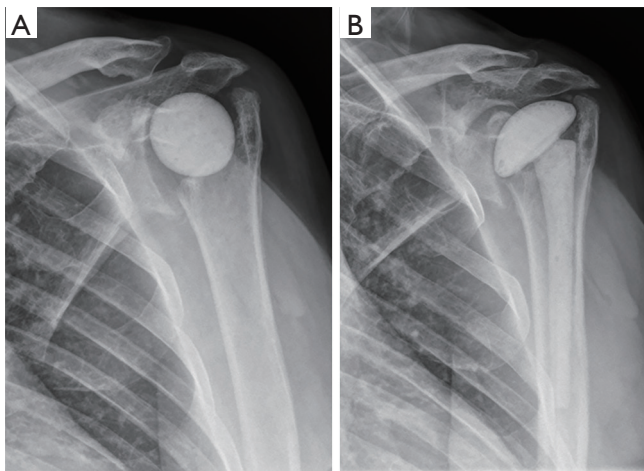
Figure 2 Antibiotic spacer. (A) stemless; (B) stemmed.

RTSA is the treatment of choice for the second-stage reimplantation. As RTSA does not rely on a functional rotator cuff, the initial debridement may be more aggressive so as to clear any potential sites of contamination which may include the rotator cuff. In a recent series of infected RTSA, two-stage revision was performed in 14/32 cases (44%). The authors report a 36% complication rate, most of which were attributed to hematoma (28). Ortmaier *et al.* reported on their series of 20 patients with infected RTSA, 60% of which were treated with two-stage revision. The authors reported a success rate of 75% with two-stage revision, however no significant differences in Constant score or VAS pain scores were found when compared to debridement, but functional outcomes were significantly improved when compared to resection (29). One retrospective multicenter study showed similar treatment success, defined by eradication of infection, in two-stage revision, resection arthroplasty, or permanent spacer placement. However, resection arthroplasty had significantly worse function (30).

One-stage revision

Single-stage revision is an attractive treatment modality as patients requiring revision typically have medical comorbidities, are of advanced age, and may have significant bone loss. A single curative procedure offers benefits for cost savings and avoids multiple procedures for the patient. Several studies have shown equivalent rates of eradication of infection in single-stage compared to two-stage revision. In a recent systematic review, Nelson *et al.* found no statistically significant differences for treatment

success between one-stage, two-stage, or resection arthroplasty, except for the highest Constant scores being in the one-stage revision patients (31). Jacquot *et al.* had 100% eradication of infection with a single-stage revision compared to 64% in the two-stage revision group, although this difference was not statistically significant (28). In a recent study, Hsu *et al.* described their single-stage treatment protocol in patients with 2 or more positive cultures for *P. acnes* with significant improvement in functional outcomes at 45 months from time of revision. This protocol does involve 6 months of antibiotics including IV and oral and resulted in 42% rate of antibiotic-related adverse events. This study involved mostly revision of hemiarthroplasty and anatomic total shoulder arthroplasty, which makes the results difficult to extrapolate to RTSA (32). Grosso *et al.* found a 5.9% recurrence rate in shoulders treated with a single-stage revision without prolonged postoperative antibiotics in those shoulders with a single positive culture at the time of revision. These patients were identified preoperatively and intraoperatively with a low suspicion for infection (33).

Frequently cultures are taken intraoperatively even when the suspicion for infection is low. Padegimas *et al.* showed a 24% positive culture rate at time of revision in cases with low suspicion for infection. The clinical importance of positive cultures in this scenario is yet to be determined, however it does not appear to affect the overall outcome in cases of one-stage revisions (34).

Resection arthroplasty

Resection arthroplasty is an option for low demand patients when revision arthroplasty is not possible. Rates of recurrence of infection range from 0–30%; however, this is typically at the cost of a poor functional outcome (28,29,35). Commercially produced articulating spacers are another option and have been used as definitive treatment in low demand patients (36).

Arthrodesis

Arthrodesis is uncommonly employed as a definitive treatment after shoulder PJI; however, it remains an option for patients with sufficient bone stock. Typically, a 4.5 mm pelvic reconstruction plate is used for fixation along the lateral humeral cortex and placed along the scapular spine with several screws. In cases of severe bone loss (>6 cm proximal humerus), a vascularized fibula graft may

be used to aid in healing (37). The fibular graft should be 4–5 cm longer than the defect in order for docking in the distal humerus. Wick *et al.* reported significantly improved pain relief in a series of patients with septic arthritis of the shoulder treated with arthrodesis. Although 90% of patients had significantly improved pain, no patient was pain-free (38).

Summary

The heterogeneity of the patient samples within the available literature, combined with relatively low patient numbers makes drawing firm conclusions regarding treatment quite difficult. The gold standard for revision RTSA remains removal of all components (and cement) and placement of revision components via a single or dual-stage reconstruction. While two-stage reconstruction is preferred for patients with PJI caused by virulent organisms, one-stage revision is likely sufficient for most cases of PJI with less virulent organisms.

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Footnote

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