



Revision Shoulder Arthroplasty

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33.1 Revision of HA

HAs have a revision rate around 20%. HAs implanted for primary osteoarthritis are mainly revised for glenoid erosion and cuff insufficiency, whereas tuberosity migration, nonunion, or malunion are the main reasons to revise a HA implanted for acute fracture or fracture sequelae [1]. An oversized humeral head is frequently identified as a cause of glenoid erosion or cuff failure. In case of soft tissue or bone deficiency, revising a HA with a TSA leads to a failure 70% of surgeries; a revision with a RSA should be preferred in this clinical setting [1].

33.2 Revision of TSA

The two main reasons for revision surgery following TSA are glenoid loosening and instability, which often coexist. Glenoid radiolucencies appear at 5 years and progress over time. Neither polyethylene with cement nor metal-backed glenoid implants have passed the test of time [1, 2]. Similar to HAs, in case of soft tissue/bone deficiency, TSA revision should be performed with RSA to avoid multiple revisions.

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33.3 Revision of RSA

The main reasons of failure of RSA are glenoid loosening, infection, and instability. Humeral complications (humeral loosening, disassembly, or fracture) increase with time and may become a major cause of revision surgery for RSA in the near future [1]. Revision of a failed RSA to another RSA, often combined with glenoid and/or humeral bone reconstruction, remains the treatment of choice. Revision of an RSA to a HA is rarely performed as it leads to a poor functional result [1].

33.4 Revision Shoulder Arthroplasty for Periprosthetic Joint Infection

Periprosthetic joint infection (PJI) is the most common reason for revision arthroplasty within 2 years of the index surgical procedure. Reports of periprosthetic joint infection's incidence commonly range from 3 to 4% in the literature, although rates as low as 0.5% and as high as 6.7% have been reported and over 15% after revision cases [4, 5]. As the utilization of shoulder arthroplasty continues to rise, shoulder surgeons must remain well versed in the diagnosis and treatment of these potentially devastating complications [4].

Less virulent organisms, such as *Cutibacterium acnes*, often cause periprosthetic joint infection following shoulder arthroplasty. *C. acnes* is associated with a nonspecific clinical presentation and traditional inflammatory markers less accurately identify its infection [4]. Similarly, the optimal treatment for shoulder periprosthetic joint infection remains unclear.

Treatment options include one-stage arthroplasty, two-stage arthroplasty, and resection arthroplasty, each with varying success rates.

33.4.1 Microbiology

The most frequently isolated organisms in shoulder periprosthetic joint infection are *C. acnes* (38.9%), *Staphylococcus epidermidis* (14.8%), and *Staphylococcus aureus* (14.5%). *C. acnes* appears also to be the most commonly isolated bacteria in patients undergoing revision shoulder arthroplasty (16.7%) [4].

33.4.1.1 *C. acnes*

Formerly known as *Propionibacterium acnes*, *C. acnes* is found around the sebaceous glands of moist skin regions.

The numerous sebaceous glands of the chest and back region produce large amounts of oily sebum, which creates an ideal environment for the lipophilic anaerobic bacterium to proliferate. The proximity of the incision site to the axilla is one proposed explanation for its role in between 31% and 70% of shoulder periprosthetic joint infection cases [4].

Furthermore, the increased quantity of sebaceous glands in male patients has also been implicated in the higher incidence of periprosthetic joint infection in this population. Anterolateral approach compared to deltopectoral approach was also associated with a higher risk of infection following open rotator cuff repair or open subacromial decompression, which may be because of the number of sebaceous glands transected [4].

C. acnes has been shown to form biofilm, especially in plasma-poor environments such

as prosthetic joints, and their presence has been shown to put patients who undergo revision at a higher risk of reinfection, with rates reaching 20%. Of note, *C. acnes* can also form biofilm on gentamicin-containing bone cement [4].

33.4.2 Prevention of Periprosthetic Joint Infection

C. acnes has been shown to survive traditional superficial skin sterilization methods in the operating room, such as povidone-iodine or chlorhexidine gluconate [4].

As a result, there have been several studies exploring novel methods for reducing the *C. acnes* bacterial load.

Benzoyl peroxide is a bactericidal agent that has been shown in the dermatology literature to reduce the *C. acnes* load by penetrating sebaceous glands, and there have been promising results in the setting of shoulder surgical procedures as well. The application of benzoyl peroxide gel the night before the surgical procedure determined a decrease of *C. acnes* load (8% versus 28%) [4].

Of note, it is still unclear whether the organisms found in the skin cultures were causative of infection or merely commensal.

Furthermore, none of these studies evaluated the efficacy of these preparations for preventing periprosthetic joint infection, which limited their validity.

Other studies have examined the effectiveness of injecting intra-articular antibiotics in a revision surgical procedure.

Intra-articular injection of gentamicin at the time of closure also resulted to reduce periprosthetic joint infection after primary shoulder arthroplasty [4].

Cefazolin is currently the perioperative antibiotic of choice in shoulder arthroplasty in patients without a severe beta-lactam allergy. Currently, the 2018 ICM states postoperative antibiotics are not required, but, if given, should not be continued beyond 24 h postoperatively [6].

33.4.3 Diagnosis of Periprosthetic Joint Infection

33.4.3.1 Risk Factors

Major risk factors for PJI are male gender, younger patients, smoke, history of previous shoulder surgery, and revision shoulder arthroplasty [5]. Reverse shoulder arthroplasty and perioperative blood transfusion are also risk factors.

Exposure to cortisone injections can increase patients' risk of developing periprosthetic joint infection, especially within 3 months of the surgical procedure.

Extremity-specific risk factors include fracture, chronic lymphedema, venous stasis, vascular compromise, and radiation fibrosis. Postoperative hematoma has also been associated with infection. Interestingly, body mass index and race are not consistently associated with an increased risk of periprosthetic joint infection [4].

33.4.3.2 Clinical Presentation

The existence of a fistula that connects with the prosthesis is pathognomonic for periprosthetic joint infection. However, the majority of patients present without a sinus tract or the classic signs of infection (e.g., fever, chills, sweats, erythema, induration, wound drainage).

The most common symptoms are shoulder pain, followed by a draining sinus, stiffness, erythema, effusion, fever, night sweats, and chills. Other findings associated with infection include worsening physical examination findings, such as decreased range of motion.

Therefore, surgeons must have a heightened index of suspicion, and any deviation from normal postoperative findings should be considered infection until proven otherwise.

The 2018 ICM divided periprosthetic shoulder infection into four categories [7]: definite infection, probable infection, possible infection, and unlikely infection. A definite infection is defined by the presence of one or more of the following criteria: (1) presence of a sinus tract from the skin surface to the prosthesis, (2) intra-articular pus, or (3) two positive tissue cultures

Table 33.1 Minor criteria for shoulder PJI

Criteria	Weight
Unexpected wound drainage	4
Single positive tissue culture with a virulent organism	3
Single positive tissue culture with a low-virulent organism	1
Second positive tissue culture (identical low-virulence organism)	3
Humeral loosening	3
Positive frozen section (5 neutrophils in ≥ 5 high-power fields)	3
Positive preoperative aspirate culture	3
Synovial neutrophil percentage > 80%	2
Synovial white blood cell count >3000 cells/ μ L beyond 6 weeks from surgery	2
ESR > 30 mm/h	2
CRP > 10 mg/L	2
Elevated synovial alpha-defensin	2
Cloudy synovial fluid	2

with phenotypically identical virulent organisms, such as *Staphylococcus aureus*. This is in contrast to low-virulence organisms, which include *C. acnes* and coagulase-negative *Staphylococcus* species. In addition to these definite criteria, the ICM also established a set of minor criteria for the definition of shoulder PJI.

A probable infection is defined as the presence of six or more minor criteria with an identified organism (Table 33.1).

A possible infection is defined as the one of the following: (1) presence of six or more minor criteria without an identified organism, (2) less than six minor criteria with a single positive culture with a virulent organism, or (3) less than six minor criteria with two positive cultures with a low-virulence organism. An unlikely infection is defined as the presence of less than six minor criteria with negative cultures or only a single positive culture with a low-virulence organism.

33.4.3.3 Radiographic Evaluation

Patients suspected to have a shoulder periprosthetic joint infection should receive radiographs, especially if they present with shoulder pain during postoperative follow-up. Although nonspecific for infection, radiographs show the overall alignment of the prosthesis and can show signs of loosening or osteolysis [5]. Serial radiographs

over time that show progressive humeral osteolysis are highly suggestive of periprosthetic joint infection. Although nonspecific for the offending organism, progressive humeral osteolysis is associated with a tenfold increase in the risk of a *C. acnes* infection [4].

Computed tomography (CT), ultrasound, and magnetic resonance imaging (MRI) are not routinely utilized because they do not provide any diagnostic findings, except for the visualization of surrounding osteomyelitis or loculated abscesses. Technetium Tc-99 m bone scans are also not routinely used because they have limited sensitivity and specificity for a shoulder periprosthetic joint infection [4].

33.4.3.4 Laboratory Evaluation

Laboratory evaluation for suspected shoulder periprosthetic joint infection should include complete blood count with differential, CRP, and ESR. Unfortunately, ESR and CRP do not have reliable sensitivity and specificity following shoulder arthroplasty, especially in the setting of indolent infections caused by *C. acnes* or coagulase-negative *Staphylococcus* species.

The Infectious Diseases Society of America (IDSA) has endorsed diagnostic arthrocentesis in all patients with suspected acute periprosthetic joint infection unless the diagnosis is clinically evident, the surgical procedure is planned, and antimicrobials can be safely withheld prior to the surgical procedure. If the patient is clinically stable, the IDSA also recommended withholding antimicrobial therapy for at least 2 weeks prior to collection of synovial fluid to increase the likelihood of recovering an organism. It is recommended to perform aspiration under fluoroscopic or ultrasound guidance to improve accuracy and maximize the sample volume [4]. However, even when a sufficient volume is obtained, the cultures and cytology are often within normal limits.

Arthroscopic tissue biopsy seems to be substantially more reliable than aspiration in terms of sensitivity, specificity, positive predictive value, and negative predictive value.

Intraoperative open biopsy with culture remains the gold standard for the diagnosis of shoulder PJI. The sensitivity of intraoperative

culture for shoulder periprosthetic joint infection has been reported to be 50% to 67%, depending on the organism. The IDSA currently recommends that surgeons obtain and send five intraoperative tissue specimens for microbiology culture. Currently, holding antibiotics prior to obtaining intraoperative cultures is not recommended.

These specimens should be grown on four to five media for a minimum of 13 to 14 days because of extended incubation period of *C. acnes* [5].

Frozen section at the time of revision surgery is an adjunct in the diagnosis of shoulder PJI; however, it requires an experienced pathologist and a negative result does not rule out infection.

The current literature does not support the use of routine implant sonication due to the low sensitivity as well as the lack of established diagnostic cutoffs for the quantification of bacteria in the obtained samples [5].

33.4.3.5 Recent Advances in Diagnosis

Recent efforts have been focused on finding innovative ways of diagnosing shoulder periprosthetic joint infection. Interleukin-6 (IL-6), a pro-inflammatory cytokine that mediates acute immune responses, has been identified as a potential indicator of periprosthetic joint infection because its serum concentration rises and falls to normal faster than CRP or ESR.

The synovial cytokine profiles of IL-6, tumor necrosis factor- α , alpha-defensin, and IL-2 are under investigation [5, 7].

33.4.4 Management

Shoulder periprosthetic joint infection is difficult to treat and the preferred management strategy remains controversial.

The treatment options for shoulder periprosthetic joint infection include intravenous antibiotics, tissue debridement with retention of the prosthesis, resection arthroplasty, one-stage and two-stage revision procedures, arthrodesis, and amputation [4].

Regardless of the ultimate treatment modality, all patients with suspected periprosthetic joint

infection should receive perioperative antibiotics at the time of the revision surgical procedure.

Cefazolin is the agent most likely to provide optimal tissue concentrations for prophylaxis against the three most common causative organisms.

Antibiotic therapy alone is usually insufficient for the management of shoulder periprosthetic joint infection and has been shown to have a failure rate of 60% to 75% [4].

Previous studies have suggested that treating shoulder periprosthetic joint infection with debridement and retention of the prosthesis is possible only if the infection is identified within 30 days of the initial surgical procedure or after less than 3 weeks from the onset of symptoms, if the implant is stable, the isolated germ is of low virulence, and complete debridement is achieved [4]. More recent investigations showed unsatisfactory results with debridement and retention of the prosthesis in terms of infection eradication rate compared with other treatments, and previous studies have shown a failure rate of 50% to 63%. The 2018 ICM currently concluded that there is not enough evidence to support or discourage the use of irrigation and debridement with implant retention for acute or chronic shoulder PJI, but it may play a role in select patients [8].

Complete removal of the shoulder prosthesis is indicated in patients who present with infections after 4 weeks postoperatively; these patients are treated either with resection arthroplasty or with one-stage or two-stage revision.

The traditional treatment protocol for shoulder periprosthetic joint infection has consisted of complete prosthesis removal, implanting an antibiotic spacer, and a second stage consisting of a revision shoulder arthroplasty.

The literature has consistently supported the efficacy of two-stage revision, with infection recurrence rates reported to be 0% to 36% [4].

Cement spacers with vancomycin alone or in combination with an aminoglycoside have both been shown to be effective treatment options, can

help to preserve the soft tissue envelope, and could be a permanent treatment option for patients with low functional demands.

Recent studies have focused on one-stage exchange because it involves less dissection and stress to the soft tissues, is quicker, and is more cost-effective. A systematic review of the shoulder arthroplasty literature found studies that showed that both one-stage and two-stage revisions provide >90% rates of eradication at a mean follow-up of 49 months. It suggested that single-stage treatment can result in less damage to the soft tissues, can avoid a second general anesthetic, and can reduce costs [9]. Another study showed almost one third of patients planned for two-stage revision did not undergo the second stage of the revision due to mortality, medical comorbidities, uncontrollable infection leading to amputation of the limb or lifetime antibiotic suppression, and unwillingness of patients to undergo a second surgery, as well as patient's satisfaction with the current status. Therefore, satisfactory results of a two-stage revision might not be achieved by almost one third of patients planned for revision [10].

Definitive treatment with an antibiotic spacer is another viable treatment option in select patients. Pellegrini et al. reported a case series of 19 shoulder PJI that were definitively treated with an antibiotic cement spacer. They reported no recurrent infections with good pain relief and improvement in outcome scores, but shoulder range of motion remained poor. They concluded that a definitive antibiotic spacer is a good option for low-demand, elderly individuals who do not wish to or are not otherwise able to undergo another operation [11]. Resection arthroplasty can provide substantial pain relief and excellent infection eradication. However, resection arthroplasty often results in functional deficits, especially with internal and external rotation. As such, resection arthroplasty is a good treatment option for elderly patients or patients with high-virulence germs, considerable tissue loss, or poor health [4].

33.5 Revision Shoulder Arthroplasty for Prosthetic Instability

Instability is one of the most frequent causes for reoperation after unconstrained shoulder prosthesis [12–14]. In literature, the rate of instability was found to be in range from 4.9% to 5.2% [15, 16]. Instability can occur in different patterns:

- **Inferior Instability:** Usually due to a shortened humerus or a failure to restore humeral length due a tumor or a fracture.
- **Superior Instability:** Usually results from a deficient superior rotator cuff.
- **Anterior Instability:** Usually from an insufficiency of the subscapularis or rotator interval with an excessively anteverted humeral component with a large head.
- **Posterior Instability:** Usually for a soft tissue deficiency associated with an incorrect version positioning of the humeral component; commonly a glenoid retroversion with elongation of the posterior capsule and excessive humeral retroversion [17].

A radiological study with an anteroposterior and axillary view is useful to categorize the direction of instability.

Depending on the instability pattern, specific revision procedures can be proposed such as repositioning or resizing the component, bone grafting procedures, and soft tissue repairs [17, 18]. A reduction of anteversion of the humeral component with repair or reconstruction of the anterior capsule and subscapularis could be proposed for anterior instability.

In case of posterior subluxation, a plication of the posterior capsule and rotator cuff and a posterior bone grafting have been proposed as surgical options. However, recurrent instability rate in case of soft tissue revision surgery is very high, and authors advocate considering revision to reverse shoulder arthroplasty [18].

Revision to a constrained design (RSA) provides better stability with good clinical outcomes and increased range of motion but worst results

than those achieved with primary implantation of RSA [16, 17].

33.5.1 Instability in Reverse Shoulder Arthroplasty

Instability is the most common complication and main cause of revision surgery following RSA [3, 19–21]. It is a “difficult to manage” complication, with high risk of revision failure and recurrent instability [3, 22].

Risk factors for instability are younger age, revision surgery, male gender, scapular notching, and greater tuberosity absence or resorption [23]. Other factors to be considered prior to revision surgery are [20]:

Previous surgery: RSA for failure of osteosynthesis, hemiarthroplasty, anatomic prosthesis, or reverse prosthesis is three times more likely to show instability than primary RSA: 7% versus 2% [24].

Deltopectoral approach: seems to be associated with a higher risk of instability compared to superolateral deltoid approach [18, 24].

“Cam effect”: mediated by soft tissue or bone block: obesity is protective against scapular notching, but induces a cam effect through fat in the upper limb and trunk [25]; humeral malunion or ossification may strike against the scapular pillar or glenosphere, inducing a leverage effect.

Bone loss or soft tissue deficiency: humeral or glenoid bone loss and soft tissue deficiency (subscapularis absent or non-inserted and/or anterior deltoid atrophy) [20].

Patients with shortened humerus due to a proximal bone loss have a higher risk of instability. Etiology of shortened humerus is various: implant migration, greater tuberosity lysis, or humeral resection that fails to restore humeral length (more frequently in tumor surgery, acute fracture, or previous hemiarthroplasty) [20]. A posterior greater tuberosity placement in setting of a RTSA for a proximal humerus fracture can also contribute to instability as the humeral component can be levered out of place with an impingement-like mechanism [26].

Glenosphere malpositioning can increase instability: excessive anteversion, retroversion, or superior inclination can place the patient at risk [27]. Glenoid medialization due to glenoid bone defect and the implantation of an excessively small glenosphere is also cause of instability [20].

33.5.1.1 Management of Instability

When facing RSA instability, it is essential to understand the etiology of instability and correct its causes.

Factors that need to be assessed are soft tissue deficiency or significant bone loss, components malposition, and impingement.

Another common cause of instability is inadequate deltoid tensioning. To restore the proper tension of the deltoid, the surgeon could increase the size of the glenosphere, increase the global amount of lateralization of the implant, and/or increase the amount of distalization on the humeral side [20, 28].

In early dislocation (within the first 3 months), without malrotation or bone defect, a closed reduction and a strict immobilization with an abduction splint is a good treatment option. The abduction splint promotes deltoid shortening and enhances the implant's coaptation force. Efficacy rates are between 30% and 50% [24].

In late dislocation (after 3 months), usually a revision surgery with correction of a technical mistakes is necessary. Restoring deltoid tension modifying the humeral shortening and/or excessive medialization is often needed. Humeral shortening can be managed by adding metal augmentation or increasing polyethylene height without changing the implants. When the shortening exceeds 15–20 mm, the humeral implant probably needs to be replaced [20].

Excessive medialization is often implicated in persistent instability despite restored humeral length. Management of excessive medialization could be achieved replacing the glenoid implant with a greater diameter glenosphere or using a bone grafting procedure (BIO-RSA) or a metallic-increased offset reverse shoulder arthroplasty (MIO-RSA) or both.

When functional subscapularis is present, reinsertion of the tendon and capsule should be performed.

33.6 Revision Arthroplasty for Prosthetic Loosening

33.6.1 Glenoid Loosening

Glenoid component loosening in shoulder arthroplasty is a leading complication and a common reason for implant failure and revision surgery [12, 14].

In the setting of anatomical shoulder arthroplasty [29], clinical presentations and x-ray with radiolucent lines are all important factors for the detection of implant loosening [30]. Patients affected by glenoid loosening often report pain and reduction of active range of motion and strength. Radiolucency around the implants has been discussed but there is no clear correlation with implant loosening [23]. Several publications showed that signs of radiolucency occurring shortly after surgery and their further progression are correlated with implant loosening [29]. Nevertheless, radiolucency can be very common especially after cemented polyethylene pegged glenoid component implantation [31]. Other radiographic signs of glenoid loosening have been proposed: superior shift of the humeral head and medialization due to erosion of the glenoid side [30, 32]. A loose glenoid component is frequently associated with a glenoid bone loss and may necessitate additional procedures to implant a new component. Bone augmentation with autograft or allograft or augmented glenoid components are necessary in a bone-deficient glenoid [33]. The reverse total shoulder arthroplasty is a useful reconstructive option capable of addressing bony and soft tissue problems [31–33].

Reverse total shoulder glenoid component loosening has a prevalence ranging from 1.7% to 3.5% [3]. To provide a stable fulcrum, the glenosphere needs a balance between compressive and shear forces. The compressive forces have a stabilizing effect on the glenosphere, while shear forces could contribute to destabilizing the com-

ponent, leading to glenoid loosening [34]. Glenoid loosening usually appears at the interface between the baseplate and the native scapula and in rare cases may involve the interface between the scapula and any bone graft used or in the body of the scapula, medial to the baseplate screws. These different types of glenoid loosening are important as they dictate the type of revision needed [35]. Conservative and surgical treatments are both valid options in RSA failures due to glenoid loosening. Conservative treatment is suggested whenever possible [35]. Revision of the glenosphere could be considered if conservative fails. Conversion to hemiarthroplasty should remain a last salvage option [36].

Bone defect in glenoid loosening is very frequent and could be classified in three grades: cavity defect (A), uncontained wall defect (B), or complex defect (C) [20]. In cavity bone defect, it can be filled by impacted allograft or synthetic graft, without using iliac crest autograft. For complex defect and unconfined wall defect, it is suggested to use an iliac crest autograft to improve consolidation without resorption of the graft [20].

33.6.2 Humeral Loosening

Aseptic humeral loosening is an uncommon complication in shoulder arthroplasty. It occurred more commonly in cohorts with long-term follow-up at rates between 0.61% and 1.4% [37, 38]. Stem loosening is more frequent after RSA than anatomical shoulder arthroplasty, probably because constraint forces associated with Grammont RSA are predominantly located on the humeral side rather than the glenoid side [37, 38].

In anatomic shoulder arthroplasty, there is no correlation between bone resorption and the clinical results [39–42]. Also, after RSA bone resorption doesn't correlate to clinical results [42]. Nevertheless, proximal humeral bone loss is the main risk factor for humeral loosening, bone resorption affects more frequently the greater tuberosity area, and this could diminish the del-

toid wrapping angle and increasing risk of instability [42].

Risk factors for bone resorption in anatomical arthroplasty reported are age, secondary osteoarthritis, high filling ratio of the implant, low bone density, large implant size, on-grow-type stem coating, and hemiarthroplasty with rotator cuff tear [43].

In RSA risk factors are a high filling ratio, female sex, and an onlay-type stem [37]. Low bone quality because of osteoporosis could explain female sex risk factor. The more proximal osteotomy performed on inlay-type stems (compared to onlay type) leads to a more proximal fixation and possibly contributes to lower the rate of bone resorption [37].

Management of humeral loosening could be very difficult especially with a bone defect scenario. In this setting, the goal of a revision surgery should be to enhance implant stability, restore humeral length, and increase the deltoid wrapping angle. Boileau et al. for a humeral defect <5 cm in elderly patients with RSA recommend to create a cement collar around the implant (cementoplasty reconstruction) to fill the bone defect or implant a prosthesis used for tumor reconstruction surgery.

In humeral defects >5 cm, some authors recommend reconstruction by massive humeral allograft [20, 44].

33.7 Revision Arthroplasty for Periprosthetic Fractures

The incidence of periprosthetic fractures is reported between 1% and 3% [45, 46], and the number of revision arthroplasties is likely to rise over time with the increasing of the number of shoulder arthroplasties performed. In comparison to fractures associated with anatomic total shoulder arthroplasty, periprosthetic fractures in the setting of RSA occur more than three times as frequently [46].

Data on this topic is affected by considerable heterogeneity in the published literature especially in the classification and outcome measures; larger and more rigorous studies are needed [45].

33.7.1 Acromial and Scapular Spine Fractures

The acromion and scapular spine are anatomic sites uniquely predisposed to fracture in the setting of RSA with an incidence estimated between 1.3 and 4.3%. This prosthetic design distalizes and medializes the center of rotation of the shoulder increasing the forces transmitted across the acromion and scapula, including the scapular spine and coracoacromial ligament [46]. More recent RSA designs such as a short, lateralized humeral stem, and inferior glenosphere offset, were designed to counteract some of the commonly encountered complications associated with RSA, including implant instability and scapular notching. Newer design alterations, particularly humeral stems with increased offset, may effectively reduce the risk of scapular notching, yet they may also increase stresses seen at the acromion. To date, there is no clear evidence of implant design on acromial fractures [47, 48].

Acromial and scapular spine fractures can occur after a minor trauma or can have an insidious onset without history of trauma. Radiographs are very often unable to detect these fractures, and CT scan is recommended in all patients with acromial or scapular pain following RSA with radiographs negative for fractures [46].

Documented risk factors are osteoporosis, lateralized glenosphere, and decreased deltoid lengthening.

Controversial results are reported regarding the integrity of rotator cuff and subscapularis repair as it could act as deltoid antagonist, thereby increasing the workload of the deltoid with an increase of acromial stresses [46]. Positioning of the superior screw above the central glenoid axis appears to be a risk factor, especially if the tip of the screw engages the scapular spine. Other possible risk factors are an onlay humeral design, a short humeral stem, and the resection of coracoacromial ligament.

Acromial and scapular spine fractures after RSA are usually treated nonoperatively or with ORIF and rarely have been treated with revision with ORIF. In case of RSA revision associated with ORIF, the aim of revision was to eliminate risk factors related to RSA design substituting the

implant with an inlay design, long humeral stem, and medialized glenosphere and without repairing the subscapularis tendon.

33.7.2 Humerus Fractures

A fracture of the humerus can occur intraoperatively or postoperatively. Major risk factors are osteopenia, female sex, post-traumatic arthritis, rheumatoid arthritis, osteonecrosis, the use of press-fit stems, and the setting of revision arthroplasty [46, 49].

The most commonly employed classification system for periprosthetic humeral fractures describes fractures in relation to the tip of the humeral stem. Type A comprised fractures proximal to the tip, type B comprised fractures at the tip and extending distally, and type C comprised fractures distal to the tip of the humeral stem [50]. Campbell et al. [51] proposed a classification system that incorporated fractures not restricted to the humeral diaphysis. In this four-part system, type 1 involves the lesser or greater tuberosity; type 2 involves the surgical neck; type 3, the metadiaphyseal junction; and type 4, the middle and distal humeral diaphysis.

The existing evidence basis to guide treatment decision-making relies on few published retrospective case series and expert opinion.

There are three main treatment strategies: the first is nonoperative treatment using orthoses, braces, or plaster casts; the second is fixation using wires, plates, and screws, external fixators, and strut cortical bone allografts with plates or customized intramedullary nail cut to size; and the third is revision arthroplasty using either a long stem to bypass the fracture, a revision stem with a strut allograft, a humeral endoprosthesis, a partial or total humeral prosthesis, or an allograft-prosthetic composite [45].

Wagner et al. [52] proposed a treatment algorithm for intraoperative humerus fracture in the setting of RSA. In this schema, fractures of the greater tuberosity are stabilized with a suture fixation construct, nondisplaced metaphyseal fractures are secured with multiple cerclage wires, and displaced fractures of the metaphysis are fixed using cables and strut allograft. Data on

nonoperative treatment show a success rate of only 50%; it is suitable mainly for frail patients with little functional demand and unfit for surgery. Risk of complication in this group of patients is around 30% (mainly nonunion or malunion) [45].

ORIF is the most frequent strategy and has a mean success rate over 90% with better results if the prosthesis is well fixed. Complication rate of 17% is reported after ORIF (more frequently transient radial nerve palsy, infection and fracture extension, or fixation failure) [45]. In most cases of loose prosthesis, revision arthroplasty is preferred over ORIF; nevertheless ORIF shows a success rate of almost 90% even in cases of loose prosthesis [45].

Revision surgery can be necessary in the setting of a Campbell type 4 fracture with failure of nonoperative treatment. Revision can be achieved with placement of a long humeral stem and multiple cerclage wires.

Unstable stems should be revised with longer stems [46].

In the setting of a tuberosity fracture after anatomic replacement, conversion to RSA is suggested if tuberosities cannot be fixed [46].

Revision arthroplasty has a success rate over 80% with a complication rate of 29% (more frequently nonunion, dislocation, dissociations of prosthetic components, and transient or permanent nerve palsy) [45].

In case of extensive humeral bone loss, a strut allograft and additional plate fixation or the use of two hemicylinders of tibial allograft to form a “sarcophagus,” used with cerclage wires but without a plate, should be used especially if the bone defect is over 5 cm [46].

Finally, a humeral endoprosthesis is an option for managing severe bone loss without allograft. Traditionally used in tumor surgery, these implants afford substantial modularity, allowing for reconstruction of large segmental defects [46].

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