MEDDOCS Open Access Publisher

ISSN: 2640-4389

Journal of Orthopedics and Muscular System

Open Access | Review Article

Complications of Reverse Shoulder Arthroplasty, A Review of Literature

***Corresponding Author(s): Amr Elshahhat**

Lecturer of orthopedic surgery, Mansoura University, Egypt.

Email: amrelshahat@mans.edu.eg

Received: June 22, 2023

Accepted: Jul 25, 2023

Published Online: Jul 31, 2023

Journal: Journal of Orthopedics and Muscular System

Publisher: MedDocs Publishers LLC

Online edition: http://meddocsonline.org/

Abstract

Complications of reverse shoulder arthroplasty have been reported widely, with its utilization in different shoulder pathologies including rotator cuff deficiency, post-traumatic sequalae, revision procedures, failed rotator cuff surgeries, and glenohumeral osteoarthritis. The most common reported complications include instability, infection, notching, loosening, nerve injury, intra-operative fractures, and glenoid failure. Considerations should be taken regarding patient selection, preoperative planning, familiarity with different reverse shoulder prosthetic designs, and surgical technique as per the precise positioning and soft tissue balancing. With all, complication rate can be declined with improvement of functional status along with the increase in longevity of implant. Considering the risk factors of each complication, the operating surgeon can prevent and treat them.

Keywords: Reverse shoulder arthroplasty; Complications; Instability; Loosening; Notching; failure; Intraoperative fractures.

Introduction

Reverse Shoulder Arthroplasty (RSA) is considered a valuable surgical option for patients with Rotator Cuff (RC) deficiency. Recently, indications have widely expanded to include glenohumeral arthritis, failed RC surgery, previous arthroplasty, or proximal humeral fractures [1,2]. The outcome of shoulder arthroplasty is influenced by many factors related to surgical indication, surgeon's experience, implant design, positioning [3], and postoperative rehabilitation [4].

With the widespread use of RSA, complications abound. The rate of complications is approximately 15%–24% [5,6]. The rate has been declining with the modern advances in prosthetic design and operative techniques. Additionally, the rate differs among studies due to different definitions of complications [7]. The complications can be classified into major or minor, also, as per the side into either humeral side or glenoid side complications, besides infection and neurovascular injuries. This article reviews different complications following RSA, with exhibiting the ways to avoid or to treat such problems.

Complications related to humeral side

I- Prosthetic instability

Prosthetic instability remains one of the most common disabling outcomings after RSA. It represents 4.7 % of total complications [7]. Recently, this incidence declined with modern implants as demonstrated in a systematic review, to account for 0.24% [8]. Arm in at-risk position (adduction, extension, and internal rotation) is the main cause for dislocation in the antero-superior direction (Figure 1) [9]. Instability usually occurs in the first six months, and of whom, half occur in the first three months [10]. Conservative management via closed reduction is often sufficient in half of patient with resultant stable shoulder, whilst recurrent instability usually necessitates one or more revision procedures.

The only guarantee for successful management of such complication is represented in determination of the cause. Early dislocation may follow different circumstances including; previous shoulder arthroplasty (hemiarthroplasty or anatomical total

Cite this article: Elshahhat A. Complications of Reverse Shoulder Arthroplasty, A Review of Literature. J Orthop Muscular Syst. 2023; 6(2): 1023.

shoulder arthroplasty) [11,12], the lack of soft tissue tension subsequent to implant malposition, improper version, glenosphere diameter, and mechanical impingement [11-13]. Axillary nerve/deltoid dysfunction, bony deficiency, and Subscapularis (Ssc) deficiency in a medialized-design RSA are also risk factors for instability [11,13].

Proper soft tissue tensioning is a must to increase the exerted compressive forces on the prosthesis, the lateral-medial and superior-inferior tensions should be restored with humeral positioning as regard to the lateral offset of tuberosity-glenoid distance and the vertical offset of acromion–greater tuberosity distance, respectively. Additionally, tensioning may be impacted by different factors related to prosthetic design (glenosphere offsets and size, humeral neck-shaft angle, and insert thickness), and surgical technique (humeral osteotomy level and glenosphere positioning) [14].

Management option should be tailored to the cause. Proper clinical and radiological assessment remain the key success for revision surgery. Implant (humeral or glenoid) mal-version should be rectified after a CT-rotational evaluation [11]. In cases of shorter humeral height compared radiographically to contralateral sound side, the height could be inclined utilizing a thicker liner or metal tray [11,15,16]. Although the more constrained humeral component can enhance implant stability, it might reduce impingement-free ROM [17]. Previous studies reported arm lengthening by 15-20 mm is sufficient to soft tissue tensioning and prosthetic stability [3,11]. If the humeral height is shorter by >15–20 mm to other side, revision of humeral stem using cemented stem or structural bone grafting is advisable [11]. Besides, the glenosphere size might require an upgrade along with inferior placement in patients with a lax soft-tissue envelope, and in those with humeral bone loss to help fill the dead space [14]. In patients with excessively Medialized Center Of Rotation (COR), glenoid lateralization should be planned [11]. If medialization is <15 mm, a larger or lateralized glenosphere can be sufficient [11,16,18]. Nonetheless, in cases with severe glenoid deficiency, surgeon shall consider bony increased offset-RSA (BIO-RSA) [11,12]. In the setting of correctly positioned components and appropriate soft-tissue tension, inferior soft-tissue impingement remains the most likely cause, all soft tissue inferior to the glenosphere approximately the inferior 180°, should be removed at the inferior axillary pouch during revision [19].

On the other hand, a Late prosthetic instability may result after alteration in implant position; this positional change can be caused by humeral stem subsidence or baseplate movement. Serial radiographic evaluation is beneficial for detection of implant loosening and subsidence. Aseptic Loosening on glenoid side is much lower than on humeral side due to the lower resultant torque stress on glenoid side with medialization [11,20], if compared to humeral side which is caused by humeral stress shielding or polyethylene debris of scapular notching [5]. Septic implant loosening usually necessitates two-stage revision.

Regardless the timing of dislocation, the first-line management typically consists of closed reduction followed by a brief period (≤6 weeks) of sling immobilization and avoidance of extension, adduction, and internal rotation. Failure to maintain reduction requires further evaluation as aforementioned.

Subscapularis management during RSA is still a matter of debate. Being an important anterior restraint against prosthetic instability in anatomical arthroplasties, its role in RSA has been extremely studied. Some demonstrated a higher risk of instability with irreparable Ssc, Fracture sequelae, and tumour surgery [21-24]. Similarly, **Boileau et al.** considered the repair in medialized-RSA designs [11-13], however, it's repair is not required in lateralized-RSA design, as horizontal deltoid compression could be sufficient for prosthetic stability [25]. On contrary, regardless implant design, **Clark et al.** [26] postulated that Ssc repair was not correlated to prosthetic stability, and reported similar dislocation rate between repair and non-repair groups. Nonetheless, a recent meta-analysis demonstrated a lower dislocation rate after Ssc repair whatever the implant-design [27], hence, Ssc tendon should be assessed preoperatively, with considering the RSA-design to be implanted.

Instability is accompanied with a considerable failure rate after revision [28]. **Chalmers et al.** [15] reported that 85% of primary RSA cases and >50% of revision RSA cases had successful outcomes after revision surgery. In this context, pre-operative planning, choice of implant-design, and intra-operative assessment of stability and impingement are advisable in all cases [29]. The accurate positioning of prosthetic components with proper tensioning of soft tissue envelope within acceptable measurement parameters is considered crucial for stability and longevity of implant [3].

II- *Humeral Component Loosening*

Loosening is defined with radiolucent lines adjacent to humeral stem. Mimicking the **Gruen et al**. classification for femoral stem loosening after total hip arthroplasty, **Gilot et al.** demonstrated similar lines resembling the former classification (Figure 2). Bone adjacent to humeral stem is divided into 8 zones. Zones 1, 2, and 3 representing the lateral aspect of the stem at the proximal, middle, and distal thirds respectively. Zone 4 is the area around the distal stem tip. Zones 5, 6, 7, and 8 represent the medial portion of the stem from the distal, middle, proximal thirds, and base, respectively. The lines are also classified as per their width as <1.0 mm, 1.0 to 1.50 mm, 1.51 to 2.0 mm or >2.01 mm. The humeral stem is radiographically at risk for clinical loosening if a radiolucent line ≥2 mm is present in ≥3 zones [30].

Humeral component loosening may occur at one of two sites: either within the cement mantle or unscrewing of the metaphyseal neck from the humeral stem. The latter can be managed by adding a built-in polyethylene bushing to the screw threads to enhance the interlock between the neck and stem [31].

III- *Humeral fractures (Postoperative & Intraoperative)*

A recent systematic review by **Shah et al.** revealed an incidence of 1.8 % of periprosthetic humeral fractures [6]. Osteopenia, rheumatoid arthritis, and revision surgeries are considered the major risk factor for periprosthetic humeral fractures [32,33]. Postoperative trauma often fractures the bone near the tip of prosthesis (stress-riser region). Intraoperative fractures usually follows operative technical issues, osteopenia, contracted soft tissues, and the use of press-fit stem (high-filling ratio) [31,34].

As illustrated in figure 3, periprosthetic humeral fractures can be classified according to **Wright** and **Cofield** [35] into type A (located at the tip of the prosthesis and extend proximally), type B (similar to A without proximal extension), and type C (distal to the prosthetic tip). Type A and C fractures can be managed conservatively, however, operative treatment should be considered for type B fractures [36]. Recently, **Kirchhoff et al**.

demonstrated an easy new classification (Table 1), targeted for fractures after RSA with the reliance upon fracture localisation, height, and prosthesis condition either stable or loose. Additionally, they considered a specific management for each type [37].

Humeral periprosthetic fractures are better avoided than managed. They should be avoided in every intraoperative step; inferior capsular release from the humerus, avoid excessive torque while positioning the arm in adduction and extension, the humeral canal is better reamed by hand, and broaching in line with the humeral shaft. Glenoid implantation should not be postponed after complete humeral preparation; as the spherical metaphyseal reamer usually leaves a thin humeral cortical shell, which is prone to fracture during glenoid exposure. Additionally, excessive fitting of the humeral stem is better avoided [28].

Prosthetic stability may be jeopardized with intraoperative metaphyseal, or tuberosity fractures; this can managed by cerclage fixation or by utilization of long stem to avoid future stem loosening [19]. When present, intraoperative diaphyseal fractures must be stabilized before stem implantation by open reduction and internal fixation (ORIF) with a cable platting and cerclage wires. The use of a long stem prosthesis may be beneficial. Conservative management of intraoperative fractures usually delay rehabilitation; hence, it is not highly recommended [19]. Management of postoperative periprosethetic humeral fractures is still debatable. Non operative management may be enough (Figure 4), however, there are concerns as per the non-union and longer healing time. On contrary, surgical intervention represents a more aggressive but time-saving solution; represented in stem exchange with fracture bypass by at least twice the cortical diameter to tolerate torsional and bending loads [38]. Other options are ORIF with platting, or cortical strut allografts acting as bone plates secured with cables. Both options represent implant-sparing procedures [31].

Table 1: Kirchhoff et al. classification for periprosthetic shoulder fractures after RSA as per fracture pattern, prosthetic stability with specific management for each type (ORIF; open reduction and internal fixation) [37].

Humeral fracture	Prosthesis stability	Management option
1; Tuberosities **2;** Spiral **3;** Oblique **4;** Distal	**S;** Stable **L;** Loose	**1-S;** Conservative or ORIF **2-S;** ORIF **3-S;** ORIF **L;** Revision by long stem RSA, or long stem RSA + ORIF

Complications related to glenoid side

I- Scapular notching

An abutment-impingement was initially described by **Sirveaux et al.** [39] as a consequence of repeated contact between humeral stem and inferior scapular neck during abduction. They developed a radiographic-based classification system (Figure 5), based upon the defect size; grade 1 shows a defect within the inferior pillar of the scapular neck, grade 2 with defined bone defect under the level of the inferior screw within baseplate, grade 3 with defect extending over the inferior screw, and grade 4 with bone defect reaching the level of central peg. In the same context, later studies documented notching also with rotational friction (frictional-impingement) [40,41]. This repeated friction produces liner wear, and notching. The resultant released fragments out of friction induces inflammatory process and osteolysis [41]. It is fundamental to seek impingement-free-ROM in all planes. Rotational impingement can occur with humeral component placement posteriorly or anteriorly on the glenoid, whilst, superior glenoid placement can lead to abutment-impingement [42].

Scapular notching is usually observed radiographically six months postoperatively (28). Its incidence relies upon different factors; glenosphere offset and position, COR, humeral component position, and prosthetic design. Possible procedures to limit notching incidence, were proposed including COR lateralization, humeral lateralization via either reducing neck-shaft angle or choosing lateralized-offset prosthesis, inferior positioning of baseplate, glenosphere inferior tilting, and utilization of a larger-diameter glenosphere. Out of the mentioned procedures, humeral neck-shaft angle and glenosphere placement are considered the most beneficial to decrease notching without risks of glenoid loosening and reducing prosthetic longevity [43,44]. **Ferrier et al**. [45] noted the lowest notching incidence and the best clinical results after humeral lowering by >24 mm.

Clinical consequences of scapular notching are still controversial. Prosthetic instability, unexplained pain, and loosening might be related. **Boileau et al.** and **Lévigne et al.** reported that neither the presence nor the size of notching impacted clinical scores [46,47], on contrary, **Sirveaux et al.** and **Simovitch et al.** demonstrated declined clinical outcome with notching [39,42]. There is no consensus on erosion progression, **Werner et al**. concluded that radiographic progress seemed to reach a plateau, others reported erosion worsening with time [48-50].

II- Glenoid loosening & failure

The highly constrained nature of early reverse shoulder prosthesis showed extremely high glenoid loosening and failure rates following the resultant high shear and torque on glenoid component. Glenoid loosening was demonstrated radiographically as radiolucent zones around glenoid component, usually within one year postoperatively [51,52]. With modern implants, the rate of loosening declined especially with inferior tilting of implanted baseplate [53].

Bone ingrowth onto implanted baseplate through neutralizing the forces across baseplate-bone interface, is the guarantee against glenoid side failure, which depends upon the surgical technique and implant design. Micromotion across baseplate-bone interface can be minimized through inferior tilting of baseplate, the use of locking screws with increased angle between them and the central peg [17,54]. Management of failed glenoid component is always challenging. Treatment options may be staged-defect grafting or one revision procedure with/without structural allograft [55].

III- Intraoperative glenoid Fracture

As declared by many authors, intraoperative glenoid fractures occur due to either reaming of osteoporotic glenoid beyond subchondral bone, or reaming prior to glenoid one contact [56]. This rare complication (Figure 6) represents 0.3% of complications [6]. Management depends upon the implant design. On the setting of baseplate with central post, the fractured fragment should be stabilized prior to baseplate implantation. On the contrary, unstable non-reconstructed glenoid bed for baseplate, necessitates hemiarthroplasty without baseplate implantation either as a last resort, or as temporary solution for later conversion to RSA [19].

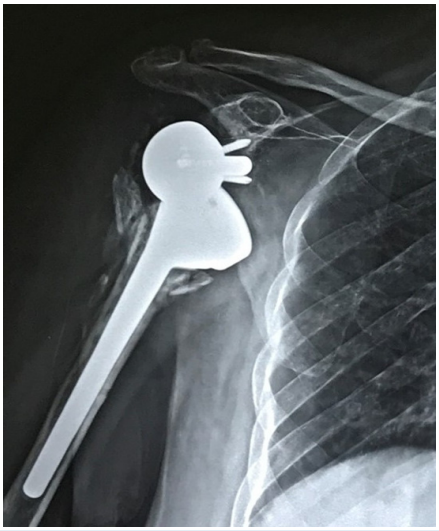

Figure 1: Anterior dislocation of RSA one month postoperatively (patient's identity is not disclosed).

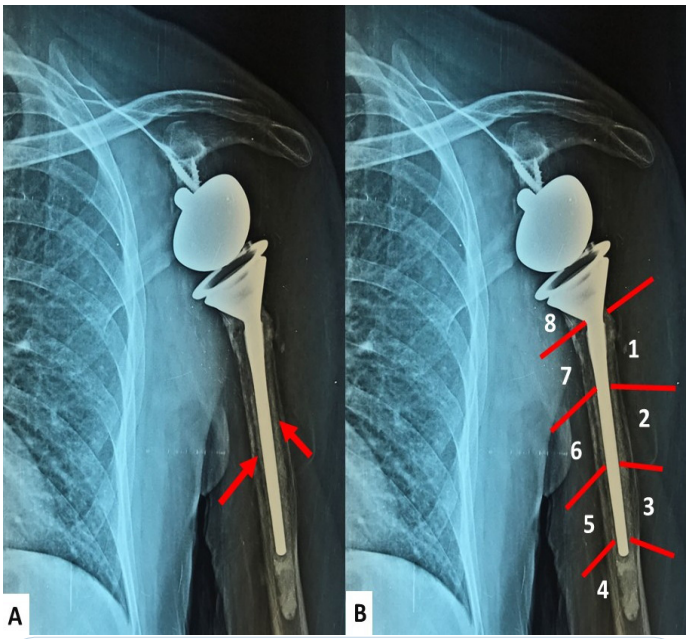

Figure 2: **(A)** Cemented humeral stem with significant lucent lines (red arrows), **(B)** The eight zones of humeral stem loosening as defined by Gilot et al.

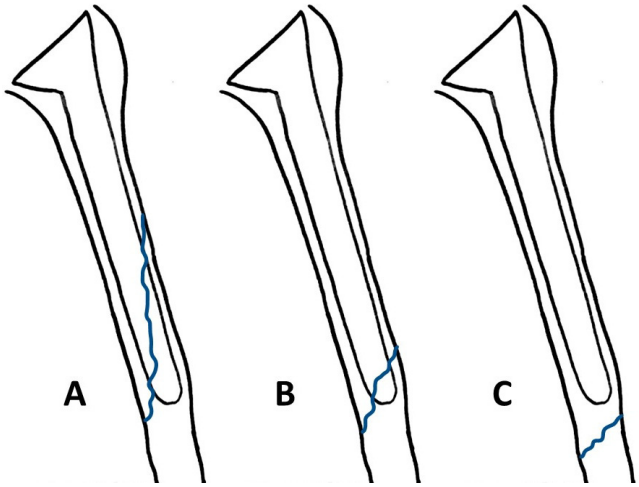

Figure 3: **Wright** and **Cofield** classification of periprosthetic humeral fractures.

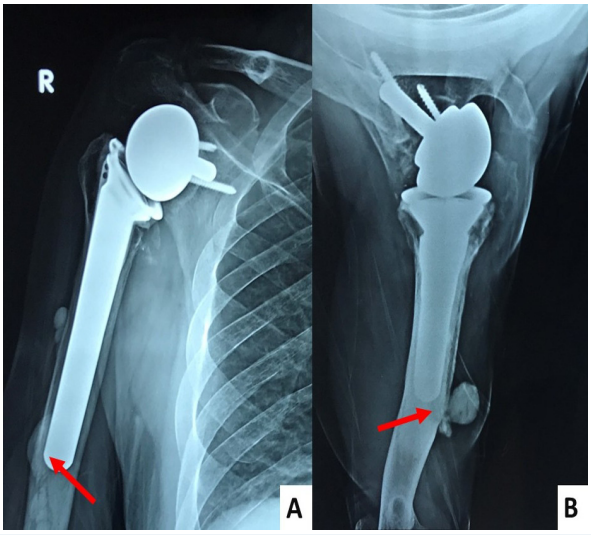

Figure 4: Healed periprosthetic humeral fracture around the tip of stem with extravasation of cement (patient's identity is not disclosed).

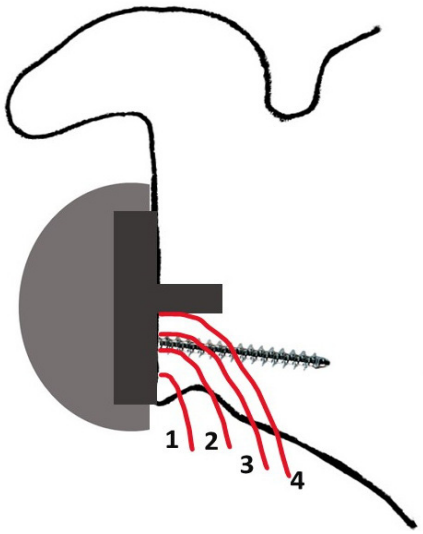

Figure 5: Illustration demonstrating the scapular notching classification.

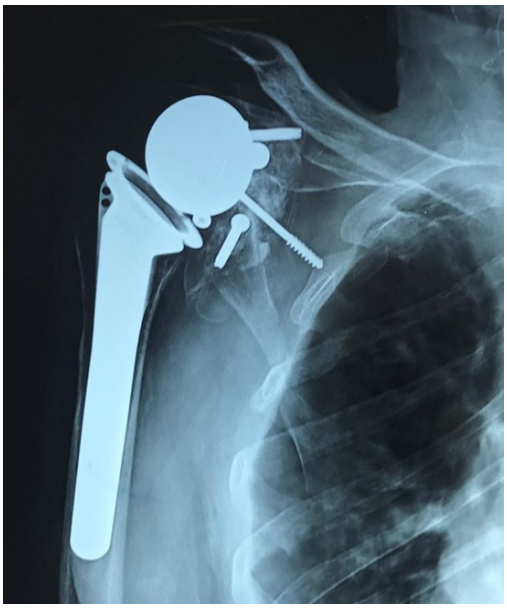

Figure 6: Baseplate malpositioning and failure following improper fixation due to intraoperative glenoid fracture (patient's identity is not disclosed).

IV Acromial & scapular fractures

Acromial or scapular fractures are considered a fatigue fracture represented around 3 to 6 months postoperatively, due to deltoid over tensioning following excessive medialization or distalization of COR. Arm lengthening >2.5 mm is considered excessive lengthening [3,57,58]. These fractures are usually correlated to osteoporosis and are relatively rare with incidence rates ranging from 0.9% to 10% [12,20,59]. Sometimes, fractures are silent without functional deficit. **Crosby** and **Hamilton** classified acromial fractures into type I; anterior acromion fracture, type II; posterior acromial body fracture posterior to acromioclavicular joint, type III; scapular spine fracture extending from tip of peripheral screw [59].

It is still recommended to limit COR distalization <2.5cm to limit acromion fracture [3,60]. Intraoperatively, the baseplate is better not placed excessively inferior, besides, a lateralized-design prosthesis can decrease incidence of scapular fractures. In addition, directing the superior screw within the baseplate toward the coracoid base could prevent scapular spine fractures [12]. Early detection might be predicted by progressive inclined acromial slope in follow-up radiographs [61]. A high suspicion of acromial fracture could be linked to patients in pain, with slowly progressing rehabilitation, and with sudden worsening shoulder function in the first year postoperative. Management of fractured scapula and acromion is still debated [19]. With conservative management, **Levy et al.** [62] demonstrated decreased shoulder function, while **Hattrup** [63] reported good results. **Crosby et al.** [59] documented high nonunion rate, and recommended surgical fixation with tension band wiring and buttress plate.

V- Glenoid Dissociation

The glenosphere is fixed to the baseplate as per the implant design via one of two methods, either a morse taper or central locking screw [26]. Dissociation of glenosphere out of the baseplate has been reported with many RSA-designs. Morse taper failure usually follows soft tissue interposition, bony impingement, single-pole engagement of glenosphere after its impaction under slight angle, fluid in the well of the female aspect of the assembly, insufficient force applied to impact the glenosphere, and incomplete-seated glenosphere due to proud or cross-threaded screws within the baseplate [64]. Incomplete glenosphere-seating, even by <1 mm, decreases the cold-weld between the glenosphere and the baseplate [64].

Considering the geometry of the utilized implant is fundamental for prevention of such complication. Appropriate glenosphere seating over the baseplate is best obtained via the utilization of the rim reamer. The outer side diameter of the rim reamer is better larger than that of glenosphere. Without, the reamer would be less effective in removing the potentially blocking interfering bone [64]. Vigorous glenosphere pull after impaction remains the principal method to verify complete glenosphere seating. Moreover, the glenosphere should be flush with baseplate when inspected on post-operative radiograph [26]. Patients must be cautious to avoid early impact loading postoperatively.

Neurovascular complications

I- Neurologic injury

Postoperative neurologic injury is often transient. It accounts for 1%–4% after RSA [65]. Out of which, brachial plexopathy and axillary nerve injuries are the most common [66]. Axillary nerve is often affected following stretch injury by retractors or prolonged arm positioning in ER and extension. Rarely, direct injury is caused by the saw or scalpel [66,67]. It may also be at risk at the junction of humeral head with the shaft in posterior metaphyseal area. Thus, care should be taken when reaming the metaphysis to avoid posterior humeral cortical violation, particularly when having a low humeral cut and using a large reamer [68].

Stretch injuries are generally reversible during the first 3 months after surgery, but some do not heal for long periods, resulting in neurologic deficits [12]. Permenant axillay nerve injury leads to arm weakness and shoulder instability [67]. Some authors recommend routine exposure or palpation of the nerve performed with advantage of the tug test [69,70]. The suprascapular nerve is at risk during glenoid implantation; the screws within the baseplate may perforate the glenoid and injure the nerve leading to infraspinatus muscle deficiency [71]. In revision surgeries, neurologic injury may be associated with removal of a well fixed cemented humeral stem, surgical dissection in altered anatomy, and presence of scar tissue [72].

II- Hematoma

A large dead space may occur after RSA, particularly with severely deficient RC, with an inclined risk for hematoma formation in 1%-20%. The possible causes for developing hematoma might be inferior glenosphere placement, glenosphere medialization, or valgus orientation of humeral component [52]. To guard against hematoma formation, surgeons can perform meticulous hemostasis intraoperatively with electrocautery, layered wound closure, and drain is better used with mentioned risk factors. Hematoma is linked to possible periprosthetic infection. persistent discharge from incision may alarm for early sinus tract formation, hence, hematoma evacuation, irrigation, and debridement might be indicated [73].

III- ***Infection***

Periprosthetic infection demonstrates 1%-10%, being one of two most common complications of RSA [5]. Early prosthetic failure within the first two years postoperatively is a strong indicator of infection [74], also, it remains the most common reason for revision within 2 years after RSA [75]. Infection is always linked to rheumatoid arthritis, revision surgeries, and formed hematoma with large dead space [76]. Other risk factors should be considered including morbid obesity, uncontrolled diabetes, malnutrition, young age <65 years, intravenous drug abuse, long operation time, and number of times the surgical room door was opened during surgery [11,28,77,78].

Shoulder surgeon should suspect possible prosthetic infection in cases with painful stiff reconstructed joint, regardless the normal serological markers and normal radiographs [79]. **Pottinger et al.** [80] reinforced the importance of Propionibacterium acnes (P. acnes), linked to nearly 52% of acute or chronic infections, additionally, aspiration rarely indicates a causative organism.

Avoiding prosthetic infection is mandatory. That might be achieved via bathing with chlorhexidine gluconate on the night before surgery [81,82], prophylactic administration of first-generation cephalosporin one hour before surgery, however, P. acnes will remain not covered [83]. During skin preparation and before draping, drying of painted chlorhexidine should be achieved [84]. Recently, benzoyl peroxide has been reported to eradicate P. acne. Limiting the number of times, the surgical room doors opening during surgery is recommended [28].

Regular changing surgical gloves, changing the blade after skin incision, frequent surgical site irrigation, irrigation with diluted povidone (1.3 g/L), injection of gentamicin at the time of closure, use of antibiotic-loaded cement (1 g of vancomycin/bone cement), and use of topical adhesives for skin closure have been reported to be effective [74,75,77,85,86].

In cases with confirmed postoperative infection, empirical antibiotics are started till causative organism is identified on culture and sensitivity for tailoring curative antibiotic therapy, some bacterial species can be evident in 3-4 days, however, slowly growing ones as Cutibacterium acnes (formerly P. acnes) may require 10-14 days for identification [87,88]. With acute onset infection (within 6 weeks of arthroplasty), irrigation, debridement, and polyethylene exchange can be sufficient. Nonetheless, chronic infection usually indicates two-stage revision. The first stage includes hardware removal, irrigation, debridement, and antibiotic spacer. Then, at least six weeks of parenteral antibiotics, lastly, prosthetic reimplant after confirmed negative cultures and blood tests 76]. Treatment of chronic infection with one-stage exchange can reduce recovery time and costs, however, it is still with a little evidence [76,89]. **Klatte et al.** [90] reported a 94% success rate with a mean follow-up period of 4.7 years. In a systematic review, both one- and two-stage revision demonstrated 85% success rates [91]. Additionally, cement spacers could be a long-term treatment option for low demand patients [91,92].

Summary

Despite the endured experience and better understanding of the fundamental ideas of RSA, complications nevertheless occur, even with the most experienced surgeons. Distinctive issues should be considered including patient selection, preoperative planning, familiarity with various RSA designs, and surgical technique as per the accurate positioning and soft tissue balancing. Taking into consideration the risk factors of each complication, the operating surgeon can avoid and treat them.

References

1. Cuff D, Pupello D, Virani N, Levy J, Frankle M. Reverse shoulder arthroplasty for the treatment of rotator cuff deficiency. J Bone Joint Surg Am. 2008; 90:1244-51.
2. Nascimento AT, Claudio GK, Rocha PB. Reverse shoulder arthroplasty: Functional results in rotator cuff arthropathy. Rev Bras Ortop (Sao Paulo). 2020; 55:106-11.
3. Elshahhat A, Selim N, Basyoni Y, Nour K. Clinico-radiological correlation of reverse shoulder arthroplasty outcomes. International Journal of Research in Orthopaedics. 2023; 9: 149.
4. DeVito P, Damodar D, Berglund D, Vakharia R, Moeller EA, Giveans MR, et al. Predicting outstanding results after reverse shoulder arthroplasty using percentage of maximal outcome improvement. J Shoulder Elbow Surg. 2019; 28: 1223-31.
5. Ascione F, Domos P, Guarrella V, Chelli M, Boileau P, Walch G. Long-term humeral complications after Grammont-style reverse shoulder arthroplasty. J Shoulder Elbow Surg. 2018; 27: 1065-71.
6. Shah SS, Gaal BT, Roche AM, Namdari S, Grawe BM, Lawler M, et al. The modern reverse shoulder arthroplasty and an updated systematic review for each complication: part I. JSES Int. 2020; 4: 929-43.
7. Zumstein MA, Pinedo M, Old J, Boileau P. Problems, complications, reoperations, and revisions in reverse total shoulder arthroplasty: a systematic review. Journal of shoulder and elbow surgery. 2011; 20: 146-57.
8. Galvin JW, Kim R, Ment A, Durso J, Joslin PMN, Lemos JL, et al. Outcomes and complications of primary reverse shoulder arthroplasty with minimum of 2 years' follow-up: a systematic review and meta-analysis. J Shoulder Elbow Surg. 2022; 31: e534-e44.
9. Wall BT, Mottier F, Walch GJJoS, Surgery E. 9: Complications and revision of the reverse prosthesis: a multicenter study of 457 cases. 2007; 16: e55.
10. Teusink MJ, Pappou IP, Schwartz DG, Cottrell BJ, Frankle MA. Results of closed management of acute dislocation after reverse shoulder arthroplasty. J Shoulder Elbow Surg. 2015; 24: 621-7.
11. Boileau P. Complications and revision of reverse total shoulder arthroplasty. Orthopaedics & Traumatology: Surgery & Research. 2016; 102: S33-S43.
12. Jauregui JJ, Nadarajah V, Shield WP, III, Henn RF, III, Gilotra M, Hasan SA. Reverse Shoulder Arthroplasty: Perioperative Considerations and Complications. JBJS Reviews. 2018; 6.
13. Zhou HS, Chung JS, Yi PH, Li X, Price MD. Management of complications after reverse shoulder arthroplasty. Current Reviews in Musculoskeletal Medicine. 2015; 8: 92-7.
14. Klein SM, Dunning P, Mulieri P, Pupello D, Downes K, Frankle MAJJ. Effects of acquired glenoid bone defects on surgical technique and clinical outcomes in reverse shoulder arthroplasty. 2010; 92: 1144-54.
15. Chalmers BP, Wagner ER, Sperling JW, Cofield RH, Sanchez-Sotelo J. Treatment and Outcomes of Reverse Shoulder Arthroplasty Dislocations. Journal of Shoulder and Elbow Arthroplasty. 2017; 1: 2471549217695260.
16. Boileau P, Melis B, Duperron D, Moineau G, Rumian AP, Han Y. Revision surgery of reverse shoulder arthroplasty. Journal of shoulder and elbow surgery. 2013;22(10):1359-70.
17. Gutiérrez S, Keller TS, Levy JC, Lee WE, Luo Z-PJCo, research r. Hierarchy of stability factors in reverse shoulder arthroplasty. 2008; 466: 670-6.
18. Helmkamp JK, Bullock GS, Amilo NR, Guerrero EM, Ledbetter LS, Sell TC, et al. The clinical and radiographic impact of center of rotation lateralization in reverse shoulder arthroplasty: A systematic review. Journal of Shoulder and Elbow Surgery. 2018; 27: 2099-107.
19. Cheung E, Willis M, Walker M, Clark R, Frankle MA. Complications in Reverse Total Shoulder Arthroplasty. 2011; 19: 439-49.
20. Farshad M, Gerber C. Reverse total shoulder arthroplasty—from the most to the least common complication. International Orthopaedics. 2010; 34: 1075-82.
21. Edwards TB, Williams MD, Labriola JE, Elkousy HA, Gartsman GM, O'Connor DP. Subscapularis insufficiency and the risk of shoulder dislocation after reverse shoulder arthroplasty. Journal of Shoulder and Elbow Surgery. 2009; 18: 892-6.
22. Raiss P, Edwards TB, da Silva MR, Bruckner T, Loew M, et al. Reverse shoulder arthroplasty for the treatment of nonunions of the surgical neck of the proximal part of the humerus (type-3 fracture sequelae). J Bone Joint Surg Am. 2014; 96: 2070-6.
23. De Wilde LF, Plasschaert FS, Audenaert EA, Verdonk RC. Functional recovery after a reverse prosthesis for reconstruction of the proximal humerus in tumor surgery. Clin Orthop Relat Res. 2005: 156-62.
24. Trappey GJt, O'Connor DP, Edwards TB. What are the instabil-

ity and infection rates after reverse shoulder arthroplasty? Clin Orthop Relat Res. 2011; 469: 2505-11.

25. Routman HD. The role of subscapularis repair in reverse total shoulder arthroplasty. Bull Hosp Jt Dis (2013). 2013; 71: 108-12.

26. Clark JC, Ritchie J, Song FS, Kissenberth MJ, Tolan SJ, Hart ND, et al. Complication rates, dislocation, pain, and postoperative range of motion after reverse shoulder arthroplasty in patients with and without repair of the subscapularis. Journal of shoulder and elbow surgery. 2012; 21: 36-41.

27. Matthewson G, Kooner S, Kwapisz A, Leiter J, Old J, MacDonald P. The effect of subscapularis repair on dislocation rates in reverse shoulder arthroplasty: A meta-analysis and systematic review. Journal of Shoulder and Elbow Surgery. 2019; 28: 989-97.

28. Kim SC, Kim IS, Jang MC, Yoo JC. Complications of reverse shoulder arthroplasty: a concise review. Clin Shoulder Elb. 2021; 24: 42-52.

29. Lädermann A, Edwards TB, Walch G. Arm lengthening after reverse shoulder arthroplasty: a review. Int Orthop. 2014; 38: 991-1000.

30. Gilot G, Alvarez-Pinzon AM, Wright TW, Flurin P-H, Krill M, Routman HD, et al. The incidence of radiographic aseptic loosening of the humeral component in reverse total shoulder arthroplasty. 2015; 24: 1555-9.

31. Norris WPPTRJA, shoulder AT. Complications and Treatment of Reverse Shoulder Prosthesis. 2009: 242.

32. Campbell JT, Moore RS, Iannotti JP, Norris TR, Williams GRJJos, surgery e. Periprosthetic humeral fractures: mechanisms of fracture and treatment options. 1998; 7: 406-13.

33. Brusalis CM, Taylor SA. Periprosthetic Fractures in Reverse Total Shoulder Arthroplasty: Current Concepts and Advances in Management. Current Reviews in Musculoskeletal Medicine. 2020; 13: 509-19.

34. Schnetzke M, Coda S, Raiss P, Walch G, Loew M. Radiologic bone adaptations on a cementless short-stem shoulder prosthesis. Journal of shoulder and elbow surgery. 2016; 25: 650-7.

35. Wright TW, Cofield RHJTJob, volume jsA. Humeral fractures after shoulder arthroplasty. 1995; 77: 1340-6.

36. Kumar S, Sperling JW, Haidukewych GH, Cofield RHJJ. Periprosthetic humeral fractures after shoulder arthroplasty. 2004; 86: 680-9.

37. Kirchhoff C, Beirer M, Brunner U, Buchholz A, Biberthaler P, Crönlein MJIo. Validation of a new classification for periprosthetic shoulder fractures. 2018; 42: 1371-7.

38. Bohsali KI, Wirth MA, Rockwood Jr CAJJ. Complications of total shoulder arthroplasty. 2006; 88: 2279-92.

39. Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Mole DJTJob, et al. Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff: results of a multicentre study of 80 shoulders. 2004; 86: 388-95.

40. Lädermann A, Gueorguiev B, Charbonnier C, Stimec BV, Fasel JH, Zderic I, et al. Scapular notching on kinematic simulated range of motion after reverse shoulder arthroplasty is not the result of impingement in adduction. 2015; 94.

41. Nyffeler R, Werner C, Simmen B, Gerber CJTJob, volume jsB. Analysis of a retrieved Delta III total shoulder prosthesis. 2004; 86: 1187-91.

42. Simovitch RW, Zumstein MA, Lohri E, Helmy N, Gerber CJJ. Predictors of scapular notching in patients managed with the Delta III reverse total shoulder replacement. 2007; 89: 588-600.

43. Frankle M, Siegal S, Pupello D, Saleem A, Mighell M, Vasey MJJ. The reverse shoulder prosthesis for glenohumeral arthritis associated with severe rotator cuff deficiency: a minimum two-year follow-up study of sixty patients. 2005; 87: 1697-705.

44. Mulieri P, Dunning P, Klein S, Pupello D, Frankle MJJ. Reverse shoulder arthroplasty for the treatment of irreparable rotator cuff tear without glenohumeral arthritis. 2010; 92: 2544-56.

45. Ferrier A, Blasco L, Marcoin A, De Boissieu P, Siboni R, Nérot C, et al. Geometric modification of the humeral position after total reverse shoulder arthroplasty: what is the optimal lowering of the humerus? Journal of Shoulder and Elbow Surgery. 2018; 27: 2207-13.

46. Boileau P, Gonzalez J-F, Chuinard C, Bicknell R, Walch GJJos, surgery e. Reverse total shoulder arthroplasty after failed rotator cuff surgery. 2009; 18: 600-6.

47. Lévigne C, Boileau P, Favard L, Garaud P, Molé D, Sirveaux F, et al. Scapular notching in reverse shoulder arthroplasty. Journal of shoulder and elbow surgery. 2008; 17: 925-35.

48. Lévigne C, Garret J, Boileau P, Alami G, Favard L, Walch GJCO, et al. Scapular notching in reverse shoulder arthroplasty: is it important to avoid it and how? 2011; 469: 2512-20.

49. Grassi FA, Murena L, Valli F, Alberio RJJoOS. Six-year experience with the Delta III reverse shoulder prosthesis. 2009; 17: 151-6.

50. Werner BC, Wong AC, Mahony GT, Craig EV, Dines DM, Warren RF, et al. Clinical outcomes after reverse shoulder arthroplasty with and without subscapularis repair: the importance of considering glenosphere lateralization. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2018; 26: e114-e9.

51. Broström L, Wallensten R, Olsson E, Anderson DJCo, research r. The Kessel prosthesis in total shoulder arthroplasty. A five-year experience. 1992: 155-60.

52. Boileau P, Watkinson D, Hatzidakis AM, Hovorka I. Neer Award 2005: The Grammont reverse shoulder prosthesis: results in cuff tear arthritis, fracture sequelae, and revision arthroplasty. Journal of shoulder and elbow surgery. 2006; 15: 527-40.

53. Gutiérrez S, Greiwe RM, Frankle MA, Siegal S, Lee III WEJJos, surgery e. Biomechanical comparison of component position and hardware failure in the reverse shoulder prosthesis. 2007; 16: S9-S12.

54. Hopkins AR, Hansen UN, Bull AM, Emery R, Amis AAJJos, surgery e. Fixation of the reversed shoulder prosthesis. 2008; 17: 974-80.

55. Holcomb JO, Cuff D, Petersen SA, Pupello DR, Frankle MA. Revision reverse shoulder arthroplasty for glenoid baseplate failure after primary reverse shoulder arthroplasty. Journal of Shoulder and Elbow Surgery. 2009; 18: 717-23.

56. Wierks C, Skolasky RL, Ji JH, McFarland EGJCo, research r. Reverse total shoulder replacement: intraoperative and early postoperative complications. 2009; 467: 225-34.

57. Roberson TA, Shanley E, Abildgaard JT, Granade CM, Adams KJ, Griscom JT, et al. The influence of radiographic markers of biomechanical variables on outcomes in reverse shoulder arthroplasty. JSES Open Access. 2019; 3: 59-64.

58. Yeazell ST, Inacio J, Malige A, Dailey H, Carolan GF. Bone density and its relation to the development of acromial stress fracture following reverse total shoulder arthroplasty. Shoulder Elbow. 2022; 14: 135-41.

59. Crosby LA, Hamilton A, Twiss T. Scapula Fractures After Reverse Total Shoulder Arthroplasty: Classification and Treatment. Clinical Orthopaedics and Related Research®. 2011; 469.

60. Cagle PJ, Brochin RL, Gluck MJ, Zastrow RK, Parsons BO, Sanchez-Sotelo J, editors. Referencing the pectoralis major tendon for humeral stem height placement in reverse shoulder arthroplasty for fracture. 2020.

61. Otto RJ, Virani NA, Levy JC, Nigro PT, Cuff DJ, Frankle MAJJos, et al. Scapular fractures after reverse shoulder arthroplasty: evaluation of risk factors and the reliability of a proposed classification. 2013; 22: 1514-21.

62. Levy JC, Anderson C, Samson A. Classification of postoperative acromial fractures following reverse shoulder arthroplasty. JBJS. 2013; 95: e104.

63. Hattrup SJ. The influence of postoperative acromial and scapular spine fractures on the results of reverse shoulder arthroplasty. Orthopedics (Online). 2010; 33.

64. Crosby-August L. Feature Articles Identifying the Complications of Reverse TSA.

65. Carofino BC, Brogan DM, Kircher MF, Elhassan BT, Spinner RJ, Bishop AT, et al. Iatrogenic Nerve Injuries During Shoulder Surgery. JBJS. 2013; 95.

66. Parisien RL, Paul HY, Hou L, Li X, Jawa A. The risk of nerve injury during anatomical and reverse total shoulder arthroplasty: an intraoperative neuromonitoring study. Journal of Shoulder and Elbow Surgery. 2016; 25: 1122-7.

67. Lädermann A, Lübbeke A, Mélis B, Stern R, Christofilopoulos P, Bacle G, et al. Prevalence of neurologic lesions after total shoulder arthroplasty. 2011; 93: 1288-93.

68. Lädermann A, Stimec B, Denard P, Cunningham G, Collin P, Fasel JJO, et al. Injury to the axillary nerve after reverse shoulder arthroplasty: an anatomical study. 2014; 100: 105-8.

69. Gill TJ, Hawkins RJ. Complications of shoulder surgery: treatment and prevention: Lippincott Williams & Wilkins. 2006.

70. Flatow E, Bigliani LJOr. Tips of the trade. Locating and protecting the axillary nerve in shoulder surgery: the tug test. 1992; 21: 503-5.

71. Wang J, Singh A, Higgins L, Warner JJJos, surgery e. Suprascapular neuropathy secondary to reverse shoulder arthroplasty: a case report. 2010; 19: e5-e8.

72. Levy J, Frankle M, Mighell M, Pupello D. The Use of the Reverse Shoulder Prosthesis for the Treatment of Failed Hemiarthroplasty for Proximal Humeral Fracture. 2007; 89: 292-300.

73. Cheung EV, Sperling JW, Cofield RHJCo, research r. Infection associated with hematoma formation after shoulder arthroplasty. 2008; 466: 1363-7.

74. Portillo ME, Salvadó M, Alier A, Sorli L, Martínez S, Horcajada JP, et al. Prosthesis Failure Within 2 Years of Implantation Is Highly Predictive of Infection. Clinical Orthopaedics and Related Research®. 2013; 471.

75. Richards J, Inacio MCS, Beckett M, Navarro RA, Singh A, Dillon MT, et al. Patient and Procedure-specific Risk Factors for Deep Infection After Primary Shoulder Arthroplasty. Clinical Orthopaedics and Related Research®. 2014; 472.

76. Cuff D, Virani N, Levy J, Frankle M, Derasari A, Hines B, et al. The treatment of deep shoulder infection and glenohumeral instability with debridement, reverse shoulder arthroplasty and postoperative antibiotics. 2008; 90: 336-42.

77. Morris BJ, O'Connor DP, Torres D, Elkousy HA, Gartsman GM, Edwards TB. Risk factors for periprosthetic infection after reverse shoulder arthroplasty. Journal of Shoulder and Elbow Surgery. 2015; 24: 161-6.

78. Simha S, Shields EJW, Wiater JM. Periprosthetic Infections of the Shoulder. JBJS Reviews. 2018; 6.

79. Shields MV, Abdullah L, Namdari S. The challenge of Propionibacterium acnes and revision shoulder arthroplasty: a review of current diagnostic options. Journal of shoulder and elbow surgery. 2016; 25: 1034-40.

80. Pottinger P, Butler-Wu S, Neradilek MB, Merritt A, Bertelsen A, Jette JL, et al. Prognostic factors for bacterial cultures positive for Propionibacterium acnes and other organisms in a large series of revision shoulder arthroplasties performed for stiffness, pain, or loosening. 2012; 94: 2075-83.

81. Hsu JE, Bumgarner RE, Matsen FA, III. Propionibacterium in Shoulder Arthroplasty: What We Think We Know Today. JBJS. 2016; 98.

82. Murray MR, Saltzman MD, Gryzlo SM, Terry MA, Woodward CC, Nuber GW. Efficacy of preoperative home use of 2% chlorhexidine gluconate cloth before shoulder surgery. Journal of Shoulder and Elbow Surgery. 2011; 20: 928-33.

83. Longo UG, Candela V, Facchinetti G, Marchetti A, Dsoke S, Mazzella C, et al. Antibiotic prophylaxis in primary and revision shoulder replacement: a systematic review. BMC Musculoskeletal Disorders. 2020; 21: 292.

84. Saltzman MD, Nuber GW, Gryzlo SM, Marecek GS, Koh JL. Efficacy of Surgical Preparation Solutions in Shoulder Surgery. JBJS. 2009; 91.

85. Ortmaier R, Resch H, Hitzl W, Mayer M, Stundner O, Tauber M. Treatment strategies for infection after reverse shoulder arthroplasty. European Journal of Orthopaedic Surgery & Traumatology. 2014; 24: 723-31.

86. Romanò CL, Borens O, Monti L, Meani E, Stuyck J. What treatment for periprosthetic shoulder infection? Results from a multicentre retrospective series. International Orthopaedics. 2012; 36: 1011-7.

87. Engesæter L, Lie SA, Espehaug B, Furnes O, Vollset SE, Havelin LIJAoS. Antibiotic prophylaxis in total hip arthroplasty Effects of antibiotic prophylaxis systemically and in bone cement on the revision rate of 22,170 primary hip replacements followed 0-14 years in the Norwegian Arthroplasty Register. 2003; 74: 644-51.

88. Trampuz A, Zimmerli W, Zimmerli WJNEJM. Prosthetic-joint infections. 2004; 351: 1645-54.

89. Kunutsor SK, Wylde V, Beswick AD, Whitehouse MR, Blom AW. One- and two-stage surgical revision of infected shoulder prostheses following arthroplasty surgery: A systematic review and meta-analysis. Scientific Reports. 2019; 9: 232.

90. Klatte TO, Junghans K, Al-Khateeb H, Rueger JM, Gehrke T, Kendoff D, et al. Single-stage revision for peri-prosthetic shoulder infection: outcomes and results. Bone Joint J. 2013; 95: 391-5.

91. Mercurio M, Castioni D, Ianno B, Gasparini G, Galasso O. Outcomes of revision surgery after periprosthetic shoulder infection: a systematic review. Journal of Shoulder and Elbow Surgery. 2019; 28: 1193-203.

92. Belay ES, Danilkowicz R, Bullock G, Wall K, Garrigues GE. Single-stage versus two-stage revision for shoulder periprosthetic joint infection: a systematic review and meta-analysis. Journal of Shoulder and Elbow Surgery. 2020; 29: 2476-86.