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Radiological changes, infections and neurological complications after reverse shoulder arthroplasty related to different design types and their rates: Part II

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- Early reported complication rates with the Grammont-type reverse shoulder arthroplasty (RSA) were very high, up to 24%.
- A 'problem' is defined as an intraoperative or postoperative event that is not likely to affect the patient's final outcome, such as intraoperative cement extravasation and radiographic changes. A 'complication' is defined as an intraoperative or postoperative event that is likely to affect the patient's final outcome, including infection, neurologic injury and intrathoracic central glenoid screw placement.
- Radiographic changes around the glenoid or humeral components of the RSA are very frequently observed and described in the literature.
- High complication rates related to the Grammont RSA design led to development of non-Grammont designs which led to a dramatic fall in the majority of complications.
- The percentage of radiological changes after RSA is not negligible and remains unsolved, despite a decrease in its occurrence in the last decade. However, such changes should be now considered as simple problems because they rarely have a negative influence on the patient's final outcome, and their prevalence has dramatically decreased.
- With further changes in indications and designs for RSA, it is crucial to accurately track the rates and types of complications to justify its new designs and increased indications.

Keywords: infection; intraoperative cement extravasation; neurologic lesion; problems; prosthesis design

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Introduction

Initial complication rates of the original Grammont-type prosthesis were reported at up to 24%.[1–3] With the expansion of indications for reverse shoulder arthroplasty (RSA), the complication rates increased,[4] which led to development of improved non-Grammont designs which led to a dramatic fall in the majority of complications.[5]

Complications after RSA can be divided into mechanical and radiographical types. We are grateful to the editors of *EFORT Open Reviews* for allowing us to present an overview divided into two parts. The Part I 'Mechanical complications and fractures after reverse shoulder arthroplasty related to different design types and their rates' has been published in this issue.[6] The goal of this second part is to review reported radiological complications, infection and neurologic injury related to the use of RSA and to analyse their occurrence based on the various prosthetic designs used. Rarer complications, such as intraoperative cement extravasation and intrathoracic central glenoid screw, will also be discussed.

Humeral radiolucency and loosening

Humeral radiolucent lines are assessed in seven zones according to the classification of Gruen et al,[7] adapted to the shoulder, and are classified according to width (< 2 mm or > 2 mm). Zone 1 is the area surrounding the greater tuberosity located at the superolateral part of the stem. Just below it are zone 2 and zone 3 placed on the lateral side of the stem in sequential order until the tip of the stem. Below, zone 4 is located on either side of the humerus. Zone 7 is the area surrounding the calcar on the superomedial part of the stem, whereas zone 5 and zone 6

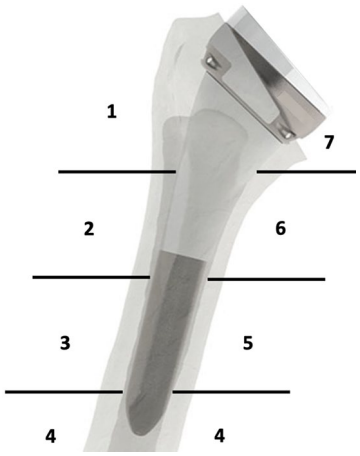

Fig. 1 Figure showing zones 1 to 7 according to the classification of Gruen[7] adapted to the shoulder.
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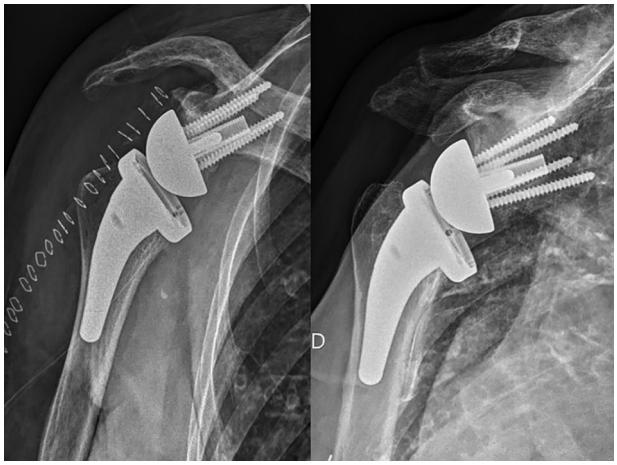

Fig. 2 Postoperative (left) and at 12-month follow-up (right) anteroposterior radiograph of a right uncemented reverse shoulder arthroplasty demonstrating subsidence. Observe the change in the vertical distance between the most superior aspect of the humeral component and the greater tuberosity.
Source: From wiki.beemed.com, with permission.

are located on the medial side of the stem in sequential order between zone 4 and zone 7 (Fig. 1).[8] Loosening is defined as displacement of the humeral component in the period between the initial postoperative radiograph and the most recent follow-up, or if radiolucencies > 2 mm are present in more than three zones.[8]

Mélis et al published a multicentre study that specifically evaluated radiological changes in 68 Grammont-style RSAs with minimum eight-year follow-up. They reported radiolucent lines around the humeral stem in 57% of shoulders,[8] which were evaluated according to the Gruen et al classification adapted to the shoulder.[7] They were more frequent with cemented components in zones 1, 2, 3, 4 and 6, equally distributed in zone 5, whereas in zone 7 they were significantly more common in uncemented RSAs. Radiolucent lines, which were more common in cemented stems, were located in the proximal zones and did not appear to progress towards loosening of the component at ten years of follow-up.[8] Other authors haven't reported humeral stem failures using a lateralized glenosphere at short and medium-term follow-up.[9] In a recent meta-analysis, Shah et al reported a pooled mean incidence of radiolucent lines around the humeral component in 12% (2419 RSAs analysed), a pooled mean incidence of humeral component loosening of 1.4% (3817 RSAs analysed), and a pooled mean revision rate for humeral component loosening of 1% (2920 RSAs analysed).[4] Similarly, Zumstein et al reported a pooled mean incidence for humeral component loosening of only 1.3% (782 RSAs analysed).[3]

Humeral subsidence

Subsidence is determined by comparing the distance between the most cephalic aspect of the greater tuberosity with the distal border of the stem according to the method introduced by Bogle et al,[10] and is empirically defined as inferior migration of the shaft greater than 5 mm between immediate postoperative and subsequent follow-up (Fig. 2).[11]

The radiological finding of subsidence following RSA has been a rarely described phenomenon. Tross et al published a multicentre study with a minimum follow-up of one year that specifically evaluated the presence of subsidence following the implantation of an uncemented short-stem RSA. They observed subsidence in 11% of cases, which averaged 1.4 mm. Although subsidence was a frequent radiographic finding, they did not observe any correlation with component loosening or decrease in clinical outcomes at short term follow-up.[10] At a minimum follow-up of eight years, Mélis et al reported humeral subsidence to be more common in Grammont-style RSA stems that were cemented compared to those with press-fit fixation (8.8% vs. 2.9% respectively).[8] Further long-term studies should help in further understanding of the relevance of subsidence as a risk factor for future loosening of the stem.

Stress shielding

Stress shielding has rarely been reported in regard to different designs of RSA (Fig. 3). Denard et al performed a multicentre study with a minimal follow-up time of two years where they compared functional outcomes and stress shielding of RSA between cement or press-fit fixation using a standard-length humeral stem with a proximal medial-lateral taper designed for proximal fixation.[12] They found that proximal lateral stress shielding was more common

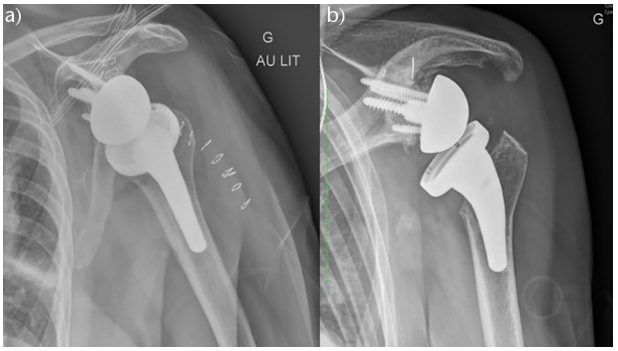

Fig. 3 Immediate postoperative (A) and one-year follow-up (B) of a left reverse shoulder arthroplasty. Observe the proximal bone resorption.

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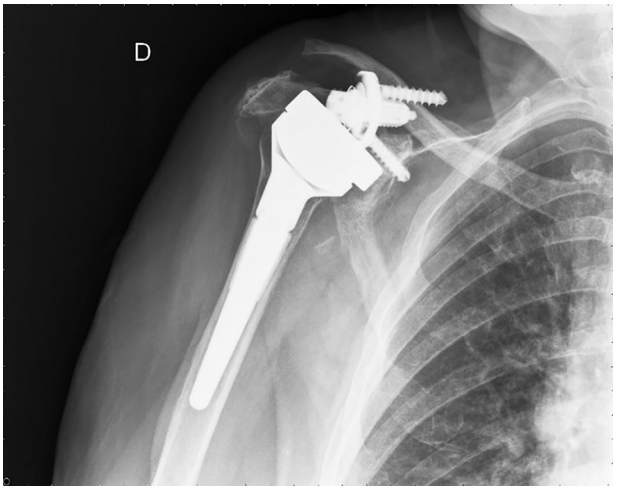

Fig. 4 Superior migration of the glenoid component of a right reverse should arthroplasty.

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in the press-fit group (68%) than in the cemented group (25%). Proximal medial changes were frequent in both groups, which could be related to the component design; as the taper design might achieve some press-fit fixation even with the cemented fixation, which would result in partial stress shielding. The changes observed were minor and there were no cases of tuberosity resorption or loosening.[12] Mélis et al compared 34 press-fit RSA to 34 RSA with cement fixation at a minimum eight years of follow-up. Proximal cortical thinning was observed in 47% of the press-fit stems and in only 5.9% of cemented stems. Partial or complete greater tuberosity resorption was observed in all press-fit stems and in 69% of cemented stems, while lesser tuberosity resorption was present in 76% and 45%, respectively. Radiographic signs of stress shielding, that were present especially with press-fit components, were associated with increasing relative stem diameter, which was greater in press-fit stems, and did not affect stability.[8] Raiss et al analysed radiographic stress shielding findings in 77 RSA short-stemmed press-fit humeral stems with a minimum follow-up of two years.[13] They found signs of stress shielding in 35% of stems, which in 17% were high adaptive changes. The high adaptations were associated with a higher filling ratio and cortical contact of the stem, which is in line with the study by Mélis et al.[8] They concluded that surgeons should try to achieve the minimal required canal filling with these type of implants in order to minimize radiographic changes.[13] Harmsen and Norris observed proximal stress shielding in 98% of cases at minimum two-year follow-up in 232 RSAs using a standard length stem designed for diaphyseal fixation.[14] These findings warrant further long-term studies to compare the method of fixation for humeral stem used in RSA in order to determine the likely different patterns of stress shielding based on stem design. Celik et al have reported that three-dimensional computerized tomography (CT) volumetric filling ratio enables early identification of patients with a short stem implant at risk for stress shielding compared to the plain radiographs, and could prove valuable in improving humeral stem designs.[15]

Glenoid radiolucency, loosening and migration

Any radiolucent lines around the glenoid screws, around the peg or below the baseplate are classified according to their width (< 2 mm or > 2 mm). Loosening is considered to be present if the glenoid component has migrated, as demonstrated by shift, tilt or subsidence, or if complete radiolucency > 2 mm is present in each zone.[8]

Mélis et al reported radiolucent lines around the glenoid component in 16% of cases but no loosening.[8] Recently, Lignel et al published a multicentre study, which included 513 patients with RSA with lateralized glenoid implants performed after proximal humerus fracture, where 25% of patients had at least a five-year follow-up. They reported a 1.8% rate of migration of the glenoid implant (Fig. 4) and 12.2% rate of loosening, defined as stage 3 or 4 notching or full radiolucent line under the baseplate. Superior tilt of the glenoid component, a short peg and an intraoperative fracture represent risk factors for loosening.[16,17] In the aforementioned systematic review on studies between 2010 and 2019 by Shah et al the pooled mean incidence of radiolucent lines around glenoid component was 7.7% (1336 RSAs analysed), whereas loosening was present in 2.3%.[4] They reported a higher reported rate of radiolucent lines but significantly lower rates of loosening compared to systematic review published in 2011 by Zumstein et al, who included studies published between 1985 and 2008, and whose rates were 2.9% and 3.5%, respectively.[3]

This notable decrease in the rate of glenoid loosening could be ascribed to significant advancement in biomaterials. Lateralized RSA designs have increased loads transferred to the bone–prosthesis interface, which led to higher rates of loosening with initial designs. However, introduction of locking-screw technology, hydroxyapatite coating and increased size (i.e. 5 mm vs. 3.5 mm) of peripheral screws have significantly diminished the rate of baseplate loosening in specific lateralized RSA design.[4] Lopiz et al published a retrospective radiographic evaluation of 105 Grammont-style glenoid components with minimum five-year follow-up.[18] They demonstrated that a considerable number of RSA show radiographic findings around the glenoid component at five years, with 37.1% exhibiting minor changes (affecting one or two screws) and 8.6% exhibiting major changes (affecting three or more screws or the central peg). Their findings account for an aseptic loosening rate of the glenoid component at 4.8%. Like Lignel et al,[17] they showed that superior tilt of the glenoid component is a risk factor for radiolucent lines as well as for aseptic loosening,[18] which is in agreement with previous theoretical observations that superior tilt increases shear forces on the glenosphere.[19] Superior approach limits exposure of the inferior rim of the glenoid and thus prevents the adequate inclination of the glenoid component, therefore predisposing to superior tilt of the glenoid component and increasing the risk of radiolucent lines or notching.[20] Lopiz et al concluded that there has been significant improvement regarding the percentage of radiological changes observed of the glenoid in RSA over the years, probably as a result of non-Grammont designs with improved biomechanics, acquired experience by the surgeons and improved knowledge of optimal glenoid component positioning.[18]

Bone spurs and heterotopic ossification

Bone spurs at the inferior glenoid or heterotopic ossifications (Fig. 5) after RSA are a relatively common finding of unknown clinical importance. Shah et al and Zumstein et al have reported in the systematic reviews the same incidence of heterotopic ossification of 0.8% (5529 RSAs analysed).[3,4] Mélis et al[8] have described a significantly higher incidence of bone scapular spurs and/or heterotopic ossifications in 75% of shoulders, although it has not been shown whether they were clinically relevant. Lignel et al reported the presence of scapular bone spurs in 43.9% of patients, without any clinical or radiographic consequences.[17] Risk factors for bone spurs are the presence of notching and the use of superolateral approach.[4] The latter confirms the hypothesis that the inferior scapular bone spur might be an osteophyte caused by the traction from an incompletely released triceps tendon, as it is more difficult to release it from the superolateral approach. Risk factors for

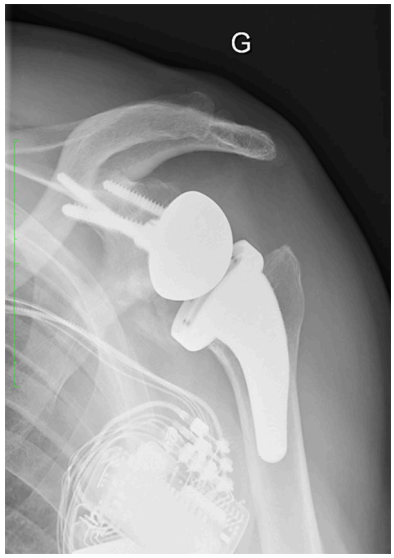

Fig. 5 Heterotopic ossification after left reverse should arthroplasty.

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heterotopic ossifications are: the extent of surgical release of soft tissues like the release of the triceps tendon in the superolateral approach,[21] cemented implants,[22] fracture (remaining fractured bone debris or possible migration of malpositioned tuberosities could act as a confounding factor in radiological evaluation), standard glenosphere, Delta III prosthesis,[18] use of bone graft,[23] and RSA combined with cerclage for complex proximal fracture with extension to diaphysis.[24] Protective factors for heterotopic ossifications are: female sex, left shoulder, eccentric glenosphere, Lima and Delta Xtend prosthesis.[18] As described by other authors, the presence of heterotopic ossification could be a by-product of a chronic foreign-body reaction of the capsule.[25] Heterotopic ossification could be found distal to the glenoid and could limit range of motion.[9] It is largely a benign and non-progressive condition that does not require additional treatment and has no long-term clinical consequences. The exception is rarely encountered grade 2 heterotopic ossifications which has a negative effect on the shoulder function during its development.[21] Importantly in heterotopic ossifications a very high degree of suspicion for infection is necessary since the evidence associating heterotopic ossification to infections (particularly with Cutibacteria) is accumulating.[26,27] Incidence of different radiological changes after RSA reported by different authors is summarized in Table 1.

Infection

The incidence of infections after primary RSA is reported in the literature to be between 1% and 15%. Zumstein et al reported in their systematic review an average

Table 1. Incidence of different radiological changes after RSA reported by different authors

Author & year of publication	Follow-up	Number of shoulders and type of RSA	Humeral radiolucency/ loosening	Glenoid radiolucency/ loosening	Humeral subsidence	Stress shielding	Bonne spurs/ heterotopic ossification
Mélis et al, 2011[8]	Minimum 8 years	68 Grammont RSA – 34 C and 34 UC components	57%/0% Radiolucent lines > 2 mm in width in more than three zones: 11.8 % C vs. 5.8% UC stems.	16%/0%	8.8% in C and 2.9% in UC stems	Proximal cortical thinning: 5.9% C vs. 47% UC stems. Greater tuberosity's partial or complete resorption: 69% C vs. 100% UC stems Lesser tuberosity's partial or complete resorption: 45% C vs. 76% UC stems	BS and/or HO: 75%
Shah et al, 2020* (included studies between 2010 and 2019)[4]	Average 3.2 years	1336 for GR, 3995 for glenoid loosening, 3817 for HL, 5529 for HO	12%/1.4%	7.7%/2.3%	N/A	N/A	HO: 0.8%
Zumstein et al, 2011* (included studies between 1985 and 2008)[3]	Minimum average 2 years	782	N/A/1.3%	2.9%/3.5%	N/A	N/A	HO: 0.8%
Lignel et al, 2018[17]	Average 55 months	513 RSA with lateralized glenoid implant	N/A	N/A/1.8% cases of migration and 12.2% of potential cases of loosening	N/A	N/A	BS: 43.9%
Lopiz et al, 2021[18]	Minimum 5 years	105 Grammont-style RSA	N/A	37.1% minor changes and 8.6% of major changes of GR. Loosening 4.8%	N/A	N/A	N/A
Tross et al, 2020[11]	Minimum 1 year	139 UC short stems RSA	N/A	N/A/0	11%	N/A	N/A
Denard et al, 2020[12]	Minimum 2 years	93 UC vs. 26 C standard length stems RSA	N/A	N/A	N/A	Proximal lateral stress shielding: 25% C vs. 68% UC stems Calcar osteolysis: 58 C vs. 43% UC stems	N/A
Harmsen et al, 2017[14]	Minimum 2 years	232 standard length stems RSA.	N/A/0	N/A	N/A	Proximal stress shielding: 98%	N/A

Note. RSA, reverse shoulder arthroplasty; C, cemented; UC, uncemented; BS, bone spur; HO, heterotopic ossification; GR, glenoid radiolucency; HR, humeral radiolucency.
*Systematic review.

infection rate of 3.8%, which included primary and revision RSA, with a higher rate in revision surgery.[3] The infection rate reported in a more recent systematic review by Shah et al was 2.4% for primary RSA cases.[4] Although the reported prosthetic joint infection rate is significantly lower than that in Zumstein et al,[3] it is still higher than that for anatomic shoulder arthroplasty.[28] Factors that might explain the higher rate of RSA infection are increased implant surface, large subacromial dead space caused by the ball-and-socket configuration, common postoperative haematoma, extensive surgical dissection, patients with compromised general health and numerous previous procedures.[4,29]

Risk factors for prosthetic joint infection of the shoulder can be divided to patient and treatment factors. Patient factors are male sex, younger patient,[28] smoking,[30] hepatitis C, HIV, Parkinson's disease and those dependent on haemodialysis.[31–34] In the majority of studies, diabetes has not been correlated with an increased risk of prosthetic joint infection.[35] It is unclear whether body mass index is a risk factor, as the current studies have reported mixed findings.[36,37] There is strong evidence associating hip and knee prosthetic joint infection with either diabetes or high body mass index (BMI). It is thus to be expected that shoulder infection incidence is also increased in these conditions.[38] Patients with transplanted organs and life-long immunosuppressant therapy can be successfully treated with a primary implant. There are no large studies on this matter but, in a small study, Hatta et al have not shown an important problem with shoulder prosthetic joint infection in patients with transplanted organs.[39] Regarding treatment factors, associations include prior non-arthroplasty shoulder surgery,[40] a history of steroid injection within three months prior to arthroplasty,[41] proximal humerus fracture,[42] revision shoulder arthroplasty,[43] perioperative blood transfusion,[44] and postoperative therapeutic anticoagulation.[45] Thus, the broad indications for RSA and the design might explain the higher prosthetic

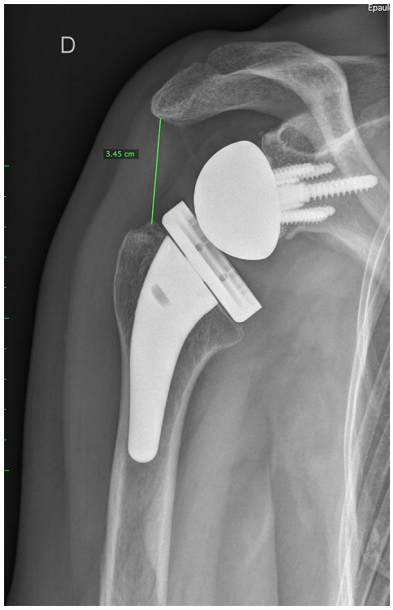

Fig. 6 Right reverse shoulder arthroplasty demonstrating a 3.5 cm acromiohumeral distance. Such subacromial dead space caused by the ball-and-socket configuration is a risk factor for postoperative infection.

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joint infection rate compared to anatomic total shoulder arthroplasty (Fig. 6).

The most commonly identified organism is Cutibacterium acnes (former name Propionibacterium acnes) which has low virulence and is normally found in the highest concentration on the chest and back region. Nelson et al published a systematic review in 2016 and showed that Cutibacterium acnes was found in 38.9% of all shoulder prosthetic joint infection followed by Staphylococcus aureus at 14.8% and Staphylococcus epidermidis at 14.5%.[46] Shoulder prosthetic joint infection due to Cutibacterium acnes presents with an indolent nature, slow progress, mild pain or stiffness, whereas an infection with a more virulent Staphyloccocus aureus may present with more pronounced symptoms of redness, swelling, drainage and systematic symptoms.[47] In 2018, the International Consensus Meeting on Musculoskeletal Infection proposed recommendations for the diagnosis and management of periprosthetic infections of the shoulder.[48] Currently recommended routine workup of shoulder prosthetic joint infection is similar to other artificial joints and includes plain radiographs, a basic set of labs including serum white blood cell count, C-reactive protein (CRP), and, most importantly, arthrocentesis with synovial fluid cell count and microbiology.[29,49] Because the cell count (in addition to histology) is dependent on the virulence of the causative organism, a lower threshold for diagnosis of shoulder prosthetic joint infection is expected due to the greater proportion of low-virulence organisms (e.g. Cutibacterium acnes).[50] Similarly, due to the low virulence of most Cutibacteria, there is no role for CRP as diagnostic criterion[50] as well as alpha defensin.[51] CRP is, however, important for general evaluation of the patient. Pre-revision tissue culture with an arthroscopic[52] or open[53] surgical procedure might prove helpful in confirming diagnosis of prosthetic joint infection in the setting of a painful shoulder arthroplasty with uncertain results of testing and no clear loosening of the components on the radiograph. The gold standard for the diagnosis of shoulder prosthetic joint infection remains intraoperative open biopsy and sonication of the explant with culture.[54] The 2018 International Consensus Meeting recommendations recommend obtaining five deep tissue specimens such as the periprosthetic membranes, capsule or humeral canal.[48] Antibiotic prophylaxis should not be omitted in presumed prosthetic shoulder infection before obtaining intraoperative cultures.[55–58] It is, however, advisable to stop antibiotics 14 days before the operation in case of presumed low-grade infection. The 2018 International Consensus Meeting does not recommend for or against topical treatment, although 3% hydrogen peroxide or 5% benzoyl peroxide have been shown to decrease the burden of Cutibacterium acnes on the skin.[48,59,60] Currently, the perioperative antibiotic of choice in shoulder arthroplasty is Cefazolin, which should be applied intravenously 30–60 minutes prior to incision in a dose of 2 grams. The 2018 International Consensus Meeting concluded that postoperative antibiotics are not necessary, but that, if administered, they should not be continued beyond 24 hours postoperatively. Proven and suspected infections should be revised operatively.

For early and late acute shoulder prosthetic joint infection a debridement with implant retention is the treatment of choice. Current literature shows that one-stage revision may be better than two-stage revision due to lower re-infection and complication rates, if it is possible to radically debride the joint.[61,62] Pellegrini et al concluded that a definitive antibiotic spacer could be used in low-demand, elderly patients with a contraindication for an additional operation.[63] A 12-week antibiotic treatment is advisable in shoulder prosthetic joint infection starting with an initial IV period[64] and including rifampicin,[65,66] in the case of debridement and retention of the prosthesis or one revision for staphylococcal shoulder prosthetic joint infection.[64,67] Chronic suppressive antibiotic therapy in select patients with retained components or failed previous treatment might also be useful. There are many dilemmas that remain unresolved regarding the shoulder prosthetic joint infection. The decrease in RSA infection rates as reported by Shah et al and Zumstein et al is unlikely to be associated with the difference in prosthetic design but is probably related to other factors such

as improved surgical technique and experience. Further high-level studies specific to the shoulder are needed to improve our current understanding.

Neurological lesion

Prevalence

Clinical neurological lesions after RSA, which most commonly affect the axillary nerve, are rarely reported, and Shah et al[4] published their overall incidence at 0.6%. The Grammont design (0.9%) had a significantly increased neurological injury rate compared to all other designs combined (0.1%). Primary RSA (0.4%) had a statistically lower rate of neurological injury compared to revision cases (1.1%). The subtotal of modern designs (0.4%) had a lower rate of neurological lesions compared to findings by Zumstein et al (1.2%).[3]

The location of the deltoid impairment can be anterior (group 1), anterior and middle (type 2) or global (type 4) (Fig. 7). They might be more common in RSA than in anatomic total shoulder arthroplasty due to the lengthening of the upper limb during RSA, the need for a greater glenoid exposure and trauma cases (Fig. 8).[68,69] Subtle neurological lesions discovered by intraoperative neuromonitoring[68,70] or postoperative electromyographic changes[68] appear to be more common than clinical neurological lesions as they have been reported in up to 63% of patients.[68] Their under-reporting might be due to common spontaneous recovery.[68,71] Even though neurological injuries are transient and rare, they might affect the clinical outcome by decreasing the deltoid strength caused by axillary nerve injury,[72] which may also lead to surgery, either neurolysis[73] or removal of the baseplate screw.[74]

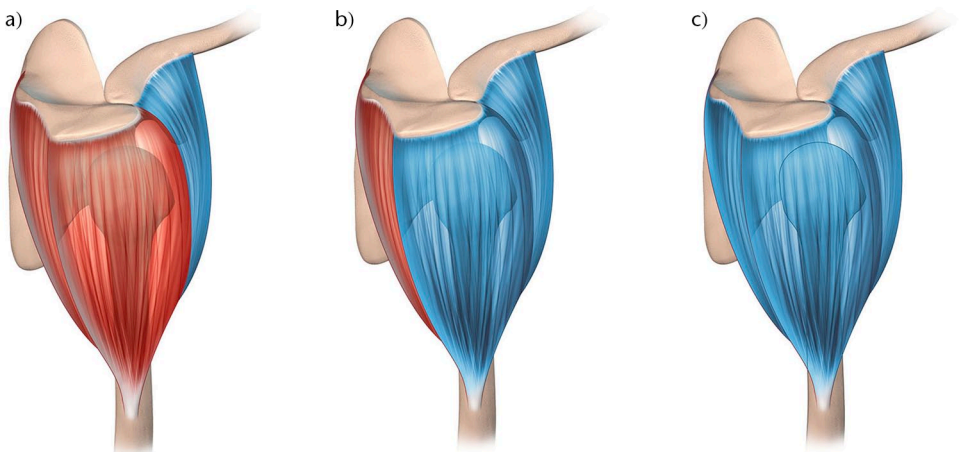

Fig. 7 The deltoid impairment due to neurological lesion can be classified according to its location and extent:[92] type 1 (A) corresponds to an impairment localized anteriorly, type 2 (B) an anterior and middle one, and type 4 (C) is a global impairment.
Source: From wiki.beemed.com, with permission.

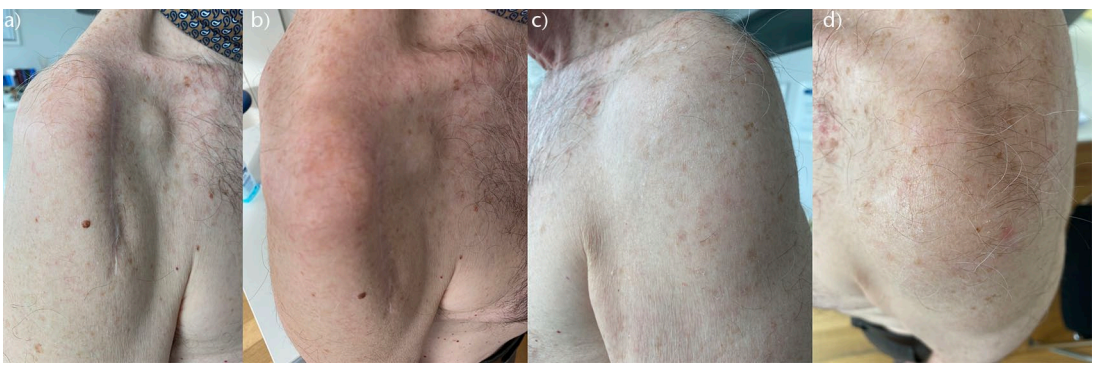

Fig. 8 Lateral (A and C) and superior (B and D) views of right and left shoulders. Note the gross atrophy of the right anterior deltoid (type 1).[92]
Source: From wiki.beemed.com, with permission.

Aetiology

Neurological injury during or after RSA implantation may be a consequence of surgical dissection, vessel injury, intraoperative positioning of the upper extremity, compression secondary to haematoma or retractors, interscalene brachial plexus block and lengthening of the arm.[68] Implanting the RSA can endanger the axillary nerve because of its nearby course to the humeral metaphysis (mean distance of 8.1 mm) and the inferior glenoid rim (mean distance, 13.6 mm).[75,76] Routine palpation and visualization of the axillary nerve during RSA has been suggested in order to avoid its injury.[77] Although, LiBrizzi et al reported a low incidence of partial temporary isolated axillary nerve injury when the nerve has not been exposed intraoperatively.[78] Additionally, superior and posterior drilling for screw positioning during baseplate placement puts the suprascapular nerve at risk. The distance from the central part of the glenoid to the suprascapular nerve cursing below the transverse scapular ligament is 28.4 mm and the distance to the spinoglenoid notch is 16.6 mm. Both distances were measured in the mediolateral direction.[76] Avoiding injury of the supraspinatus nerve, which could be injured during placement of the posterior screw while passing through the spinoglenoid notch, is especially critical in cases where the infraspinatus muscle is functional.[79] Indirect injuries caused by traction are believed to be the main mechanism for lesions caused by arm lengthening[68] and/or external rotation during humeral and glenoid preparation.[70] Intermittent nerve 'time-out' recovery phases in neutral position and avoidance of prolonged periods in extreme arm positions might prove beneficial in lowering the rate of neurological injury.[71] Additionally, cadaveric studies have shown that lateralization might lead to a lesser stretch on the axillary nerve compared to distalization.[80] Kim et al reported in their study of 182 shoulder with RSA a significant correlation between neurologic deficit and distalization.[81] Accordingly, Shah et al found a higher neurological injury rate in RSA with a medialized centre of rotation (0.8%) compared to prostheses with a lateralized centre of rotation (0.2%); however, the difference was not statistically significant.[4] Wagner et al found a different conclusion in their study. They analysed early complications after 137 bony increased offset (BIO) RSAs with either an onlay or an inlay stem. The minimum follow-up was three months. Axillary nerve neuropraxia was observed in 11% of onlay stems compared to 0% of inlay stems.[82] Lowe et al reported a lower rate of postoperative neurologic lesions using a 135 degree neck-shaft angle compared to a Grammont-style RSA.[83] Overall it appears that lateralization is protective for the brachial plexus, whereas distalization increases the risk of neurological injury. Accordingly, Lädermann et al have shown that the risk of neurological injury increases significantly with lengthening greater than four centimetres. Although, it seems that a ratio that considers the total length of the upper extremity of the patient, thus representing a percentage of lengthening, would be more accurate than absolute lengthening threshold in centimetres. However, this hypothesis needs to be cautiously applied, as lengthening for more than two centimetres compared with preoperative measurement might raise the incidence of postoperative neurological injury. Consequently, strategies have been devised to restrict upper-extremity lengthening in RSA.[84] If there is a high risk of dislocation, such as in revisions or proximal humeral bone loss, larger-diameter glenoid components, a superior approach and bony or prosthetic lateralization of the glenosphere are advised for use to prevent excessive tension.[85] However, if the lengthening is expected to be over four centimetres based on the preoperative planning, Nagda et al propose to use intraoperative nerve monitoring.[86]

Intrathoracic central glenoid screw

An unusual and previously unreported complication was published just recently by Frandsen et al,[87] who described a complication of RSA in which a long central baseplate screw was oriented through the scapula, subscapularis fossa, chest wall and all the way into the thoracic cavity. This case shows that entering the thoracic cavity is a possibility when longer than usual screws are used to fix the baseplate of RSA. It demonstrates the significance of knowledge of the glenoid anatomy and screw orientation, particularly in cases of advanced glenoid deformity. Especially if the glenoid is retroverted and the baseplate is placed at right angle to the face of the eroded glenoid, the central screw points towards the thorax. Surgeons should be aware of this potential life-threatening problem when they are dealing with a type B2, B3 or C glenoid and using long screws: the most common lengths of the central screw are 25–35 mm (Fig. 9). Surgeons should be cautious of a baseplate screw longer than 40 mm. The risk of this injury is not related to prosthetic design.

Intraoperative cement extravasation

Cement extrusion has been an unusual complication after RSA (Fig. 10). It has been well reported after hip arthroplasty, but not as much after shoulder arthroplasty. The tip of the humeral stem lies in immediate proximity of the spiral groove, where the radial nerve lies. Cement extravasation in this region could lead to the thermal injury of the radial nerve due to the cement polymerization. Levy et al

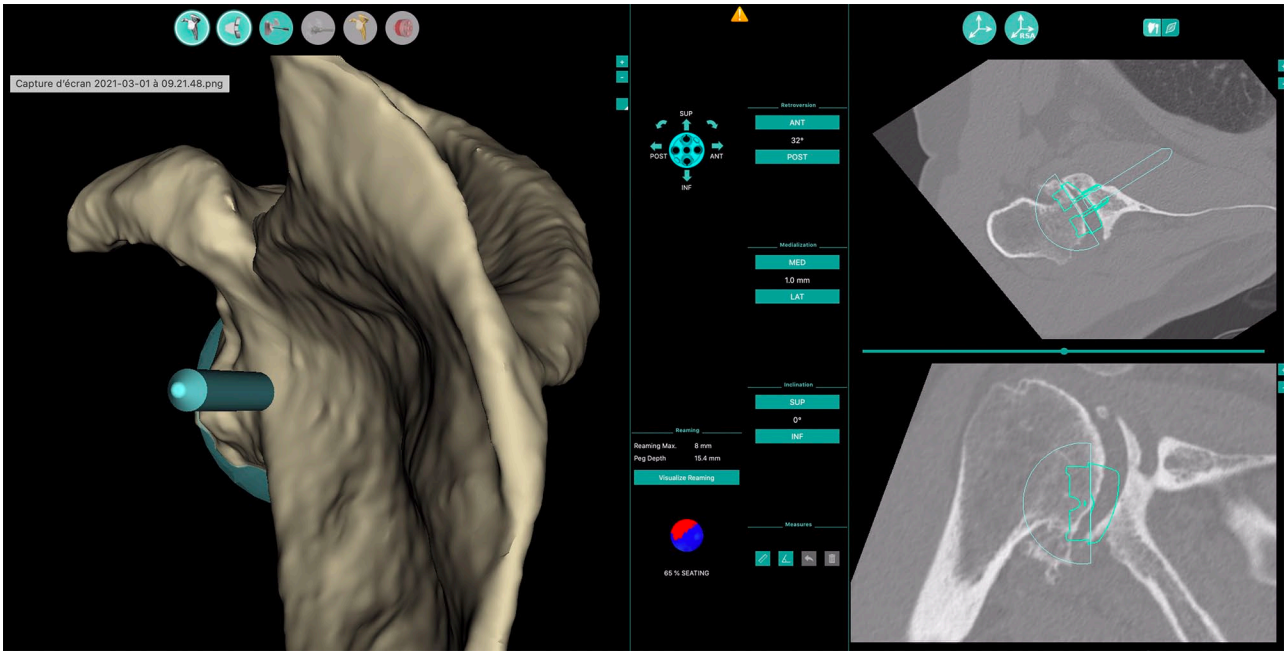

Fig. 9 Preoperative planning with 3D (right) and 2D (left) reconstruction views of a right B3 glenoid. Observe the proximity of the rib cage despite the patient's musculature.

Source: From wiki.beemed.com, with permission.

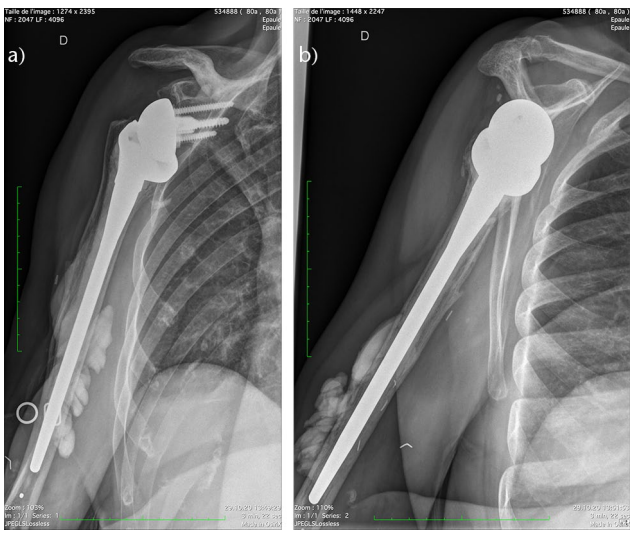

Fig. 10 Postoperative (A) shoulder anteroposterior and (B) scapular Y view of reverse shoulder arthroplasty with an example of cement extravasation which happened intraoperatively and was noticed postoperatively.

Source: From wiki.beemed.com, with permission.

described a case of radial nerve injury after RSA revision.[88] Most commonly, cement extravasation occurs due to cortical perforation or fracture. Its increased risk is associated with aggressive reaming, endosteal notching and cortical thinning close to the distal end of the prosthesis.[89,90] Sherfey et al[91] proposed hand-reaming of the humeral canal in order to avoid a fracture. Initial treatment of radial nerve injury consists of observation for three to four months for incomplete lesions or lesions in continuity. Electrodiagnostic studies are useful for monitoring the evidence of recovery and to establish the extent of the nerve injury. Failed recovery after six months after surgery is an indication for surgical treatment.[92] Successful removal of the cement causing radial nerve palsy has been previously reported. The risk of this injury is not correlated to prosthetic design.

Difference in complication rates and types depending on RSA design

The impact of specific RSA designs is described in Table 2. The comparison between the results published by Zumstein et al [3] (included studies between 1985 and 2008) and Shah et al[4] (included studies between 2010 and 2019) is noted in Table 3.

Conclusion

Our review of the recent literature on the topic of RSA and its complications shows that the percentage of radiological changes after RSA is not negligible and remains

Table 2. Difference in complication rates depending on specific reverse shoulder arthroplasty (RSA) design

Implant design type		Effect on the complication rate
Glenoid	Lateral offset	An eccentric glenosphere is a protective factor for heterotopic ossification, whereas a standard glenosphere is a risk factor for heterotopic ossification.[17]
	Inferior tilt	Placing the glenoid baseplate in 10 degrees of inferior inclination in order to avoid superior inclination decreases the likelihood of radiolucent lines[17] and loosening.[15,16]
	Varus neck-shaft angle	The use of a 135 degree neck-shaft angle lowers the incidence of neurologic injuries compared to 155 degree Grammont-style RSA.[82]
Humerus	Polyethylene	Repetitive contact between polyethylene and bone may result in polyethylene wear debris, chronic inflammation and osteolysis,[24] radiolucency around the glenoid component,[93] presence of an inferior bone spur and ossification in the glenohumeral space.[7]
	Onlay vs. inlay stem	Onlay stem increases distalization, which leads to increased stretch on the axillary nerve and risk of nerve injury.[79,80,83]
	Press fit fixation vs. Cemented	Radiolucent lines are more frequent in cemented humeral components and are most commonly found in the proximal zones of the stem. They did not appear to progress towards loosening of the component at ten years of follow-up.[7] Proximal stress shielding is more common in press-fit stems.[7,11]

Table 3. Differences in complication rates between results published by Zumstein et al (included studies between 1985 and 2008) and Shah et al (included studies between 2010 and 2019)

Complication type	Complication rate published by Zumstein et al	Complication rate published by Shah et al
Radiolucency humerus/loosening	N/A/1.3%	12%/1.4%
Radiolucency glenoid/loosening	2.9%/3.5%	7.7%/2.3%
Infection	3.8%	2.4%
Neurological lesion	1.2%	0.6%

unsolved. However, such changes should be now considered as simple problems because they rarely have a negative influence on the patient's final outcome and their prevalence has dramatically decreased. Also there has been a considerable decrease in the majority of complications over the years, probably as a result of modifications in the design, materials, biomechanics of the prosthesis, recommendations related to positioning and the experience in RSA implantation acquired by the surgeons. With further changes in indications and designs for RSA, it is crucial to accurately track the rates and types of complications to justify its new designs and increased indications.

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