7 Revision Total Shoulder Arthroplasty: Epidemiology and Causes

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7.1 Introduction

The history of shoulder arthroplasty begins in the late nineteenth century with Themistocles Gluck and Jules Emile Péan [1], but its clinical contribution to shoulder surgery remained relatively anecdotal until the initial design created in 1952 by Dr. Charles Neer, which served as a solution for complex proximal humerus fractures in which avascular necrosis and ankylosis were common complications [2]. At that time, the design was a monobloc humeral stem with only three sizes, and there was no option to resurface the glenoid. In 1974, he published his results with total shoulder arthroplasty for primary osteoarthritis, with an early design of a cemented polyethylene glenoid component [3]. Since then, shoulder arthroplasty design has continued to evolve into a wide variety of anatomic and reverse systems, including stemmed, stemless, cemented, cementless, and modular implants.

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7.2 Epidemiology

The incidence of shoulder replacement surgery is increasing worldwide. A 141.4% increase has been reported between 2008 and 2017 in Australia, with an annual incidence of 26/100,000 inhabitants in 2017 [4]. A similar trend has been reported in other countries, such as Norway, Sweden, New Zealand, Denmark, and Germany, with annual incidence rates anywhere from 8 to 34/100,000 [5].

Along with that dramatic increase, there has been a concomitant rise in the number of revision surgeries. With a reported revision rate of 2.8–10.9% [4, 6, 7], an increasing number of revision procedures can be expected as surgical indications are expanded.

The most common indications for total shoulder replacement include inflammatory arthritis, primary osteoarthritis, instability arthritis, postcapsulorrhaphy arthropathy, rotator cuff-deficient arthritis, advanced avascular necrosis, and intra-articular fractures. The underlying etiology seems to influence the clinical outcome and longevity of the implant.

In that regard, national registries have proven to be excellent tools to further analyze revision surgery. The Australia National Joint Registry of 2018, for example, is rich with information. In Australia, the revision rate for hemi-resurfacing arthroplasty is 12%, and the main reasons for revision are glenoid erosion and pain, which

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account for almost 50% of revision cases. This is followed by rotator cuff insufficiency and component loosening. Of the total revisions, 54% follow a reverse shoulder arthroplasty, and 45% follow an anatomic arthroplasty. Patients aged 65–74 have a 50% reduced hazard ratio for revision compared to patients <55 years. There appears to be no difference in revision rates when comparing the underlying diagnoses in stemmed hemiarthroplasty (8.4% for fracture vs. 9.3% for osteoarthritis).

The indication for revision, however, does seem to vary according to the underlying diagnosis. In those cases where hemiarthroplasty was performed for a fracture, the most common reasons for revision were rotator cuff insufficiency, followed by instability, or dislocation. For those whose primary diagnosis was osteoarthritis, glenoid erosion was the most frequent reason for revision, followed by instability. Cemented stems and patients older than 75 years had a lower revision rate in the fracture group.

Anatomic total shoulder arthroplasty in the Australian National Joint Registry has demonstrated a rapid decrease since 2010 with a simultaneous increase in reverse shoulder arthroplasty, which accounted for over 70% of all the total shoulder arthroplasties performed during 2017. The revision rate for anatomic versus reverse shoulder arthroplasty was 12.6% and 7% at 10 years, respectively. Anatomic shoulder arthroplasty did not show different revision rates when performed for fracture, osteonecrosis, or osteoarthritis.

Rotator cuff insufficiency, instability, and loosening account for almost two-thirds of the reasons for revision in anatomic arthroplasties. Half of the revisions were of the humeral component only, and 20% of them involved revision of both the humeral and glenoid components. There was an increased rate of revision with cementless glenoid components and in patients younger than 55 years.

In the case of reverse shoulder arthroplasty, there was an increased rate of revision at 3 months when performed for fracture, but the rate stabilized after that. Instability, infection, loosening, and fracture accounted for over 85% of the revision causes. Age was not a reason for revision when performed for osteoarthritis, but when performed for fracture or rotator cuff arthropathy, patients older than 75 years had a lower revision rate [4].

7.3 Causes for Revision

7.3.1 Infection

Periprosthetic joint infection after total shoulder arthroplasty has been reported to have an incidence between 1% and 4% and accounts for 3–5% of all complications following anatomic total shoulder arthroplasty [8–11]. A higher infection rate has been reported following reverse shoulder arthroplasty, and it has been found to be up to 6.11 times greater than after anatomic shoulder arthroplasty [12]. It has been hypothesized that postsurgical hematoma formation in the subacromial space may contribute to its development [13, 14].

A systematic review by Zumstein et al. reported a 2.9% rate of deep infection rate after primary RTSA and 5.8% after revision RTSA [15]. Walch et al. compared their results after RTSA between the years 1995 to 2003 versus 2003 to 2007 and found a marked decrease in infection rates between those time periods (from 4% to 0.9%). The authors postulated that surgeon experience, perhaps through more refined indications and surgical technique, may be paramount to avoiding or minimizing this complication [16].

Some patient populations are at greater risk for deep infection, such as patients with rheumatoid arthritis. These patients reportedly have up to 2.6 times higher risk of infection after joint arthroplasty [17, 18]. A case-control study by Bala and colleagues found an increased risk of infection in patients with HIV infection (OR 1.36; 95% CI, 1.01–1.82) [19].

Smoking has also been correlated with increased infection rates with a hazard ratio of 7.27 for current smokers and 4.56 for former smokers (those who had not smoked within 1 month prior to surgery) [20]. In addition, an increased risk of infection after total shoulder

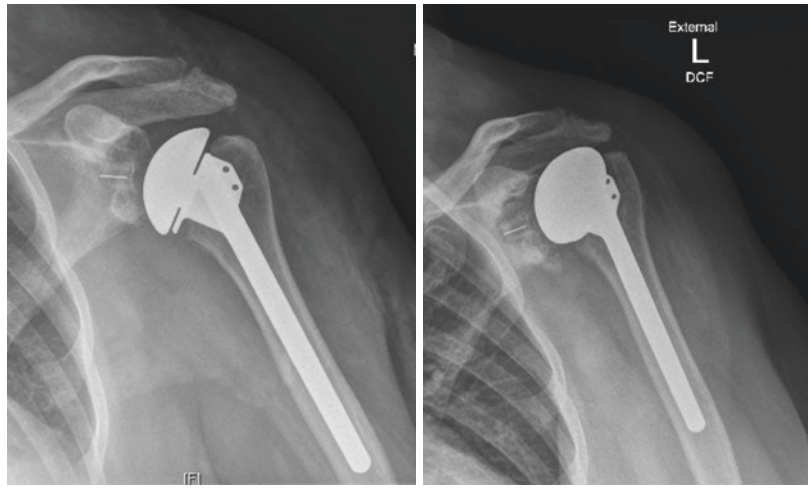

Fig. 7.1 In these images, the picture on the right shows an early glenoid component loosening, 1 year after the index procedure (picture on the left). A guided aspiration was obtained, and cultures were positive for *C. acnes* infection

arthroplasty has been found in male patients, those with a traumatic indication, prior local infection, prior non-arthroplasty shoulder surgery, revision arthroplasty, long-term corticosteroid use, and the need for perioperative allogeneic red blood cell transfusion [21, 22].

The most commonly cultured organisms in an infected shoulder arthroplasty are the *Cutibacterium acnes* (formerly Propionibacterium acnes) and coagulase-negative *Staphylococcus* spp. It is common to find these organisms in the setting of a subacute infection, where pain may be the only apparent manifestation and the classic signs of infection, such as fever, erythema, warmth, and purulence may be less prominent. A careful history can reveal details that help with the diagnosis, such as pain at rest and stiffness.

C. acnes is a well-known gram-positive rod found in the skin as a commensal, with younger male patients having a higher bacterial burden. It has been implicated in chronic skin diseases, such as acne vulgaris, and deep infections associated with prosthetic devices. Torrens et al. isolated positive cultures for *C. acnes* in the deep layers of 18.8% of their patients undergoing a primary reverse total shoulder arthroplasty. Of those cases, however, with a minimum follow-up of 1 year, only one patient (1.1%) developed an infection at 6 months after the procedure, suggesting that the presence of this organism does not guarantee an infection and may not be the only risk factor [23]. *C. acnes* infection is more frequently associated with male patients, cloudy synovial fluid, humeral osteolysis, humeral loosening, glenoid wear, and membrane formation (Fig. 7.1) [24].

More "classic" clinical findings suggesting infection may be encountered in the setting of a more aggressive organism, such as *Staphylococcus* or *Streptococcus* spp. In these instances, bone osteolysis and implant loosening, swelling, erythema, and increased blood infection markers may be present [12, 21, 25].

Diagnosis of infection can often be difficult, with pain and limited range of motion being the most common clinical complaints [26]. Good-quality radiographs can help rule out conditions that may mimic or coexist with an infected shoulder arthroplasty, such as post-arthroplasty rotator cuff failure. It is common practice to obtain a baseline laboratory analysis with white blood cells (WBC) (percentage polymorphonuclear cells), erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP). Computed tomography (CT) scans can be useful to detect osteolysis and to assess remaining bone stock. Ultrasonography and magnetic resonance imaging (MRI) with metal subtraction protocols can determine the presence of local abscesses, effusion, or osteomyelitis. Scintigraphy can detect inflammation but may not be useful in low-grade infections [27, 28].

Synovial fluid analysis from an aspiration or at the time of revision surgery should include cell count, gram stain, cultures for aerobes, anaerobes,

fungi, and mycobacteria and should be held for up to 4 weeks [24]. Unfortunately, a negative culture or gram stain does not always rule out infection. Intraoperatively, at least five biopsy samples should be sent for gram stain and frozen section [29]. Interestingly, increased body mass index, diabetes severity, and asymptomatic bacteriuria or abnormal urinalysis have not been associated with increased rates of infection [12, 30–32].

7.3.2 Instability

7.3.2.1 Instability After Anatomic Total Shoulder Arthroplasty (TSA)

Instability after anatomic total shoulder arthroplasty is a relatively common complication, with a reported prevalence ranging from 1% to 3% [11, 33]. It can occur secondary to insufficient bone stock, inadequate soft tissue balance, component malalignment, or loosening.

Severe primary osteoarthritis, as well as post-capsulorrhaphy arthritis, can lead to excessive acquired retroversion of the native glenoid. Anterior wear is more uncommon, but it can be found in patients with chronic anterior glenohumeral dislocations, glenoid fractures, or rheumatoid arthritis. Failure to identify and correct this deformity can result in glenoid component malalignment and either posterior or anterior instability. Humeral component malpositioning is usually less critical, but it can also play a role in instability.

Diagnosis can be difficult, and a careful physical examination is paramount. In some patients, dislocation of the glenohumeral joint can be obvious radiographically, but in the setting of subluxation, findings will be more subtle. Excessive translation of the humeral head or a positive load-and-shift test can help the examiner in the diagnosis of these cases [34, 35].

Anterior instability after anatomic total shoulder arthroplasty has been reported in 0.9% of the patients [11] and has been associated with subscapularis failure, retroversion of the humeral component of less than 20° [36], anterior glenoid deficiency, and anterior deltoid dysfunction [11]. Of these causes, it is thought that subscapularis dysfunction plays a major role. In these patients, a positive lift-off test and/or belly press test can be found [37].

Management of the subscapularis during the initial surgery remains controversial, as some authors report improved outcomes after a lesser tuberosity osteotomy (LTO) versus a tenotomy or peel technique [38]. This clinical finding has been supported by biomechanical analyses [39, 40]. However, the peel technique or tenotomy of the subscapularis avoids the potential complication of LTO nonunion [41]. To date, there is insufficient high-level clinical evidence to strongly support one technique over the others.

In addition to technique, overstuffing the joint with an excessively large humeral head and medialization of the tendon insertion may lead to failed subscapularis failure. Excessively early mobilization, aggressive physical therapy, or postoperative trauma can also disrupt the subscapularis tendon repair.

Posterior instability after TSA occurs with a similar frequency as anterior instability (1%) [11] and has been associated with soft tissue imbalance. While posterior rotator cuff dysfunction and capsular laxity have been most commonly implicated, component malalignment and posterior bone loss can also play a role [34, 42]. Glenoid retroversion over 20° and humeral component in more than 45° of retroversion have been described as potential causes of posterior instability [36]. Sanchez-Sotelo and colleagues recommended that surgeons pay close attention to the humeral neck cut angle and the subscapularis tendon repair and address any posterior glenoid bone loss to minimize the potential for this complication. In addition, posttraumatic osteoarthritis or preoperative humeral subluxation should be carefully evaluated [34].

Rotator cuff failure is one of the most common complications after anatomic total shoulder replacement. A recent analysis of complications reported to the US Food and Drug Administration (FDA) demonstrated that among all the complications found after 1673 anatomic total shoulder replacements, posterior-superior rotator cuff and subscapularis failure were second only to glenoid component failure, representing 15.4% of all the

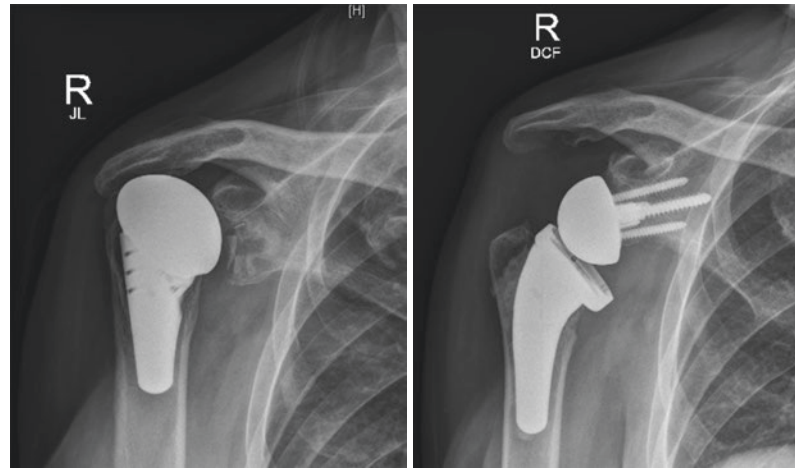

Fig. 7.2 Rotator cuff failure can lead to superior instability. The radiograph on the left demonstrates proximal migration of the humerus, which led to glenoid component fixation failure through the so-called *rocking horse* mechanism. This patient eventually underwent revision surgery to a reverse shoulder arthroplasty (right)

complications [9]. Rotator cuff failure allows the humeral head to migrate proximally, leading to superior instability (Fig. 7.2). Reported in up to 3% of cases [11], superior instability may be the single most common direction of instability following anatomic shoulder arthroplasty.

The rotator cuff can be compromised during the index procedure, specifically if an aggressive humeral resection is performed or if the cut is placed in too much retroversion [43]. Postoperative rotator cuff failure can also occur, with reported rates from 1.3% to 5.8% [11, 37]. Several factors have been found to affect superior instability: fatty infiltration of the infraspinatus, rotator cuff tear size, coracoacromial arch insufficiency, anterior deltoid dysfunction, humeral head overstuffing and malpositioning, and tuberosity nonunion in the setting of fracture [44, 45].

Inferior instability often occurs when the humeral length is not restored and deltoid tensioning is therefore not achieved. This has been reported to be more common after four-part proximal humerus fractures, where the stem can be accidentally seated too low due to a loss of anatomic references. Warren recommends inferior distraction of the humerus to detect this issue intraoperatively. When this maneuver is performed, the head should ideally remain within the upper one-third of the glenoid. Inferior instability may also occur in a setting of an axillary nerve palsy or rotator interval insufficiency in which the dynamic stabilizers are inadequate to hold the glenohumeral joint reduced [42].

7.3.2.2 Instability After Revision Total Shoulder Arthroplasty (RTSA)

Trappey et al. reported an instability rate after RTSA of 5% following primary cases and 8% following revision arthroplasty [46]. The mechanism of dislocation is typically adduction and internal rotation and most commonly occurs within the first 3 months following surgery. Up to 50% of these will have good outcomes with conservative treatment after successful closed reduction. Late dislocations that occur over 3 months after the index procedure often require surgical treatment [47].

Abdelfattah et al. proposed a classification system for instability after reverse total shoulder arthroplasty. They described three main categories: loss of compression, loss of containment, and impingement.

They further divided loss of compression into undersized implants, loss of deltoid contour, humeral height loss, subscapularis deficiency, acromial/scapular fracture, and deltoid dysfunction (Fig. 7.3).

Loss of containment can be subclassified into alteration of depth/radius ratio of the humerosocket and mechanical failure (such as glenosphere-baseplate dissociation, stem fracture, or humerosocket dissociation at the trunnion).

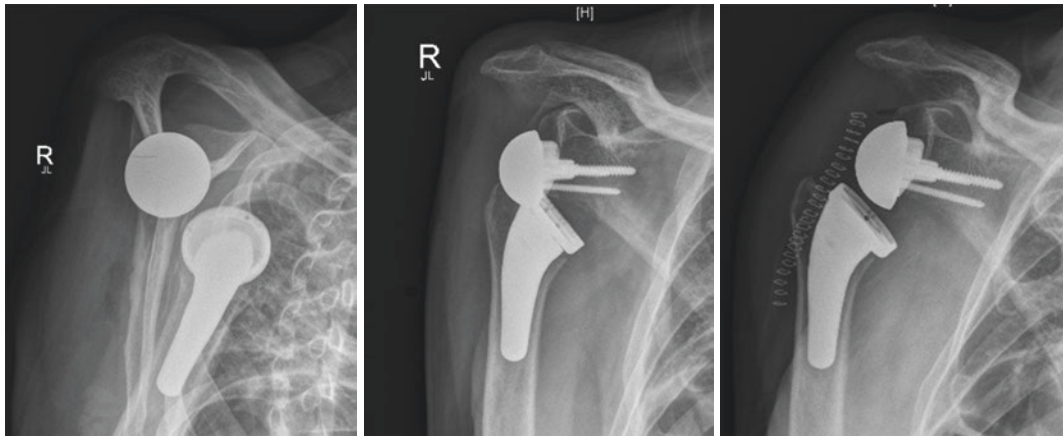

Fig. 7.3 This patient sustained an early dislocation after a reverse total shoulder arthroplasty (left). He underwent a closed reduction, but examination under anesthesia revealed instability of the implant (center). Therefore, revision to a larger glenosphere and a retentive polyethylene was warranted (right)

Impingement can occur in a setting of a large body habitus, with the axillary soft tissue creating a levering-out effect with traction from the weight of the arm. Furthermore, soft tissue or bony impingement can occur in a fracture setting with unreduced retained tuberosities, malunion, or heterotopic ossification; prosthetic malalignment may play a role if the humeral component prematurely contacts the glenoid neck in adduction [48]. This can be modified by changing the glenosphere size, the baseplate placement, offset or tilt or the neck-shaft angle, and version of the humeral component [49].

Trappey and colleagues also found that patients with an irreparable subscapularis had a higher rate of instability [46]. A meta-analysis by Matthewson et al. concluded that subscapularis repair decreases the rate of instability, and in those cases when it cannot be repaired, a lateralized center of rotation results in significantly lower dislocation [50]. Owing to the preservation of the subscapularis tendon insertion, a superior subscapularis-sparing approach may lower the risk of dislocation, with reported rates of instability as low as 0%. However, glenoid exposure and baseplate placement using this approach may be significantly more challenging [51]. Subscapularis involvement in RTSA instability remains controversial in the existing literature, as similar clinical results with or without subscapularis repair have been reported [52].

7.3.3 Component Loosening

7.3.3.1 Anatomic Total Shoulder Arthroplasty Loosening

Prosthetic loosening has been reported to represent 12.4–39% of the complications after anatomic total shoulder arthroplasty [11]. Radiolucencies, calcar resorption, or scapular notchings are common findings after anatomic and reverse shoulder replacement, but not all of them may be clinically relevant. In the presence of pain or gross implant migration, however, further investigation is warranted.

Glenoid component loosening occurs more frequently than aseptic humeral component loosening, representing over 80% of fixation failures [11]. Positive radiographic findings of lucencies about the component vary from 12% to 94% in the literature, but these do not necessarily correlate with clinical findings. In this regard, surgical technique must be meticulous, as it has been suggested that the presence of lucent lines and further frank loosening may be related to the presence of cement on the backside of the glenoid component. This may indicate suboptimal bone preparation of the native glenoid and/or suboptimal seating of the component [53, 54].

Loosening can occur due to uneven force distribution in the setting of glenohumeral instability (the so-called rocking horse mechanism) [55] due to proximal migration of the humeral head in

the setting of rotator cuff failure or due to infection, lack of bone stock, or poor bone fixation. Shoulder biomechanics may also play a role. Compared to other joints, the humeral head appears to have larger "play in the socket," which may explain the faster polyethylene wear that has been found in explanted shoulder liners when compared to equivalent hip inserts [56].

Papadonikolakis found an asymptomatic radiolucency rate of 7.3% per year and symptomatic loosening of 1.2% per year, with more asymptomatic lucencies found in keeled versus pegged implants [57]. Biconcavity of the native glenoid and increased glenoid retroversion may also lead to increased component loosening. Walch et al. found a 21% loosening rate in biconcave glenoids and a 44% complication rate associated to retroversion greater than 27° [58].

Others have found that metal-backed glenoid implants have a revision rate up to three times higher than all-polyethylene components [57]. The Australian registry demonstrated an increased revision rate in both fixed and modular metal-backed glenoid components. They reported a significantly higher revision rate of non-cross-linked vs. cross-linked glenoid components with a hazard ratio of 2.38, but they found no differences in the revision rate between cemented versus hybrid glenoid components in total shoulder arthroplasties [4].

Stem aseptic loosening is much less common than glenoid failure, accounting for 7% of the complications after TSA [11]. In defining stem loosening in non-cemented stems, Sperling described eight radiographic zones around the humeral stem and concluded that a humeral component was "at risk" if a lucent line 2 mm or greater was found in at least three zones [59]. Sanchez-Sotelo used the same parameters to successfully evaluate radiographic loosening in cemented stems [60]. Changes at the bone-implant interface on the humeral side in the presence of a glenoid component have raised concerns about osteolysis and symptomatic loosening in the setting of polyethylene particle debris [45, 60].

7.3.3.2 Reverse Total Shoulder Arthroplasty Loosening

Boileau reported that among all the causes that led to revision surgery after a failed RTSA, 21% were due to humeral side complications. It was the second most common cause of revision after instability. He found that humeral loosening was often related to biological causes (polyethylene wear and metallic debris), in addition to mechanical causes (rotational forces) [47]. Radiographic loosening is rare, with a reported prevalence of less than 1% [61], but proximal humerus bone loss in a proximal humerus fracture setting, for instance, can decrease mechanical strength of the humeral stem leading to an increased risk of humeral-sided failure [62].

Glenoid component loosening is uncommon in the setting of RTSA and can be minimized by careful surgical technique [63]. Avoidance of superior tilt, placement of the baseplate at the most inferior aspect of the glenoid, and achievement of adequate primary stability that allows bone ingrowth are paramount [47, 63].

The influence of scapular notching on glenoid component loosening after reverse shoulder arthroplasty remains controversial, as some series report increased loosening rates related to scapular notching (Fig. 7.4) [14, 64, 65], while others report no association [15, 66, 67]. The use of a superior approach has been reported to increase prevalence of scapular notching [67], which suggests that this approach may indirectly increase the risk of loosening. Lateral and inferior offset of the glenosphere, on the other hand, may minimize radiographic loosening, though some lateralized designs have been reported to potentially lead to a higher rate of component dissociation [68].

7.3.4 Periprosthetic Fractures

Periprosthetic fractures can occur both intraoperatively and postoperatively. The rate of intraoperative periprosthetic fractures has been reported to be between 1.3% and 5.1% [9, 11, 69], with a similar distribution between humeral and glenoid fractures [25]. Female sex, greater number of comorbidities, and a primary diagnosis of posttraumatic osteoarthritis have all been associated to higher rates of periprosthetic fracture [25].

The increased risk in women may be explained by the fact that rheumatoid arthritis and osteoporosis are more common in this population [70].

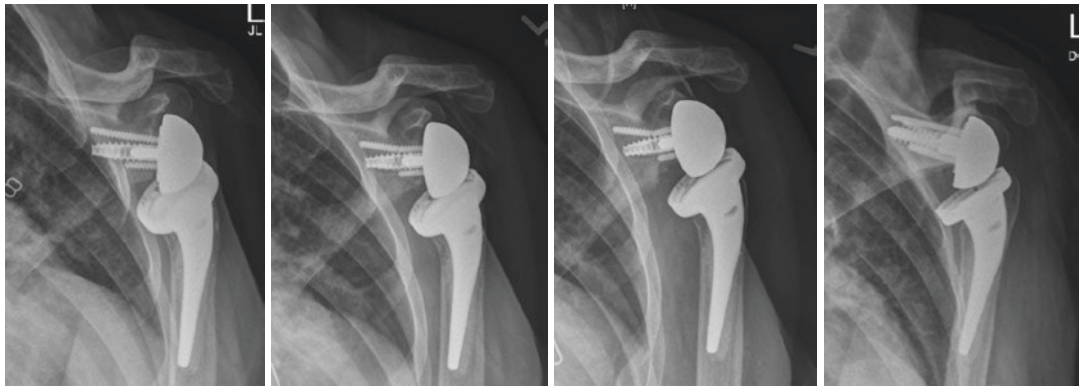

Fig. 7.4 Note the progression of the fixation failure of the baseplate with radiographic evidence of scapular notching and a broken screw and the subsequent glenoid component revision

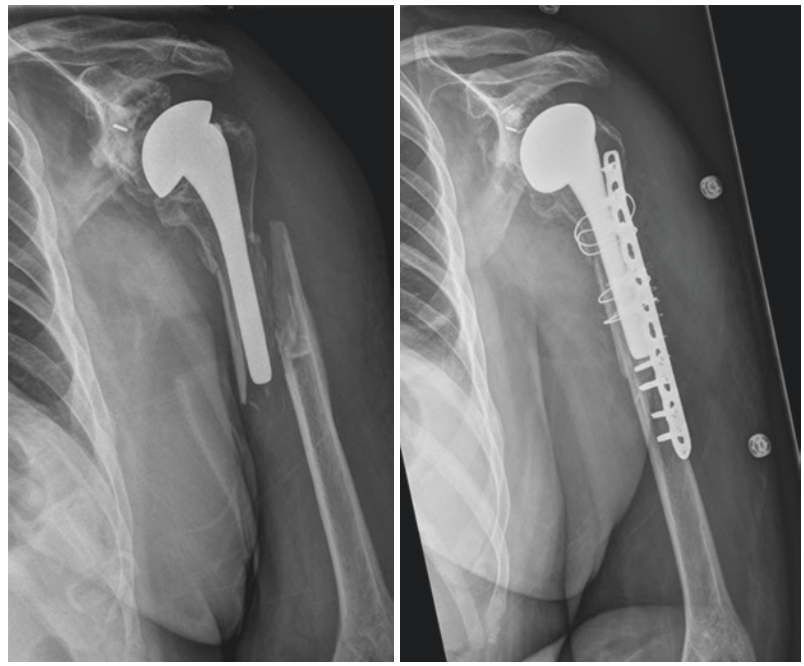

Fig. 7.5 This 64-year-old patient sustained a fall, resulting in a type B fracture, according to the Cofield and Wright classification (left). Intraoperatively, the stem was deemed well-fixed, and therefore open reduction and internal fixation were performed (right)

The relationship between posttraumatic osteoarthritis and intraoperative fracture may be related to the increased joint stiffness in these patients, placing greater torque forces during retraction, which eventually may lead to an intraoperative fracture. Implant stability and fracture pattern may ultimately determine if further intervention is required, such as exchange to a longer stem or open treatment with internal fixation [71].

Postoperative periprosthetic fractures have been reported to occur in 1–3% of cases [72]. Wright and Cofield described the most widely used classification of periprosthetic fractures. According to their classification, type A fractures do not extend beyond the tip of the stem, type B fractures start around the stem and end distal to the tip of it, and type C fractures are distal to the tip of the stem [73].

When evaluating these fractures, implant stability and remaining bone stock will determine further treatment (Fig. 7.5). Campbell described a system to classify bone quality, in which the

bone is considered normal if the ratio between the mid-shaft cortices and the shaft diameter is greater than 50%, mild osteopenia if it is between 25% and 50%, and severe osteopenia if it is below 25%. He found that 75% of the patients in his series of periprosthetic fractures met the definition for osteopenia.

While implant stability is ultimately determined intraoperatively, preoperative radiographs can help the surgeon plan and predict fixation stability. As described earlier, when lucent lines greater than 2 mm are found in at least three of the eight zones described by Sperling, the surgeon may anticipate stem loosening [59]. Implant subsidence or tilt can also help determine the quality of stem fixation before the procedure and allow the surgeon to prepare accordingly.

7.4 Conclusions

While total shoulder replacement has added to our ability to salvage painful shoulders following severe trauma or late-stage arthrosis with and without rotator cuff deficiency, we have also learned that there are limitations to the expectation for a functional, pain-free shoulder. While complications following shoulder arthroplasty can be frustrating for both the patient and surgeon alike, it is unfortunately a reality that all arthroplasty surgeons will encounter at some point in their career.

Recognizing complications and potential failure may be difficult, since many of the signs and symptoms can be nonspecific, such as pain, weakness, and stiffness. However, timely recognition and accurate diagnosis are critical to avoiding a suboptimal outcome. Careful history, physical examination, and good quality imaging studies are essential, but further testing is often necessary and may include blood work, aspiration, CT, MRI or ultrasonography.

Perhaps as important as early diagnosis, however, may be striving to avoid complications altogether. By understanding the common modes of failure, learning to avoid them, and careful patient selection, surgeons may ensure better outcomes for their patients. As we continue to care for ever increasing numbers of patients with end-stage shoulder degeneration and severe trauma, we must continue to exercise judicious indications and meticulous technique and undertake thoughtful review of our outcomes.

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