12 Complications: Infection, Subscapularis Insufficiency, Periprosthetic Fracture, and Instability

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Infection

Infections after shoulder arthroplasty are relatively rare but nevertheless have considerable impact on outcomes. Periprosthetic infections in the shoulder differ vastly from those of other joints in that the most common pathogen is *Propionibacterium acnes*, a difficult organism to isolate. Treatment is often based on a high index of suspicion. Incidence has been reported from 0.4 % to 4 % [1–3], although the real incidence may be higher. Infection is associated with component loosening and pain. Although diagnostic techniques have improved, accurate diagnosis can still prove challenging. Treatment options are based on multiple factors including pathogen, associated bone loss, and patient-specific details.

Propionibacterium acnes is the most commonly described pathogen, and *Staphylococcus aureus* and coagulase-negative *Staphylococcus* are the next most common. A variety of other organisms have been identified [1, 2]. *P. acnes* is a gram-positive bacillus commonly found in the axilla in great abundance [4]. Given that it is a normal skin flora and has low virulence, its role in infection is poorly understood.

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Diagnosis

Unexplained or new onset of pain after shoulder arthroplasty should immediately raise suspicion of infection. Acute systemic symptoms such as fever or sepsis are rare on presentation but can occur in immunocompromised patients (rheumatoid arthritis, sickle cell anemia). Patients with any progressive lucency or bone loss on serial X-rays should be screened for infection. Both *P. acnes* and coagulase-negative *Staphylococcus* have relatively low virulence. Definitive diagnosis can be difficult and cultures usually require extended incubation time of tissue samples (up to 21 days) [4]. Adjuvant means of diagnosis have been developed with varying levels of success. The gold standard for diagnosis remains positive cultures from open biopsy of multiple tissue samples. The difficulty with revision surgery is that infection must be excluded before proceeding. A reliable diagnosis allows the surgeon to plan for a one-stage versus a two-stage revision surgery [5].

Typical preoperative workup should include biological markers such as C-reactive protein (CRP), sedimentation rate (ESR), and white blood cell count (WBC). These markers often lead to false-negative results, with normal or only

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slightly elevated values despite active infection [6]. Fluoroscopic joint fluid aspiration has been proposed by certain authors; however these have had typically low sensitivity (12.5 %) [7]. A newer method has recently been described using arthroscopy to obtain tissue biopsies. Dilisio et al. compared results from these biopsies to cultures obtained during the subsequent open revision procedure. They found a 100 % sensitivity/specificity/negative and positive predictive value [8]. This was in contrast to fluoroscopically obtained aspirates, which had a sensitivity of only 16 %. They concluded that arthroscopic biopsy in the setting of a presumed or possibly infected shoulder arthroplasty is a reliable means of confirming diagnosis and identifying the causative agent [8]. Villacis et al. recently looked at interleukin-6 (IL-6) as a diagnostic marker for infection. They obtained serum values for all patients undergoing revision surgery and considered a positive intraoperative culture as a diagnosis of infection. Overall sensitivity and specificity were 14 % and 95 % respectively [9]. They concluded that serum IL-6 levels were not an effective method of diagnosis of shoulder arthroplasty infection. Following this, another group looked at using synovial fluid IL-6 as a marker of infection. Sensitivity and specificity were 87 % and 90 %, respectively, and both preoperative and intraoperative measurements correlated to each other. They suggested that preoperative fluoroscopic-guided aspiration with IL-6 measurement could be a useful adjunct for diagnosing infection [10].

Consistent intraoperative diagnosis of latent infection is very useful for surgical decision-making during revision surgery. Unfortunately, gram stain is rarely contributory in this setting, and culture results may take up to 21 days for *P. acnes* to become positive. Frozen section has been used with arthroplasty in other joints with varying success [11, 12]. Grosso et al. looked at the sensitivity of frozen section for diagnosis of infection in revision shoulder arthroplasty [13]. Using standard guidelines of five polymorphonuclear leukocytes per high-powered field in five fields as a positive result, they found a 50 % sensitivity and 100 % specificity for *P. acnes* infection. They then modified the criteria to be a sum of ten polymorphonuclear leukocytes in five fields. With the new criteria, the sensitivity rose to 72 %, while the specificity remained at 100 %. The authors recommended lowering the threshold for a positive screening in order to increase the yield of frozen section.

Risk Factors

The preponderance of *P. acnes* infection in the shoulder can be in part attributed to the numerous sebaceous glands and hair follicles of the axilla in close proximity to the surgical incision. Patients developing infection generally have identifiable risk factors in up to 50 % of the time [2, 6]. Specific risk factors include diabetes, systemic lupus erythematosus, rheumatoid arthritis, previous surgical procedures, and remote infection. Other risk factors include chemotherapy, corticosteroid therapy or intra-articular steroid injections, coagulopathy, renal failure, fluid and electrolyte disorders, and a diagnosis other than primary osteoarthritis (cuff tear arthropathy, acute proximal humerus fracture or nonunion, avascular necrosis) [2, 6, 14]. Smucny et al. looked at inpatient development of infection and found a direct correlation with length of stay. The risk of a surgical site infection (SSI) increased by 14 % per additional day of hospitalization [14]. Morris et al. looked at risk factors associated with infection after reverse shoulder arthroplasty (RSA) specifically. They found that previous failed arthroplasty and younger age were the only two independent risk factors for infection [15]. According to their findings, patients above the age of 65 were less likely to develop infections after RSA.

Prevention

Preventing SSIs should be a priority because treatment is often complicated and can require multiple interventions. Matsen et al. attempted to locate the areas of the surgical site most likely to find *Propionibacterium* in patients undergoing revision. They found positive cultures in an unprepared epidermal layer in 16/18 men and 7/12 women. Initial and final dermal cultures were obtained prior to antibiotic prophylaxis and were positive in 11/20 for the men and none of the women. They concluded that surgical preparation did not completely eliminate dermal *P. acnes*, and it persists in sebaceous glands in significant quantities (10^5 or greater.) [16]. Deep cultures were positive in 12/20 cultures for the male patients and only 1 of the females, and this was correlated with the dermal cultures [17]. They concluded that males were more likely to have *Propionibacterium* present in their wound than females, and this is despite adequate skin preparation. Lee et al. confirmed these results finding that 70 % of patients undergoing TSA had a positive epidermal culture for *P. acnes* immediately following skin preparation with chlorhexidine prep.

Other studies have evaluated for the presence of *P. acnes* in primary surgeries. Levy et al. obtained intra-articular cultures during primary TSA in patients who had not had prior shoulder surgery. They found positive cultures in 23/55 (42 %) patients [18]. All patients were treated with 4 weeks of oral antibiotics and no patient developed infective signs. The authors hypothesized that low-grade infection with *P. acnes* may even play a role in the development of OA; however this has not been substantiated [19]. Matsen et al. examined patients undergoing TSA for primary osteoarthritis without a history of infection. Cultures were obtained after receiving intravenous antibiotic prophylaxis and were positive in three out of ten patients (7/50 specimens) [20]. The authors concluded that even with adequate skin prep and appropriate antibiotic prophylaxis, *P. acnes* is very commonly found in the surgical site. The relevance of its presence is difficult to interpret, but presence may be a risk for infection.

Antibiotic prophylaxis usually involves a first-generation cephalosporin (cefazolin) and has been shown effective at reducing the overall infection rate [21]. Despite this success, several authors believe an alternative prophylaxis regimen should be used to specifically address the *Propionibacterium* problem [20]. Finally, the use of antibiotic-loaded cement in total shoulder arthroplasty has been supported by at least one study. Nowinski et al. retrospectively compared two cohorts of total shoulder arthroplasties: one using antibiotic cement and the other with normal cement. These two groups were well matched, and they found a 3 % higher infection rate in the group using normal cement [3].

Treatment

Treatment for infected joint arthroplasty is debatable and there is a lack of consensus among shoulder surgeons. Treatment with antibiotics and retention of the prosthesis, for eradication or chronic suppression, has very high failure rate, up to 60–75 % [22]. This should be reserved for patients that are either medically unfit for surgery or refuse to undergo revision. Resection arthroplasty is another therapeutic option that should be kept as a last resort. A review of patients after resection arthroplasty demonstrated a successful elimination of infection and reasonable pain relief (a mean reduction of 4.3 points on the VAS scale); a majority (13/17) of patients had no or very limited functional ability in the affected shoulder [23]. Therefore, resection is an option in end-stage cases.

The mainstay of treatment for prosthetic joint infection includes either single- or two-stage revision arthroplasty combined with prolonged intravenous antibiotic therapy. Single-stage revision has the advantages of lower cost, decreased morbidity, and potentially better outcomes. The drawbacks include a theoretically higher reinfection rate and the need for subsequent surgery. Several studies have reported good outcomes with single-stage revision without a higher than expected risk of reinfection [22, 24, 25]. Another recent study demonstrated a 94 % infection-free survivorship at a mean of 4.7 years following single-stage revision [26]. The protocol used by the surgeons included intraoperative tissue samples to confirm infection, thorough debridement and irrigation of the surgical field, reimplantation with antibiotic-loaded cement, and postoperative IV antibiotics for an average of 10.6 days [26].

Two-stage revision arthroplasty is the preferred method for treating prosthetic joint infections of the shoulder for most surgeons. The protocol consists of explantation with aggressive debridement and antibiotic spacer placement and prolonged IV antibiotic treatment. A tissue biopsy and/or joint aspirate culture with evaluation of inflammatory blood markers (CRP, ESR, WBC) follows IV antibiotic treatment, and second-stage reimplantation takes place when confident that there is elimination of infection. There is limited data on results of this protocol, likely due to the relatively low incidence rate of infections in shoulder arthroplasty. Coste et al. reported on ten patients treated with two-stage revision. Their cohort had a 20-point increase in the mean constant [27] score; however there was persistent infection in four patients (40 %) with one patient undergoing a second revision [22]. Strickland et al. reported on 19 shoulders undergoing staged treatment, with 7 shoulders (37 %) having persistent infection [28]. They also reported 14 complications and concluded that while staged revision offered a better chance at infection eradication, it was associated with significant morbidity and low functional outcome results [28]. Sabesan et al. evaluated two-stage revision using reverse arthroplasty in 17 patients. They had one persistent infection (6 %) and 35 % complication rate, including five reoperations for instability [29]. Cleary, this is a challenging clinical problem without a definitive and predictable solution. Figure 12.1 demonstrates a protocol for treating suspected or confirmed prosthetic joint infections of the shoulder.

Periprosthetic Fracture

Periprosthetic humerus fractures are rare with an incidence of 0.6–3 % of all shoulder arthroplasties. The majority of these fractures involve the

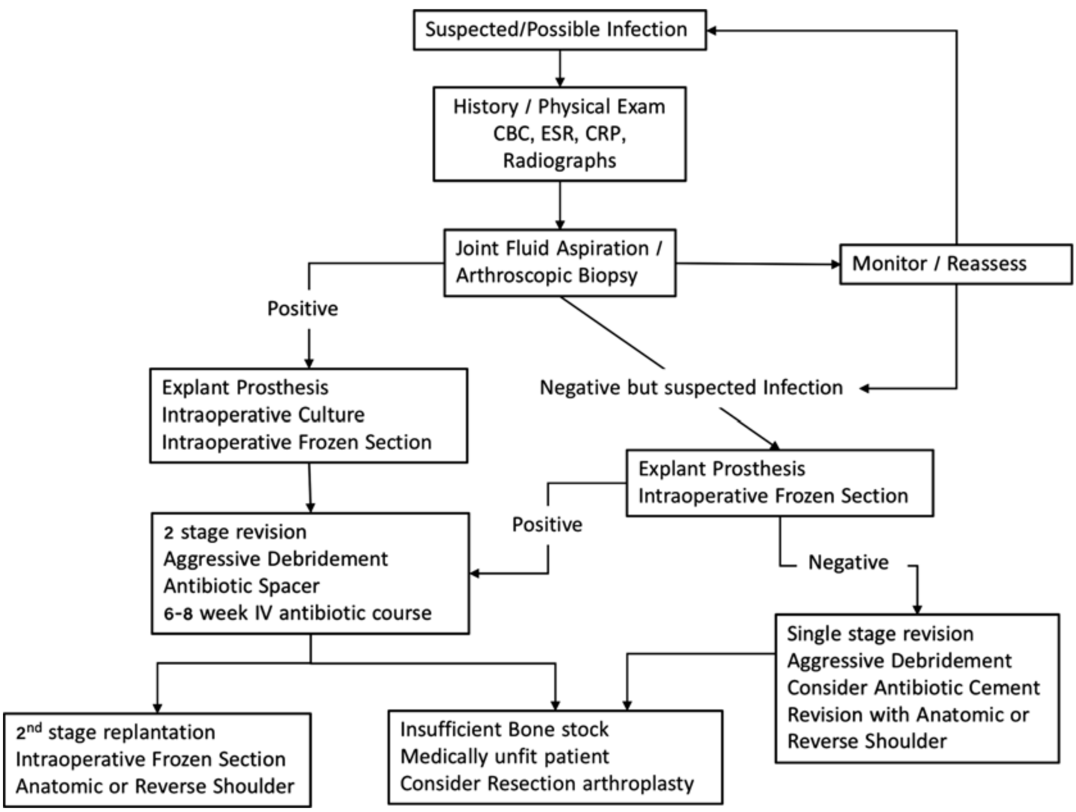

Fig. 12.1 Treatment algorithm for suspected/confirmed shoulder arthroplasty infection

humerus. Glenoid periprosthetic fractures are rare and most often occur in metal-backed implants (such as reverse shoulder arthroplasty baseplates). A vast majority of humeral fractures occur intraoperatively secondary to technical errors. Technical errors include poor patient positioning and inadequate surgical exposure. This results in excessive traction and rotation and can encourage cortical breach due to increased leveraging on bone and soft tissues. Oversized implants also cause fractures [30]. Patient age and sex, osteopenia, and rheumatoid arthritis are risk factors for periprosthetic fractures [30]. In one series, 85 % of fractures occurred in women with an average age of 71 years [31]. Others also found that RA was present in 55–100 % of patients with postoperative humerus fractures [32, 33].

Nonunions for periprosthetic fractures occur in higher frequency compared to other humerus fractures [32]. Several factors are thought to play a role, including relative stress shielding, increased force transmission, and potential distraction caused by an oversized stem [32]. Delayed healing is similarly seen in patients with RA, female sex, and osteopenia.

Prevention

Prevention of periprosthetic fractures is key because treatment options are often difficult. Adequate patient positioning helps reduce forced manipulation of the shoulder during component preparation, especially during canal reaming. Fully releasing all soft tissue adhesions in both the subacromial and subdeltoid spaces will decrease the torsional forces through the humeral shaft during manipulation. Finally, inferior capsular release and rotator interval release help achieve excellent glenoid exposure and protect the humerus from retractors and excessive external rotation.

Technical errors during reaming also lead to fractures. Initial reaming should be started lateral to the center of rotation and posterior to the biceps groove. This helps to avoid varus placement of the reamer and lateral cortical breaching. Reaming should be collinear to remain within the confines of the cortical bone and avoid cortical notching. Several other techniques during reaming (using hand-controlled reamers, limiting reaming to the earliest cortical chatter, using slightly undersized trials and implants) can help minimize stress through the humeral cortex. A press-fit stem also increases the relative risk for a fracture to 2.9 compared to a cemented component [34]. Reverse arthroplasty stems have a flared proximal component that can increase stress risers through the metaphysis during implantation. Postoperatively, patients who have had notching or canal transgression, a varus-positioned stem, an ipsilateral total elbow arthroplasty, or a loose stem are all at an increased risk for future fracture.

Fracture Classification

Fractures about a humeral implant are classified according to location. Wright and Cofield described three types of fractures: type A is centered near the tip of the stem and extends proximally, type B is centered around the tip, and type C is located distal to the stem [33]. Campbell and Iannotti described a similar classification system based on location. Type I fracture involves the tuberosities, type II is in the metaphyseal region, type III is located around the tip of the stem, and type IV is distal to the tip in the diaphysis [35]. Osteopenia is an important risk factor for periprosthetic fractures. It is classified according to ratio of the cortical thickness compared to the width of the humeral diaphysis. A ratio >50 % indicated normal bone, 25–50 % indicated mild osteopenia, and <25 % indicated severe osteopenia. Based on this definition, osteopenia has been reported to be present in 75 % of the periprosthetic humeral shaft fractures [35, 36].

Treatment

Factors to consider include the location, stability of the fragments, stability of the prosthesis, and bone quality. Fracture treatment is dictated according to fracture type and characteristics. Nonoperative management is preferred for minimally displaced, stable fractures in patients with body habitus amenable to bracing. Surgical treatment is recommended for patients with grossly unstable fractures, with loose stems, or with displaced fractures that have failed nonsurgical treatment [36].

Intraoperative fractures, as a rule, should be addressed at the time of surgery. If discovered, tuberosity fractures should be repaired with cerclage fixation using heavy nonabsorbable suture or wire. Fractures involving the humeral shaft can be bypassed with a longer stem and supplemented with cerclage wires, strut allografts, or plate fixation as needed.

Treatment of fractures occurring postoperatively depends on implant stability. In general, loose implants should be revised. Fractures involving the tuberosities can be treated conservatively when they are not displaced or minimally displaced. Displaced fractures can be treated similarly to those found intraoperatively. Proximal fractures are treated with a long-stemmed prosthesis that bypasses the fracture by two or three cortical widths [30, 35]. Stems may be cemented or press fitted and supplemented with wires and allograft without significant impact of healing rates [32]. Fractures around the distal aspect of the stem can be treated with revision using a longer implant, open reduction internal fixation (ORIF), or a combination of both (Fig. 12.2a–c). Hybrid fixation using a locking plate and cerclage wires can be used with a stable humeral stem. Very distal fractures are treated similarly to non-periprosthetic diaphyseal humerus fractures. In the absence of bone loss and stem loosening, fixation using standard or locking plates is used with or without supplemental wires (Fig. 12.3a–c).

Treatment of periprosthetic glenoid fractures is often more complex and is completely dependent on implant stability and bone stock. These fractures typically occur with reverse shoulder prostheses. Small fractures occurring intraoperatively can be ignored if sufficient stability of the baseplate is achieved. Otherwise, long-pegged implants with extra screw fixation are a good option to maintain a steady component. If a baseplate cannot be safely implanted, staged surgery is advisable with fracture fixation occurring in the first surgery. The second stage is used for reimplantation, with or without the use of supplemental bone graft.

Outcomes

Outcomes reporting for periprosthetic humeral fractures are reserved to case series and level IV evidence [30, 34, 35, 37, 38]. Kumar et al. reported on 16 postoperative fractures occurring at a median time of 49 months from initial surgery. All fractures healed; however, those treated operatively healed in a mean time of 278 days compared to 180 days for nonoperative treatment [30]. Although this may seem counterintuitive, it is due to the initial, unsuccessful nonoperative treatment in the surgical group that lasted a mean of 123 days. Another study reviewed 21 patients with periprosthetic humeral fractures and found average time to union was 2.3 months for fractures treated surgically compared to 3.5 months for those undergoing conservative treatment [35]. Athwal et al. reviewed a large series of 45 intraoperative fractures which included 20 tuberosity fractures, 16 humeral shafts, 6 metaphyseal, and 3 combined fractures [34]. All fractures united at an average of 17 weeks although subanalysis revealed displaced shaft fractures took significantly longer to heal (mean 22.5 weeks). Overall outcomes for patients sustaining fractures around a primary arthroplasty were found to have satisfactory to excellent outcome in 24/31 patients. Fractures occurring around a revised humeral component tended to have worse outcomes, although it is not known if this is due to the revision itself. Best outcomes were found in patients with non-displaced tuberosity fractures [34].

Recently, Andersen et al. reported on 36 patients with postoperative fractures treated with ORIF or revision surgery with or without fixation [37]. All fractures in the ORIF group healed at an average time of 6.8 months, compared to 7.7 months in the revision group. A majority of patients returned to pre-fracture ASES scores regardless of the treatment modality.

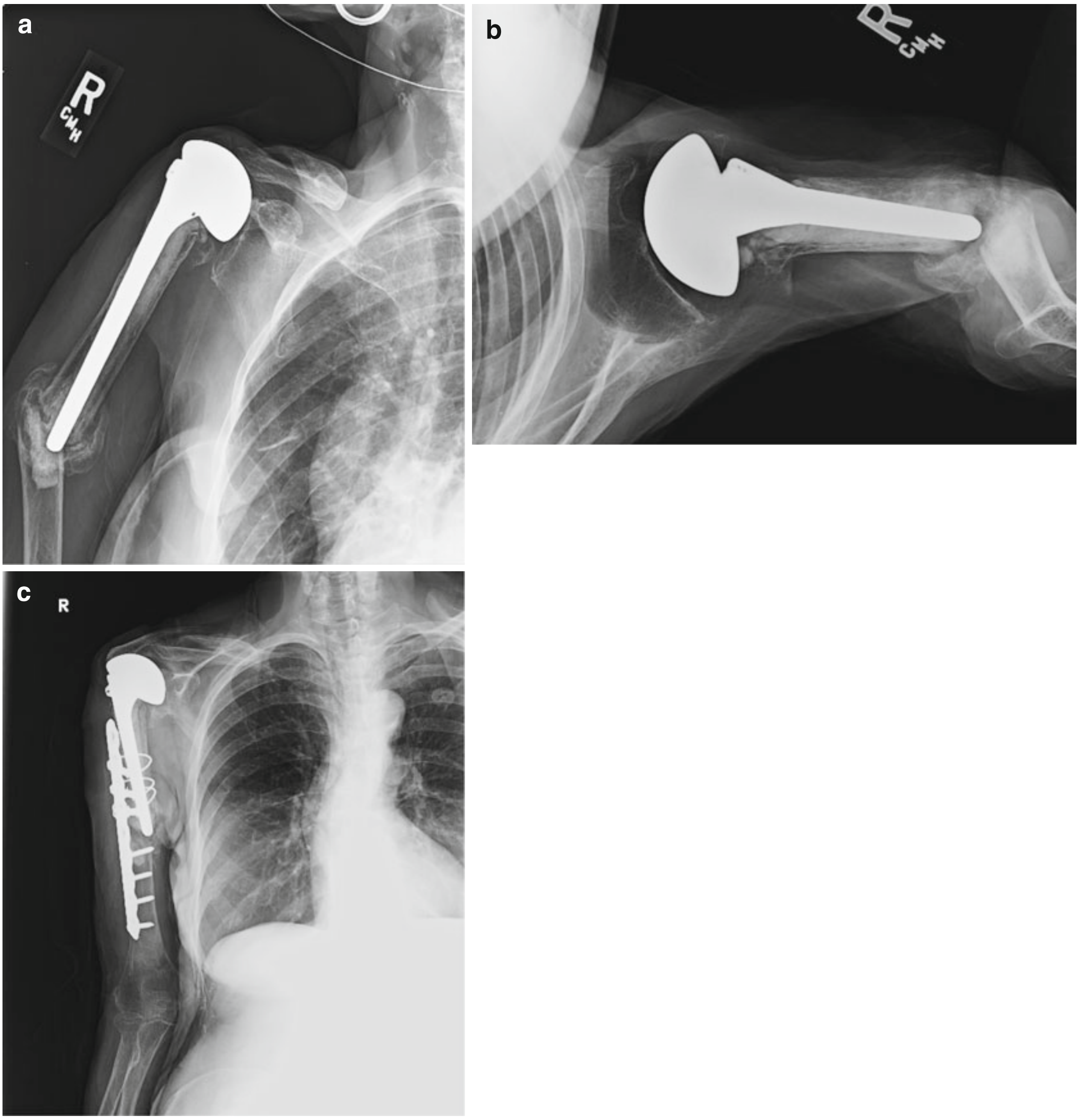

Fig. 12.2 (**a**, **b**) AP and axillary views of a Type III periprosthetic humeral fracture. (**c**) Postoperative x-ray showing treatment with open reduction and internal fixation using hybrid fixation with screws and cerclage wires

Periprosthetic humeral fractures are a rare and challenging clinical problem. Efforts should be made to prevent their occurrence by using proper operative techniques. Special care should be taken in patients with documented risk factors (osteopenia, RA, revision surgery, etc.) to avoid increasing stress on the humerus. Intraoperative fractures are treated based on location, fracture stability, and stem fixation. Postoperative fractures are treated similarly with the exception that nonsurgical management may be attempted in certain fracture patterns. Tuberosity fractures are addressed using suture or wire fixation. Unstable meta-diaphyseal fractures around a well-fixed stem are treated with plate and screw constructs with or without cerclage wires and cortical struts. Loose stems should be revised and made to bypass the fracture by at least two cortical widths. Fractures distal to the tip of the stem are treated like standard humeral shaft fractures with stable osteosynthesis that bypasses the stem sufficiently.

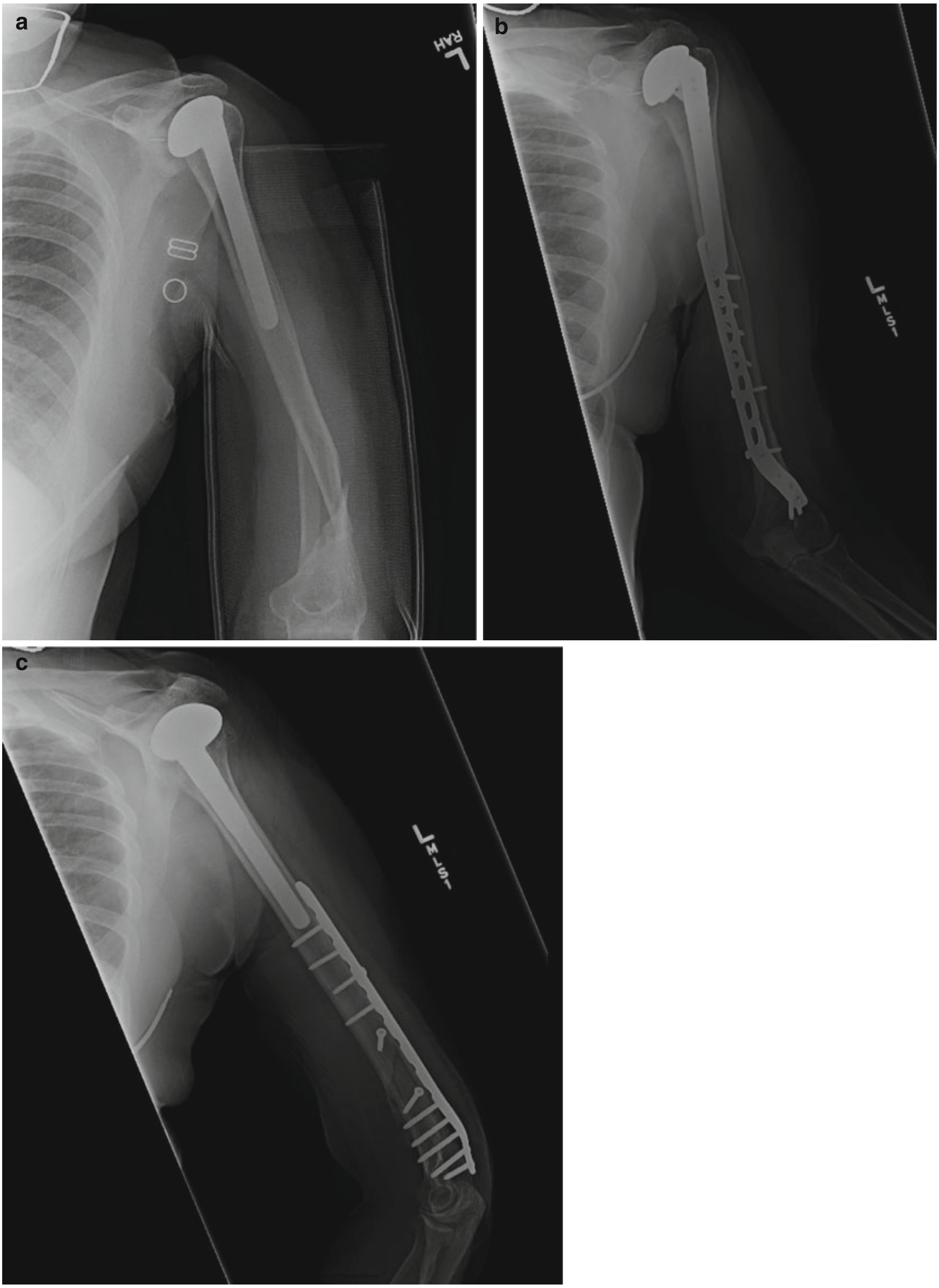

Fig. 12.3 (**a**) Preoperative X-ray for a Type IV periprosthetic fracture. (**b**, **c**) Postoperative x-rays showing open reduction and internal fixation

Shoulder Arthroplasty Instability

Instability after shoulder arthroplasty is a rare complication, occurring in about 5 % of all replacements [1, 39]. This rate has been reported to be much higher for reverse shoulder arthroplasty, up to 15–28 % [40, 41]; however this is likely due to initial learning curve reported in these early series. Instability is specific to the type of implant used. Instability following total shoulder arthroplasty is generally related to component malposition, component loosening, soft tissue deficiency, or a combination of all of these. Dislocation following reverse shoulder arthroplasty is related to component malposition, trauma, or component wear.

Instability following anatomic shoulder arthroplasty can be divided into anterior and posterior instability. Anterior instability is related to component anteversion, subscapular deficiency, or a combination of both [42, 43]. Revision for anterior instability does not usually result in renewed stability. Two large series reported that less than 50 % of patients regained stability following revision surgery [42, 44, 45]. Treatment options include component revision, subscapularis repair, pectoralis major transfer, soft tissue supplementation, and reverse shoulder arthroplasty [44, 46, 47]. Conversion to reverse shoulder arthroplasty was found to solve instability in 94 % of patients in one recent study [48].

Posterior instability is usually caused by soft tissue laxity (posterior capsule in chronically subluxated shoulders or biconcave glenoid) or excessive retroversion of components. Treatment consists of component revision, posterior capsular plication, postoperative immobilization, or revision to reverse shoulder arthroplasty. Soft tissue management and component revision resulted in 64 % of good outcomes in one study [44]. A recent series found that revision to reverse shoulder arthroplasty helped regain stability in 95 % of patients [49].

The reverse shoulder arthroplasty (RSA) is a semi-constrained implant with inherent stability provided by component shape. Postoperative instability has been reported as high as 68 %, but recent analyses estimate the incidence closer to 0–8 % [50, 51]. Component positioning has a definite impact on stability. A biomechanical study found that glenoid version had little to contribute to inherent stability, which is logical because the spherical nature of the implant should change very little with slight degrees of version change [52]. The position of the humeral component, however, greatly influences inherent stability in both the resting position and the 90° abducted position. With a neutral glenosphere, there was a 20 % increase in stability for each 10° of anteversion placed in the stem, starting at 20° of retroversion [52]. Gallo et al. reviewed the first 57 RSAs and found an overall instability rate of 15.8 %, all occurring within the first 6 months of the initial surgery [41]. They found component malposition or infection to be responsible of all cases. They concluded that the steep learning curve for reverse shoulder arthroplasty likely explains the high instability rate in this series. Another recent study reviewed all RSAs done at one institution and found a 2.9 % instability rate. The mean time to dislocation was 3.4 weeks postoperatively. All patients underwent initial attempt at closed reduction and was successful in 81 % of cases. Ultimately, 7 of 11 patients (64 %) needed revision surgery [51]. Another report describes similar success with initial treatment with closed reduction, resulting in a 62 % revision-free survival. Black et al. reported on six patients undergoing revision RSA for instability. They found only a 50 % retention rate, with two patients undergoing resection arthroplasty and a third remaining in fixed anterior dislocation [53].

Overall, instability following shoulder arthroplasty is a difficult problem to treat. Depending on the type of dislocation, initial closed reduction can be an effective treatment. Recurrent instability must be treated with revision surgery to address the cause (soft tissue deficiency, component malposition, infection.) For incurable instability in anatomic total shoulder arthroplasty, revision to reverse shoulder arthroplasty is a good salvage operation. Recurrent instability following revision reverse shoulder arthroplasty has a very poor prognosis and often leads to resection arthroplasty or hemiarthroplasty.

Subscapularis Insufficiency

Subscapularis rupture following total shoulder arthroplasty is a rare complication that can lead to pain, weakness, and instability [54]. Multiple risk factors have been described including revision operation, oversized head, subscapularis lengthening, and noncompliance with postoperative activity restrictions [54]. Also, patients with significant internal rotation contracture and insufficient release at the time of surgery are at high risk for subscapularis tear [54]. A recent biomechanical study found that a deficient subscapularis induced a compensatory decrease in force of the infraspinatus muscle. This force decrease was balanced by an increase of the supraspinatus and middle deltoid. Consequently, the deficient subscapularis induced upward migration of the humeral head with eccentric contact patterns and higher stress in the glenoid component [55]. Regardless of the method used to address the subscapularis when performing arthroplasty, function and strength of the tendon take roughly 24 months to recover [56]. Even at 2 years, only 15 % of patients return to normal function of the subscapularis [56]. Although there is no difference in functional outcomes between a subscapularis peel, tenotomy, and lesser tuberosity osteotomy [57], one advantage of the osteotomy is the ability to see failure on X-ray (Fig. 12.4). Ives et al. found that patients with a symptomatic TSA had a 51 % prevalence of subscapularis tear on ultrasound compared to 9 % in individuals with an asymptomatic TSA [58]. Ideal treatment consists of early repair with or without supplementation of a pectoralis major transfer [54, 59]. Ultimately, although patients undergoing tendon repair, with or without tendon transfer, regain most function, their objective outcomes are decreased [54].

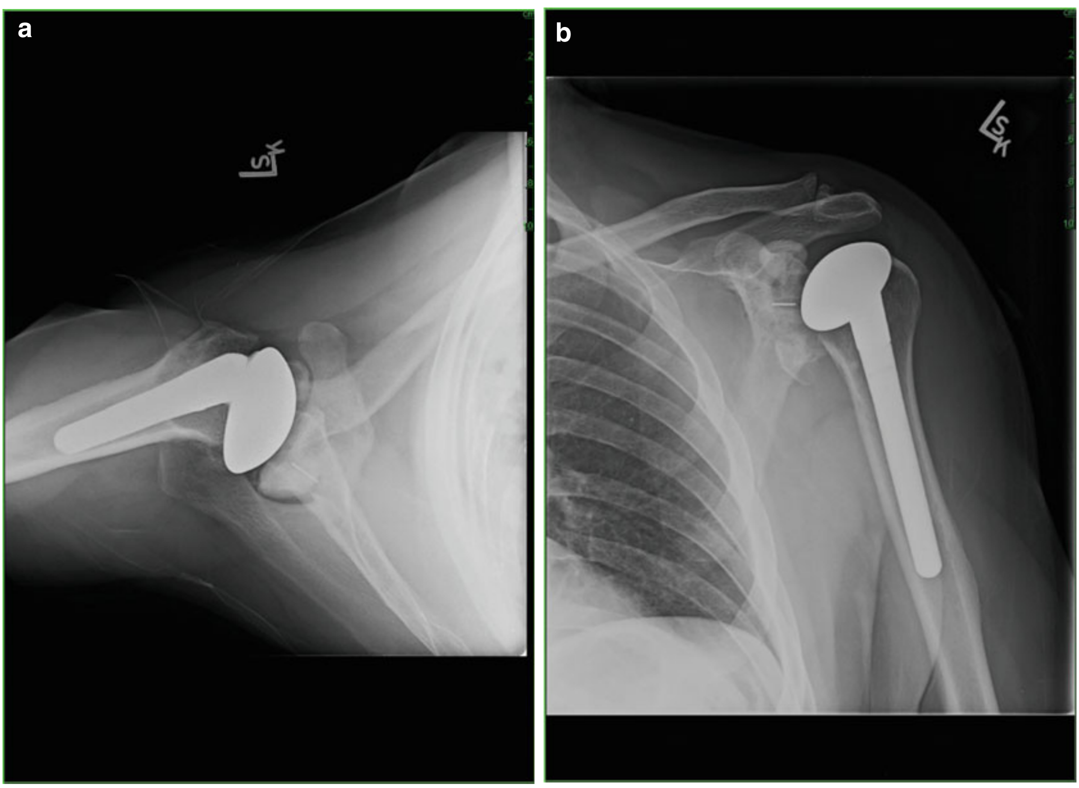

Fig. 12.4 Axillary (**a**) and AP (**b**) x-ray views of a left shoulder in a patient with early failure of a lesser tuberosity osteotomy. The tuberosity has migrated medially and inferiorly

Conclusion

Shoulder arthroplasty provides dramatic improvements in functional outcome for patients suffering from osteoarthritis. Complications of shoulder arthroplasty are rare; however, they can severely impact these outcomes. Ideally, surgeons would take every necessary precaution to avoid these complications. Unfortunately, even when all precautions are taken, some complications will undoubtedly occur. In these cases, a systematic approach to both diagnosis and treatment, as outlined in this chapter, is necessary to ensure the best possible outcomes.

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