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Revision/Failed Radial Head Arthroplasty

Emilie J. Amaro, Eric S. Dilbone, James P. Hovis, and Donald H. Lee

Introduction

The radial head confers significant stability to the elbow joint while also allowing for multiplanar range of motion. Radial head fractures are common, accounting for 1.5–4% of all fractures, and occur in approximately one third of elbow fractures [1, 2]. The radial head is a key stabilizer to valgus, axial, and posterolateral stress, and therefore appropriate clinical management is paramount in order to restore elbow function. The management of radial head fractures is dependent on fracture morphology, comminution, displacement, articular involvement, ligamentous stability, and associated injuries of the elbow [3].

Several classification systems exist to help guide the clinical management of radial head fractures. Mason first classified radial head fractures in 1954, and a modified classification has been created based on the degree of comminution and displacement. A Mason-type I injury describes a nondisplaced or minimally displaced fracture, a Mason-type II injury describes a displaced fracture, while a Mason-type III injury describes a comminuted and displaced fracture of the radial head [1]. In 1962, Johnston described a fourth type which involves a radial head fracture as well as an ulnohumeral joint dislocation [4]. These classifications were later modified by Broberg, Morrey, and Hotchkiss [5, 6].

There is a general consensus that Mason I and Mason II radial head fractures without mechanical blocks to motion can be managed with a short period of immobilization followed by early range of motion. Several studies have demonstrated that long-term outcomes are largely favorable with nondisplaced or minimally displaced radial head fractures treated with nonoperative management [7, 8]. Mason II fractures with displacement that interfere with motion are frequently treated via open reduction internal fixation (ORIF) with countersunk screws, headless compression screws, or plate fixation. However, Mason III fractures with significant comminution are challenging injuries to manage, and debate remains over the standard treatment. Surgical options include ORIF, radial head excision, and radial head arthroplasty [6]. Ring et al. performed a retrospective study on 56 patients and demonstrated that Mason II and Mason III fractures with 3 or less articular fragments have favorable outcomes with ORIF [9]. However, fractures with more than three articular fragments had poor outcomes defined as early failure or nonunion, decreased range of motion, or a fair or poor rating using the Broberg and Morrey rating system[9]. Thus,

E. J. Amaro · E. S. Dilbone · D. H. Lee (✉)
Vanderbilt University Department of Orthopedics, Division of Hand Surgery, Nashville, TN, USA
e-mail: emilie.j.amaro.1@vumc.org; eric.dilbone@vumc.org; donald.h.lee@vanderbilt.edu

J. P. Hovis
Arizona Center for Hand Surgery, Phoenix, AZ, USA

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ORIF is effective for fractures with a few articular fragments, whereas fractures with significant comminution are better managed with radial head excision or prosthetic replacement.

Radial head excision is a reasonable surgical option in patients with a comminuted radial head fracture with stable elbow and forearm ligaments. Herbertsson et al. reviewed 61 patients with Mason II and Mason III fractures treated with radial head excision and found that patients had a good or fair functional outcome with minimal change in range of motion at 18 years following surgery [10]. However, radial head resection leads to altered elbow and wrist kinematics contributing to several anatomic complications. The radial head acts as a restraint to axial load by maintaining the anatomic length of the forearm, and is also an important secondary stabilizer to valgus stress, particularly in a ligamentous deficient elbow with a concomitant medial collateral ligamentous injury [11]. While displaced and comminuted radial head fractures may occur in isolation, they are commonly associated with concurrent ligamentous and bony injury about the elbow. An anatomic study performed by Beingessner revealed that radial head resection led to impaired rotational kinematics and elbow laxity to varus and valgus stress in a ligamentous deficient elbow [12]. Thus, radial head resection is contraindicated in radial head fractures with associated elbow instability, particularly with a deficient medial collateral ligament. Furthermore, proximal migration of the residual radius following radial head resection often leads to ulnar-positive variance and chronic wrist pain [13]. Radial head resections are therefore contraindicated in Essex-Lopresti fractures, defined as radial head or neck fractures with associated injury to the DRUJ and interosseous membrane. Subsequent resection in this situation would destabilize the forearm.

The advent and further advances of radial head prostheses have vastly impacted the way complex elbow trauma is treated. Radial head arthroplasty remains the treatment of choice in complex, comminuted radial head fractures with concomitant ligamentous or bony injury [14, 15]. Radial head prostheses restore elbow stability and range of motion. In 2001, Moro et al. studied 25 patients with unsalvageable radial head fractures and found that 17 patients had excellent/good outcomes and only 3 had poor outcomes using the Mayo Elbow Performance Index following radial head arthroplasty [15]. All patients reported high subjective markers and satisfaction with the procedure. Furthermore, several studies have demonstrated better outcomes with arthroplasty when compared to ORIF in the treatment of Mason III fractures. Ruan et al. demonstrated that when using the Broberg and Morrey functional elbow assessment, 92% of patients treated with arthroplasty had a good or excellent result, while only 12.5% of patients treated with ORIF demonstrated good or excellent results [16]. Chen et al. demonstrated that radial head arthroplasty was associated with fewer complications compared to ORIF when treating comminuted radial head fractures [17].

Radial head prosthetics have also been used in chronic conditions affecting the radiocapitellar joint including malunion, nonunion, and post-traumatic arthritis. However, radial head arthroplasty is not without complication. Complications requiring reoperation are cited in up to 45% of cases [18]. Implant loosening, technical failure, stiffness, radiocapitellar arthritis, and infection are all known complications of radial head arthroplasty.

Current Concepts in Reconstruction

The first reported radial head arthroplasty was performed in 1941 by Speed using a ferrule cap [19, 20]. Following initial experimentation, silastic radial head implants became popular in the 1960s with a design developed by Alfred Swanson [21]. Initial reports demonstrated favorable clinical outcomes, which were thought to be secondary to maintaining radial length and radiocapitellar contact [21]. However, long-term data published in the early 1980s demonstrated that silastic particles lead to a reactive synovitis [22]. Furthermore, the silastic material was too deformable leading to high rates of implant fracture and residual elbow instability [23]. Silicone implants have poor biomechanical properties and therefore are now seldom used in practice. After silastic implants fell out of favor in the early 1980s, radial head implants have undergone innovations in design and presently most are manufactured using cobalt-chrome, titanium, or pyrolytic carbon [19, 24].

Currently, there are two major designs used in radial head replacements, unipolar and bipolar prosthetics [25]. Unipolar constructs are generally noncemented stem designs that are fit loosely within the radial canal or are secured to the proximal radial canal with press-fit insertion. With the smooth designs, the stem component is intentionally left loose to allow for radiocapitellar congruence with forearm range of motion [26]. Due to the loose fit, there is a lucency surrounding the implant stem seen on radiographs that is expected, although the long-term clinical relevance of this lucency is unknown [27]. Press-fit designs have a stem coating to allow for stem bony ingrowth. Immense care must be taken in press-fit designs as microfractures are common when inserting the stem [28]. Bipolar stems have a constrained joint at the radial head-neck junction to reapproximate the native joint [27]. Bipolar prosthetics are typically cemented or press fit into the radial canal to limit the degrees of freedom built into the implant. Bipolar designs are thought to decrease stress while increasing congruity at the radiocapitellar joint although this remains unproven. Both unipolar and bipolar implants are typically modular in design, i.e., have separate radial stem and head components, that allow for various combinations of head and stem sizes.

Outcomes

Outcomes with radial head arthroplasty to treat complex elbow trauma appear satisfactory [17, 29]. A review performed by Bonnevialle et al. demonstrated that satisfactory clinical outcomes were seen in 60–80% of cases [30]. However, many of the studies evaluated short-term outcomes with long-term outcomes being largely unknown [31]. Laumonerie performed a large literature review demonstrating that reported rates of reoperation following radial head replacement range from 0 to 45% [18]. Furthermore, Duckworth et al. reviewed 105 patients who underwent radial head replacement following elbow trauma and found that 28% of patients required a reoperation within 6.7 years [32]. This was further validated by Cristofaro et al. who found a 25% rate of reoperation in patients who underwent a radial head replacement with an 8-year follow-up period [33]. Both younger age and silastic implants were independent and significant risk factors for further surgery [32].

However, Harrington et al. provided contradictory outcomes demonstrating that metal radial head prosthetics provide elbow stability with a few complications in patients with a mean follow-up of 12 years [14]. Furthermore, Reinhardt et al. performed a study evaluating the rate of reoperation and cost of treating radial head fractures with ORIF compared to radial head arthroplasty. The results demonstrated that following ORIF, patients were more likely to undergo a reoperation and had a higher total cost of care when compared to patients who underwent a radial head arthroplasty [34]. These results held true through a subgroup analysis evaluating patients both with and without a concurrent elbow dislocation [34]. Thus, radial head arthroplasty remains both a cost-effective and clinically successful treatment method for radial head fractures. However, radial head arthroplasty is not without complications. Commonly reported complications include aseptic loosening, stiffness, technical and implant failure, radiocapitellar arthritis, and infection [35].

Aseptic Loosening

A recent systematic review regarding failure modes of radial head arthroplasty cited symptomatic, aseptic loosening as the most common mode of failure (Fig. 6.1a–c) [35]. Based on post hoc analyses, 30% of implants failed due to aseptic loosening, with an average time to failure of 34 months [35]. Aseptic loosening is seen among all methods of fixation including press-fit,

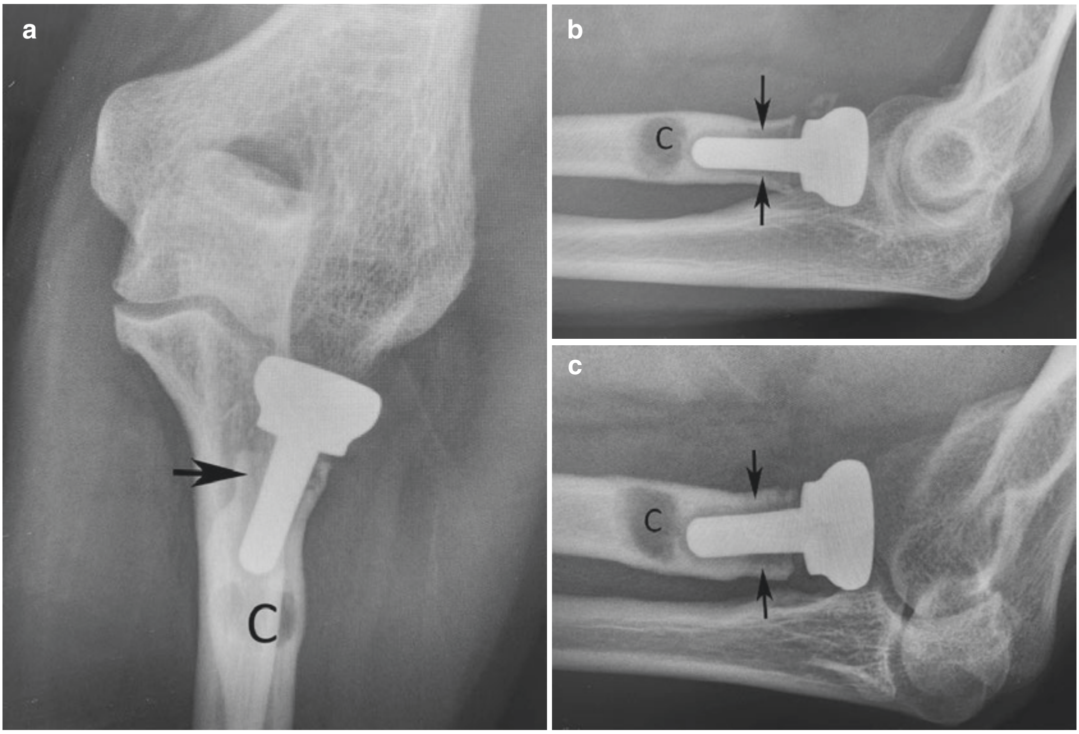


Fig. 6.1 (**a**–**c**) Anteroposterior (**a**), lateral (**b**), and oblique (**c**) radiographs of the elbow with loosening of a press-fit radial head implant. Note the area of lucency around the stem (arrows) and cyst formation (C) distal to the tip of the implant

cemented, loose fitting, and expandable stems. As discussed, unipolar designs can be placed with a loose fit within the intramedullary canal to allow for radiocapitellar congruence with forearm range of motion. This can be seen radiographically as a lucency surrounding the implant. However, progression of the radiolucency radiographically can be associated with clinical pain and loosening of the implant.

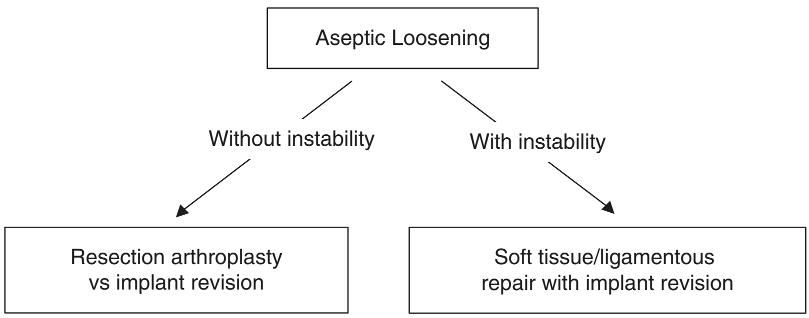
One study found a lower incidence of aseptic loosening among bipolar designs compared to unipolar designs and hypothesized that this is secondary to lower stress transmission at the bone-implant interface [31]. Studies have demonstrated that bipolar prosthetics indeed have less micromotion and reduced stress at the bone-implant interface [36]. Furthermore, cemented bipolar arthroplasties and loose-fitting smooth unipolar implants are associated with less loosening than press-fit designs [37–39]. This suggests that poor bony ingrowth onto the stem leads to increased micromotion, which facilitates loosening of press-fit designs. Further advances in press-fit stem designs are needed, and surgeon preference and familiarity with the implant should factor into the choice of implant design used. As aseptic loosening remains the most commonly cited mode of failure in patients with radial head arthroplasty, patients should have close and long-term radiographic follow-up.

Treatment of aseptic loosening of a radial head implant includes implant revision, with or without cement and a longer stem implant, or implant removal [40]. Preoperative serologic studies and intraoperative cultures should be obtained. The choice of implant (unipolar vs. bipolar) and fixation technique (cemented vs. uncemented) will vary with the implant design and intraoperative factors such as anatomy of proximal radius at the time of revision. Other potential options could include total elbow arthroplasty (in cases of ulnohumeral arthritis) and radiocapitellar prosthesis (not currently available) (Algorithm 6.1) [35].

Stiffness

Stiffness is a common complication following elbow trauma or reconstruction and can be secondary to multiple etiologies including soft tissue contractures, heterotopic ossification (HO), extra- and intra-articular malunions, nonunions, and loss of articular cartilage [41, 42]. In the setting of radial head arthroplasty, stiffness is caused by oversizing the radial head implant, implant loosening and migration, heterotopic ossification, or soft tissue contractures. Stiffness following radial head arthroplasty is common and has been cited as the mode of failure in 20% of all cases [35]. In one meta-analysis of patients with failed radial head arthroplasty undergoing revision surgery for stiffness, loose-fitting prostheses were revised 7 times more frequently when compared to press-fit prosthetics (20 of 53 loose-fit prostheses versus 3 of 47 press-fit prostheses; $p < 0.01$) [35]. Among the 20 intentionally loose-fit prostheses, unipolar designs were revised for stiffness more often than bipolar designs.

Heterotopic ossification (HO), an abnormal formation of bone, has a predilection for the elbow joint and is the leading cause of extrinsic elbow contracture leading to clinical stiffness (Fig. 6.2a,



Algorithm 6.1 Treatment algorithm for failure due to aseptic loosening

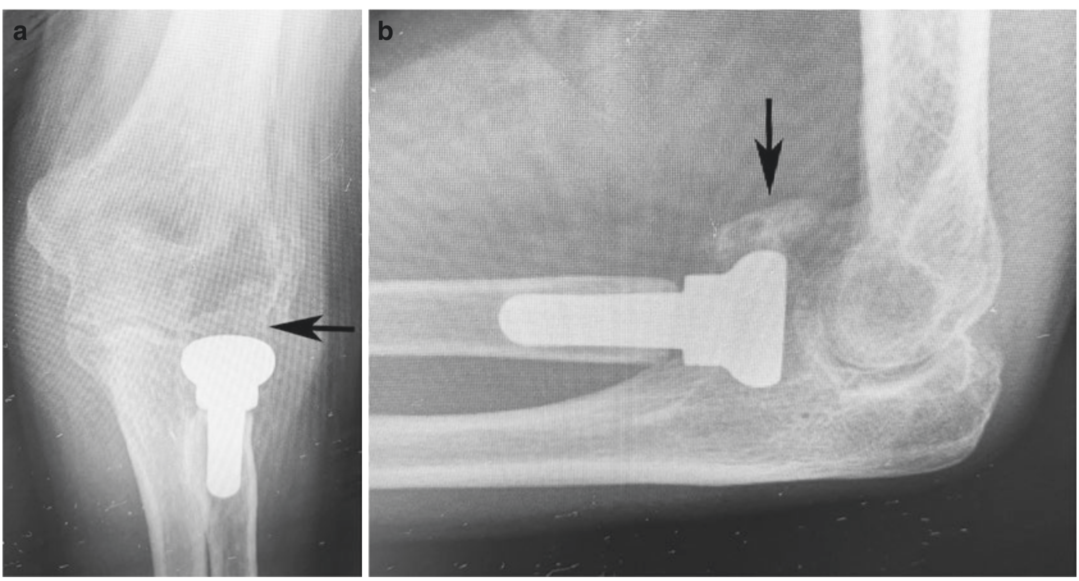
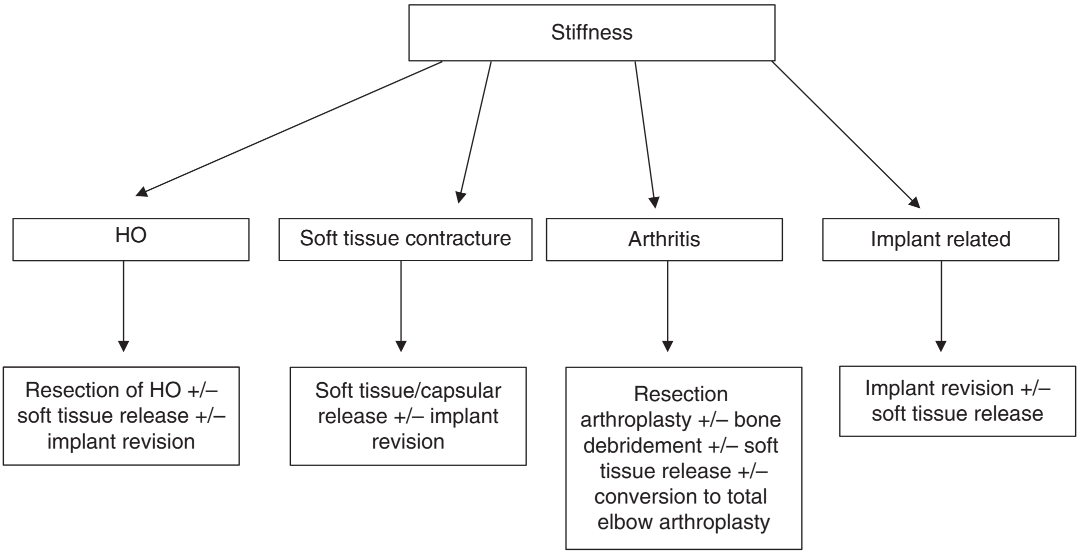


Fig. 6.2 (**a**–**b**) Anteroposterior (**a**) and lateral (**b**) radiographs of non-bridging heterotopic ossification (arrow) following a radial head replacement



Algorithm 6.2 Treatment algorithm for failure due to stiffness

b) [43]. The rate of HO following elbow trauma has been reported to be as high as 89% [44]. HO is a frequent complication following radial head arthroplasty. Moro et al. found a 30% rate of HO following radial head replacement, while Ha et al. reported that 38% of all patients showed signs of HO [15, 27]. Furthermore, 53% of these patients required removal or revision of implants due to heterotopic ossification [27]. As HO can impair functional outcomes, many studies have been performed on mechanisms to prevent abnormal bone formation. Currently, NSAIDs and radiotherapy are the two therapies used to prevent HO. However, their efficacy is not well established and these therapies are not without risk. NSAIDs have been shown on the molecular level to impair bone formation, while radiotherapy is associated with skin breakdown and poor wound healing. Therefore, the decision to prophylactically treat patients following a radial head replacement secondary to elbow trauma is very provider specific and varies significantly throughout the literature [45].

The indication and type of operative treatment of elbow contractures following a radial head replacement is dependent on the degree of elbow stiffness, functional impairment, and the etiology of the stiffness (soft tissue, heterotopic ossification, arthritis, implant-related problems). Soft tissue contractures without arthritis, heterotopic ossification, and implant-related problems (loosening, improper sizing) can be treated with capsular release. In elbows with mild to moderate arthritis or heterotopic ossification, limited bone debridement may be used to augment soft tissue release. Severe arthritis, however, would require some form of arthroplasty (fascial interposition or total elbow arthroplasty). In cases of radial head implant-related elbow stiffness (loose implant, improper sizing, implant-related arthritis), options include implant revision, with or without cement and a longer stem implant, and implant excision (Algorithm 6.2).

Technical and Implant Failure

While radial head replacement appears to be a reproducible and systematic surgical procedure, there are several technical considerations that must be made. In particular, maintaining the anatomic length of the radius has been found to significantly impact elbow kinematics and load transfer at the ulnohumeral joint with direct clinical repercussions. Glabbeek et al. studied the

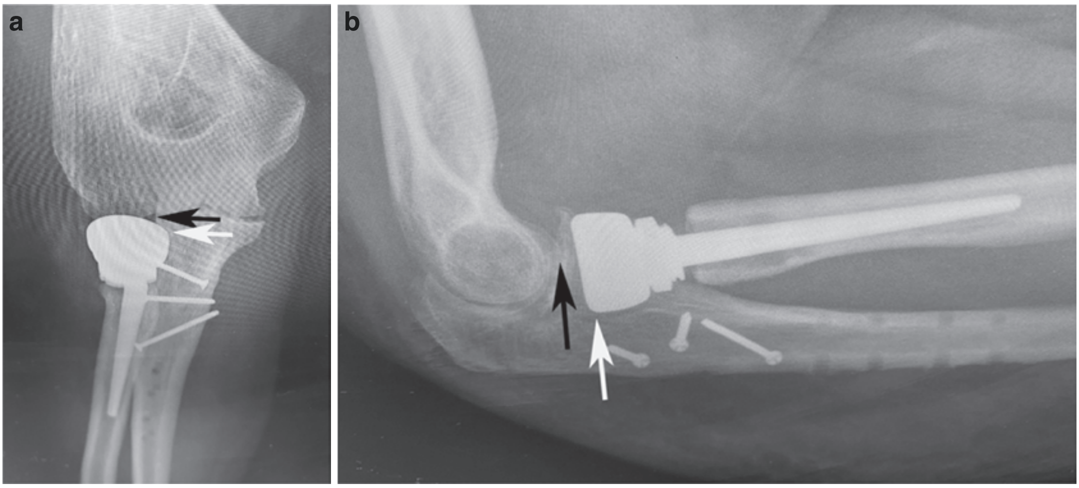


Fig. 6.3 (**a–b**) Anteroposterior (**a**) and lateral (**b**) radiographs of a shortened radial head implant (white arrow) placed shorter than the proximal margin of the lateral coronoid facet (black arrow)

kinematics and forces at the elbow in cadaveric elbows with resected radial heads that were artificially lengthened or shortened [46]. Their data suggest that lengthening or shortening the radius by as little as 2.5 mm affected the varus/valgus stability at the elbow as well as contact pressures at the radiohumeral and ulnohumeral joints. Shortening the radius led to valgus laxity at the elbow with the ulna maintaining an internally rotated position (Fig. 6.3a, b). Overlengthening the radius, or overstuffing, led to a varus deformity of the elbow, which was most pronounced at 30 degrees of elbow flexion. Lengthening the radius by 5 mm led to such a profound overstuffing of the joint that the sensors became irreversibly deformed, distorting further data collection. Furthermore, Cohn et al. performed a cadaveric study and found that only 2 mm of radial lengthening could be tolerated without significant overloading of the radiocapitellar joint [47]. These studies clearly demonstrate that small deviations from the anatomic length of the radius can lead to significant changes in joint stability and forces across the elbow.

Overlengthening is a relatively frequent complication of radial head arthroplasty (Fig. 6.4a, b). Burkhart et al. followed 19 patients following a bipolar radial head prosthetic and found that 2 cases of dislocation and 1 case of bony erosion were attributable to overlengthening [29]. Overstuffing the joint is thought to lead to pain, early onset of radiocapitellar arthritis, and stiffness. As cadaveric studies have demonstrated that small changes in radial length lead to large biomechanical changes, it is difficult to ascertain an exact percentage of cases that fail directly due to overstuffing. However, appropriately sizing both the radial head diameter and length is paramount to a satisfactory outcome in radial head replacement.

Radial head implant sizing is typically templated by the size of the explanted radial head as well as by the fracture fragment sizes. Radiographic findings that indicate overstuffing mainly rely on joint symmetry. The proximal aspect of the radial head should be at the level of the most proximal extent of the lesser sigmoid notch or the lateral edge of the coronoid (Fig. 6.5). At the time of surgery, the radial head implant under fluoroscopy can appear up to 2 mm proximal to the most proximal margin of the lesser sigmoid notch due to the thick cartilage in this location [48]. Additionally there should be no widening of the lateral aspect of the ulnohumeral joint relative to the contralateral elbow, and the medial ulnohumeral joint space should be parallel [49].

Other technical failures include the failure to repair ligamentous injury following repair of the radial head in a ligamentous deficient elbow. As

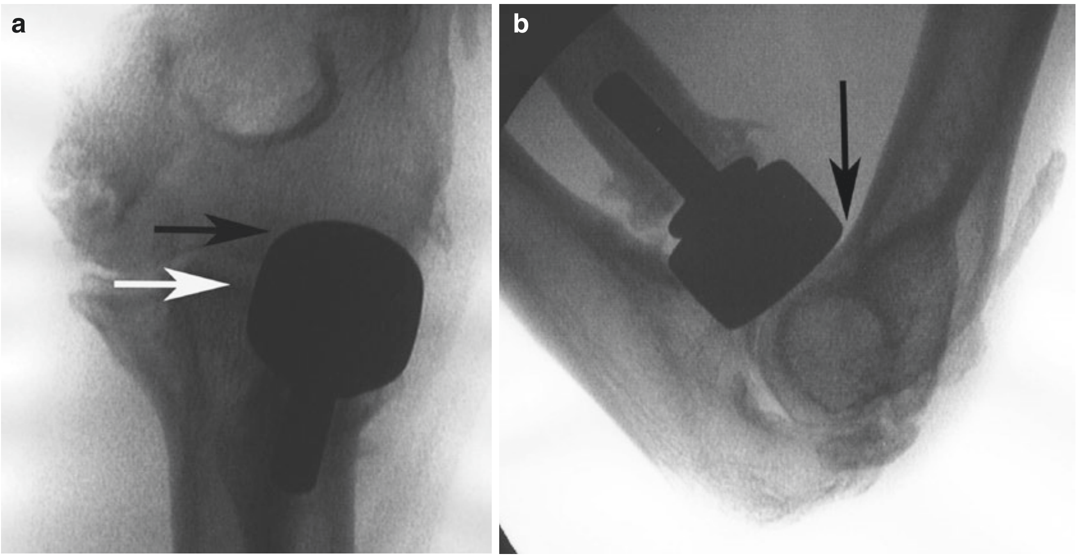


Fig. 6.4 (**a**–**b**) Anteroposterior (**a**) and lateral (**b**) radiographs showing a large radial head implant that overstuffs the radiocapitellar joint. Note that the proximal margin of the radial head implant (black arrow) is too proximal to the proximal margin of the lateral coronoid facet (white arrow) (**a**). The implant also blocks elbow flexion (black arrow) (**b**)

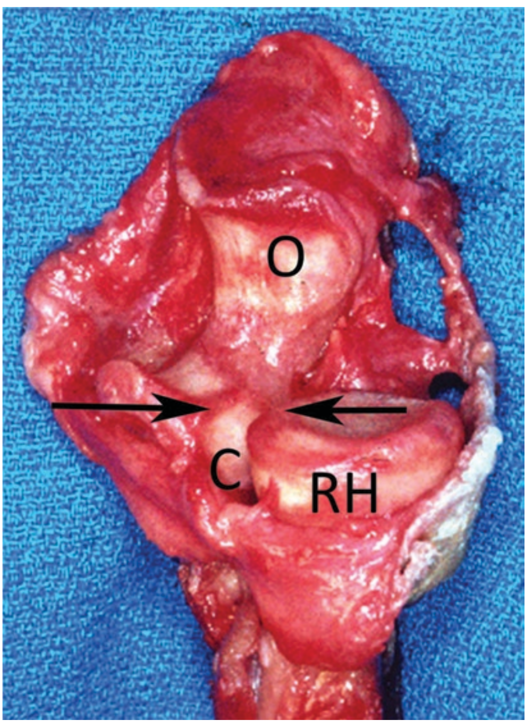


Fig. 6.5 Cadaveric specimen showing the colinear alignment (two arrows) of the lateral coronoid facet (C) and radial head (RH). Olecranon process (O)

previously discussed, the radial head is a secondary stabilizer of the elbow, particularly to axial and posterolateral forces. Thus, in the setting of a concurrent ligamentous injury, failure to repair soft tissue structures can lead to posterolateral instability (Fig. 6.6) [50]. A study performed by Allavena analyzed bipolar prosthesis and found that in 22 patients, 6 patients demonstrated persistent posterolateral subluxation on postoperative radiographs, and 3 patients required a revision for ligamentous or capsular repair [51]. Recurrent instability is a common mode of failure following radial head arthroplasty. A literature review performed by Laumonerie found 9 cases of significant instability requiring operative revision in 80 total patients following insertion of a radial head prosthesis [18]. The surgeon must therefore critically evaluate the ligaments of the elbow and plan for concurrent reconstruction along with radial head replacement.

Finally, as discussed, both unipolar and bipolar implants have separate radial stem and head components, which allow for various combinations of head and stem sizes. A less common complication that can occur with modular implants is implant dissociation requiring implant revision (Fig. 6.7a, b). This can occur due to inappropriate sizing of the components and residual instability of the elbow allowing for significant motion of the components as well as due to mechanical failure of the linkage mechanism.

The indication and type of operative treatment for a technical failure or radial head implant failure is dependent upon the mode of failure. In cases of failure secondary to overstuffing or overlengthening of the implant without radiocapitellar arthritis or instability, options include implant revision to the appropriate size or implant removal. In elbows with radiocapitellar arthritis, the implant may be downsized or removed. In cases of elbow posterolateral instability following a radial head implant, lateral collateral ligament repair or reconstruction is warranted. Implants that have failed secondary to dissociation or breakage are generally revised or removed. In cases of implant revision, the type of implant used (standard vs. long stem) and type of fixation (cemented vs. noncemented) depend on the conditions of the proximal radius at the time of the revision (Algorithm 6.3).

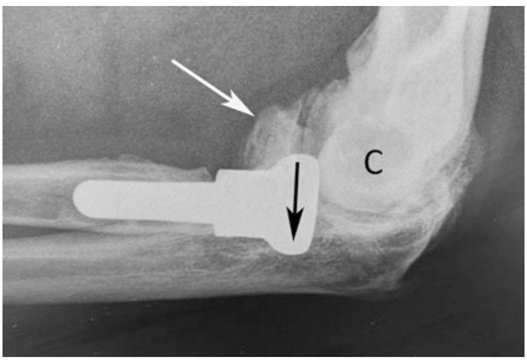


Fig. 6.6 Lateral radiograph showing residual posterior subluxation of the radial head (black arrow). Note that there is significant periarticular elbow joint arthritis (white arrow). Capitellum (C)

Radiocapitellar Arthritis

The radiocapitellar joint bears approximately 60% of forces transmitted through the native elbow, demonstrating its high predilection for osteoarthritis [52]. As described by Glabbeek and Cohn, radial head arthroplasty done with any change in radial length can greatly impact radiocapitellar and ulnohumeral joint pressures, which can lead to early wear and arthritic changes [46, 47]. Secondary radiocapitellar arthritis is a frequent radiographic finding after radial head arthroplasty and can lead to significant postoperative pain in some patients. Radiocapitellar arthritis has been reported in up to 70% of patients following radial head arthroplasty [15]. In a study performed by Ha et al., which evaluated 244 patients following

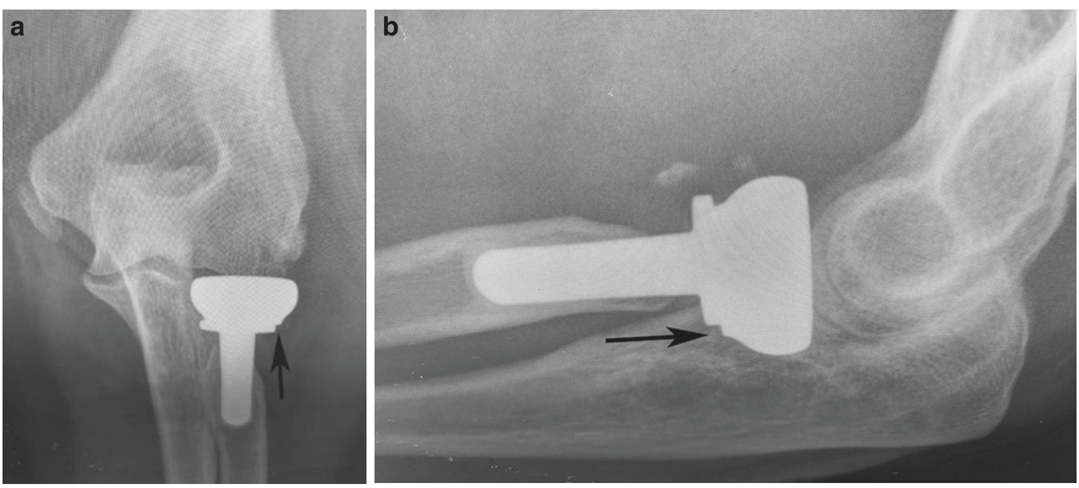


Fig. 6.7 (**a**–**b**) Anteroposterior (**a**) and lateral (**b**) radiographs showing loosening of the radial head component relative to the stem. The radial head is slightly laterally (**a**) and posteriorly (**b**) shifted (arrows) relative to the stem

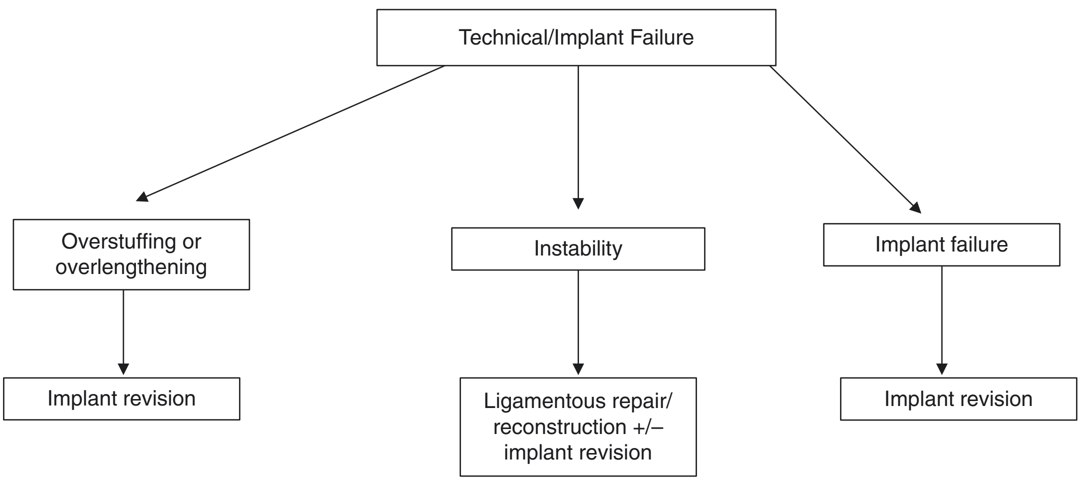
radial head arthroplasty, radiocapitellar arthritis was seen in 28% of patients and was more common in unipolar constructs when compared to bipolar constructs [25]. Bipolar constructs are designed to improve joint congruence and therefore may be less likely to impart wear on the capitellum. However, Popovic et al. reported a 58% rate of capitellar wear following the use of bipolar prosthetics indicating that the type of prosthetic may not affect wear rates [37].

Radiocapitellar arthritis is treated expectantly. If symptoms progress and begin to significantly impact quality of life, options can include downsizing of the radial head implant, a radiocapitellar joint resurfacing implant (not currently available), resection arthroplasty with anconeus interposition or tendoachilles allograft interposition, and conversion to a total elbow arthroplasty (in cases of significant ulnohumeral arthritis) (Algorithm 6.4) [53, 54].

Infection

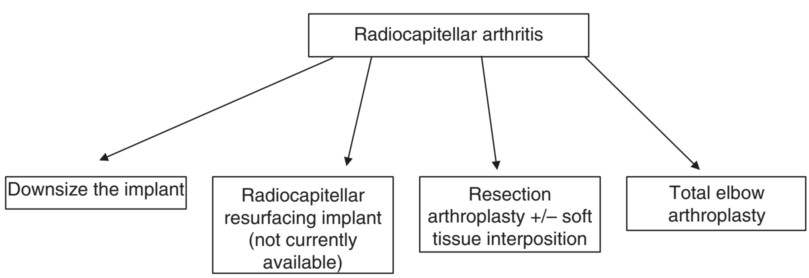
Deep infection is an uncommon but catastrophic complication of radial head arthroplasty. Laumonerie et al. reported 3 cases of deep infection following 80 radial head replacements; all 3 cases required explantation and revision [18]. Furthermore, Neuhaus et al. studied 14 cases requiring revision and found that 2 patients required reoperation secondary to a chronic, deep infection [55]. Lastly, Cristofaro studied 119 patients following radial head arthroplasty with only 1 patient experiencing a deep infection requiring revision [33].

Similar to other joint arthroplasty, radial head prosthetic infections can be divided into early and late infections. Early infections typically occur within the first 3 weeks of operative intervention and are directly related to surgical and sterile technique, operative time, wound closure, wound



Algorithm 6.3 Treatment algorithm for failure due to techical error or implant failure

Algorithm 6.4 Treatment algorithm for failure due to radiocapitellar arthritis



healing, open fractures and perioperative antibiotic administration [56]. If a deep postoperative infection occurs acutely, a thorough irrigation and debridement is indicated with retention of the implant. A 6-week course of microbial tailored antibiotics is typically adjunctive to the operative debridement. Superficial infections, while more common, are typically treated with a short course of oral antibiotics. Subacute infections may be best treated with implant removal with or without insertion of an antibiotic spacer and a secondary reimplantation in the setting of residual instability.

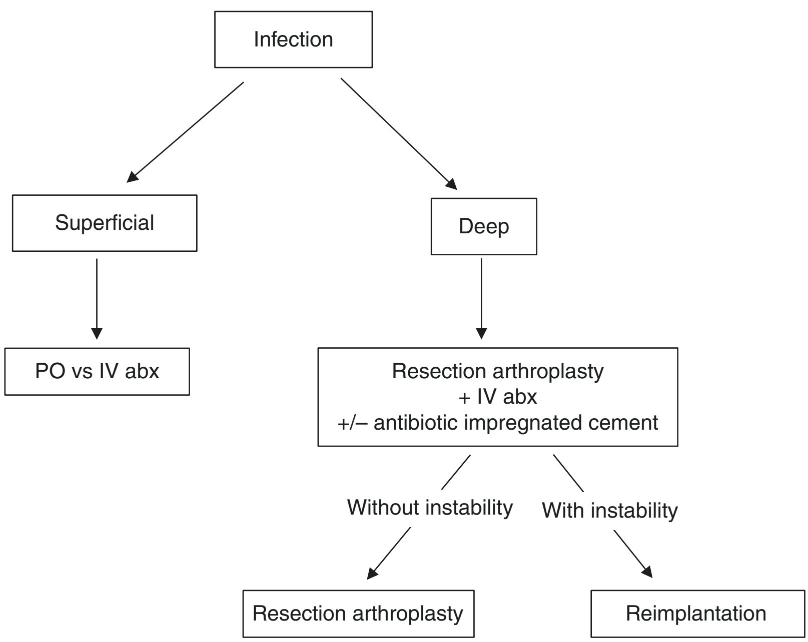
Late prosthetic infections present a far more challenging clinical scenario. No data currently exists regarding isolated radial head replacement, but the total elbow replacement literature cites *Staphylococcus aureus* as the most common microbial species in prosthetic elbow infections [57]. Late infections typically occur secondary to bacteremia or due to direct inoculation through a wound or trauma. As orthopedic implants allow for the formation of biofilms, chronic infections typically require radial head explantation, with or without an antibiotic-impregnated cement spacer, with possible revision arthroplasty following a course of IV antibiotics (Algorithm 6.5).

Radial Head Arthroplasty Failure

Revision following a failed radial head prosthesis presents a number of challenges that require individualized consideration. Patient-specific considerations include but are not limited to age and level of activity, presence of symptoms/pain, proximal bone stock, quality of capitellar chondral surface, concomitant ulnohumeral osteoarthritis, cemented vs. press-fit implant, surgeon preference, and level of comfort performing revision procedure. Multiple options exist for revision including explantation of the prosthesis, removal of prosthesis and revision with a different radial head prosthesis, revision to total elbow arthroplasty, and revision to partial elbow arthroplasty or radiocapitellar prosthesis. Of reported revisions in current literature, 69% of revision surgeries involved isolated explantation of the prosthesis, 25% exchanged the radial head prosthesis, 3% were revised to a total elbow arthroplasty, and 3% were revised to a radiocapitellar prosthesis or partial elbow arthroplasty [35].

When determining the best option for revision, the stability of the elbow needs to be considered. A radial head prosthesis can be used to help stabi-

Algorithm 6.5 Treatment algorithm for failure due to infection



lize the elbow while the collateral ligaments heal [9, 58]. Following ligamentous healing it is safe to remove the prosthesis as subluxation or dislocation of the elbow would be very unlikely. Prior studies have demonstrated satisfactory functional outcomes in patients who undergo a radial head resection, and it is therefore reasonable to remove the prosthesis and not replace it in the setting of a stable elbow and forearm [59].

If ligamentous instability persists, exchange of the radial head prosthetic or conversion to a total elbow arthroplasty is needed. However, there is no clear consensus on the ideal management of a failed arthroplasty, and several patient-specific factors must be taken into consideration [60].

Radial head arthroplasty is an evolving technique that offers a solution to radial head and neck injuries. With numerous differing implants and multiple fixation strategies available, it is still unclear which is preferred. Although promising short- and mid-term results have been seen with radial head arthroplasty, it remains a complex procedure requiring meticulous attention to detail. An understanding of the injury pattern, patient characteristics, radiographic parameters, and implant used are required to improve outcomes and reduce complications.

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