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Management of the failed radial head arthroplasty

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- Primary radial head arthroplasty (RHA) produces good or excellent results in approximately 85% of patients. However, complications are not uncommon and have been described in up to 23% of cases.

- The number of RHA is increasing, and consequently the absolute number of complications is expected to rise as well. The decision on whether to revise or remove the prosthesis seems more likely to depend on the preference of the surgeon or the hospital, rather than on objectifying problems with the prosthesis.

- The current article presents an algorithm for the work-up and treatment of most complications that can occur following RHA.

- Five subgroups of problems were identified: osteoarthritis, stiffness, instability, infection and implant-related issues.

- In short, the preferred treatment depends mainly on the chondral condition and stability of the elbow joint.

Introduction

The radial head plays an essential role in valgus stability of the elbow and axial stability of the forearm. It has been estimated that with the elbow extended, about 60% of the axial forces are transmitted across the radiocapitellar joint.[1,2] In order to restore the stability in case of comminuted fractures or complex elbow trauma, radial head arthroplasty (RHA) may be indicated.[3] However, only replacing the radial head (in, for instance, terrible triad injuries) may not be sufficient to restore stability. It should rather be implemented in adjunction to ligamentous and/or coronoid repair to regain full elbow stability.

In the last decades, there has been an annual increase of 8% in elbow arthroplasty procedures.[4] In addition, there is also an increasing body of literature on the outcome of this procedure. In general, primary RHA shows good or excellent outcomes in about 85% of patients. However, complications are not uncommon and have been described in up to 23%.[5] Although most articles report short-term follow-up of RHA only, the relatively high number of complications has become evident.[5–7] The most prevalent reasons for revision or failure of RHA are symptomatic loosening, stiffness, pain, oversizing or overlengthening, dissociation of the prosthesis, erosions of the capitellum and progressive symptomatic osteoarthritis of the ulnohumeral joint.[8] Since this embodies a broad range of complications, with variable (and sometimes unknown) causes, it may be difficult to treat them in a standardized way.

Moreover, the decision on whether to revise or remove the prosthesis seems more likely to depend on the preference of the surgeon or the hospital, rather than on objectifying problems with the prosthesis.[9] Therefore, the aim of the current article is to provide an evidence-based algorithm for the work-up and treatment of failed RHA. All recommendations are based on a critical appraisal of the literature on (revision) RHA that was recently systematically reviewed by our study group.[7,10] See also Table 1. That same literature search was the basis for the current article. As we found that the literature on this subject is scarce, we combined it with the expert opinion of three highly experienced, high-volume elbow surgeons.

Radial head arthroplasty

The most common indications for RHA are non-reconstructible radial head fractures where the stabilizing function of the radial head is compromised. This may be the case in acute comminuted fractures of the radial head that are not amendable by open reduction and internal

Table 1. Articles describing the results and complications following radial head arthroplasty

Prosthesis	Manufacturer	References
MoPyC	Tornier	- Sarris, 2012[64] - Ricón, 2012, 2018[55, 65] - Lamas, 2011[66] - Hackl, 2017[26] - Lópiz, 2016[67]
Judet Floating Radial Head (CRF II) (now Radial Head System)	Tornier	- Burkhart, 2010[68] - Celli, 2010[69] - Popovic, 2007[70] - Dotzis, 2006[71] - Brinkman, 2005[72] - Smets, 2000[73] - Judet, 1996[74] - Viveen, 2017[75] - Van Hoecke, 2016[76] - Heijink, 2016[55] - Kodde, 2016[13]
Katalyst	Integra	- Berschback, 2013[77] - Zunkiewicz, 2012[78] - Sershon, 2018[5]
Evolve	Wright Medical	- Schnetzke, 2014[79] - Watters, 2014[80] - Chien, 2010[81] - Shore, 2008[82] - Doornberg, 2007[83] - Grewal, 2006[84] - Ashwood, 2004[85] - Strelzow, 2017[86] - Moghaddam, 2016[87] - Kachooei, 2016[9]
ExploR	Biomet	- Laflamme, 2017[88]
Anatomic Radial Head System	Acumed	- El Sallakh, 2013[89] - Flinkkilä, 2012[90] - Levy, 2016[91]
Radius Head Component	LINK	- Yan, 2015[92] - Wretenberg, 2006[93]
Guepar	DePuy Johnson & Johnson	- Allavena, 2014[94] - Laumonerie, 2017[6]
Radial Head	Corin	- Katthagen, 2013[95]
rHead	Small Bone Innovations (SBi)	- Rotini, 2012[96] - Laumonerie, 2017[6]
Richards	Smith & Nephew	- Shore, 2008[82] - Moro, 2001[97] - Harrington, 2001[98]
Solar Radial Head	Stryker Howmedica Osteonics	- Chapman, 2006[99] - Knight, 1993[100]
rHead	Avanta	- Flinkkilä, 2012[90]
Evolutive	Aston Medical	- Laumonerie, 2017[6]

fixation. Other reasons for replacement are chronic cases with instability after a radial head resection, malunion or nonunion.

The first report on RHA was published in 1941,[11] and many articles with modifications on the implant rationale have been published since. Radial head prostheses (RHP) may vary in terms of fixation technique, material, polarity and modularity. Over the last decades, many different types of RHP have been developed, with various combinations of these properties. For most types of RHP the results have only been reported in a few articles. Some prostheses have been taken off the market after a short period of availability.[12] Although it is not always clear why a prosthesis is not available anymore, in general, high numbers of complications were reported. Reported complications

have consisted of nerve palsy, instability, stiffness, persistent pain, (superficial) infection, complex regional pain syndrome (CRPS) and symptomatic hardware.[10] Revision surgery was performed in a significant group of patients that experienced complications (23%) following primary RHA. A systematic review on RHA by our study group showed that, on average, 8% of radial head prosthesis had been revised early, within four years of follow-up.[7] There was no significant difference in revision rate between the various RHA designs in the analysis. The following reasons for revision were found: symptomatic loosening (30%), stiffness (20%), pain (17%), overstuffing (9%), dissociation of the prosthesis (5%) and symptomatic osteoarthritis (OA, 4%).[7]

Since RHA is being performed more frequently, and complications are seen in about 25% of patients, it is imperative for surgeons to have some strategies to handle these complications. We therefore developed a flowchart as a guide to dealing with these problems (Fig. 1). One of the objectives of the algorithm was to list evident symptoms and diagnoses for failure and revision of the prosthesis, in order to allow more uniform reporting in future literature. For instance, we consider pain as a symptom, not a final diagnosis. The flowchart starts therefore with four different *symptoms* that patients may pass through. Next, a specific *advanced work-up* is suggested per symptom. Following the results of this work-up, five groups of *diagnoses* were proposed. Subsequently, for each of these diagnoses, *treatment options* were suggested based on available literature. The consecutive steps in the flowchart will be discussed in detail in the following paragraphs.

Symptoms

Four main reasons for patients to seek medical care following RHA are reported. *Pain* is the most frequent complaint. It can be the only symptom but can also be accompanied by *stiffness* or *instability*. Pain can be the only sign of a low-grade *infection*, whereas more fulminant infections will show swelling, erythema, a fistula or even systemic symptoms in advanced cases.

As always, the interpretation of symptoms starts with careful history taking. The patient may have had pain from the first moment after the implantation of the radial head or may have developed pain at a later stage. The first is more likely with overstuffing and malalignment, or early failure based on septic or aseptic failure of implant fixation. The latter may be the case in late loosening of the prosthesis, capitellar erosion or progressive posttraumatic arthritis. A history of wound healing problems may suggest an infection, whereas a prolonged period of immobilization before or after surgery or malalignment may both result in elbow stiffness. A history of progressive pain of
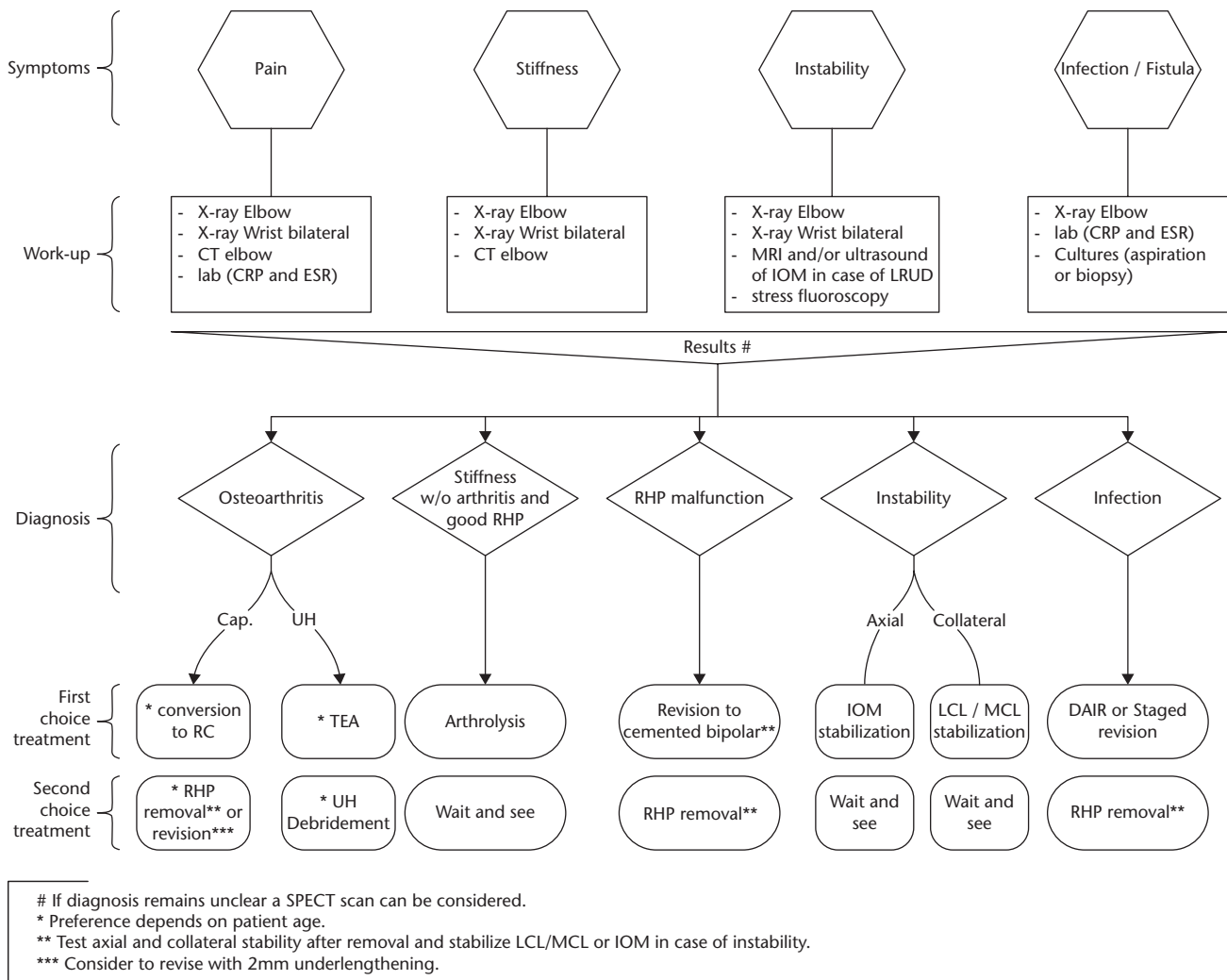
Fig. 1 Flowchart for the management of the failed radial head arthroplasty (RHA). The flowchart should be interpreted with the details provided in the text.

the wrist may suggest an injury of the interosseous membrane (IOM) (i.e. Essex-Lopresti lesion).

Physical examination focuses on scars around the elbow, range of motion, soft tissue swelling, joint effusion, skin temperature, pain on palpation or during loaded and unloaded motion of the joint, stability of the elbow and neurovascular status. Careful examination of the wrist including the distal radioulnar joint (DRUJ) should be performed as well.

Advanced work-up

Each of the symptoms described in the algorithm (Fig. 1) may require its own additional exams. The first step is

always to perform plain radiographs in the anteroposterior and lateral direction. These may give information on implant-related issues such as loosening, malalignment, subluxation or dissociation of the prosthesis. They may also show ulnohumeral osteoarthritis, osteolysis of the radial neck, erosion of the capitellum or heterotopic ossification (HO). Well-fixed press-fit RHP may show signs of proximal osteolysis.[13]

Laboratory testing of inflammation parameters such as erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) and leucocyte count (LC) may offer information on the possibility of an infection. LC has a sensitivity of 45% for periprosthetic joint infection (PJI) in general and is therefore rarely helpful. ESR (> 30 mm/h) has a sensitivity

of 75% and a specificity of 70%, and CRP (> 10 mg/L) a sensitivity of 88% and specificity of 74% for PJI in general. The combined sensitivity of the latter two tests is 96%, suggesting that if both tests are negative, a PJI is unlikely.[14] The sensitivity and specificity of these test for RHA infection are not known. When these are elevated or increasing without another source of infection subsequent aspiration for cultures is necessary, although it is less sensitive in comparison to its use in lower extremity infections.[15] Multiple samples biopsy (with prolonged incubation period) is the best method to reveal an infection.[16] Obtaining these samples should be performed at least two weeks after cessation of antimicrobial therapy, in order to detect cases of low-grade infection.[17]

In case of pain, stiffness or instability it is recommended to test for ulnar impaction syndrome (impingement between the ulnar head and the lunate) and DRUJ instability, including bilateral radiographs of the wrists.[18] Computed tomography (CT) scanning is advised when a patient presents with pain and/or stiffness of the elbow. It is more accurate for assessment of overstuffing, gives more detailed information on the exact location and geometry of HO, and can more accurately detect loose bodies, ulnohumeral osteoarthritis or erosion of the capitellum.[19] Dual energy CTvscanning reduces the scattering that is produced by the prosthesis and increases accuracy.[20]

In case of instability of the elbow, several radiological modalities are available to support this. If an IOM injury is suspected, the diagnosis can be made on a (3 Tesla) magnetic resonance image (MRI) of the forearm, an ultrasound by a dedicated musculoskeletal radiologist or elbow/wrist surgeon, or dynamic examination under fluoroscopy.[21] Injuries of the medial collateral ligaments (MCL) or lateral collateral ligaments (LCL) can be assessed with MRI or ultrasound, but the sensitivity to detect pathology of the lateral ulnar collateral ligament is reported to be insufficient to rule out injury solely based on negative imaging. In case of clear valgus (milking manoeuvre, moving valgus stress test) or varus instability (varus stress test, pivot shift test) dynamic examination under fluoroscopy may be sufficient to detect it.

Diagnosis and treatment

The results of the work-up will eventually lead towards a diagnosis that will match one of the five groups of complications pictured in (Fig. 1). Positive cultures confirm the presence of an (low-grade) infection. Proximal migration of the radius on radiographs and/or IOM injury on MRI, ultrasound or fluoroscopy suggests axial instability. The diagnosis of instability can be made from clinical examination and advanced imaging. Stiffness of the elbow can present either with or without OA and/or implant failure. This evaluation can be made on the plain radiographs and

CT scan. Finally, there is a variety of implant-specific failures possible: loosening, (sub)luxation, malalignment, dissociation, breakage of the prosthesis or overstuffing. Overstuffing can mean either oversizing, when the head of the prosthesis is too big, or overlengthening, when the head of the prosthesis is placed too high in relation to the ulna. The five different groups of diagnosis are comprehensively described below.

Osteoarthritis

OA of the elbow following RHA can either involve the capitellum or the ulnohumeral joint. Erosion of the capitellum can be the result of cartilage damage during trauma but might also be provoked by overlengthening of the prosthesis, or due to the hard surface of the prosthesis against the cartilage. Isolated capitellum wear can be treated by a capitellar-resurfacing component. Some small case series showed good results after a radiocapitellar arthroplasty.[22-24] It is important to be informed whether the RHP is compatible with the capitellar component. If this is not the case, the RHP should be revised as well during the procedure. One option to overcome this problem is to order a patient-specific designed prosthesis (Fig. 2).[25] Although this is an experimental option at the moment, it may become the definite solution in the near future. Another option we use in our clinic today is *under*lengthening of the prosthesis by 2 mm. This decreases radiocapitellar contact forces but still stabilizes the proximal radioulnar joint and provides valgus stability. Biomechanical evidence for this concept in native radial heads has recently been published.[26] While there are no long-term results of this procedure available, the short-term results in our clinic are promising. If the elbow and forearm remain stable after removal of the RHP during the
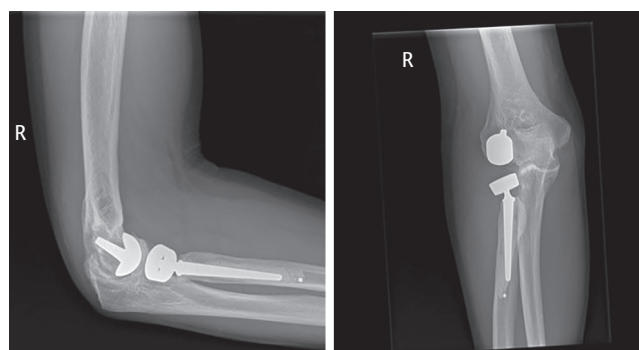
Fig. 2 This patient had been treated with a radiocapitellar arthroplasty for posttraumatic arthritis. The radial head component had been removed, and not replaced, due to loosening. Months later the patient presented to our clinic with severe pain and instability. As the original component was no longer available at the time of the second revision, the radial head component was revised with 2 mm of underlengthening, and a patient-specific head that was compatible with the existing capitellar implant.

surgical procedure, the radial head may not need to be replaced,[27] although this could potentially lead to proximal radioulnar impingement (rubbing of the proximal radial stump against the proximal ulna) under loaded rotational activities.

In case of symptomatic ulnohumeral osteoarthritis, there may be a reason to convert to a total elbow arthroplasty (TEA). This may the optimal solution for elderly and low-demand patients. In younger and more active patients, a TEA is contra-indicated, as literature on long-term outcomes is scarce. Moreover, a significant amount of complications (up to 62–90%) have been reported following TEA.[28-35] When TEA are implanted for post-traumatic sequelae, only 6% involve primarily the radial head; the majority of cases have a distal humeral fracture or severe ligamentous injury.[36] To the best of our knowledge there are no specific case series on TEA following failed RHA, but the short- and mid-term outcomes of TEA for posttraumatic conditions of the elbow are good.[37, 38] In order to postpone a TEA in younger and active patients, a (arthroscopic) debridement of the elbow might be warranted.[39]

Stiffness without osteoarthritis and good RHP

In the first six months after implantation of the RHP there is a good chance to improve the mobility of the elbow with conservative treatment. Various strategies such as physical therapy, dynamic and/or static progressive splinting are recommended in the literature.[40, 41] Surgical arthrolysis can be indicated for those patients with persistent impairment of the functional range of motion despite adequate conservative treatment. Restriction in range of motion is often the result of capsular adhesions or HO around the elbow, leading to impingement. This can be managed by open or arthroscopic arthrolysis and, if necessary, removal of the HO.[42, 43] An open arthrolysis of the elbow is usually performed via a lateral approach (through the previous incision). The RHP and anterior compartment of the elbow can be reached through Kocher's, Kaplan's interval or through an extensor tendon split. It is important to assess the RHP for possible overstuffing. On the other hand, when the ulnar nerve is symptomatic it is advised to include an ulnar nerve release and the arthrotomy could be performed from the medial side. If a flexion limitation of 100° or worse is present, a release of the posterior bundle of the MCL should be added after releasing the cubital tunnel, since this ligamentous structure can be partially responsible for the contracture.

Overlengthening can be evaluated based on the level of the lesser sigmoid notch of the ulna.[44] Even if there are no radiographic signs of loosening, this should always be evaluated. Biopsies should always be performed to rule out a low-grade infection. Issues with the RHP should be addressed instantly. Following debridement of the anterior compartment, the posterior compartment can be debrided as well as described with the lateral column procedure.[45] Arthroscopic arthrolysis is a less invasive procedure for performing an arthrolysis. It is generally not a problem to perform a debridement of the anterior and posterior compartments for an experienced elbow arthroscopist. Although we are not aware of any studies describing the outcome of arthroscopic arthrolysis after metallic RHA, one small series on arthroscopic removal of silicone RHA showed satisfactory outcomes.[46] If there are issues with the RHP encountered during the procedure, it will be necessary to switch to an open approach and address them. In case of HO, administration of non-steroidal anti-inflammatory drugs following surgery might prevent recurrence of HO.[47, 48]

RHP malfunction

Several problems regarding RHP has been described in the literature. The most common issues are overstuffing, dissociation of the head component, (sub)luxation, malalignment and loosening.[42, 49]

Loosening of the RHP may be difficult to diagnose. O'Driscoll described evident signs of loosening on radiographs in (11/14) 79% of cases, but 3/14 loose protheses had a questionable or normal radiograph. The latter patients had only radial sided forearm pain.[50] On the other hand, radiolucency on radiographs is described in up to 92% of cases for some implants without any clinical signs of loosening.[7] A CT scan may provide more information, and radiographs should always be interpreted in the light of clinical symptoms. A loose RHP may be revised to a cemented RHP or by press-fitting a larger uncemented stem.[50]

As described before, *overstuffing* can be assessed based on the position relative to the lesser sigmoid notch of the ulna.[44, 51] Plain radiographs will only show overlengthening in severe cases.[19] In case of overstuffing, it is sometimes necessary to revise the implant, whereas some implants can be shortened in situ (for instance changing the head component of a bipolar implant).

Dissociation of the head component is more common in bipolar implants but can occur in modular rigid designs as well.[52] In case of dissociation of the head it is essential to critically evaluate the snap-on mechanism. The most probable cause would be a surgeon's error. Possible other causes for this mode of failure could be malalignment, malrotation and instability of both the radioulnar and the ulnohumeral joint, as these may increase forces on the snap-on mechanism.[53] A new head component, or a completely new prosthesis, may be needed, but more extensive surgery may be called for if instability is present.

Subluxation of the radial head prosthesis is sometimes seen in cases of instability or chronic *malalignment* of the radius on the capitellum (Fig. 3).[54] In these cases a revision with a cemented bipolar implant may compensate for a
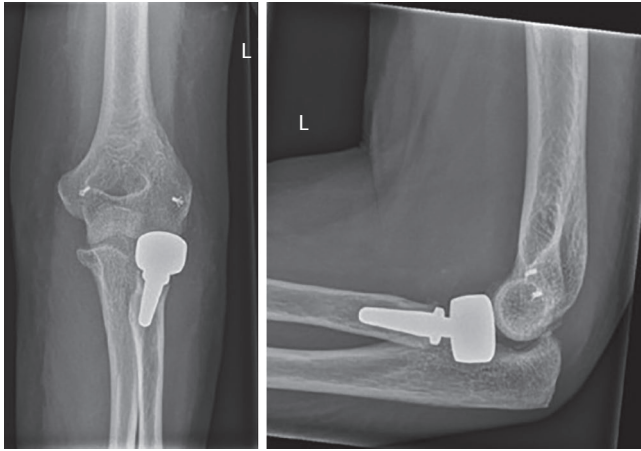
Fig. 3 Subluxation of the radial head prosthesis (RHP) with malalignment and after lateral collateral ligament (LCL) repair.

mild malalignment.[54] In case of a chronic malalignment, however, the capitellar cartilage may have been severely damaged, adding a difficult problem to solve. It should then be decided whether to replace the capitellum, '*under*lengthen' the revised RHP, or remove it without replacing it. In the latter case, it is of utmost importance to assess the stability of the collateral ligaments and the IOM after removal of the RHP. In case of instability one should typically address this with a ligamentous reconstruction.

Instability

Primary ligament repair during placement of an RHP is most often performed for the LCL.[55] The LCL may have been torn during initial trauma (for instance terrible triad injuries), or could have been injured during the approach of previous surgical procedures. In case of acute LCL rupture, a primary repair may be sufficient to solve the problem. In chronic cases, a reconstruction of the lateral ulnar collateral ligament (LUCL) is usually necessary. An algorithm for the management of lateral elbow instability was recently proposed by a member of our study group.[56] Several studies on LUCL reconstructions have been published, all with different fixation techniques and different kinds of grafts.[57] There is no evidence for superiority of one specific surgical technique.

Both the radial head and the MCL provide valgus stability of the elbow. The MCL is the primary restraint to valgus stress with the radial head being the secondary.[2, 58] Insufficiency of the MCL is normally well tolerated in the non-overhead-athletic population. Strengthening of the dynamic stabilizers (flexor-pronator muscles) can compensate for an MCL tear.[59] However, if the secondary stabilizing function of the radial head is compromised, a good MCL is much more important. In patients with valgus instability following RHA it is therefore important to assess the function of the MCL. In chronic cases of valgus instability with a good functioning RHP, an MCL reconstruction can be considered. Many articles on MCL reconstructions (in overhead-athletic populations) have been published.[60] The (modified) Docking technique appears to be superior over Jobe's figure-of-eight technique.[61] Case series on LCL or MCL reconstructions following RHA have not been published.

IOM injuries have been reported in up to 100% of patients with a Mason type-2 or -3 fracture of the radial head on MRI.[62] It is thought that with implantation of an RHP longitudinal stability is restored sufficiently for the IOM to heal. In chronic cases of insufficiently managed radial head fractures, it is possible that the IOM remains unstable. This is especially the case when proximal migration of the radius is observed on plain radiographs. If there is persistent axial instability of the forearm following RHA, an IOM reconstruction may be warranted. However, the literature on this procedure is scarce, particularly in patients after RHA, so the exact incidence of this problem is currently unknown.[57]

Infection

The surgical plan for infection following RHA depends on numerous factors including the type of microorganism, comorbidity, soft tissue status and duration of the infection. There are basically two options available in case of infection. The first option is to preserve the RHP and perform a debridement and implant retention (DAIR) procedure or a staged revision of the RHP. The second option is to remove the prosthesis. Both treatment options are combined with combination of intravenous and oral antibiotics for a longer period. The type of antibiotics and length of treatment depend on the type of microorganism, therefore perioperative cultures should always be taken before antibiotics are given if no preoperative cultures have been performed. Guidelines on treatment options such as removal versus retention of the implant in case of periprosthetic infection of the elbow have been written by Morrey et al.[15] Most knowledge on periprosthetic elbow infections is from TEA.[63] The guidelines on possible implant retention will also apply to RHA, with the advantage of RHA being that removal of the prosthesis will be better tolerated.

Combination of diagnoses

When several diagnoses are suspected at the same time, the most important to act on is infection. Treatment of other diagnoses should start when an infection has subsided. In case of absence of infection, the primary diagnosis to act on is status of the RHP. In this case the RHP is removed and revised for a new RHP or a different arthroplasty (TEA or RadioCapitellar prosthesis (RCP)). Thus,

chondral status dictates treatment secondary to RHP malfunction. If the RHP functions well, the only diagnosis that may lead to revision is symptomatic osteoarthritis. So, this diagnosis is the third in line to act on. Instability can co-occur with RHP malfunction and/or osteoarthritis, and in those cases stabilization of the IOM or LCL/MCL can be performed concomitant to the revision of the RHP. In Fig. 1, specific treatment for stiffness is only indicated in case of a good RHP and chondral status.

Discussion

The amount of RHA is increasing, and the numbers of complications and revisions are expected to rise as well.[4] Revision or removal of the prosthesis is in general a popular solution for failure. The purpose of the current article was to provide an algorithm for the management of complications following RHA. Treatment options for the five subgroups of diagnoses are provided. In short, the preferred treatment depends mainly on the chondral condition and stability of the elbow.

Capitellar erosion is an important difficulty after RHA. As mentioned before, there is currently no RCP on the marked. The low volume of RCP placements makes it commercially less interesting to develop, and the assessment of complications challenging. Still, there are clear benefits of an RCP above a TEA for the patient. Long-term studies are needed to evaluate the alternative of RHA revision with 2 mm of *under*lengthening, or patient-specific implants.

The radial head is thought to be essential as valgus and axial stabilizer, but also for tensioning of the LCL complex and for proportional load transfer in the elbow.[2, 58] Revision of the prosthesis seems therefore preferable. Long-term studies are, however, needed to 'prove' for instance that radial head resection will lead to increased ulno-humeral loading and thus more (symptomatic) degeneration of the ulnohumeral joint. The same applies to the effect of stabilizing the elbow in case of RHP removal with, for instance, internal bracing of the MCL.

We believe that one of the most important things to keep in mind, considering failed RHA, is that failure of this procedure may be independent from the implant itself and is not a complication by definition. In particular, problems with osteoarthritis and instability in the short term after RHA may be due to wrong treatment (or indication for RHA) in the first place. If there are signs of evident humeral degeneration, an RCP or TEA may be a more appropriate treatment than RHA as index operation. A revision of the RHA is thus not necessarily a failure of the RHA, but rather a failure of primary management. The same applies to instability. Radial head fractures for which an RHA is indicated very often have associated ligamentous injuries or coronoid fractures that need to be addressed during primary surgery. Failure to do so may lead to instability during follow-up and subsequent revision surgery.

Conclusion

Complications are not uncommon after RHA, and adequate management can be challenging. The current article presents an algorithm for the work-up and treatment of most complications that can occur following RHA. Five subgroups of problems were identified: OA, stiffness, instability, infection and implant-related issues. Primary treatment should act on assessment and function of the RHP. Secondary issues that dictate treatment strategy are the chondral condition and stability of the elbow. The literature on this subject is limited and higher level of evidence needed.

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