Ed INVITED REVIEW

Shoulder & Elbow

Shoulder & Elbow
2017, Vol. 9(1) 61–70

DOI: 10.1177/1758573216677200
sel.sagepub.com
SAGE

Primary elbow arthroplasty: problems and solutions

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Abstract

Prosthetic replacement of the elbow joint has continued to improve over time. Widespread implantation of certain designs has led to identification a few successful elements of elbow arthroplasty, as well as several opportunities for improvement. Current hot topics in elbow arthroplasty include triceps-preserving exposures, implantation of components with better-expected wear performance, management of the ulnar nerve, prevention of infection, and the development of successful cementless components. Total elbow arthroplasty has the potential to improve pain, function and quality of life for many patients with articular destruction secondary to inflammatory arthropathy or as a consequence of trauma. Continued advances in this field are key to make this operation as reliable and lasting as hip or knee arthroplasty.

Keywords

arthroplasty, elbow, surgical advances

Introduction

Joint replacement has become a worldwide reliable long-term solution for millions of individuals with end-stage joint degeneration affecting the knee, hip and shoulder. However, prosthetic replacement of other joints, namely the ankle and the elbow, has lagged behind larger joint arthroplasty in terms of both long-term failure and complication rates.

For years, elbow arthroplasty was performed mostly for patients with polyarticular inflammatory arthritis. However, the availability of more effective disease-modifying antirheumatic drugs (DMARDs) has resulted in a decrease in the number of individuals with rheumatoid arthritis developing end-stage joint destruction. Those who do develop significant degeneration in the joint are often asymptomatic (as a result of DMARDs) and so may still not be ideal candidates for total elbow arthroplasty. Simultaneously, the indications for elbow arthroplasty have been expanded. As a result, elbow arthroplasty is now oftentimes considered for patients with severe 'unfixable' distal humerus fractures or sequels of trauma (i.e. post-traumatic arthritis and distal humerus non-unions). Some of these individuals will subject their arthroplasty to much higher demands, thus increasing the likelihood of mechanical failure and the need for high-performance implants. In addition to potential issues and complications related to implant fixation and wear, additional problems can occur in the replaced elbow, with the most common being triceps insufficiency, ulnar neuropathy and deep infection.

The present review focuses on a few worrisome issues currently debated amongst experts in elbow arthroplasty, as well as some confirmed or potential solutions that hopefully will continue to improve the reliability of primary elbow arthroplasty. As a result, we should be able to provide better care to our patients.

It Is Still All About Exposure

The ideal surgical exposure to perform an elbow arthroplasty continues to be debated, and it should probably be tailored to patient features and the underlying diagnosis.

Over the last three decades, most surgeons have favoured exposures that to some extent violated

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the attachment site of the triceps on the olecranon. Two very common exposures are the Bryan–Morrey approach and the midline triceps split approach. Figures 1 and 2 ilustrate the various triceps-off and triceps-on exposures. In the Bryan–Morrey approach,[1] the extensor mechanism is mobilized from medial to lateral by sharp detachment of the triceps off the olecranon in continuity with the anconeus muscle and the ulnar periosteum. In the classic triceps split approach,[1] the triceps is divided in line with the subcutaneous border of the ulna and its attachment site detached from the olecranon and elevated half medially and half laterally. Both approaches provide wide exposure of the elbow joint for arthroplasty. They both require transosseous repair of the triceps to the olecranon and postoperative protection for a few weeks.

Although the overall results of elbow arthroplasty in rheumatoid patients using these exposures have been reported to be satisfactory, a number of patients will experience weakness in extension. The true rate of triceps insufficiency with these exposures is unknown because few studies have specifically assessed triceps function after elbow arthroplasty. The reported rate of clinically significant triceps weakness is relatively low; in a systematic review on complications after elbow arthroplasty, Voloshin et al.[1] reported a 1.2% to 1.8% rate with the Bryan–Morrey and triceps split exposures. However, the perception by many elbow surgeons is that the rate of triceps failure is higher but under-reported because it may not be detected unless strength is tested in close to terminal extension, or because surgery to repair or reconstruct the triceps may not be offered or considered when patients are doing otherwise well.

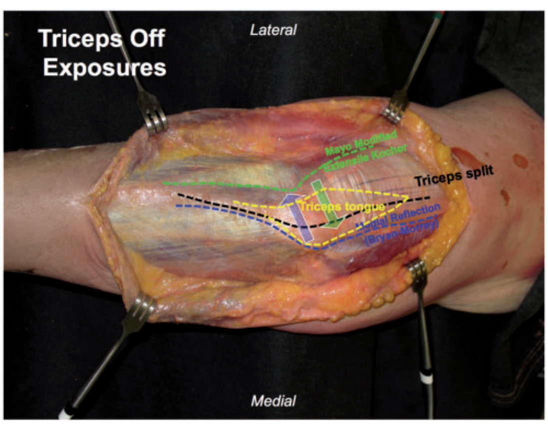

Figure 1. Triceps-off exposures.

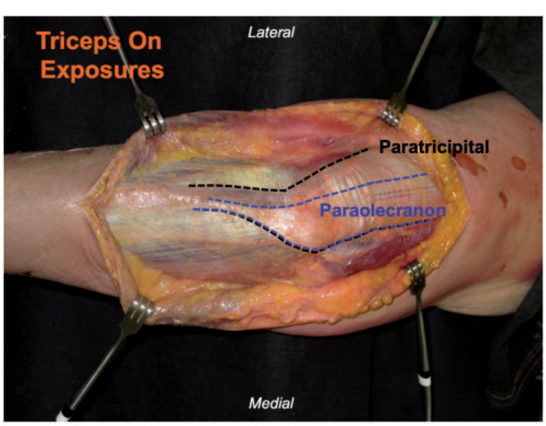

Figure 2. Triceps-on exposures.

Studies on rotator cuff have shown that tendon to bone healing after surgical repair rarely or never replicates the tendon–fibrocartilge–bone structure of primary tendon attachment sites.[2] For these reasons, exposures that do not violate the direct attachment of the triceps on the olecranon are very appealing. These include the bilaterotricipital approach, the paraolecranon approach and the triceps tongue approach.

The bilaterotricipital approach is not new in elbow surgery in general, or for elbow arthroplasty in particular. It was initially described for the management of supracondylar fractures in children.[3] When elbow arthroplasty was first described as a treatment alternative for distal humerus non-unions, the bilaterotricipital approach was recommended and performed:[4] the non-united distal humerus was exposed and removed subperiosteally on both sides of the triceps, creating a working space that allows prosthetic instrumentation and implantation. This has become the exposure of choice when elbow arthroplasty is performed for distal humerus fractures and non-unions.[5–7] However, the use of this exposure in the presence of a largely intact distal humerus (rheumatoid or post-traumatic arthritis) is much more demanding, and requires a complete circumferential capsulectomy with release of the humeral origin of both collateral ligaments and both the flexor and the extensor groups. Humeral exposure is adequate, although exposure of the ulna can be a problem. In patients with a very large, muscular triceps exposure can be particularly difficult.

The lateral paraolecranon approach has been recently described in an attempt to leave the triceps to olecranon attachment undisturbed but the muscular mass of the triceps is split.[8] The medial side of the exposure is identical to the bilaterotricipital approach, through the medial side of the triceps and with detachment of the common flexor group and medial collateral ligament off the humerus. Laterally, the triceps is split in line with the lateral aspect of the olecranon so that the medial triceps is left on the olecranon and the lateral triceps is mobilized laterally with the anconeus. This exposure provides an easier approach but does not leave the triceps completely undisturbed. The study by Struder et al.[8] demonstrated better strength in extension with the lateral paraolecranon approach compared to a triceps split approach.

The triceps tongue was also described a long time ago.[9] In the original description, a very large portion of the triceps was reflected as a tongue. When this approach is used for elbow arthroplasty, a much smaller tongue may be used. A major benefit of this exposure is the ability to minimize the extent of skin flaps to be raised. It also allows leaving the ulnar nerve *in situ*. In addition, with this exposure, it is possible to dislocate the elbow posteriorly, releasing only the distal attachments of the collateral ligaments and leaving the common flexor and extensor groups untouched. Unlinked implants will be more stable in these circumstances, provided that the tongue heals.

A definitive randomized control trial comparing all these exposures is lacking. Such a study would be difficult to complete because of the relatively low number of elbow arthroplasties being performed, as well as the wide range of indications. In our opinion, the bilaterotricipital approach is of choice for patients with substantial distal humerus bone loss (distal humerus fractures, distal humerus non-union, end-stage inflammatory arthritis with severe bone destruction). Otherwise, we favour a triceps tongue or a Bryan–Morrey approach for patients with a compromised soft-tissue envelope, a paraolecranon approach for patients with a wide triceps and a bilaterotricipital approach for patients with a relatively narrow triceps.

Handling The Ulnar Nerve

Persistent ulnar neuropathy is another complication of primary elbow arthoplasty that is probably underreported. Because of its anatomic location, the ulnar nerve may need to be mobilized to some extent to safely perform an elbow arthroplasty. Parallel to the controversy on ulnar nerve management for internal fixation of distal humerus fractures, the literature is not completely clear on the ideal management strategy for the ulnar nerve at the time of elbow arthroplasty.

Some studies have documented a 25% rate of temporary and 10% of permanent ulnar neuropathy with routine transposition,[10] whereas others have documented minor transient changes in a few patients.[11] Spinner et al.[12] carefully evaluated 10 rheumatoid elbows that underwent an elbow arthroplasty without transposition of the ulnar nerve.[12] Prior to surgery, four elbows had evidence of ulnar neuropathy. At the most recent follow-up, ulnar nerve symptoms improved in two of the four patients with pre-operative neuropathy, and two patients without pre-operative neuropathy developed it after surgery. In a more recent study by Dachs et al.,[13] on 78 elbow arthroplasties performed with *in situ* decompression and no transposition, the rate of ulnar neuropathy was 5%, and this became permanent in half of the patients. In the systematic review by Voloshin et al.,[1] 50 of the 64 studies included reported on ulnar nerve handling. Routine transposition was reported in 31% of the studies. The rate of substantial ulnar nerve complications was $2\% \pm 3.3\%$ with transposition and $3.2\% \pm 3.1\%$ with *in situ* decompression.

Elbow stiffness is known to represent a risk factor for ulnar neuropathy in patients undergoing contracture release, especially when flexion is severely limited.[14–16] Thus, ample decompression or transposition is probably justified in patients with severe stiffness undergoing elbow arthroplasty.[13] Similarly, patients with pre-operative ulnar neuropathy should be considered for ample decompression or transposition.

The ability to perform a simple limited decompression at the time of elbow arthroplasty is partly linked to the exposure selected. The bilaterotricipital and paraolecranon approaches typically require substantial translation of the forearm with respect to the humerus, which may endanger the integrity of the ulnar nerve unless transposed. Some studies have reported mobilizing the nerve with the medial muscular flap when performing a triceps-on approach and repositioning the nerve in its anatomic location at the end of the procedure.[13] However, we have found it difficult to avoid ulnar nerve transposition when performing a triceps-on approach. On the other hand, the triceps tongue approach appears to be ideal for limited ulnar nerve decompression.

Currently, I perform a subcutaneous nerve transposition in patients with pre-operative neuropathy, severe stiffness or when a triceps-on approach is selected. Simple decompression is performed less commonly in the setting of a triceps tongue or Bryan–Morrey approach when patients have a good arc of motion pre-operatively and no pre-operative evidence of ulnar neuropathy.

Implant Performance

Mechanical failure of the elbow implants (in the form of loosening, wear or osteolysis leading to fracture) appears to be the main limiting factor to offer elbow arthroplasty to younger, active patients with the same confidence as hip or knee arthroplasty. Traditionally, elbow arthroplasty has been reserved for patients over the age of 60 or 65 years. In addition, patients are often recommended to avoid use of the replaced side for lifting. However, it is important to realize that patients end up using their replaced elbow beyond their recommended restrictions. Barlow et al.[17] surveyed 113 patients after primary or revision elbow arthroplasty and reported that over 90% performed moderate-demand activity, with 40% performing high-demand activities.

Reported failure rates have varied widely depending on the implant used and the underlying diagnosis. The best long-term results reported to date have been with use of the Coonrad–Morrey design in patients with inflammatory arthritis (Figures 3 and 4).[11,18] We just completed a study on 461 elbow arthroplasties implanted in rheumatoid patients using this particular implant. At a median follow-up of 10 years (range 3 years to 30 years), component revision or removal had been performed in 11%, with survivorship rates free of revision for aseptic loosening of 88% at 20 years. However, the failure rate reported with this implant has been higher in patients with acute distal humerus fractures,[19] distal humerus non-union,[7] and particularly in post-traumatic arthritis.[20] Throckmorton et al.[20] reported on 85 Coonrad–Morrey elbow arthroplasties performed in patients with post-traumatic arthritis. The rate of failure was 19%, and the 15-year survival rate using revision or resection for any reason as an end-point was 70%.

Figure 3. Anteroposterior radiograph 20 years after a Coonrad–Morrey elbow arthroplasty was implanted in a patient with rheumatoid arthritis.

Figure 4. Lateral radiograph 20 years after a Coonrad–Morrey elbow arthroplasty was implanted in a patient with rheumatoid arthritis.

A number of features related to implant design are believed to be important for the mechanical performance of elbow arthroplasty (Table 1).[21] The main modes of mechanical failure are stem loosening, polyethylene wear and osteolysis, potentially leading to periprosthetic fracture (Figure 5).

Stem loosening

Rates of stem loosening have been relatively low with certain implants. On the humeral side, implantation of a component with an anterior flange is considered to be important.[22] The humeral flange captures the anterior cortex of the distal humerus with or without an interposed graft. When grafts are used, radiographic incorporation of the graft is often visualized, which is interpreted as loading of the flange–graft–cortex. The

Table 1. A few factors with substantial impact on elbow arthroplasty performance.

• Stem fixation
○ Surface treatment
○ Humeral flange
○ Impingement
○ Linking (?)
• Wear
○ Design of the articulation
○ Polyethylene quality
○ Lateral column load-sharing
○ Implant rotation
○ Soft-tissue balance
○ Linking (?)

Figure 5. Lateral radiograph shows catastrophic loosening of the ulnar component with severe osteolysis and a periprosthetic fracture.

anterior flange provides resistance against bending and rotational forces that might otherwise result in loosening.

We now know that surface treatment of the stems is particularly important. Cemented fixation continues to be standard at this point. A major difference between elbow prosthesis and hip femoral component stems is that cement fixation appears to require some kind of surface treatment to provide sufficient macrointerlock to prevent loosening. Even modern implants have shown an unexpectedly high aseptic loosening rate when manufactured with no coating; this is resolved by coating the stem surface. The type of coating is also important: precoating the ulnar component of the Coonrad–Morrey arthroplasty with polymethylmetacrylate led to high rates of loosening with catastrophic osteolysis.[23] Plasma spray coating seems to have solved the problem.

Impingement has also been reported to contribute to loosening in some circumstances.[24] With a linked implant, as the elbow is flexed, if there is impingement anteriorly (as a result of bone, cement or thickened soft-tissues), the ulnar component is pulled out through a pistoning mechanism. Every effort should be made to achieve full flexion without impingement by selecting the right implant, avoiding excessive deep insertion of the ulnar component, removing bone from the coronoid and anteriorly extruded cement if needed, and avoiding impingement on the radiocapitellar side of the joint as well.

Debate continues over the possible adverse effects of linking on stem loosening (linking and wear are discussed later). Other than the effect of linking on ulnar pistoning just described, the adverse effects of linking on stem fixation are theoretical, although they have been difficult to substantiate with data. A linked implant in theory will transmit more stress to the implant–cement–bone interface compared to an unlinked implant, provided that their constraint is similar (some unlinked implants are actually highly constrained). Increased stresses would translate into a higher risk of loosening. However, the few studies that have compared linked and unlinked implants have reported a higher revision rate with unlinked implants.[25] Of course, these studies are tainted by the mix of poor first-generation unlinked designs included. Newer unlinked implants will hopefully perform better than previously.

Polyethylene wear

Polyethylene wear is perceived as a major limiting factor for the widespread use of elbow arthroplasty in younger, more active patients. Polyethylene wear is difficult to analyze in studies published to date. Revision for isolated polyethylene wear has been uncommonly reported.[26] However, polyethylene wear is commonly found at the time of revision surgery when performed for other conditions.[20,27,28] A number of reasons may lead to underestimation of polyethylene wear. Radiographic evidence of wear is difficult to visualize unless radiographs are perfectly positioned or obtained under stress.[29] In addition, patients with minimally symptomatic wear may not be offered revision surgery. Finally, most patients do not require revision for wear until the second decade of life of their implant; short to mid-term follow-up studies will not capture this reoperation category.

Modern implants have incorporated a number of features to decrease polyethylene wear and hopefully function as high-performance prostheses. The geometry of the articulation of both the Latitude EV prosthesis (Wright–Tornier, Memphis, TN, USA) and the Nexel prosthesis (Zimmer Biomet, Warsaw, IN, USA) was designed to avoid edge-loading and distribute the loads through a wider surface area of polyethylene. The Latitude EV prosthesis was designed so that the humeral component can articulate with either the native or a replaced radial head; the aim is that sharing of loads through the lateral column of the elbow will decrease wear (Figure 6). It can also be used in an unlinked fashion, theoretically protecting against both loosening and wear. The Nexel prosthesis incorporates a humeral bearing aiming to protect the articulation when using the upper extremities to stand up from a chair or use a walker. It also incorporates vitamin E-treated polyethylene.

Figure 6. Modern elbow implants offer a high-performance articulation and the possibility of lateral column load sharing.

Figure 7. Anteroposterior radiograph of a patient with long-standing deformity of the elbow secondary to a childhood injury.

Figure 8. Lateral radiograph of a patient with long-standing deformity of the elbow secondary to a childhood injury.

Wear is also influenced by certain surgical factors, especially component rotation and soft-tissue imbalance. Malrotation of the humeral and/or ulnar component will lead to increased edge loading.[30] Malrotation of the humeral component is especially likely to occur in the absence of distal landmarks (distal humerus fracture or non-union), whereas ulnar component malrotation can easily occur when using a triceps-on approach. In a cadaveric study, Sabo et al.[31] showed that the flexion–extension axis is internally rotated by approximately 15° (12° in males and 16° in females) in reference to the posterior cortex of the humerus, and approximately 3° in reference to the transepicondylar axis. Thus, the humeral component should be implanted in approximately 3° of internal rotation in reference to the transepicondylar axis; in the absence of distal humerus, the component should be implanted in 15° of internal rotation in reference to the posterior cortex of the distal humeral shaft. Regarding ulnar component rotation, the proximal ulna has a flat subcutaneous surface that is almost perfectly perpendicular to the plane of the greater sigmoid notch.[32] Thus, the ulnar component should be implanted so that it is perpendicular to this flat dorsal spot.

Edge-loading of an articulation with perfectly rotated components can still happen in the presence of substantial soft-tissue imbalance. Arthritic elbows with a long-standing angular deformity are particularly at risk.[26] Cubitus varus deformities secondary to childhood injuries represent a classic example. The asymmetric contracture of the medial soft-tissues, and particularly the medial aspect of the triceps, will tend to angle the elbow arthroplasty in the same direction unless the contracted soft-tissues are released or rebalanced (Figures 7 and 8). Not uncommonly, in these

Table 2. Prevention of infection in elbow arthroplasty: specific considerations.

• Discontinuation of DMARDs
• Selective elbow aspiration
• Antibiotic-impregnated cement
• Intra-operative use of
○ Betadine solution
○ Vancomycin powder
○ Limb infusion with antibiotics
• Wound healing
○ Minimize raising cutaneous flaps
○ Immobilize elbow in extension
○ Selective use of incisional VAC systems

DMARDs, disease-modifying antirheumatic drugs; VAC, vacuum-assisted closure.

circumstances, the medial triceps needs to be rerouted so that the triceps line of pull is centralized over the ulna.

Deep Infection

Deep infection continues to be more common after elbow arthroplasty than in other anatomic locations. In addition, deep infection after elbow arthroplasty is particularly devastating, and the resultant cost is substantial as well. A few factors have been mentioned as contributory to the higher infection rate complicating elbow arthroplasty. These include the relative immune suppression of patients with inflammatory arthritis, the high frequency of previous surgery in patients requiring arthroplasty after trauma and the relatively fragile soft-tissue envelope of the elbow joint.[21,33]

Prevention of deep infection cannot be overemphasized. General prophylactic modalities utilized in arthroplasty surgery are supplemented with a few specific additional measures (Table 2). For patients with inflammatory arthritis on DMARDs, these medications should be withheld between 1 week and 6 weeks around the time of surgery depending on their pharmacokinetics.[18] We have a low threshold to consider a pre-operative aspiration of the elbow joint for culture in patients with a remote history of infection complicating trauma or previous open fractures.

Most surgeons consider the use of antibiotic-impregnated cement.[21,33] Additional modalities are being considered based on spine and hip and knee arthroplasty literature. Sprinkling vancomycin powder inside the surgical wound,[34] or the use of a diluted solution of povidone iodine (betadine),[35] at the time of closure may be employed. Anecdotally, some surgeons noted a decrease in infection rates using a Bier block (double pneumatic tourniquet and intravenous access) to perfuse the limb with antibiotics.

Wound healing represents a priority after elbow arthroplasty. Raising cutaneous flaps should be minimized whenever possible. Application of a compressive dressing and immobilization of the elbow in extension for the first few days after surgery helps decrease wound complications. In patients at risk for substantial swelling or haematoma, a postoperative incisional vacuum-assisted closure (VAC) sponge may be considered.[36]

As mentioned before, deep infection after elbow arthroplasty is disturbing. Removal of well fixed implants and cement from the elbow is challenging, especially on the ulnar side. The canals are extremely narrow and very easy to perforate, which increases the risk of uncontrolled fracture and, on the humeral side, may endanger the radial nerve.[37] This explains a growing interest in the design of successful cementless prostheses. When performing a primary arthroplasty, it is extremely important to use cement restrictors and to place them just distal to the tip of the stems. We also add methylene blue to polymethylmetacrylate to aid in cement visualization if removal becomes necessary. When infection does occur in patients with a prior elbow arthroplasty, not uncommonly, the extensor mechanism ends up being deficient.[38] A triceps-on approach should probably be favoured in patients with a very high risk of deep infection.

Arthroplasty By Diagnosis

Inflammatory arthritis

Currently, the classic rheumatoid patient with polyarticular disease and very limited activity has been replaced with much more active individuals that may only have their elbow joints severely involved. Key elements of elbow arthroplasty in inflammatory arthritis include temporary discontinuation of DMARDs, and the selection of the right approach based on patient's features. Patients with extremely compromised skin are probably better off with a triceps tongue or Bryan–Morrey approach to allow more limited flap raising and decrease the risk of blisters and wound complications. Otherwise, a triceps-on approach may be selected, especially in patients with involvement of the lower extremities who use assistive walking devices and need perfect extension strength. When the humeral architecture and collateral ligaments are well-preserved, modern unlinked prosthesis are attractive, although they do carry some risk of instability.

Distal humerus fracture

This has become one of the fastest growing indications for elbow arthroplasty, and is not uncommonly performed by surgeons who are less familiar with elbow replacement surgery.[5] Patient selection is extremely important, and arthroplasty should only be considered for fractures that are unfixable or occur in an elbow with previous end-stage joint destruction. The bilaterotricipital approach is of choice, and avoidance of wound complications is the number one priority. The traumatized soft-tissues and skin are particularly prone to poor healing when arthroplasty is performed. The results obtained are outstanding for the first 3 years to 5 years, although they deteriorate over time.[19]

Post-traumatic arthritis and distal humerus non-union

Elbow arthroplasty in patients with previous trauma is particularly challenging. Not uncommonly, these patients have previously undergone one or more surgical procedures. They may present with complicating factors (retained hardware, ulnar neuropathy, severe stiffness, gross malalignment, substantial bone loss). In addition, younger patients requiring elbow arthroplasty in these circumstances are most likely to abuse their elbow.[17]

As mentioned before, we have a low threshold to aspirate these elbows if infection is a possibility. The exposure needs to be tailored to each individual. Distal humerus non-unions are exposed through a bilaterotricipital approach. Post-traumatic elbows may be exposed through a Bryan–Morrey, triceps tongue, paraolecranon or bilaterotricipital approach after careful consideration of the pluses and minuses for each particular elbow. Surgical samples for cultures should always be obtained. The ulnar nerve may have previously been transposed and it may be located in a completely unpredictable location, prone to iatrogenic injury at the time of exposure. If the nerve cannot be palpated prior to surgery, consideration should be given to tracing it under ultrasound. When the ulnar nerve is still in the groove, not uncommonly, it needs to be transposed to prevent neuropathy in patients with severe stiffness or post-traumatic perineural scarring.

Care must be taken to implant the components in adequate rotation, which may be particularly challenging in patients with severe structural abnormalities. Also, the surgeon must be ready to rebalance the medial and lateral soft-tissues and reroute the triceps in patients with long-standing angular deformities. Finally, it is likely that the patients will benefit from use of high-performance implants and lateral column load sharing.

A Few Final Thoughts

Implant replacement of the elbow joint has the potential to improve pain, function and quality of life for many patients with articular destruction secondary to inflammatory arthropathy or as a consequence of trauma. By the same token, elbow arthoplasty is associated with a relatively high rate of complications and mechanical failure. Preventing infection remains the key.

Even though the reported rates of triceps insufficiency and ulnar neuropathy are not that high, elbow surgeons must perceive higher rates because most recent efforts have been devoted to the development and application of triceps-on exposures and revisiting the management of the ulnar nerve. It is probably best to master more than one exposure and to tailor the approach to the underlying diagnosis and other patient's characteristics.

Long-term implant performance will hopefully improve as we better define the relative indications of linked and unlinked constructs and improve our ability to avoid residual impingement, insert components in perfect rotation and depth, take advantage of load-sharing through the lateral column, and develop techniques for soft-tissue balancing. Newer high-performance implants are promising, although design flaws continue to occur even with the latest products released. It will be exciting to witness additional improvements over time that will continue to offer solutions to problems identified through high-quality research.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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