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Distal humerus nonunion: evaluation and management

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- Despite recent improvements in surgical implants and techniques, distal humerus nonunion does occur between 8% and 25% of the time.
- Careful identification and improvement of any modifiable risk factors such as smoking, metabolic disorders, immunosuppressant medications, poor nutritional status and infection is mandatory.
- A recent computed tomography scan is paramount to determine the nonunion pattern, assess residual bone stock, identify previously placed hardware, and determine whether there is evidence of osteoarthritis or malunion of the articular surface.
- Internal fixation is the treatment of choice in the majority of patients presenting with reasonable bone stock and preserved articular cartilage; total elbow arthroplasty is an appealing alternative for elbows with severe destruction of the articular cartilage or severe bone loss at the articular segment, especially in older, female patients. Internal fixation requires not only achieving a stable fixation, but also releasing associated elbow contractures and the liberal use of bone graft or substitutes.
- Although reported union rates after internal fixation of distal humerus nonunions are excellent (over 95%), the complication rate remains very high, and unsatisfactory results do occur.

Keywords: arthroplasty; diagnosis; distal humerus; elbow; infection; internal fixation; nonunion; treatment

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Introduction

Distal humerus fractures are relatively uncommon injuries, accounting for approximately 2% of all fractures.[1] The overall incidence in adults is 5.7 cases per 100,000 per year.[1–3] Similar to other extremity fractures, the fracture mechanism of the distal humerus has a bimodal distribution, with the first peak in young patients following high-energy trauma (which is often associated with motor vehicle accidents or sports-related injuries), and the second in osteoporotic elderly patients following low-energy trauma, which often results from a fall. The prevalence of distal humerus fractures in the elderly has been predicted to increase by up to three fold by 2030.[4]

Despite improvements in surgical implants, such as anatomic precontoured locking plates for open reduction and internal fixation (ORIF), and a better understanding of the surgical principles and objectives to consider in order to optimize internal fixation, nonunion after internal fixation of distal humerus fractures does occur between 8% and 25% of the time. Thus, compared to other humerus fracture locations – less than 4% for proximal and less than 2% for diaphyseal fractures,[5–6] nonunion after surgical management is more frequent in distal fractures.[2,7,8] Nonunion may also occur after nonoperative treatment of distal humerus fractures, occasionally recommended for selected individuals.

The objectives of this article are to review the evaluation of patients presenting to the orthopaedic surgeon with a distal humerus nonunion, to delineate the relative indications of internal fixation and elbow arthroplasty, to summarize outcomes reported in different studies published to date, and to provide a few technical pearls to facilitate management of this challenging complication.

Patient evaluation

History

Patients presenting with a distal humerus nonunion often complain of various degrees of pain as well as poor elbow function secondary to limited range of motion and instability. Severe bone loss may lead to a flail elbow. In addition, there may be an associated ulnar neuropathy.

Careful questioning should be directed to understanding the mechanism of injury for the index fracture (high-energy fractures and severe associated soft tissue injuries), all treatment attempts to date, and whether there are reasons to suspect a deep infection (prolonged drainage after surgery, treatment with antibiotics, prior debridement). It is also particularly important to identify any risk factors for nonunion or infection with the potential to be corrected prior to further surgical management. These include smoking, poor nutritional status, metabolic disorders, immunosuppressant medications, active inflammatory processes and poor quality of the surrounding soft tissues. The age and gender of the patient,[9,10] anticipated activities to be performed with the involved upper extremity, and overall perceived compliance are also important for the decision-making process. It is important to collect and review previous medical records, and in particular all prior operative reports.

Physical examination

Examination of the affected elbow typically starts with assessment of the soft tissue envelope to identify previous skin incisions, areas of skin compromise, or the presence of a draining sinus. When the soft tissue envelope is severely compromised, it may be necessary to consider tissue expansion procedures or flap coverage, which in many practices requires involving a plastic surgeon.[9] Range of motion may be difficult to assess, and not uncommonly motion occurs through the nonunion site as opposed to the joint itself. It is important to identify other limb disabilities;[9] shoulder stiffness, for example, carries the potential to increase mechanical stress through the elbow nonunion. The Mayo Elbow Performance Score (MEPS) and the Quick DASH score are very useful outcome tools to assess both the condition of the elbow and the overall function of the upper extremity.

The integrity of the extensor mechanism should be assessed as well. Finally, an accurate neurological exam is mandatory. Assess the ulnar, radial and median nerve function and when in doubt, get an electromyogram (EMG). Try to localize the ulnar nerve: is it still palpable in the gutter or under the skin? Was transposition of the ulnar nerve mentioned in prior surgical reports? Preoperative ultrasonographic mapping of the location of the ulnar nerve may be useful whenever the nerve cannot be clearly palpated or reports regarding a transposition are inconsistent.

Imaging studies

All sequential radiographs and prior computed tomography (CT) scans should be reviewed. Particular attention should be paid to the complexity of the initial injury and the quality of the initial fixation attempt. Nonunion complicating a well-performed internal fixation should raise concerns regarding infection, lack of compliance, malnutrition, and other comorbidities. However, poor quality of fixation is the most common cause of nonunion.[11,12]

Current good quality radiographs and a recent CT are paramount to determine the nonunion pattern, assess residual bone stock (Fig. 1 A–C), identify previously placed hardware (Fig. 2 A and B), and determine whether there is evidence of posttraumatic osteoarthritis or associated malunion of the articular surface.[11] As mentioned by Jupiter,[13] because the articular block is usually flexed, it may appear even smaller on anteroposterior radiographs. Based on careful review of imaging studies, the surgeon will try to determine the need and the feasibility of revision internal fixation, the need and style of bone graft, appropriate tools for hardware removal, and the ideal internal fixation construct. Occasionally, when the internal fixation appears stable, low-intensity pulsed ultrasound bone stimulation or bone grafting without revision of the fixation may be considered for delayed union and nonunion respectively.

Based on the imaging studies, one can classify the distal humerus nonunion according to the AO/OTA fracture classification. However, the initial fracture is usually partially healed (most often the intra-articular part), and therefore the Mitsunaga et al[14] classification is more suitable. This classification considers five types: supracondylar, T-condylar, lateral condylar, transcondylar and medial condylar.

Infection work-up

The value of preoperative testing for deep infection in all patients presenting with a distal humerus nonunion has not been investigated in detail. Abnormal blood cell count, sedimentation rate, or C-reactive protein raise the possibility of infection. Distant possible sources of infection also have to be ruled out (urinary tract, dental and others). Regarding the elbow, our preference is to send all patients for an ultrasound-guided aspiration of both the nonunion site and the joint space. Fluid for culture is not always obtained. Patients presenting on antibiotics are recommended to stop their antibiotic intake two to four weeks prior to the aspiration.

When the concern for infection is very high (extensive erythema, drainage), staged procedures should be considered, as mentioned below. Our preference is to also routinely send samples of tissue for pathology and cultures at the time of revision surgery for internal fixation or arthroplasty. Currently, we send one sample to be processed for frozen sections read intraoperatively for the presence of acute inflammation, three samples of tissue for routine cultures, one additional sample for DNA/RNA bacterial amplification, and one sample for sonication of implants and culture of the sonicate fluid. Each tissue sample should be obtained with a separate knife blade and a separate instrument.

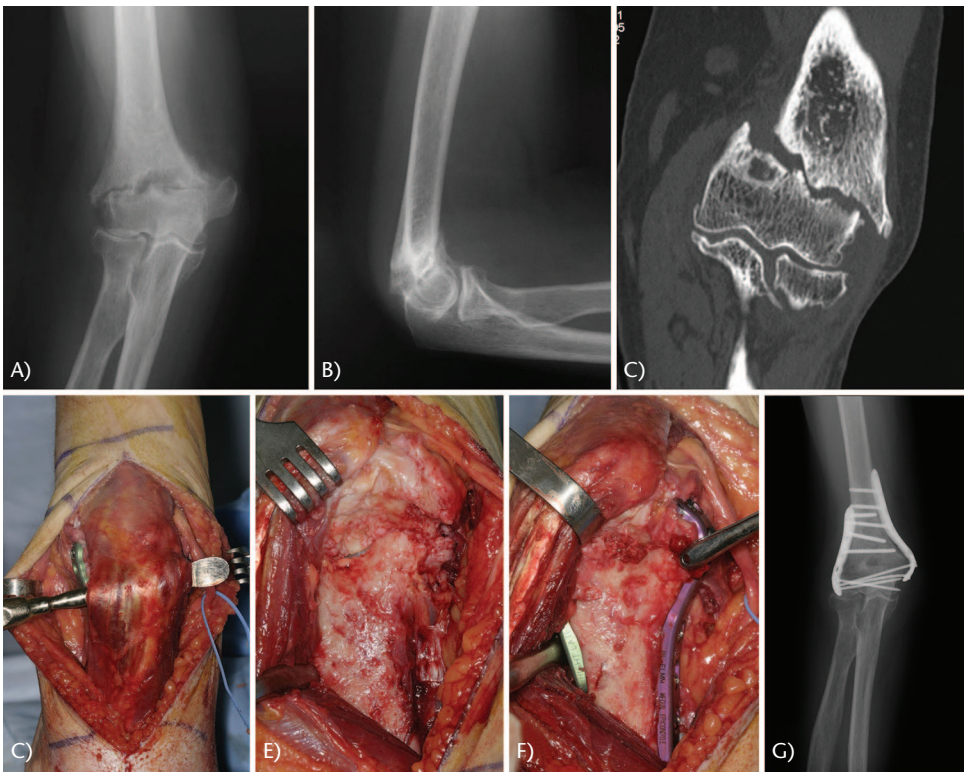

Fig. 1 (A and B) Nonunion after conservative treatment of a supracondylar fracture. (C) Bone stock evaluation with computed tomography. (D) Triceps on approach. (E) Nonunion before fibrous tissue debridement. (F) After fibrous debridement, reduction and fixation with two parallel plates. (G) Postoperative radiographs (three months after surgery).

Management

Decision making

Three basic options are considered for the management of patients presenting with an established distal humerus nonunion: continued nonoperative management, internal fixation or total elbow arthroplasty. The decision-making process to recommend the ideal treatment for each patient can be complicated.

Conservative management is a very reasonable option for low-demand individuals able to cope with their nonunion, especially when the risk of medical complications, persistent nonunion or infection are particularly high. Some patients may benefit from fabrication of a custom-made orthosis to provide some stability to the elbow. However, most patients that we see in our practice do not find conservative management acceptable.

When further surgery is considered, the pluses and minuses of internal fixation and arthroplasty need to be carefully balanced. *Arthroplasty* is appealing, since it is technically easier and requires much less postoperative rehabilitation. However, the mechanical failure rate at mid to long term is unacceptable in younger males, and complications, when they happen, can be catastrophic. We favour *internal fixation* for the majority of patients presenting with reasonable bone stock and well-preserved articular cartilage. Total elbow arthroplasty is selected for elbows with severe destruction of the articular cartilage or severe bone loss at the articular segment, especially in older, female patients.

For patients with an unreconstructible joint who are not eligible for arthroplasty due to persistent deep infection or compliance issues, *arthrodesis* is a salvage procedure which provides stability and pain control.[9] However, fused elbows are extremely limiting functionally and arthrodesis in young active patients therefore remains controversial. In addition, obtaining a solid fusion may be challenging in the presence of distal humerus bone loss or infection. *Whole allograft replacement* is not recommended because of poor functional results and high complications rates. Complications include infection, persistent instability and graft resorption.[15] Dean reported only a 43% rate of satisfaction, with complications in 70% and hardware removal in 20% of the elbows.[16]

Internal fixation

The goals of internal fixation for distal humerus nonunion are more complex than the goals of internal fixation for acute fracture. In addition to (1) restoring the geometry of the articular segments, (2) achieving stable internal fixation, and (3) protecting the ulnar nerve; distal humerus

Fig. 2 (A and B) Nonunion after failed open reduction and internal fixation. (C) Nonunion after hardware removal and before fibrous tissue debridement. (D) After fibrous debridement, reduction and fixation with two parallel plates. (E) Postoperative radiographs.

nonunions may also require (4) releasing the contracted elbow joint, (5) adding bone graft or substitutes, (6) dealing with retained hardware, and occasionally (7) restoring the integrity of the elbow extensor mechanism (olecranon osteotomy nonunion, triceps rupture).

Surgical technique

Patients with prior surgery usually present with a healed posterior midline skin incisions that may be used for exposure. An effort should be made to incorporate prior skin incisions whenever possible. Identification and protection of the ulnar nerve should be performed next. Complete dissection of the nerve is considered when the nerve cannot be protected otherwise, as well as for patients with severe preoperative ulnar neuropathy. There is no evidence in the literature that favours transposition at the time of internal fixation for acute fractures,[8,17] and the same is probably true for distal humerus nonunions. Identification and protection of the radial nerve is also important in elbows with severe distortion of the anatomy and when a long lateral plate is planned to be used.

If the extensor mechanism already presents an area of discontinuity (triceps rupture, olecranon nonunion), deep exposure is achieved through the area of discontinuity. For elbows with an intact extensor mechanism, our preferred deep exposure for internal fixation of a distal humerus nonunion is an olecranon osteotomy. The exceptions would be transcondylar nonunions with a completely normal distal articular surface and the rare circumstances when the decision to proceed with internal fixation or elbow arthroplasty

will be made intraoperatively; in these circumstances we favour Alonso-Llames' bilaterotricipital approach (Fig. 1D)[18] or King's lateral para-olecranon approach.[19]

Regardless of the exposure selected, careful restoration of the continuity of the extensor mechanism is extremely important to achieve at the end of the procedure. As such, when incomplete healing of the extensor mechanism (after previous triceps split or detachment for example) is discovered during surgery, it is preferable to use the same triceps approach. As mentioned by Jupiter,[13] one must be careful when elevating the olecranon from the distal humerus at the time of olecranon osteotomy, because the cartilage surfaces of the olecranon and distal humerus might be really adherent and articular damage may be caused by stripping off the subchondral bone if this is performed too aggressively.

Once the nonunion is exposed and retained hardware has been removed, any elbow joint contractures should be released. Failure to address stiffness in distal humerus nonunion increases the chances of a poor outcome: postoperative motion exercises will lead to excessive stress at the supracondylar nonunion region, which might contribute to persistent nonunion, and range of motion will be limited in those elbows where the nonunion heals but the contracture was not addressed.

For very complex distal humerus nonunions, it may be better to plan for a staged procedure to obtain union in the first surgery and motion in a second surgery once union is confirmed. However, in the majority of elbows it makes sense to achieve union and motion in the same surgery. The posterior capsule is properly released when the extensor mechanism is mobilized in the majority of elbows. On the contrary, the anterior capsule needs to be formally resected, which can typically be performed through the nonunion site. Care must be taken to avoid inadvertent damage to the median and posterior interosseous nerve at the time of anterior capsulectomy. The collateral ligament origins and the overlying flexor and extensor masses need to be preserved to decrease the risk of instability or avascular necrosis. Rarely, for relatively higher nonunions, it is best to first fix the nonunion and then perform an anterior capsulectomy through the anterior window of the lateral column procedure.[9]

Meticulous attention is then paid to performing adequate bone preparation by removing all interposed fibrous tissue as well as areas of bony sclerosis (Fig. 1E and Fig. 2C). Samples for pathology and cultures can be sent at this point as mentioned above. Reduction of the articular segments should be anatomic whenever possible; on the contrary, reduction at the supracondylar level is rarely anatomic but rather consists of obtaining adequate contact while maintaining reasonable alignment, avoiding excessive flexion/extension or varus/valgus deformity. Rotation is best evaluated by checking the forearm position while rotating the shoulder. Temporary fixation is achieved with Kirschner wires, and fluoroscopy can be used to assess the quality of reduction. If good contact between proximal and distal fragments cannot be achieved, metaphyseal shortening should be considered.[2] Shortening up to 2 cm (in extreme cases 3 cm) is well tolerated and does not considerably weaken the triceps. When shortening is performed, the distal fragment must be translated anteriorly to create room for both the coronoid and radial head during flexion. To maintain extension, bone has to be excavated at the posterior aspect of the humerus to recreate a new olecranon fossa. If the bone defect is too big to obtain compression with shortening, structural bone autograft may be required, typically from the iliac crest.

Stable fixation is best achieved by two parallel plates with long interdigitating screws (Fig. 1 F and G, Fig. 2 D and E). Some authors prefer the 90°–90° configuration.[9] This position is sometimes useful when a coronal plane fracture is present. Compression of nonunited fragments may be obtained with a large reduction clamp first, and maintained with screws applied in compression mode. Further compression may be achieved by undercontouring of the plates. Finally, in selected cases, a third plate, for example, a one-third tubular plate in buttress configuration, may be added to increase construct stability.[11] Cancellous bone graft (from the iliac crest or olecranon metaphysis) or bone graft substitutes (or both) may be applied at the fracture lines before compression. When iliac crest bone grafting is considered, we will often apply two corticocancellous bony plates – one on each column – fixed across the nonunion site with screws. Before closure, fluoroscopic images should be taken to confirm reduction and alignment, and intraoperative range of motion should be assessed and recorded.

Postoperative management

After surgery, the elbow is immobilized in extension with an anterior plaster splint and is kept elevated for one or two days. Use of sprinkled vancomycin powder prior to closure and application of a vacuum-assisted closure (VAC) sponge and system may be considered. Immobilization in extension may be extended for a longer period of time if there is delayed healing of the wound or if excessive swelling persists. As with many other elbow surgeries, early motion exercises are key, and thus active range of motion exercises begin within a day or two of surgery. However, bone healing is prioritized, and the rehabilitation regimen must be customized to the stability of the fixation, bone quality and soft tissues. Physical therapy, continuous passive motion, and splints may be used based on the surgeon's preferences.

Table 1. Studies reporting the results of nonunion treated with ORIF

First author	Year	Cohort (*n*)	Age Mean (range)	Follow-up months	High E	ROM pre	ROM po	Complication rate %	Satisfaction %
Ackerman[10]	1988	17	40 (20–70)	45.8	11	–	76.0	–	–
Sanders[29]	1990	5	56 (22–81)	40.0	–	–	86.0	11	35
McKee[30]	1994	5	44 (25–62)	26.4	3	57.0	106.0	40	40
Simonis[31]	2003	14	55 (20–81)	10.0	8	49.0	84.0	20	60
Helfet[12]	2003	52	47 (16–88)	33.0	19	71.0	94.0	36	69
Ali[32]	2005	16	47 (19–82)	38.5	8	–	96.0	–	–
Allende[33]	2009	24	45 (19–73)	46.0	13	45.0	98.0	–	81
Niu[20]	2012	22	34 (17–60)	39.3	11	74.5	111.4	42	–
Ouyang[34]	2013	11	41 (19–60)	29.1	8	41.3	114.1	14	77

Note. ROM, range of motion.

Reported outcomes

Table 1 provides an overview of reported outcomes after ORIF for distal humerus nonunion from nine separate studies. These studies encompass a total of 166 patients with a mean age of 44.8 ± 15.2 years (range, 16 to 88 years) at the time of surgery. Sixty-eight of the patients were female (41%). The mechanism of injury involved high-energy trauma for 81 patients (48.8% of the cases). The mean time between injury and surgery for nonunion was 17.1 ± 24.8 months (range, 1 to 192 months). The majority of patients (n = 128) had a limited preoperative flexion–extension arc (mean 61.22 ± 16.9 degrees, range 0 to 105 degrees). The mean follow-up was 35.4 ± 27.6 months (range 3 to 198 months).

With regard to the surgical technique utilized, a posterior approach was used in almost all of the cases, and half of the nonunions were approached through an olecranon osteotomy, depending on the fracture type. The ulnar nerve was always identified except in 20/22 cases in the study by Niu et al.[20] The ulnar nerve was anteriorly transposed in 79/149 cases (53%). Autograft was used in the majority of the cases. The graft of choice was the iliac crest, with the tip of the olecranon as a common alternative. Eighty-eight patients underwent arthrolysis with true capsulectomy at the time of internal fixation of the nonunion.

Fracture union was achieved in 96.9% of the cases (86–100%) in 5.5 ± 3.4 months (range, 2.4 to 6.0 months). At most recent follow-up, the mean flexion–extension arc was 95.69 ± 20.13 degrees (range, 17 to 148 degrees). There were no differences in final range of motion between elbows subjected to arthrolysis (95.41 ± 12.4; n = 82) and those without (95.15 ± 23.8; n = 60, p = 0.93), although this may be partly related to a selection bias of not performing arthrolysis in nonunions with less severe joint contracture. The most recent mean MEPS was 85.6 ± 12.7 (range 55 to 100; n = 54 patients) and outcome was satisfactory in 73.9% of cases (n = 73 patients, but varying among the six studies between 35% and 82%).

Complications reported in these seven studies included infection, ulnar nerve neuropathy (nine elbows), radial nerve palsy (five elbows), and need for additional surgery (for nerve release, grafting, capsular release, or hardware removal). The complication rate (98 patients in these seven studies), including minor complications, was 23% (range, 11% to 42% depending on the study).

Total elbow arthroplasty (TEA)

As mentioned previously, elbow arthroplasty is considered in two circumstances: (1) severe associated destruction of the distal humerus articular cartilage and (2) lack of sufficient bone stock on the distal segment to allow stable internal fixation (Fig. 3 A–C). Elbow arthroplasty should be considered with caution in younger patients, especially males, as well as those with a history of deep infection.[21,22] Distal humerus hemiarthroplasty represents an attractive option for younger individuals with an unreconstructible distal humerus, but the reported experience in nonunions is very limited.

Surgical technique

Elbow arthroplasty for distal humerus nonunion is often performed through a ‘triceps-on’ approach (either bilaterotricipital or lateral para-olecranon). The nonunited distal humerus is resected, creating ample working space for canal preparation and component implantation. Some advocate preservation and internal fixation of the medial and lateral columns with their respective

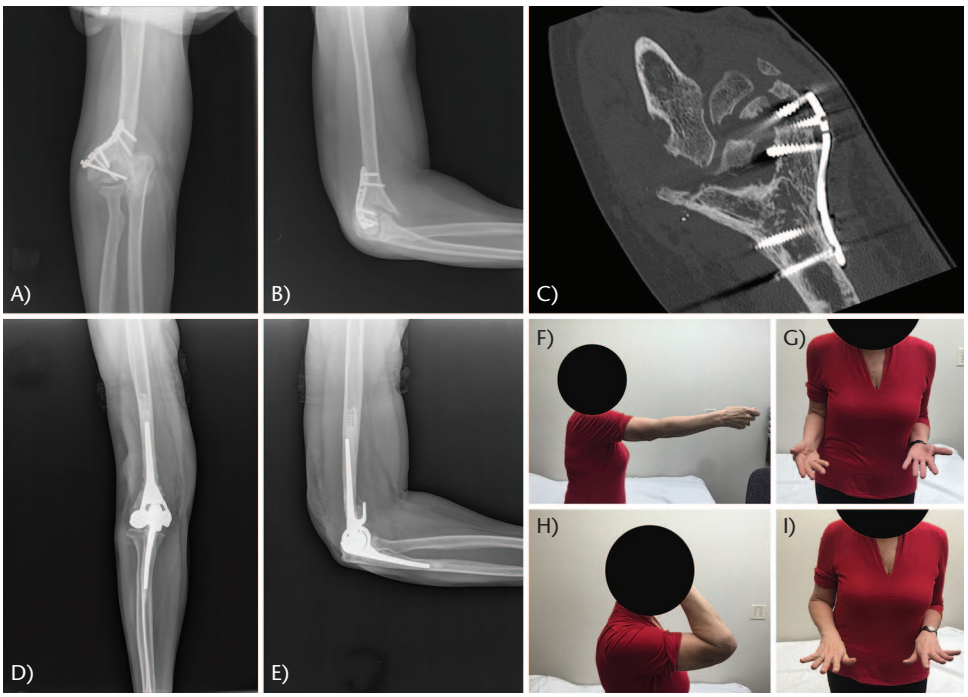

Fig. 3 (A–C) Nonunion after failed open reduction and internal fixation with poor bone stock. (D) AP radiograph showing the total elbow arthroplasty (condyles resected). (E) Lateral radiograph showing the total elbow arthroplasty with healed anterior bone graft. (F–I) Clinical photographs of the function at three months.

ligamentous and muscular origins when arthroplasty needs to be considered for younger, active patients. Most of the times, in elderly patients, fractured condyles are excised (Fig. 3 D and E).

Meticulous attention must be paid to cementing the components in the correct depth and rotation. Malrotation of the ulnar component is known to occur more commonly with 'triceps-on' exposures. Malrotation of the humeral component may occur due to lost landmarks as a consequence of the distal humerus nonunion. Rotation of the ulnar component may be judged in reference to the radial head or dorsal aspect of the olecranon. Rotation of the humeral component may be judged in reference to the anterior cortex of the distal humerus, posterior cortex of the distal humerus (slight internal rotation), or the location of the intermuscular septi.

Most surgeons use cemented fixation of both components, especially considering that elbow arthroplasty is selectively performed in elderly patients with osteopenia. We prefer to add antibiotic powder and methylene blue to polymethylmethacrylate. The depth of insertion of the humeral component can be adapted to each elbow: deeper insertion of the humeral component will facilitate elbow extension, whereas cementing the humeral component proud can compensate for distal humerus bone loss without the need for allograft support or custom humeral components in the vast majority of elbows. Even if the fractured columns are repaired, most surgeons favour linking the implants. Depending on the implant selected, articulation between the humeral component of the arthroplasty and the native radial head, which is preserved in the majority of elbows, may provide the opportunity for lateral column load sharing to hopefully decrease polyethylene wear over time.

Every effort should be made at the time of closure to seal the joint by obtaining a good repair of the common flexor and common extensor origins to the medial and lateral aspects of the triceps. Some surgeons advocate routine application of vancomycin powder to hopefully decrease the overall infection rate. After meticulous closure of the skin, consideration may also be given to application of an incisional vacuum-assisted closure (VAC) sponge and device, again in an effort to prevent infection. The elbow is then immobilized in extension with an anterior plaster splint for 14 days, since wound healing takes precedence over motion.

Postoperative management

Two weeks after surgery, staples or sutures are removed and, provided the skin incision is healed, active range of motion exercises are initiated. Since the implants are cemented and the triceps attachment to the olecranon is preserved, no protection of the elbow is required. Patients are educated about the risk of polyethylene wear with

Table 2. Studies reporting the results of nonunion treated with total elbow arthroplasty

First author	Year	Cohort (*n*)	Age Mean (range)	Follow-up months	High E	ROM pre	ROM po	Complication %	Satisfaction %
Figgie[35]	1989	14	65 (31–77)	60.0	–	–	100	36	57
Cil[21]	2008	92	65 (32–84)	72.0	–	–	113	43	78
LaPorte[36]	2008	12	61 (36–81)	63.0	–	–	117	75	92
Pogliacomi[37]	2015	20	72 (54–84)	65.0	–	–	–	30	90
*Morrey[23]	1995	39*	67 (40–89)	50.4	–	–	–	18	86

Note. ROM, range of motion.
*39 patients also included in Cil[21]

heavy use of the elbow, and they are requested to return for a clinical and radiographic evaluation at regular intervals. As mentioned before, our perception is that recovery after elbow arthroplasty is easier and faster than after internal fixation (Fig. 3 F–I).

Reported outcomes

A summary of studies reporting on the outcome of TEA for distal humerus nonunion is depicted in Table 2. Two studies[21,23] reported results for the same series of 39 patients, leaving five studies (138 patients) for analysis. The mean age was 65.6 ± 11.7 years (range, 31 to 84 years), and 103 patients were female (74%). The mechanism of injury for the index fracture was not clearly reported in the majority of the studies. Mean time between fracture and surgery was 41 ± 125 months (range, 4 to 672 months). The mean follow-up period was 69 ± 48 months (range, 6 to 240 months). A triceps sparing ('triceps-on') approach was used for 100 patients (72.5% of cases). Regarding functional outcomes, the mean postoperative flexion–extension arc was 111.9 ± 19.2 degrees (range, 65 to 150 degrees) and the mean MEPS was 81.9 ± 15.8 (range, 15 to 100). Results were considered satisfactory in 109 elbows (79%). However, the overall complication rate was high (60 elbows, 43.19%) and the overall reoperation rate was high as well (39 elbows).

Special considerations

Occasionally, distal humerus nonunion presents with substantial associated formation of *heterotopic ossification*. This finding should raise the concern for an associated deep infection. Provided infection is excluded, heterotopic ossification mases can be removed at the time of surgery and used as bone grafts if needed when internal fixation is the treatment strategy selected. There are no data from which to judge the efficacy and safety of heterotopic ossification prophylaxis at the time of internal fixation of a distal humerus nonunion; however, extrapolating from literature on acute fractures, we do not recommend prophylaxis in order to maximize the chances of healing of the nonunion as well as of the olecranon osteotomy when performed.

Nonunions complicating articular shear fractures of the distal humerus may be treated with arthroplasty, internal fixation and, rarely, partial resection. When internal fixation is selected, nonunions involving only the capitellum may be approached through the anterior window of the lateral column procedure,[24] whereas more complex nonunions typically require exposure through an osteotomy of the lateral epicondyle or the olecranon. Headless compression screws[25] are valuable, but conventional plates and screws may be needed too.

Recalcitrant nonunions with substantial segmental bone loss at the diaphysis may require special reconstructive techniques, including augmentation using a vascularized fibular autograft.[26] Mullett et al[27] have also described the use of a forearm vascularized graft. Bone transportation techniques using an Ilizarov may be considered as well.

Infected distal humerus nonunions may represent a formidable challenge. In the absence of drainage, conservative management may be the best option. When reconstruction is considered, a two-stage approach is favoured by most. In the first stage, hardware removal and debridement with local delivery of antibiotics is followed with a six-week course of intravenous antibiotics before the second stage can be considered. When the plan is to proceed with internal fixation in the second stage, local antibiotic delivery may be provided with antibiotic-loaded beads made of cement or certain bone graft substitutes; the elbow may be stabilized with a brace and rarely requires temporary use of an external fixator with pins very far away from the planed reconstruction.[13,28] When the plan is to proceed with arthroplasty at the time of the second stage, we favour the use of an 'internal fixator' in between stages, placing bars or pins in the canals of the humerus and ulna, linked with a pin-to-bar, pin-to-pin, or bar-to-bar connector, and stabilizing the whole construct with antibiotic-loaded cement. The value of advanced imaging studies or a repeat aspiration just prior to the second-stage surgery is unknown, but it can definitely be considered, in addition to surgical biopsies for culture, in selected cases when the suspicion of persistent infection after the first stage is really high.

In the case of *unexpected positive cultures at the time of surgery*, a six-week course of intravenous antibiotics should be given, followed by oral antibiotics until union with or without implant removal. Chronic suppressive oral antibiotic treatment is recommended for life in patients with positive unexpected cultures at the time of elbow arthroplasty.

Summary

Distal humerus nonunion is a relatively rare condition due to the relatively low incidence of distal humerus fractures. Through careful evaluation of the patient's history, physical examination and imaging studies, one should be able to (1) understand why the fracture did not heal and (2) identify any modifiable risk factors that can be improved before proceeding with surgery.

Although conservative management and salvage procedures are considered selectively, the majority of distal humerus nonunions are managed with internal fixation, with some requiring elbow arthroplasty. Internal fixation often requires not only achieving a stable fixation, but also releasing associated elbow contractures and the liberal use of bone graft or substitutes. Elbow arthroplasty is reserved for elderly patients with the ability to comply with postoperative restrictions; provided no complications occur, elbow arthroplasty provides a satisfactory solution. Although reported union rates after internal fixation of distal humerus nonunions are very high (over 95%) reoperation and complication rates remain high as well, and unsatisfactory results do occur. The same holds true for elbow arthroplasty. As such, there is room for improvement in the surgical management of distal humerus fractures.

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