Distal humeral fractures in the adult

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Abstract

The management of distal humeral fractures in adults presents a unique set of challenges. Almost always they necessitate operative management, which might include complex intra-articular fracture fixation of very comminuted free fragments in an already complex joint, or, increasingly, novel arthroplasty techniques. Clinicians managing these injuries must be confident that they possess the requisite skills set, and, in the UK at least, this in itself is under scrutiny. This summary aims to acquaint the reader with the basic knowledge sufficient to begin to understand the approaches to managing these injuries, and some of the decision-making difficulties that are encountered.

Keywords adult; approaches; distal humerus; elbow arthroplasty; fixation; fracture

Introduction

Whilst not common injuries, fractures of the distal humerus present particular challenges to the treating surgeon. Intra-articular fractures are often difficult to reconstruct, and patients frequently present with co-morbidities, thus trends recently have been towards arthroplasty. However, as we shall see, there are multiple options, and the challenge is often in decision-making with the patient rather than the surgery itself.

We shall consider the basic sciences of the joint, and surgical approaches, before the considerations of patient and fracture assessment and the management options in detail.

Anatomy

The elbow consists of three bones forming three separate joints. The humerus, ulna and radius form the ulno-humeral, radio-capitellar and proximal radio-ulnar joint. The trochlea of the distal humerus and the semilunar notch of the proximal ulna form a sloppy hinge. An overall arc of motion greater than 100° allows for most day-to-day functions and should be the minimum goal of treatment efforts.

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A sound appreciation of the anatomy of the distal humeral and elbow anatomy is essential when attempting to reconstruct injuries. The radiocapitellar articulation is a pivot joint. In conjunction with the two radio-ulnar joints it allows forearm rotation. It also provides stability to resist valgus loading.

The distal humerus itself is made up of the radial and ulnar columns and the trochlea as the intermediate fragment.

The orientation of the trochlea in relation to the long axis of the humerus results in a carrying angle of 4–8° valgus. In relation to the axis formed by the medial and lateral epicondyles the trochlea and thereby the flexion–extension axis is rotated about 5° internally.[1] This is relevant in fixation and arthroplasty.

The capitellum is angled 30–40° anteriorly in relation to the humeral shaft, which should be considered in reconstruction.

The ulnar nerve usually runs posterior to the medial epicondyle and always posterior to the intermuscular septum which originates from the medial supracondylar ridge. In the elbow it usually can be found posterior to the medial epicondyle between the two heads of flexor carpi ulnaris. The nerve is usually visualized and protected in posterior approaches.

On the lateral side the radial nerve runs between brachioradialis and brachialis, anterior to the intermuscular septum, which arises from the well palpable lateral supracondylar ridge. The nerve needs to be identified and protected if surgical dissection extends proximal to the distal quarter of the humerus.

In the proximal aspect of the triceps aponeurosis the border formed by triceps muscle and aponeurosis slopes from proximal medial to distal lateral leading to a curved course of the tendon laterally. On the medial side the tendon is straight. The sloped proximal aspect is a good approximation of the course of the radial nerve and can be used to locate the nerve during surgical exposure.

The triceps tendon inserts on a rather narrow area on the olecranon process, its aponeurosis spreads out further distally and blends with the forearm fascia. This lateral triceps expansion can be distinguished from the tendon proper and utilised for surgical exposure. The average tendon thickness is about 12 mm in the proximal aspect and decreases to 6 mm at the insertion.[2]

Clinical and radiological assessment

The encounter with any patient with an injury should begin with overall assessment of the patient– is this an isolated injury, and is there any concern regarding any other possible injuries such as to the axial skeleton or head? When distal humeral fractures occur as part of a multisystem trauma clearly their management will be in the context of this. Finally, is there any concern regarding any acute events leading to the patient's injury, such as falls due to syncope in the elderly?

In the assessment of the isolated injury, a history of its mechanism and timing is integral. Prior to treatment or surgery or underlying conditions of the elbow may be relevant. Management may hinge on the timing since the injury – late presentation is not unusual particularly if already seen in another centre.

An often very important element of the history, as we will see, is the functional demands and status of the patient. A very elderly patient with multiple co-morbidities may demand a very different approach from a young, working individual. We will consider this further.

Examination of the entire patient may be relevant as noted above. Assessment in general however is no different from any other injury assessment – the condition of the skin and soft tissues, particularly excluding open injury, the alignment of the limb, and, possibly most importantly, a thorough assessment of the neurological status and vascular supply of the distal extremity. This should be documented carefully.

Adequate imaging is vital for correct decision-making. Plain X-rays may be taken before and/or after application of a temporary splint. Frequently however it is difficult to ascertain the exact injury pattern from simple X-rays. If there is any concern regarding the injury, particularly if it is unclear whether the injury involves the articular surface, a CT scan is mandated. However, in complex injury patterns, a scan of a markedly displaced fracture may be still difficult to interpret. Intraoperative films taken with traction in the operating room may provide very valuable additional information for final planning.

In the context of distal humeral fractures acutely, MRI scanning has little additional value.

Classification of distal humerus fractures

As is often the case in the management of skeletal trauma, there are a multitude of classifications available. However, in principle we need to focus on those that are reproducible, encompass the spectrum of injuries seen, and aid in our decision-making.

Two classification systems are in predominant use. The Jupiter and Mehne[3] (Figure 1) classification is in common use. Three categories are described: intra-articular, extra-articular but intra-capsular fractures, and extra-capsular fractures.

The intra-articular fractures are subdivided into single and bi-column injuries. Single column intra-articular fractures include the coronal shear (trochlear and capitellar fractures). This classification has particular utility regarding surgical planning, and in approach especially. The description includes the predominant fracture line and therefore dictates the primary goal of fixation. However, it is perhaps over-simplistic regarding more complex intra-articular fractures– the 'H' pattern is the only description for comminution at the joint line, all other fracture patterns being a simple intra-articular split.

The AO Foundation/Association of the Study of Internal Fixation (AO/ASIF) classification[4] is also reproducible, comprehensive, and provides characterization of distal humeral fractures much like the Jupiter and Mehne classification. It is readily available through the online AO surgery resource (www2.aofoundation.org/wps/portal/surgery). Figure 2 shows the broad A (extra-articular), B (partial articular) and C (complete articular) patterns.

In common with the other proximal and distal parts of long bones, the classification is divided into extra-articular, partial articular, and intra-articular, with subdivisions thereof. The partial articular section includes coronal shear injuries: capitellar and trochlear fractures.

Ultimately, as can be seen from the online reference, the precise characterization of the injury pattern will, at least in part, dictate the management, including the approach to any fixation contemplated. The AO classification provides greater descriptions for the complete (bi-column) articular fractures – multiple sub-groups are available depending on the level of the fracture and the degree of comminution at metaphyseal and joint line elements.

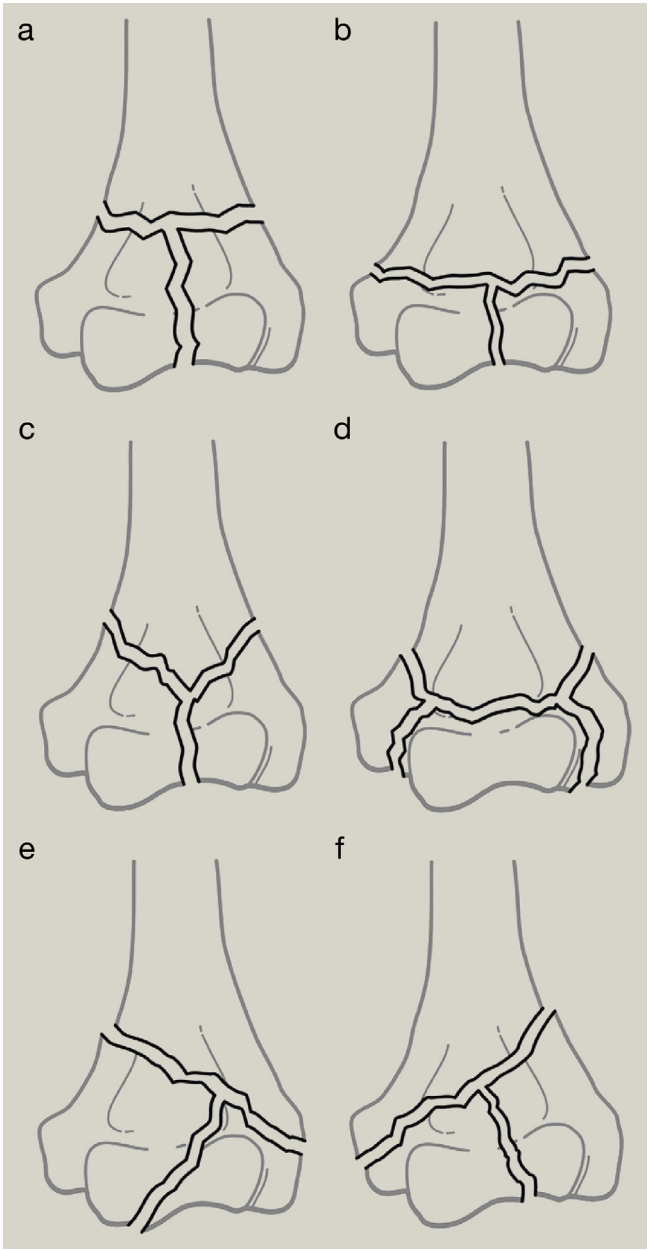

Figure 1 Intra-articular injuries: high (a) and low (b) T-shaped injuries, Y-shaped (c), H-shaped (d), and medial (e) and lateral (f) lambda-pattern injuries. Reproduced from reference 17 with permission from Elsevier.

Conservative management

The majority of distal humerus fractures are managed operatively due to their frequent extension into the joint, the difficulties in controlling short distal segments non-operatively, and the propensity for the elbow to stiffen if immobilized. Those which are intra-articular will generally be managed by the AO principles of anatomical reduction, absolute stability, and early range of movement. In no joint is this more pertinent than the

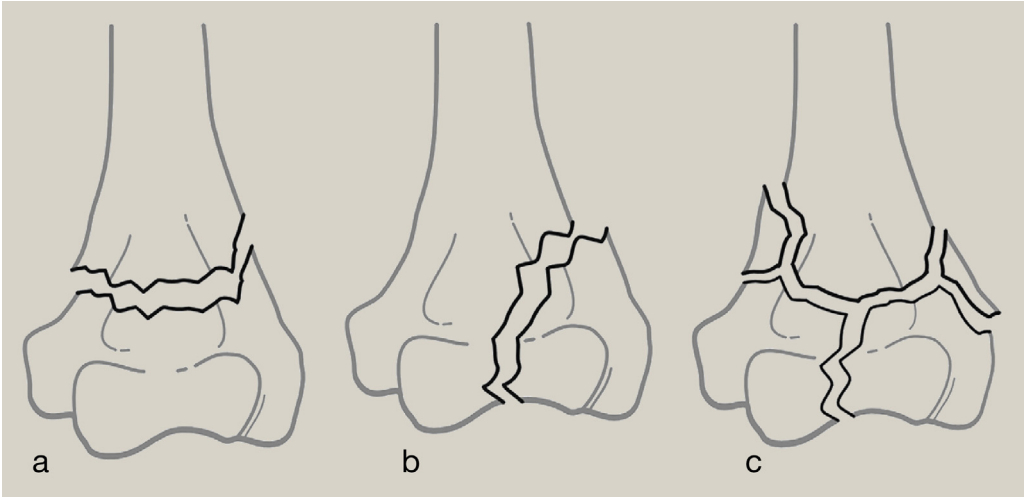

Figure 2 AO Foundation classification of distal humeral fractures: (a) extra-articular, (b) partial articular and (c) complete articular patterns. Reproduced from reference[17] with permission from Elsevier.

elbow – the tendency of the joint to stiffen after injury and/or surgery is well-documented. Whatever our method of treatment therefore, early range of movement is the key.

Undisplaced fractures, and those which are extra-articular, are tempting to manage conservatively. However, immobilization for a short period may result in joint stiffness rather than sufficiently stiff callus formation, and commencement of movement may preferentially cause stress the fracture site due to stiffness, resulting in non-union. On the other hand, prolonged immobilization may result in bony union but also in joint stiffness sufficient to severely compromise function and require operative intervention. Conservative management in general is the exception rather than rule in this group of injuries.

Nevertheless, there may be patients in whom the goals of treatment are different. Patients with significant medical co-morbidities, and/or low demands due to cognitive status, might be managed conservatively. The goal of treatment may simply be to avoid complications of surgery, and enable sufficient comfort and function to allow the hand to the mouth, or even less. Fracture union is not the goal – adequate comfort and functional use of the limb is. A recent series of 40 patients[5] showed acceptable functional range of motion in most survivors in this high-mortality group.

Therefore if conservative management is to be contemplated in specific circumstances (very low demand and high mortality patients), minimal splintage for initial pain relief, followed by range of motion as comfort allows, is likely to give the best results.

Operative management

Approaches

For treatment of distal humerus fracture (with the exception of isolated capitellar fractures, for which a lateral approach may be chosen with caution) a posterior approach should be chosen. There is a multitude of posterior approaches, which can be categorized as olecranon osteotomy, triceps splitting, triceps reflecting and triceps-on approaches.

For extra-articular and simple articular fracture a triceps-on approach (paratricipital and lateral paratricipital) usually is sufficient. It can easily be converted to an olecranon osteotomy if access proves inadequate.[6]

The ulnar nerve has to be identified, mobilized and protected during any posterior approach to the elbow.

Olecranon osteotomy

This approach provides maximal exposure of the distal humerus articular surface. This however is achieved at the expense of violating a native joint, and is best used for complex intra-articular fractures. Care should be taken if a total elbow arthroplasty may be required or for isolated capitellar fractures when a triceps-on approach should be used, at least initially. Olecranon osteotomy is considered to provide the best exposure of the joint surface, with only the exception of the anterior capitellum. It is therefore the approach of choice for the treatment of complex intra-articular fractures. It does however mean violating a native joint, has the additional risk of delayed or non-union and the aforementioned risks of hardware-related complications. The use of this approach precludes insertion of a total elbow arthroplasty. Also, it has recently been suggested that even olecranon osteotomy may not provide the visualization previously thought.[7] Clearly, the fixation of the osteotomy in itself adds time and additional complications. Advocated methods include tension band wiring, a long partially threaded 6.5 cancellous screw (which should be drilled prior to performing the osteotomy), and plating. Each method presents its own profile of cost, technical skill, complication risk (particularly migration and non-union) and likelihood of removal. Tension band wiring is the authors' treatment of choice in view of low cost and risk of complications. Attention to detail can help avoid risk of removal of metal, but the definite possibility of this occurrence should be carefully explained to the patient. More recently a suture-only method of olecranon fracture fixation has been described which may be of use in avoiding metalware-related complications. The authors of this technique also utilise this for osteotomy fixation but robust evidence for this is lacking.[8]

Triceps-on approaches are preferable and usually sufficient for extra-articular, simple intra-articular fractures as well as insertion of hemiarthroplasties and some total elbow replacements for trauma.

Approach: the triceps insertion is isolated by incising the joint capsule on either side of it as well as incising the triceps expansion. As a variant of the original approach the anconeus muscle should be peeled off the lateral border of the olecranon and left in continuity with the lateral triceps. Thereby the anconeus is left innervated and provides dynamic stability. The osteotomy should be V-shaped with the tip directed distally to add primary stability. It should be located proximal to the coronoid process at the deepest point of the semilunar fossa. This area is devoid of cartilage and therefore called the bare area.

Paratricipital approach (Alonso-Llames)[6]

The triceps tendon is left intact, with 'windows' exploited on medial and lateral aspects of the distal humerus as described above.

This approach can easily be converted to an olecranon osteotomy.

Approach: after a standard posterior incision, skin flaps are raised and the ulnar nerve identified, mobilised and protected.

The joint capsule is elevated off the olecranon tip and the triceps lifted off the posterior humerus. The triceps tendon is left intact.

If an arthroplasty is planned the collateral ligaments are released off the humeral origin. The distal humerus can now be delivered on either side of the tendon.

Triceps-splitting approach (Campbell[9])

The triceps tendon is divided longitudinally in the midline, both sides are peeled off the olecranon to the sides.

The triceps tendon and its expansion are repaired transosseously.

This approach provides excellent exposure to the distal humerus. The theoretical risk of triceps weakness was not confirmed in a study by McKee which compared this approach to olecranon osteotomy.[10]

Triceps-sparing approach (Bryan-Morrey[11])

This approach can be used for fixation of distal humerus fractures or insertion of an elbow arthroplasty (hemi or total).

The whole triceps is taken off the from medial to lateral, optionally with a thin flake of bone off the olecranon. The distal triceps expansion and antebrachial fascia is left intact and therefore the extensor mechanism is not fully disrupted. The elbow joint can now be 'delivered' from under the extensor mechanism.

At conclusion of the procedure the tendon is repaired meticulously, ideally transosseously, to prevent triceps weakness.

Triceps-reflecting anconeus pedicle (TRAP) approach (O'Driscoll[12])

This is similar to the Bryan-Morrey approach on the medial side, but laterally the extensor mechanism is detached distally in a flap that includes anconeus, resulting in a proximally based flap of triceps and anconeus.

At conclusion of the procedure the tendon is repaired meticulously, ideally transosseously, to prevent triceps weakness.

Lateral approaches

These approaches provide exposure of any aspect of the lateral side of the elbow. In the context of distal humerus fractures this applies to capitellar fractures or isolated lateral column fractures.

The Kocher approach uses the interval between anconeus and extensor carpi ulnaris.

The Kaplan approach utilises the interval between extensor digitorum communis posteriorly and extensor carpi radialis longus and brevis anteriorly.

Approach: either a direct lateral incision or a posterior midline incision can be used to start this approach.

A lateral incision is centred on the lateral epicondyle.

The lateral epicondyle and supracondylar ridge are palpated and sharply dissected. The lateral ulnar collateral ligament (LUCL) is ideally left intact, but can be detached from its humeral origin if required for access. It is repaired via an anchor at the end of the procedure.

Internal fixation

The operative fixation of distal humeral fractures has undergone a revolutionary change in the last 20 years. The AO principles of management, in particular pertaining to intra-articular fractures are followed: these are, anatomical reduction, absolute stability and early active rehabilitation. Specific to the distal humerus, meticulous reduction of the joint surface and metaphyseal compression are key to a successful outcome. Immediate mobilization is particularly relevant in the elbow with its propensity to stiffness. Until the advent of anatomical plating systems, and those with locking screw technology, achievement of these aims in the distal humerus, particularly in low fractures, was extremely difficult. To achieve the greatest possible stability, placement of a dynamic compression plate (DCP) on the posterior aspect of the lateral column was generally advocated, along with a more malleable one-third tubular plate directly on the medial column; so-called perpendicular plating. However, often the hold from the few 3.5 mm screws that could be placed distally was poor.

The introduction of anatomical plating systems with smaller distal screws allowed more screws to be placed in the distal fragments. O'Driscoll[13] in particular popularized the use of parallel plates to achieve maximum screw length from both columns into the distal fragments. He suggested that two principles must be satisfied:

1. Fixation in the distal fragment must be maximized.
2. All fixation in distal fragments should contribute to stability between the distal fragments and the shaft.

There are eight technical objectives by which these principles are met:

1. Every screw in the distal fragments should pass through a plate.
2. Engage a fragment on the opposite side that is also fixed to a plate.
3. As many screws as possible should be placed in the distal fragments.

4. Each screw should be as long as possible.
5. Each screw should engage as many articular fragments as possible.
6. The screws in the distal fragments should lock together by interdigitation, creating a fixed-angle structure.
7. Plates should be applied such that compression is achieved at the supracondylar level for both columns.
8. The plates must be strong enough and stiff enough to resist breaking or bending before union occurs at the supracondylar level.

Furthermore, the additional stability obtained by the use of locking screws can be utilised. Contemporary distal humerus fixation systems therefore allow alternative plate and screw positions, with or without the use of locking screws (Figure 3).

Whatever the system, the stability of the construct that can be gained, even in osteoporotic bone, means that few fractures can be considered 'unfixable'. Papers considering the outcomes of fixation in these cases published before this modern era should be interpreted accordingly, as will be discussed below.

The approach used is dependent predominantly upon the fracture pattern, but is also dependent upon the fixation devices to be used, and surgeon experience and preference. There is a trend away from olecranon osteotomy as other approaches have been developed that allow almost equivalent exposure of the articular surface, but olecranon osteotomy remains the gold standard to achieve optimum vision of complex intra-articular fractures.

Ultimately, if fixation is chosen to treat an intra-articular fracture, we must make every effort to ensure anatomical reduction, and to allow sufficient stability for early movement. O'Driscoll's principles, outlined above, provide a good framework for this. In practical terms, sufficient visualization should be achieved to ensure anatomical [NP6] reduction. Most surgeons advocate provisional K wire fixation of the articular fragments initially. Small fragments may indeed be definitively fixed with threaded wires, small (2 mm) screws or embedded screw systems. Traditional AO principles then suggest individual screw fixation of the fragments. Care must be taken if this is performed to differentiate between compression and position screw usage. If a small segment of articular surface is missing, compression will ultimately malreduce the articular surface and leave it incongruent. O'Driscoll advocates the use of long position screws through plates: if this is to be done, the fragments should be held compressed whilst the screws are passed, using large fracture-reduction clamps. If individual screws are used to secure the articular segment, then dual column plates, or medial and posterolateral plates, are used to secure the articular segments to the shaft ideally with compression. Care must be taken to ensure

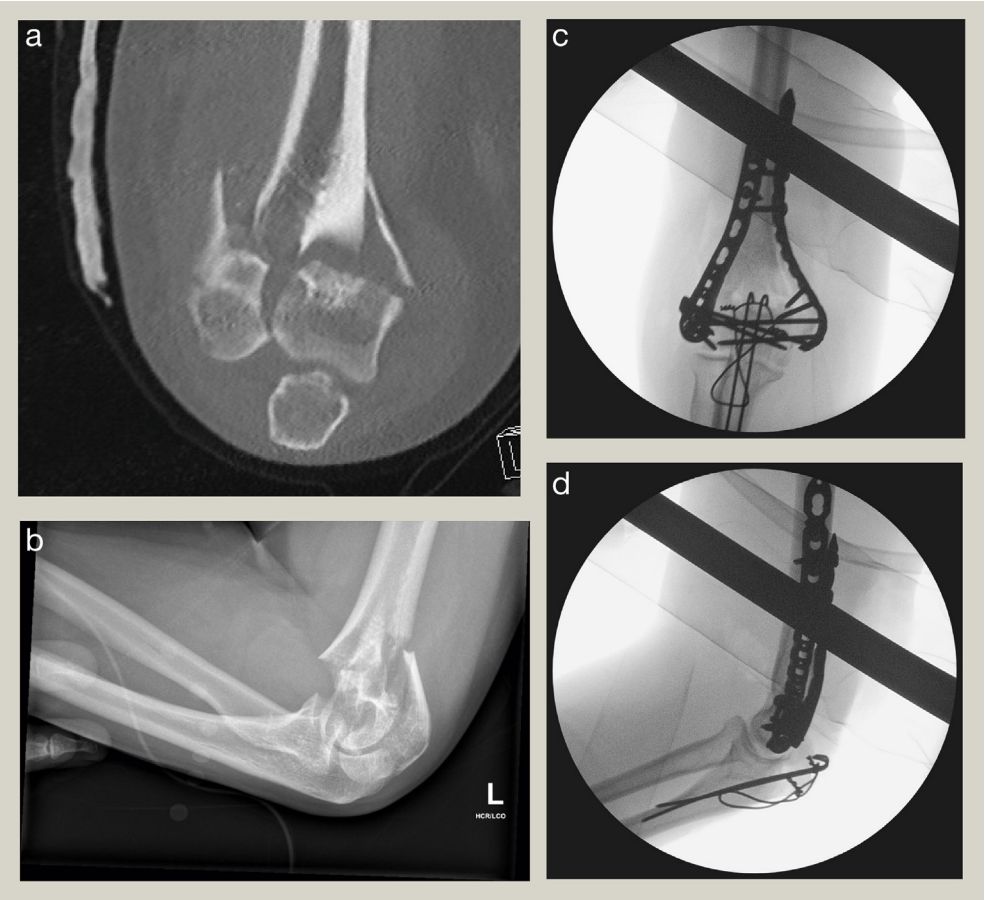

Figure 3 Examples of contemporary distal humerus fixation postoperative X-rays. (a) Coronal CT and (b) lateral view of C3 distal humerus fracture. (c and d) Intraoperative views after repair of olecranon osteotomy. A 90:90 ssytem was used, to allow both multiple crossed screws distally and multiple screws posterior to anterior in the caplitellar fragment.

that sufficient hold is achieved in the distal segment. Using O'Driscoll's principles, the plates are already secured to the distal fragments with long screws; thereafter it remains a relatively simple task to fix them approximately to the shaft under compression mode.

In principle, O'Driscoll's system – given that it advocates the use of long screws through plates – favours parallel plating on each column. The use of posterolateral plating along with a medial plate means that only short screws can be placed distally using the posterior plate. However, in contemporary systems there are additional holds for screws to be passed lateral to medial through the fragments in a similar mechanism to O'Driscoll.

Fractures at or below the level of the olecranon fossa should be fixed with a plate on each column. For extra-articular transverse fractures proximal to the olecranon fossa, sufficient holes may be achieved with a single plate. Specific plate designs are available to give multiple locking screw purchase in the distal fragment using such a single plate.

Coronal shear fractures present a particular set of difficulties. Care must be taken to ensure that the anatomy of the fracture is fully understood (CT may be considered mandatory). A single capitellum fragment with an intact posterior lateral column may be fixed through a lateral approach with front-to-back, or back-to-front, buried screws. However, if the posterior lateral column is not intact, a posterior lateral plate will be required to fix the capitellum to the supracondylar region. Equally, if the fracture extends more medially than the capitellum, the exposure from a purely lateral approach is likely to be inadequate, and therefore a posterior approach, often involving olecranon osteotomy, may be required. Again, if there is intact posterior bone then simple fixation of the fracture to the intact posteriorly bone may be possible. However, if in doubt, plates along each column with long screws into the articular fragments are advisable.

Arthroplasty

Given the aim of a stable, functional, congruous and painless elbow for early mobilization, and challenges of severe articular comminution/bone loss, poor bone quality and co-morbidities with low functional demands in the elderly, total elbow arthroplasty (TEA) has been advocated as a solution to these issues. Indications for TEA include low transcondylar and coronal shear fractures not amenable to fixation, as well as failed internal fixation. Patients with pre-existing arthritis, particularly inflammatory, are ideal candidates. Contraindications are contaminated open fractures and infection. Advantages include early mobilization. In the recent past, linked designs have predominated. Designed for inflammatory arthritis in which inherent elbow stability may be lost requiring intrinsic stability in the prosthesis, they are useful in trauma to bypass loss of stability also often present. However their disadvantages include risks of aseptic loosening, polyethylene wear, osteolysis and periprosthetic fractures. The last decade has seen increased popularity of the linked TEA for distal humeral fractures in the elderly. In 2008 the Canadian Orthopaedic Trauma Society[14] group published a randomized controlled trial of fixation and TEA in elderly patients showing shorter operative times, improved outcomes and lower reoperation rates with TEA, and subsequently this option has gained popularity. However, bear in mind the modern principles of fixation as advocated by O'Driscoll were published in 2005;[13] it might be suggested the outcomes may have been different if the fixation cases were managed in the light of these suggestions. Equally, the complications of TEA are considerable.

The introduction of new elbow arthroplasty systems has seen the emergence of the distal humeral hemiarthroplasty. This implant is shaped like the distal humerus and can therefore articulate with the native proximal ulna. As the proximal ulna is not replaced younger patients (where implantation of a total elbow replacement would be deemed at high risk of future loosening) with unreconstructable fractures can be considered. If future replacement of the ulna is required the anatomically shaped humeral spool can be changed to the standard shape to articulate with the ulnar component. Advantages include the avoidance of the linked hinge systems previously used, and theoretically reduction therefore of polyethylene wear. However, as with any unlinked system, ligamentous stability is paramount and must be restored if the implant is to succeed. Disadvantages include, as with any hemiarthroplasty, wear on the remaining native articular surface and the need for further revision surgery. Whilst gaining popularity, particularly in place of linked TEA, the evidence so far for this approach is lacking. Small series with mid-term results (up to 8 years) are the only data available to date.[16]

Rehabilitation

The main aim of rehabilitation is to mobilize the elbow as soon as possible. For undisplaced fractures, a couple of weeks of immobilization with an above-elbow plaster is acceptable. Occasionally, a plaster cast can be used for a couple of weeks after surgery to allow the soft tissues to settle down. Generally, allowing mobilization of the elbow as comfort allows and improving passive range of movements with physiotherapy input is essential.

Decision-making/options

In the decision-making regarding the management of distal humeral fractures, many factors have to be taken into account. These include patient factors, issues surrounding the fracture itself, the soft tissue envelope, and the demands of the patient. Practical decisions need to be made on whether to operate, fixation versus arthroplasty, be it linked, unlinked or hemi. The approach must be carefully considered to allow the surgical plan to be executed whilst avoiding additional complications.

Nevertheless, surgeon factors are also key –surgeons faced with managing these injuries must constantly ask themselves whether they can offer the patient the options of treatment to allow an optimal outcome. This is particularly true of elbow arthroplasty, and, in the UK, there is a contemporary debate as to whether elbow arthroplasty should only be offered in certain centres by certain surgeons, driven by the evidence that many elbow arthroplasty surgeons perform very few of these procedures. This has been analysed by national organizations including Getting It Right First Time (GIRFT) and the British Elbow and Shoulder Society (BESS). The outcome of this debate will impact

upon the management of patients with distal humeral fractures in ways that will have to be carefully considered. ◆

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