Review article

THE OPERATIVE MANAGEMENT OF DISPLACED FRACTURES OF THE PROXIMAL HUMERUS

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Fractures of the proximal humerus may involve either the true articular surface of the glenohumeral joint, the gliding surface of the subacromial joint, or both. Glenohumeral motion and strength rely on intact joints and on the co-ordinated interplay of the muscles and tendons around the shoulder. Contraction of the muscles of the rotator cuff creates a stabilising compressive force, with a downward orientated vector which allows smooth elevation of the humerus in conjunction with an upwardly orientated force created by contraction of the deltoid. In pathological states, glenohumeral kinematics are disturbed. For example, poor repositioning of the greater tuberosity, after a displaced fracture, will interfere with abduction, although the deltoid still pulls the humerus upwards,^{1,2} because the cuff will not be able to produce the necessary torque for this movement to occur properly.

Although these fractures are probably best treated by operation, their complex pattern, comminution and displacement make secure anatomical fixation difficult. The bone may be of poor quality because of coexisting osteoporosis. Rigid fixation and anatomical reduction are not always possible and techniques must be used to restore the anatomy sufficient to allow painless function. With severely comminuted and displaced patterns of fracture prosthetic replacement may be the only solution.^{3,4} The surgeon must therefore be aware of the technical options which will allow him to reach realistic goals. Techniques must be utilised which will provide sufficient stability to achieve bony union, early mobilisation and, ultimately, pain-free function. Depending on the degree of osteoporosis and the comminution of the fracture, a variety of surgical options should be considered. In some cases rigid fixation will achieve anatomical restoration while in others the anatomy will have to be sacrificed in order to achieve stability, with a predictably different outcome.

Anatomy of the glenohumeral joint

The anatomy of the glenohumeral joint is complex and in the case of fracture the components must be reconstructed if the kinetics of the joint are to be preserved.^{1,2}

The dynamics of this highly mobile joint are the consequence of its particular bony anatomy and of its soft-tissue envelope. The skeletal anatomy of the glenohumeral joint comprises two retroverted non-constrained articular surfaces. That of the glenoid is pear-shaped because of the anterior incisura acetabuli. Mallon et al⁵ have made measurements of the glenoid and found a mean transverse diameter of 24 ± 3.3 mm, a mean superoinferior diameter of 35 ± 4.1 mm, a mean posterior version of $2.0 \pm 4.2^\circ$ (-7 to -12) and a mean radius of curvature of 36.6 ± 7.4 mm (24 to 50).

The proximal humerus has a cartilaginous surface which is tilted 45° upwards and about 20° posteriorly with reference to the distal intercondylar line.⁶ Using radiological techniques, Cyprien et al⁷ and Debevoise, Hyatt and Townsend⁸ measured humeral retroversion. The former found a mean value of $26.9 \pm 12.22^\circ$ on the right and $21.2 \pm 11.02^\circ$ on the left. The latter group determined a mean value of 61.6° (47 to 65) on the right and 60.8° (47 to 85) on the left. The quasispherical surface of the humeral head occupies approximately one-third of a sphere with an angular value ranging between 120° and 150° . The radius of curvature in the axial plane is 22 ± 1.7 mm and the radius of curvature in the coronal plane is 24 ± 2.6 mm.⁹

The vascular anatomy of the humeral head plays a major role in the outcome of trauma. A devascularised head will collapse and become incongruent, with the development of secondary arthritis. The arteria arcuata circulates within the humeral head and receives its blood supply from four major sources: the metaphyseal artery, the branch of the anterior circumflex artery in the bicipital groove, arteries from the rotator cuff and the medial branch of the posterior circumflex artery.¹⁰⁻¹² Because of this arterial pattern a fracture through the anatomical neck will lead to complete devascularisation of the fragment of the head which carries the articular surface (Fig. 1).

The power link between the scapula and the humerus is ensured by the glenohumeral muscle groups which directly cross the joint, namely the teres major, the deltoid with its

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Fig. 1a

Fig. 1b

Fig. 1c

Figure 1a – Diagram of the sources of vascularisation of the humeral head. Figure 1b – Diagram showing fracture through the anatomical neck cutting off all blood supply to the head. Figure 1c – Diagram showing the line of the fracture sufficiently lateral to spare the posterior circumflex artery and preserve some blood supply to the head from that source. This may be seen in valgus-impacted fractures with good medial contact (1, circumflex artery; 2, axillary artery; 3, ascending branch of the posterior circumflex artery; 4, arterial supply of the rotator cuff from the thoracoacromial and suprascapular arteries; 5, ascending branch of the anterior circumflex artery; 6, anterior circumflex artery; 7, intraosseous metaphyseal artery).

three functionally independent anterior, middle and posterior segments, and the rotator cuff. The last consists of the musculotendinous units of subscapularis, supraspinatus, infraspinatus, and teres minor.¹³ The biceps and its tendinous long head may also be considered as part of the rotator cuff. The biceps tendon is a valuable surgical landmark separating the lesser from the greater tuberosity and therefore is of help in identifying the various fragments with their attached cuff tendons when dealing with a displaced fracture of the proximal humerus. The structures medial to the biceps tendon are subscapularis and the lesser tuberosity while those lateral to it are part of the greater tuberosity and attached tendons of supraspinatus and infraspinatus.¹⁴

The axillary nerve is at risk in these fractures.¹⁵ It supplies the deltoid and teres minor muscles and should be tested for motor and sensory function on the lateral aspect of the shoulder before any attempt at manipulation for fracture of the humeral head. At operation it should be visualised or at least palpated, since it lies anterior to subscapularis before plunging beneath the tendon of subscapularis and the glenohumeral capsule into the quadrilateral space on its way to the deltoid and to teres minor. The nerve is tensed in internal rotation and relaxed in external rotation.¹⁵

The integrity of the musculocutaneous nerve should also be checked clinically, including its motor innervation of biceps and the sensory supply to the medial forearm. It is usually not necessary to visualise the nerve at operation but

it must be borne in mind that it enters the biceps approximately 5 to 8 cm below the tip of coracoid although this distance has been shown to be very variable.¹⁶

Vascular lesions are infrequently associated with fractures of the proximal humerus.¹⁷ In the presence of a fracture an enlarging ecchymosis or a painful tense haematoma should alert the surgeon to underlying haemorrhage which is either venous or, more rarely, arterial. Ideally, angiographic assessment should be considered. If this is not possible surgical exploration is mandatory.

Classification of the fractures

Many schemes of classification have evolved in order to guide treatment and to aid in determining the prognosis. Codman¹⁸ first suggested that the number and type of fragment found in each fracture may play an important role. Neer^{3,4} and Brien et al¹⁹ refined this concept into an accepted classification which takes account of the amount of displacement, if more than 1 cm linear and 45° angular, of each fragment and the number of fragments involved. The presence or absence of dislocation is also important (Fig. 2). The Association for the Study of Internal Fixation (AO-ASIF)²⁰ has also developed an alpha-numeric classification scheme which differentiates between articular and extra-articular fractures (Fig. 3). These systems of classification have their shortcomings and do not always show inter- and intraobserver reliability.^{21,22} Furthermore, none takes into account the quality of the bone or soft tissues.

Fig. 2

Diagram of Neer's classification.³

These difficulties may pertain more to imaging techniques than to the patterns of the fracture themselves, and future developments in imaging may improve these schemes. Nevertheless, although they may not always be accurate enough for reliable assessment of each individual patient, they have brought considerable understanding to the interpretation of the patterns of fracture and to patient care.

Preoperative assessment

A thorough history should be taken to determine the circumstances of the fracture. These injuries tend to occur in a population which is at particular risk. In eight published series between 1974 and 1995, totalling 487 cases in

patients with a mean age of 65.7 years and a mean follow-up of three years (maximum 14), there were 78 reported deaths (16% of all cases)²³⁻³⁰ (Table I). It is therefore important to determine exactly the nature of the injury and to look for associated medical conditions.³¹

High-energy injuries such as occur in motor-vehicle accidents usually produce significant associated injuries. In the absence of injury a pathological fracture should be suspected and an underlying tumour sought. The absence of injury in a fracture-dislocation must make epilepsy a consideration and the possible causes should be assessed. Moderate injury, such as a fall in the home, must raise suspicions of osteoporosis and this will call for preventive measures. Persistent pain after a fall with initially negative

Fig. 3

Diagram of the AO-ASIF classification.²⁰

radiographs should alert the physician to repeat the investigation with added views; often a hidden fracture of the tuberosity will be revealed. In these cases of almost undisplaced fractures there is the risk of an underlying tear of the rotator cuff and this should be investigated by ultrasonography or MRI. Adequate neurological and vascular investigations may also be necessary.

Radiological investigations

For a successful diagnosis of a fracture of the proximal humerus it is imperative to have two views perpendicular to each other. The glenohumeral joint line should be completely open with no overlap of the head upon the glenoid. The most common standard projections are the true AP view of the glenohumeral joint perpendicular to the plane of the scapula and the axillary view parallel to this plane

and perpendicular to the acromion. These can *always* be accomplished. The axillary view necessitates only a few degrees of abduction or, if the arm is held in internal rotation by a bandage, a Velpeau view can be made in which the patient leans backwards with the x-ray beam directed superoinferiorly from the top of the shoulder on to a cassette located at the patient's elbow. AP internal and external rotation views may be helpful but are difficult to obtain in cases of acute injury. Scapular Y views are sometimes of use but are notoriously difficult to interpret and, unless perfectly performed, should not be used to exclude, for example, posterior fracture-dislocations.¹⁴ CT is a useful adjunct and three-dimensional reconstructions can show features not readily recognisable on plain films.³²⁻³⁴ MRI may accurately delineate suspected soft-tissue injury. In case of doubt angiography should be used to determine vascular integrity. Other imaging techniques

Table I. Mortality of patients with fractures of the proximal humerus from eight series reported in the literature

Author	Treatment	Reported mean age (yrs)	Number of cases	Reported number of patients deceased at follow-up (number, %)	Maximum reported follow-up (yrs)
Svend-Hansen ²⁹	Operative and closed	66	63	8 (12)	7
Keene et al ²³	Closed	68	92	32 (34)	12
Lim et al ²⁵	Operative and closed	62	31	7 (22)	6
Stableforth ²⁸	Hemiarthroplasty	67	81	6 (7)	14
Ko and Yamamoto ²⁴	Operative	52	17	1 (5)	5
Rasmussen et al ²⁶	Closed	77	65	15 (23)	4
Zyto et al ³⁰	Operative and closed	71	47	6 (12)	3
Schai et al ²⁷	Operative and closed	66	91	3 (3)	14

such as scintigraphy may be difficult to interpret in the acute phase of a fracture of the proximal humerus and should be reserved for more chronic conditions associated with previously undiagnosed trauma.

Surgical approaches

Deltopectoral approach. In displaced fractures of the proximal humerus the most common surgical approach is the deltopectoral with the patient in the 'beach-chair' or semi-sitting position.^{3,4} General anaesthesia is used and sometimes a scalene block may be performed before intubation. This allows for lighter anaesthesia and the absence of pain on awakening will prevent uncontrolled movement by the patient and therefore protect the osteosynthesis. An oblique incision 15 cm long is made starting from below the clavicle and passing over the coracoid. After appropriate haemostasis of the subcutaneous tissue, the deltopectoral interval and the cephalic vein are identified. If there is difficulty in finding the interval because of swelling the search should be made more proximally near the clavicular insertion of the deltoid and pectoralis major muscles where, usually, the interval widens. The cephalic vein is left either with the deltoid muscle or with the pectoralis muscle. It may be ligated. The conjoined tendons are then retracted and a curved blunt retractor is placed under the deltoid muscle around the fragments of the humeral head in the subacromial space after blood clot and bursal tissue have been removed. The axillary nerve is identified and palpated by sliding the index finger under the conjoined tendons on to the anterior aspect of subscapularis. It is then important to locate the biceps tendon and to use it as a landmark to help to identify the fragments of the greater and lesser tuberosities with their attached tendons. With two-part fractures involving the surgical neck, the alignment of biceps may reflect the adequacy of the reduction. In a fracture in which the lesser tuberosity is not detached but where the surgeon wishes to inspect the articular surface, a small incision through the interval can be made and the articular surface observed. All the tendinous structures should then be identified with stay sutures. Reduction may be accomplished by various techniques from the use of

plates and screws in particularly strong bone to obtain a 'rigid' fixation, to relying on osteosutures or wires to obtain a tension-band construct. This last technique may be particularly indicated in the presence of osteoporosis. A control radiograph should always be obtained before closure. In order to obtain a satisfactory view the x-ray tube should be placed on the contralateral side of the patient and the cassette applied to the body of the scapula. This will give a view perpendicular to the plane of the scapula allowing interpretation of the quality of the reduction and of the position of the tuberosities.

Transdeltoid split approach. In cases of isolated fractures of the tuberosity or if an intramedullary device is employed, it is sometimes sufficient to use a transdeltoid split approach. The patient is in a semi-sitting position and the skin incision may follow the direction of the muscle fibres along the upper deltoid at the junction of the anterior and middle thirds or as a vertical 'sabre-cut'. The deltoid is split along its fibres no more than 5 cm from the acromion in order to avoid injury to the axillary nerve. The cuff is then identified and the haemorrhagic subacromial bursa partially removed. The fragments of the fracture are then identified and reduced. Fixation may be by means of isolated screws, wiring or heavy sutures. If proximal intramedullary nailing is chosen the same approach can be used. The tendon of supraspinatus is split to allow the introduction of the nail into the tuberosity. The proximal part should be buried under the level of the articular cartilage. Image-intensifier control is essential to ensure a satisfactory outcome.

Overview of surgical technique

Plate fixation. In a two- or three-part fracture occurring in strong bone, usually in a younger or very active individual, the goal should be to attain anatomical reconstruction in order to achieve the best possible function.³⁵ As these fractures are intra-articular, rigid fixation is needed to avoid secondary loss of reduction. In order to obtain an optimal reduction, an open procedure using either the transdeltoid split, for an isolated fracture of the greater tuberosity, or the deltopectoral approach should be used. The fragments of

Fig. 4

Radiographs showing plate osteosynthesis. Figure 4A – A 35-year-old woman with a two-part displaced fracture (AO type A3). Figure 4B – This was treated by rigid fixation with plate osteosynthesis.

Fig. 5

Radiographs and CT showing osteosynthesis with screws. Figure 5A – A 34-year-old man with a head-splitting fracture-dislocation. Figure 5B – Osteosynthesis with compression screws. The prognosis was guarded with the possibility of collapse of the head.

the fracture must be carefully identified and tagged with stay sutures at the tendon-bone interface using the long head of biceps as a landmark. Usually, it will be possible to reposition the fragment of the head on to the metaphysis and to obtain provisional fixation with Kirschner (K-)

wires. This is especially true of fractures which are aligned in varus, while in valgus-impacted fractures, if the impaction is extreme, the head may be disimpacted and held in place by an intercalated bone graft. In this situation, and when using this technique, care must be taken not to disturb

Fig. 6

Radiographs of a 69-year-old woman showing A) a four-part valgus-impacted fracture (AO type C2) and B) the technique of osteosuture because of poor bone quality. Heavy sutures (Ethibond no 6) were placed at the tendon-bone junction of the greater and lesser tuberosities and tied around a 4.5 mm cortical screw placed in the intact metaphyseal region 2 cm below the fracture.

Fig. 7

Radiographs of a 69-year-old woman showing A) a four-part valgus (AO type C2) fracture after a fall from a height and B) osteosuture with satisfactory function.

the soft-tissue attachments of the medial head-neck junction (Fig. 1c). It is in this area that the medial circumflex artery penetrates the humeral head and this tissue may carry the remaining blood supply.^{36,37} The greater and/or lesser tuberosities are also reduced and a contoured T-plate (ASIF 3.5 or 4.5 mm) is applied, taking care not to injure the long head of biceps. Screws are then inserted and the stay sutures may be either removed or tied into the plate holes or transosseously, if needed, for further stability (Fig. 4).

In the case of a limited head-splitting fracture, which is usually associated with a dislocation, screw fixation only may be used. In these cases, however, the vascular supply of the head is compromised and the prognosis remains guarded^{38,39} (Fig. 5). Newer designs of implant (ASIF

Locking Compression Plates) have screw heads which lock into the plates thus allowing angular stability of the screws in relation to the plate. These types of implant give improved stability and may therefore speed bony healing and functional recovery.

Osteosuture. For three- and four-part fractures occurring in older individuals or patients with fragile osteopenic bone, the aim is to obtain a reduction which is anatomical enough to allow acceptable function.⁴⁰⁻⁴³ In valgus-impacted three- or four-part fractures the anatomy may be restored by pulling the tuberosities below the level of the head without disturbing it or its vascularisation. Osteosuture requires the use of wire, cable or heavy sutures such as Ethibond no. 6 to obtain fixation. A deltopectoral approach in a semi-

Fig. 8

Radiographs of a 35-year-old man showing A) a valgus four-part (AO type C2) fracture after a fall from a height, B) a trial of plate fixation with unacceptable reduction (an intraoperative decision was made to introduce a hemiarthroplasty) and C) four years later. Figure 8D – Photographs show excellent, painless function with a full range of movement and symmetrical strength. He works full-time as a cook.

sitting position will allow the surgeon to visualise the bone fragments. The head of the humerus is impacted on to the metaphysis in a stable valgus position. The greater and lesser tuberosities are identified and heavy sutures, wire or cable, are passed through the fragments at the bone-tendon junction. These sutures are then fixed to the metaphysis between 1 and 2 cm below the metaphyseal fracture line either through transosseous holes or tied around a screw with washers (4.5 mm) introduced into the metaphysis. The long head of biceps will give orientation as to the reduction of the fragments. It should lie within its groove and be in a straight vertical line from its origin to the muscle belly. A radiograph should be taken before closure of the wound to ascertain the quality of the reduction (Figs 6 and 7).³⁷

Extramedullary pinning. Many techniques have been described, all of which entail closed reduction and percutaneous pinning of the fragments using an image intensifier either under local, regional or general anaesthesia.⁴⁴⁻⁴⁸ Two to three K-wires are inserted into the cephalic fragment from the distal insertion of the deltoid and another two to three into the fragment of the tuberosity from above. Care must be taken to avoid the axillary nerve and other neurovascular structures. The pins may be left protruding through the skin and can be removed six to eight weeks later. If they are cut beneath the surface of the skin their ends must be bent at 90° to avoid potentially fatal migration into the thorax or other cavities. This technique should be reserved for situations in which open surgery is not possible and the quality of the bone is of sufficient strength to hold the pins, which would displace in osteoporotic bone.

Intramedullary pinning. Fasciculated multiple pinning is an established technique.⁴⁹⁻⁵¹ This requires general, local or regional anaesthesia. The supracondylar area of the distal humerus is prepared and an oval opening is made at least 1 cm above the olecranon fossa. Using image-intensifier guidance, long K-wires with bent tips are passed up the humeral shaft with two to three introduced into the head and another two to three twisted so that they obtain purchase within the greater tuberosity. The bone must be sufficiently strong to allow fixation by the K-wires thereby avoiding protrusion into the subacromial or glenohumeral joint.

In some two-part fractures it is possible to combine intramedullary pinning with tension-band wiring. In this technique two Ender-type nails are inserted through the humeral head, using a transdeltoid split approach, and into the shaft. Wires are then passed through the eyelets, crossed and fixed transosseously into the metaphyseal region below the line of the fracture. This will have the effect of a tension band and augment the stability of the construct.⁴¹

Intramedullary nailing. This is used for the fixation of fractures of the proximal humerus including three- or four-part fractures.⁵² The patient is usually placed in a semi-sitting position under general, local or regional anaesthesia. A transdeltoid split approach is used. The rotator cuff is exposed and incised and the nail is passed through the head, at the interface of the tendon and cartilage, into the shaft of the humerus. The fragments of the head are then held together with locking screws introduced with the appropriate jig. Care must be taken to avoid damage to the axillary nerve and the tendon of the long head of biceps.

Prosthetic replacement. In the case of four-part fractures in which vascularisation of the head is compromised or with an intra-articular head-splitting fracture, prosthetic replacement may be considered.^{3,4,53-55} Technical problems such as determination of the height of the prosthesis, the diameter of the head, version of the head, the fixation and height of the tuberosity, the type of fixation and the diameter of the stem, must be carefully addressed. The height of the prosthesis can be determined either preoperatively by radiography of the contralateral side, allowing a preoperative plan to be made, or intraoperatively as judged by the position of the line of the fracture; there is usually a medial metaphyseal beak at the site of the fracture at the junction of the head and neck. The tension of the soft tissue when pulling the tuberosities around the head will also give an indication as to the appropriate height and size of the head. Usually, the diameter of the head of the prosthesis should be the same or very close to the measured diameter of the retrieved head, the exception being fracture-dislocations which are either anterior or posterior, in which added stability may be sought by using a head of slightly larger diameter. As a rule the version of the head should be determined with the arm at the side and the forearm on the abdomen; the centre of the head of the prosthesis should be facing the centre of the glenoid. Too much retroversion may stretch the rotator cuff and lead to pull-out of the tuberosity and too little may lead to loss of stability. In the case of posterior fracture-dislocations, less retroversion may ensure better stability, and inversely in the case of anterior fracture-dislocations more retroversion than usual may be necessary. The determination of retroversion should therefore not only rely on bony contours and fixed angles, such as 20° to the epicondyles of the distal humerus and 30° to the forearm, but should be tailored to each individual shoulder. The tuberosities should be fixed to the stem and the holes in the fins should be avoided. Sutures should pass circularly around the stem and when tightened should compress the fragments onto it. If necessary, bone graft taken from the head of the humerus can be placed between the stem and the tuberosities, the goal being to have the

tuberosities heal to one another. Sutures should also fix the tuberosities vertically to the shaft, thus lowering them 10 to 15 mm below the top of the head of the prosthesis. The stem should be cemented; non-cemented stems cannot ensure primary stability. The diameter of the stem should not be too tight in case it produces stress-shielding reactions resulting in loss of bone from the proximal humerus around the stem (Fig. 8).

Complications

The most common complications after surgical treatment of fractures of the proximal humerus are stiffness, persistent pain, postoperative infection, failure of fixation, osteonecrosis and late rupture of the rotator cuff.^{14,56}

To avoid stiffness, the fixation must be stable enough to allow immediate passive movement so that adhesive scarring is limited and recovery of function is allowed. This applies to all forms of fixation and especially to patients treated by hemiarthroplasty and reattachment of the tuberosities. Persistent pain has many causes including non-union, musculotendinous damage, instability, capsulitis, osteonecrosis, migration of the implant, neurovascular damage and low-grade infection. All of these must be considered and the appropriate diagnostic procedures performed.

Postoperative infection is always a possibility and must be borne in mind at all times. In the shoulder, the signs and symptoms of infection may be minor and loss of glenohumeral joint space, accompanied by persistent pain and discomfort, may be the first indications before any other radiological or biological evidence. In case of doubt intra-articular aspiration must be performed with culture of the fluid obtained. After aspiration, and with the needle left in place, contrast medium should be injected into the joint and a radiograph taken to establish that the aspiration was from the joint. The diagnosis may show that the infection is either acute (<three weeks), intermediate (between 3 and 8 weeks) or chronic (>8 weeks). In all cases surgical revision

Fig. 9

Radiographs showing malunion and protrusion of an intramedullary flexible nail in a three-part fracture.

Fig. 10

Radiographs of a 52-year-old man showing A) a valgus four-part (AO type C2) fracture after a fall, B) osteosuture with satisfactory union and C) at 24 months, aseptic necrosis with collapse of the humeral head.

Fig. 11

Proposed algorithm for the surgical treatment of displaced fractures of the proximal humerus.

and debridement are necessary. In acute infection, the implants may be left in place if they contribute to stability. In the intermediate situation judgement must be made as to whether to remove or leave the implants and a secondary intervention may have to be contemplated, such as fusion or reimplantation of the prostheses. In chronic infection removal of the implant is mandatory. An intravenous antibiotic regime should be started, preferably with the guidance of a specialist in infectious diseases.

Secondary failure of fixation may be due to poor technique or to poor bone stock (Fig. 9). The risks of a further

operation must be weighed carefully against the chances of success. In the case of early avulsion of a tuberosity less than six weeks after insertion of a hemiarthroplasty, refixation should be attempted to avoid superior migration of the head of the prosthesis and loss of function.

Nonunion of fractures of the proximal humerus is uncommon, but when it occurs it is disabling and should be dealt with surgically. Fixation may be obtained by various methods including plates or intramedullary implants. Occasionally, it is necessary to supplement the construct with a bone graft.⁵⁷ Walch et al⁵⁸ have described a technique in

which a cortical graft from the fibula or iliac crest is introduced into the fragment of the humeral head and into the diaphysis. A compression plate and screws give stability and the intramedullary graft allows solid purchase for the screws. Osteonecrosis cannot be avoided but a meticulous surgical technique should strive to preserve the blood supply of all fragments. Usually, however, osteonecrosis is well tolerated by the patient when the head and tuberosities have been reconstructed as closely to the normal anatomy as possible⁵⁹⁻⁶¹ (Fig. 10).

Tearing of the lateral part of the rotator cuff may occur with a hemiarthroplasty when the subacromial space narrows progressively. In case of chronic pain, reconstruction of the cuff may be the solution.

Rehabilitation

In the immediate postoperative period control of pain is a primary concern. Patients should benefit from a scalene block performed immediately before operation and, if possible, the catheter should be left in place and the pain controlled by a PCA (patient controlled anaesthesia) computerised pump.⁶² After inserting a percutaneous catheter into the sheath of the interscalene plexus, 20 to 30 ml of ropivacaine 0.5% should be given before operation. Post-operatively, a PCA pump connected to the catheter allows the infusion of 5 to 10 ml/hour continuously for up to 72 hours. The patient can self-administer boluses of 10 to 15 ml every 60 to 90 minutes depending on tolerance, body-weight and other factors. During this period the arm is passively mobilised and elevated in the plane of the scapula as high as tolerated, two to three times a day. The patient is also encouraged to exercise the hand, wrist and elbow. On the third postoperative day the wound is covered with a watertight dressing and mobilisation in hydrotherapy commences. This is continued for six weeks after which active and passive movements are undertaken. Strengthening exercises are started at ten weeks depending on the fracture or consolidation of the tuberosity. It usually takes about a year to achieve optimum function, but this may still improve for a further 12 months.

Conclusions

Fractures of the proximal humerus are complex injuries involving two articulating surfaces, the glenohumeral joint and the subacromial arch. Ideally, the principles of reconstruction of the articular fracture, including the restoration of the anatomy and stable fixation, with minimal injury to the soft tissues and to the vascular supply, should be applied. The head and tuberosities should be carefully repositioned to avoid weakness due to shortening of musculotendinous units and a decreased moment arm, and to diminish stiffness and pain because of secondary subacromial impingement or excessive scarring. The options as to the surgical approach or the type of implant used depend on the

pattern of the fracture, the quality of the bone encountered, the patient's goals and the surgeon's familiarity with the techniques (Fig. 11). An adequate surgical technique will minimise complications and an aggressive rehabilitation regime will ensure the best possible result.

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