Transosseous Suture Fixation of Proximal Humeral Fractures. Surgical Technique

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Transosseous Suture Fixation of Proximal Humeral Fractures

Surgical Technique

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ABSTRACT FROM THE ORIGINAL ARTICLE

BACKGROUND: The optimal treatment of displaced fractures of the proximal part of the humerus remains controversial. We evaluated the long-term functional and radiographic results of transosseous suture fixation in a series of selected displaced fractures of the proximal part of the humerus.

METHODS: Over an eleven-year period, a consecutive series of 188 patients with a specifically defined displaced fracture of the proximal part of the humerus underwent open reduction and internal fixation with transosseous sutures. Twenty patients were lost to follow-up and three died before the time of follow-up, leaving a cohort of 165 patients (ninety-four women and seventy-one men; mean age, fifty-four years) available for the study. Forty-five (27%) of the injuries were four-part fractures with valgus impaction; sixty-four (39%) were three-part fractures; and fifty-six (34%) were two-part fractures of the greater tuberosity, thirty-six (64%) of which were associated with anterior dislocation of the shoulder. All fractures were fixed with transosseous, nonabsorbable, number-5 Ethibond sutures. Associated rotator cuff tears detected in fifty-seven patients (35%) were also repaired. Over a mean follow-up period of 5.4 years, functional outcome was assessed with the Constant score. Follow-up radiographs were assessed for fracture consolidation, malunion, nonunion, heterotopic ossification, and signs of impingement, humeral head osteonecrosis, and degenerative osteoarthritis.

RESULTS: All fractures, except for two three-part fractures of the greater tuberosity, united within four months. The quality of fracture reduction as seen on the first postoperative radiograph was regarded as excellent/very good in 155 patients (94%), good in seven (4%), and poor in three (2%). Malunion was present in nine patients (5%) at the time of the last follow-up; six of the nine had had good or poor initial reduction and three, excellent/very good reduction. Humeral head osteonecrosis was seen in eleven (7%) of the 165 patients; four demonstrated total and seven, partial collapse. Fifteen patients had heterotopic ossification, but none had functional impairment. Four patients had signs of impingement syndrome, and two had arthritis. At the time of the final evaluation, the mean Constant score was 91 points, and the mean Constant score as a percentage of the score for the unaffected shoulder, unadjusted for age and gender, was 94%.

CONCLUSIONS: The clinical and radiographic results of this transosseous suture technique were found to be satisfactory at an average of 5.4 years postoperatively. Advantages of this technique include less surgical soft-tissue dissection, a low rate of humeral head osteonecrosis, fixation sufficient to allow early passive joint motion, and the avoidance of bulky and expensive implants.

LEVEL OF EVIDENCE: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

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INTRODUCTION

The management of displaced proximal humeral fractures is challenging and often reflects the personal experience of the physician treating the injury. Regardless of the treatment protocol used, these fractures present challenges in restoring humeral alignment, joint surface congruity, and rotator cuff function while maintaining humeral head vascularity. Over the last fifteen years, we have used a technique of transosseous suture fixation for a large number of displaced proximal humeral fractures. These have included four-part valgus impacted fractures, three-part fractures or fracture-dislocations, and two-part fractures of the greater tuberosity with or without associated dislocation of the humeral head. With use of this technique in four-part valgus impacted fractures, the impacted head, the greater tuberosity, the lesser tuberosity, and the upper part of the metaphysis are sutured together in a cruciate fashion, and in three-part fractures, the displaced tuberosity is sutured to the intact one as well as through drill holes in the metaphyseal area. Finally, in two-part tuberosity fractures, the displaced tuberosity is sutured to the intact one and to the adjacent metaphyseal area. Stable fixation can be obtained in each of these fractures, allowing for early shoulder motion with a low risk of osteonecrosis and hardware-related complications.

Other techniques of transosseous fixation of two-part or three-part fractures with use of wires, tapes, or sutures have previously been proposed by other authors[1-3]. Regarding the method proposed by Hawkins et al.[1], our surgical technique differs in that it can also be applied to four-part valgus impacted fractures and utilizes nonabsorbable sutures instead of wires, which can cut through the bone, especially in osteoporotic patients, and can more easily fatigue, resulting in the need for the removal of broken or migrated wire fragments in some patients.

SURGICAL TECHNIQUE

Preoperative evaluation includes a thorough clinical examination, focused on the presence of any neurovascular deficit, and a standard radiographic trauma series of the shoulder (an anteroposterior radiograph in the scapular plane as well as lateral and axillary radiographs) (Fig. 1). In order to minimize discomfort, the axillary radiograph is usually done with the patient in a supine position, under the supervision of the attending physician. Additional radiographic views (anteroposterior in external rotation or in internal rotation with 15° of

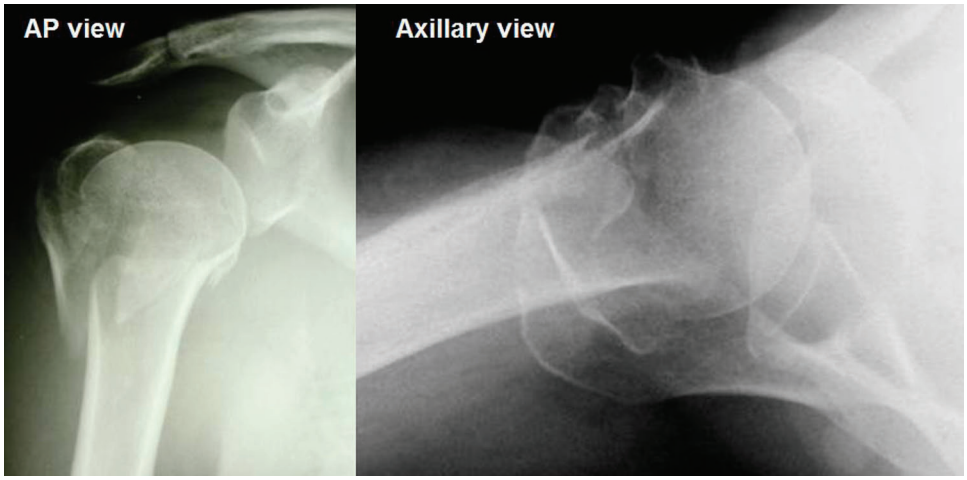


FIG. 1

Preoperative radiographs of a four-part valgus impacted fracture. Note the displacement of the greater tuberosity, the impaction of the humeral head, and the absence of lateral displacement of the head fragment on the anteroposterior (AP) radiograph.

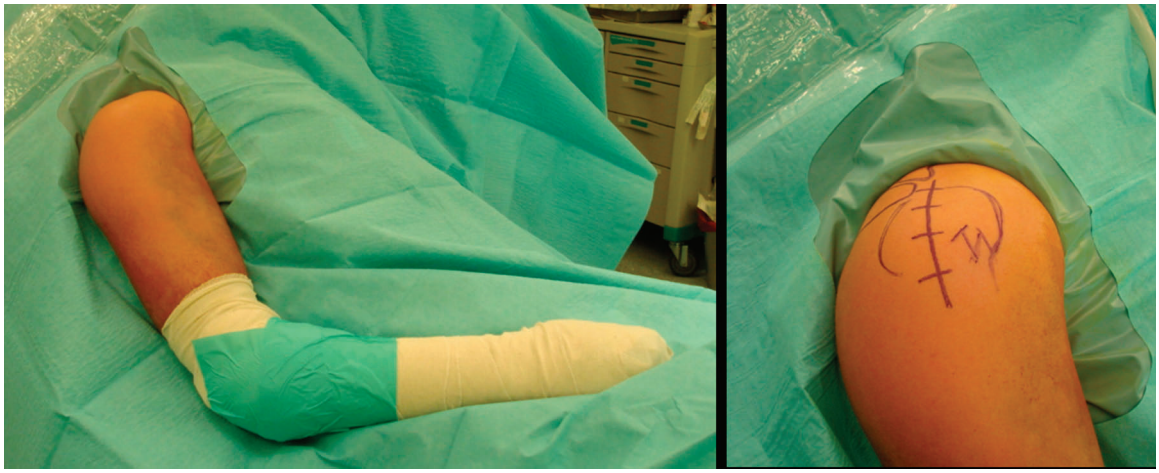


FIG. 2

The patient is placed in the beach-chair position (left), and the skin incision extends no more than 6 to 7 cm distal to the anterolateral tip of the acromion (right).

cephalic tilt) and computed tomography can be useful in selected patients.

After induction of general anesthesia, the patient is placed in the beach-chair position with at least 60° of flexion at the waist. Two folded sheets are placed beneath the medial border of the scapula to bring the shoulder girdle forward, facilitating access to the glenohumeral joint. A second-generation cephalosporin is administered preoperatively and for the first postoperative day. The entire upper extremity is prepared and draped in a manner that allows full and unrestricted positioning of the arm during the procedure.

The fractured area is exposed with use of the lateral transdeltoid approach, by developing an interval between the anterior and middle portions of the deltoid muscle. The skin incision is made from the anterolateral tip of the acromion, extending laterally and distally for approximately 6 to 7 cm (Fig. 2). With use of blunt dissection, the deltoid is split for 4 to 5 cm distal to the acromion (Fig. 3). Rotation and abduction of the proximal part of the humerus in this surgical window allows adequate visualization of both tuberosities and the metaphyseal area, thus minimizing the risk of iatrogenic injury to the axillary nerve. In patients with metaphyseal extension of the fracture, the nerve is identified and protected by the surgeon's finger.

Fixation of Four-Part Valgus Impacted Fractures

Soft-tissue attachments to the fracture fragments are carefully preserved to prevent devascularization of the humeral head. The fracture lines between the tuberosities are identified and gently separated, facilitating access to the humeral head. Invariably, the humeral head is facing superiorly with the tuberosities displaced to either side of it (Fig. 4). While the impacted valgus position of the humeral head fragment is preserved, two heavy nonabsorbable sutures are passed through the bone of the head fragment, 1 cm proximal to the fracture line at both the medial and the lateral border of the articular surface. Additional sutures are then passed through each tuberosity fragment (or near the site of tendon insertion into the fragment in osteoporotic bone or when intensive comminution is present), and the rotator cuff tendons are mobilized (Fig. 5). Finally, two additional pairs of sutures are inserted laterally and medially through 2.7-mm drill holes in the diaphysis (Fig. 6). These sutures are then passed through the opposite tuberosity, near the musculotendinous junction, and

on to the neighboring area of the articular segment (i.e., from the medial diaphysis toward the greater tuberosity and from the lateral diaphysis toward the lesser tuberosity as well as to the adjacent articular fragment). Once all sutures are in place, the tuberosities are approximated to the diaphysis and recessed just below the top of the head fragment. Then each suture is tied individually and to each other in a cruciate arrangement that allows stable fixation of all parts of the fracture to all others (Fig. 7). Any further loosening of the sutures, because of fracture compression, is corrected by tying additional knots between the free suture ends once more in a cruciate manner. A schematic representation of the surgical technique in a four-part valgus impacted fracture is shown in Figure 8 with the appropriate order of suture passage and the final knot-tying. When completed, eight sutures will have been placed. Each tuberosity contains four suture ends (two distinct sutures, one to each side of the shaft fragment, and two shared sutures to the neighboring tuberosity), and the head fragment contains two distinct sutures (both going through the proximal holes in the shaft fragment) (Fig. 8, *c*). Any associated tears of the rotator cuff tendons are also repaired with nonabsorbable sutures.

Fixation of Three-Part Fractures (Fig. 9)

The same principles of fixation are used for three-part fractures.

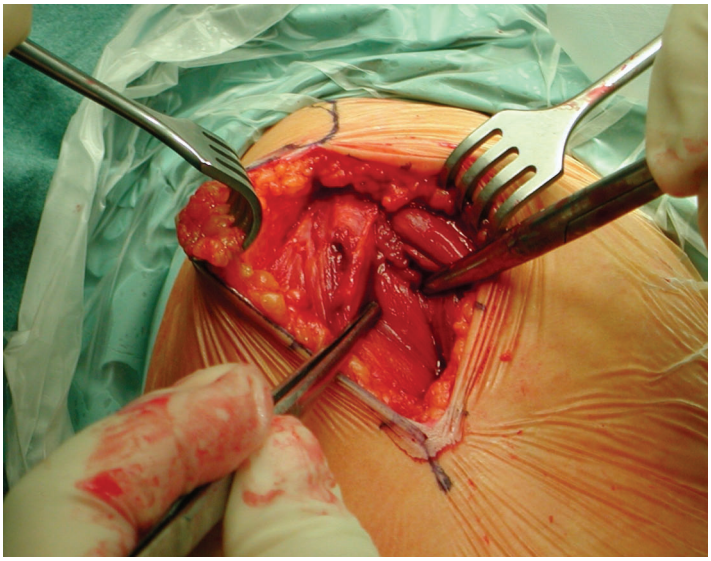


FIG. 3

The split of the deltoid extends no more than 4 to 5 cm in order to avoid iatrogenic injury to the axillary nerve.

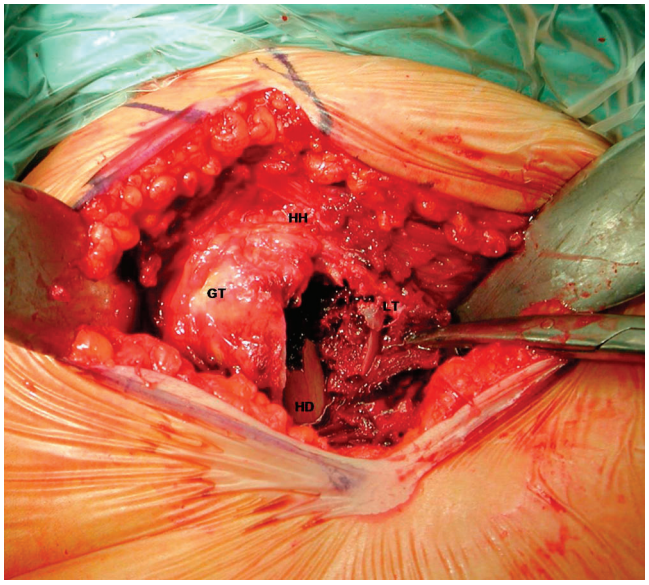


FIG. 4

Intraoperative photograph made after exposure of a four-part valgus impacted fracture. Soft-tissue attachments to the fracture fragments are carefully preserved to prevent devascularization of the humeral head. The fracture lines between the tuberosities are then identified and gently separated. GT = greater tuberosity, LT = lesser tuberosity, HH = humeral head, and HD = humeral diaphysis.

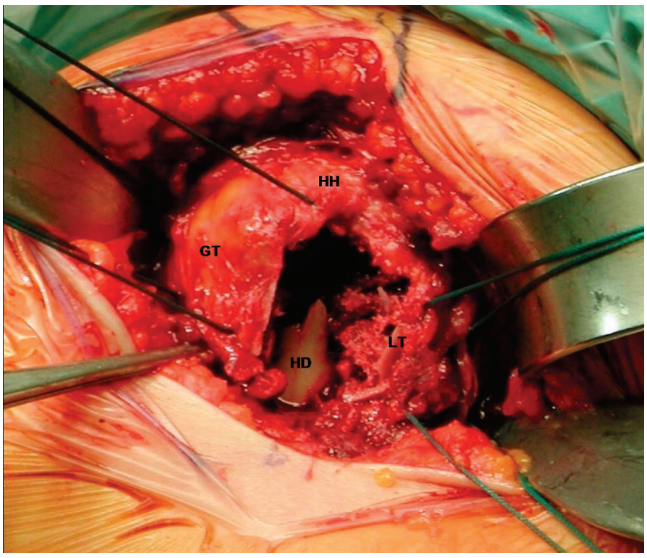


FIG. 5

The first suture is passed through the head fragment and the greater and lesser tuberosities. GT = greater tuberosity, LT = lesser tuberosity, HH = humeral head, and HD = humeral diaphysis.

In this type of fracture, the humeral head is typically rotated either internally or externally, and care must be taken to achieve an adequate reduction in both the frontal and sagittal planes. Initially, two sutures are placed through the displaced greater tuberosity and then through the intact lesser tuberosity. Two additional pairs of sutures are inserted laterally and medially through 2.7-mm drill holes in the diaphysis. These sutures are directed into the opposite tuberosity (i.e., the medial diaphysis toward the greater tuberosity and the lateral diaphysis toward the intact lesser tuberosity). When completed, six sutures will have been placed, with each tuberosity containing four suture ends (two distinct sutures to the opposite side of the shaft fragment and two shared sutures to the neighboring tuberosity) (Fig. 9, *c*). Once all the sutures are in place, they are tied individually and then to each other in a cruciate arrangement that allows stable fixation of all parts, one to the other. Loosening of the sutures, because of fracture compression, is corrected by tying additional knots between the free suture ends in a cruciate manner. Associated rotator cuff tears are repaired with nonabsorbable sutures.

Fixation of Two-Part Fractures of the Greater Tuberosity (Fig. 10)

When anterior dislocation of the shoulder accompanies fracture of the greater tuberosity, the patient is lightly sedated in the emergency department to facilitate reduction. Only one or two efforts are made to reduce the dislocation by closed means. If closed reduction fails, the patient is transferred to the oper-

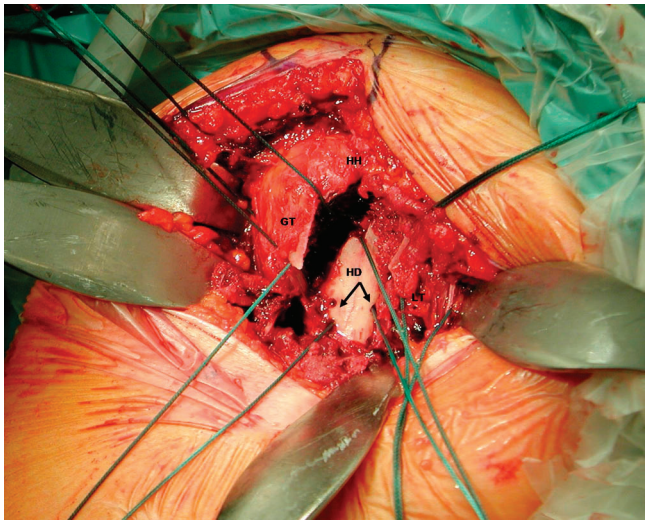


FIG. 6

Additional sutures are placed through drill holes in the medial and lateral aspects of the humeral diaphysis (HD). The black arrows indicate the drill holes in the diaphysis. GT = greater tuberosity, LT = lesser tuberosity, and HH = humeral head.

ating room for open reduction under general anesthesia. In our series, twenty-nine (52%) of the fifty-six patients with two-part fractures of the greater tuberosity had a characteristic longitudinal tear in the rotator interval. Complete avulsion of the supraspinatus tendon was seen in five patients; complete avulsion of the infraspinatus tendon, in three; and combined avulsion of both tendons, in two patients. To repair the fractures, two sutures are passed from the upper part of the greater tuberosity through the lower part of the metaphysis (through a corresponding drill hole) and into the upper part of the cortical bed of the humeral head, near the fracture line. Three additional sutures are passed through the lower part of the tuberosity fragment and directed to the upper, middle, and lower parts of the cortical bed and metaphyseal area. When completed, five sutures will have been placed. Two distinct sutures connect the upper tuberosity fragment to the bed of the head and shaft, while three sutures secure the lower part of the tuberosity fragment to different fixation points in the shaft and metaphysis (Fig. 10, *c*). Once all sutures are in place, the cortical edge of the tuberosity fragment is reduced to align with the edge of the fracture bed on the proximal part of the humerus and the sutures are carefully tied in a cruciate fashion with care being taken to prevent overreduction and to avoid further comminution. The longitudinal tears in the rotator cuff are repaired with nonabsorbable sutures.

Once the fracture has been repaired, gentle mobilization of the humerus of up to 90° of abduction and 30° of external and internal rotation is tested intraoperatively. The intraoperative impression of a stable construct that moves as a single unit in all directions presumes the adequacy of fixation and avoids the need for intraoperative radiographic examination. The deltoid flaps are then reapproximated with use of absorbable sutures in a figure-of-eight manner. The subcutaneous tissue is closed with absorbable sutures, and the skin is closed with a subcuticular technique. A Velpeau dressing secures the arm to the chest wall. It is converted to a simple sling on the second postoperative day. Postoperative radiographs in the recovery room document the adequacy of reduction and fixation (Fig. 11).

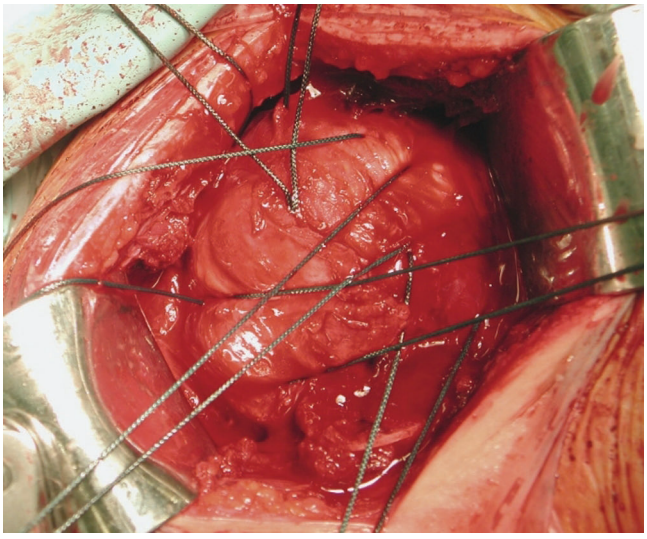
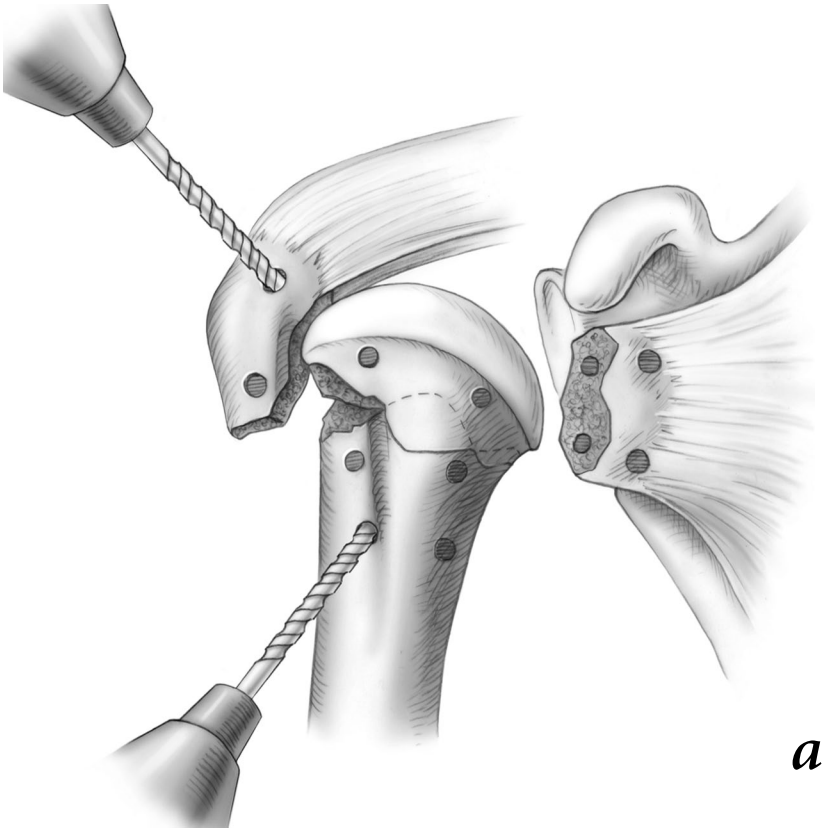


FIG. 7

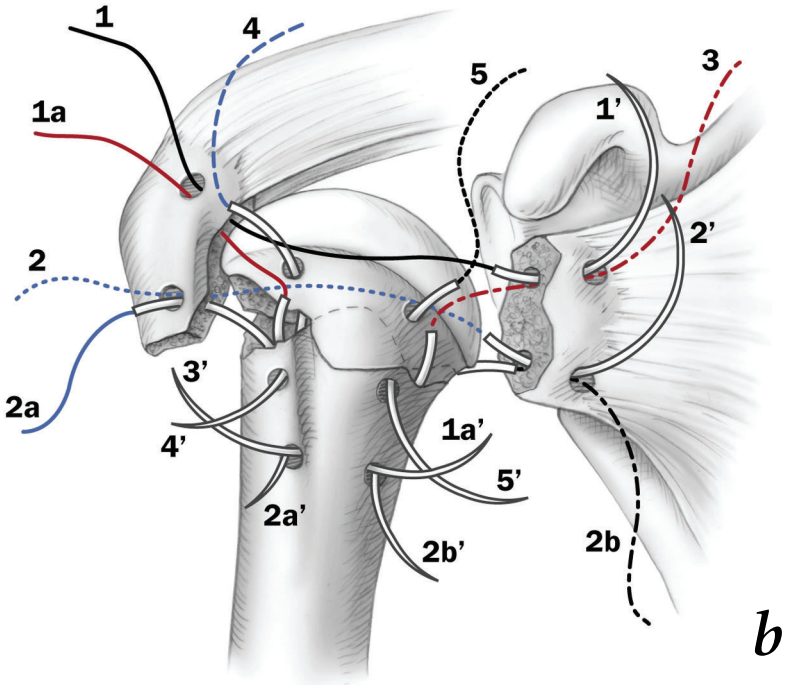
The fixation is demonstrated just prior to final tying of the knots. There is an adequate reduction and balance of the involved rotator cuff tendons. The fracture site has been closed, and both the tuberosities have been placed below the articular margin of the humeral head. Note the cruciate nature of the sutures.

REHABILITATION PROTOCOL

A closely monitored, three-phase rehabilitation program is administered to all patients. Initially, this consists of pendulum exercises starting on the second postoperative day and continuing until the third or fourth postoperative week. The second phase includes active-assisted range-of-motion exercises for a period of five to ten weeks. In the final phase, commencing at approximately three months after surgery, active dynamic shoulder motion and strengthening exercises are prescribed until the sixth postoperative month.



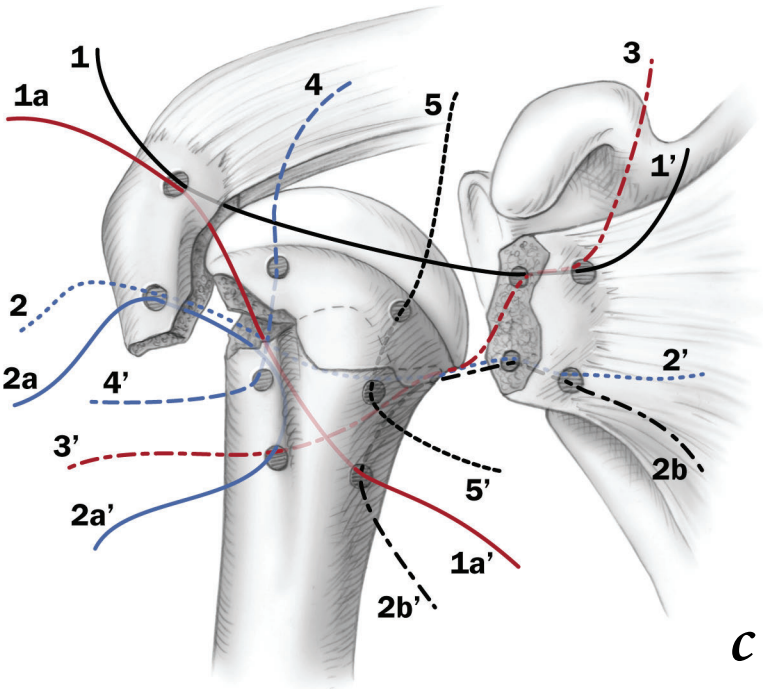
a



b

A four-part valgus impacted fracture of the proximal part of the humerus. *a:* Drawing showing the drilling of the greater and lesser tuberosities, the head fragment in its valgus impacted position, and the lateral and medial metaphyseal areas. *b:* The sutures are passed through the holes in the appropriate order as indicated by the numbers. *c:* The sutures are in place. The tuberosities are pulled down below the level of the top of the head and are tightened not only to each other but also to the metaphysis overlapping the lateral cortex. *d:* The postreduction appearance after tightening of all of the knots.

FIG. 8



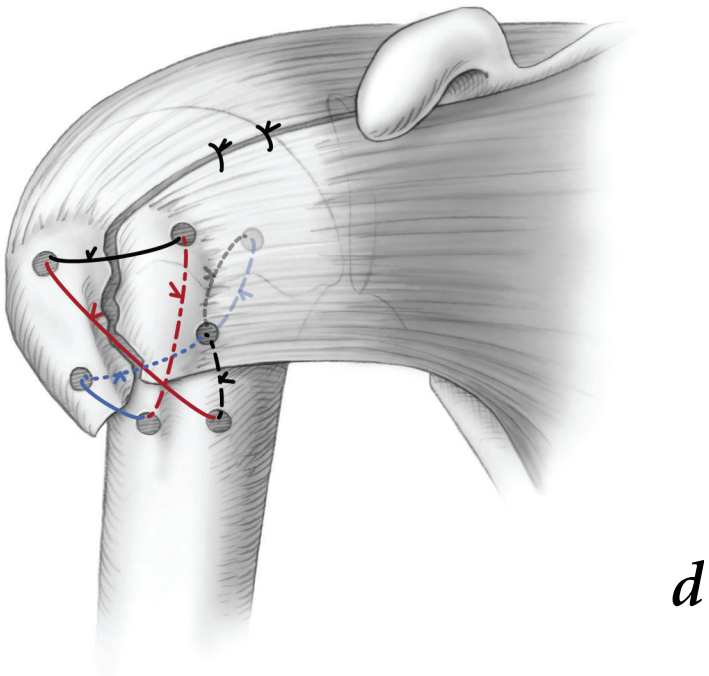
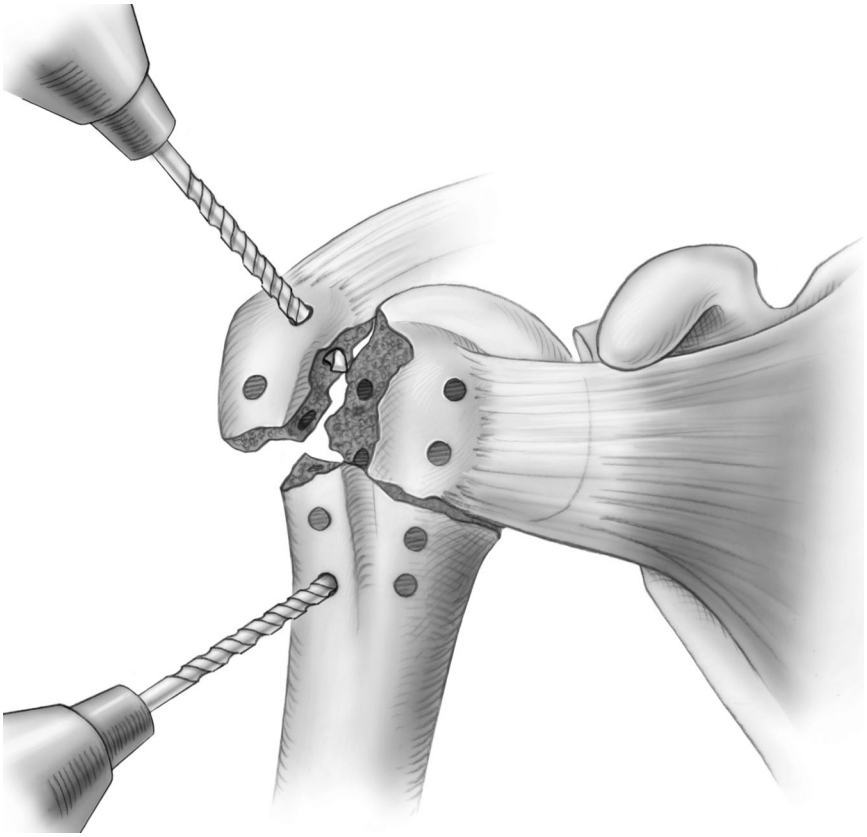


FIG. 8 (CONTINUED)



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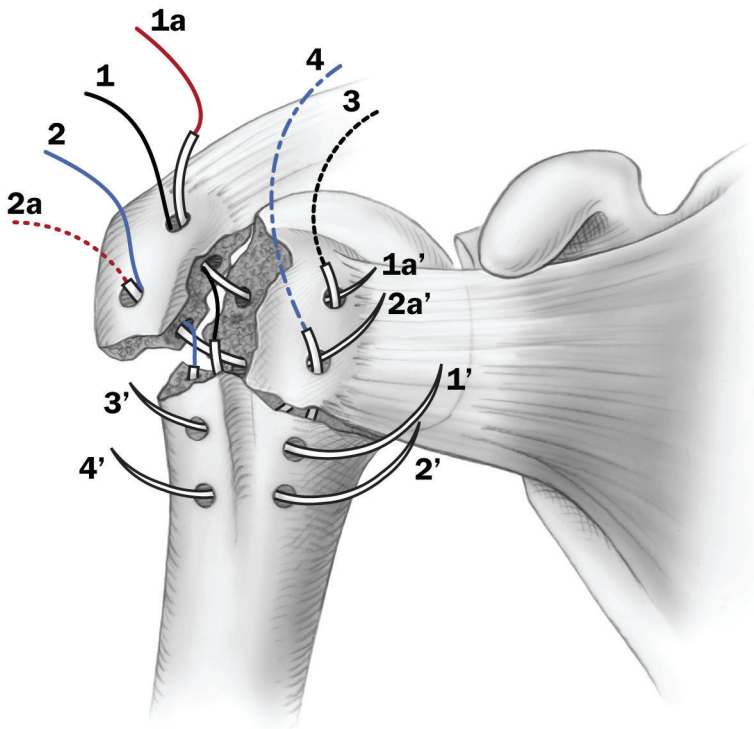
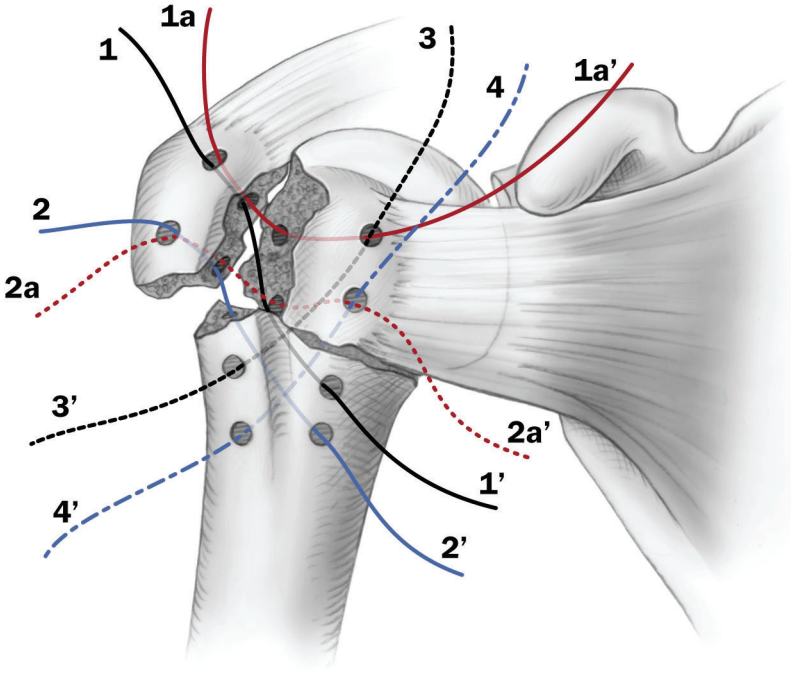


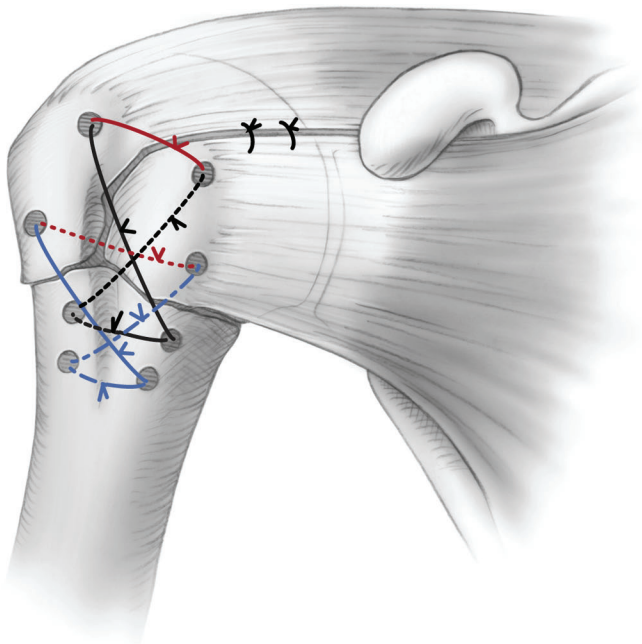
b

A three-part fracture of the proximal part of the humerus. *a:* Drawing showing the drilling of the greater tuberosity, the humeral metaphysis, and the lesser tuberosity. *b:* The sutures are passed through the holes as indicated by the numbers. *c:* The sutures are in place. *d:* The postreduction appearance after tightening of all of the knots.

FIG. 9

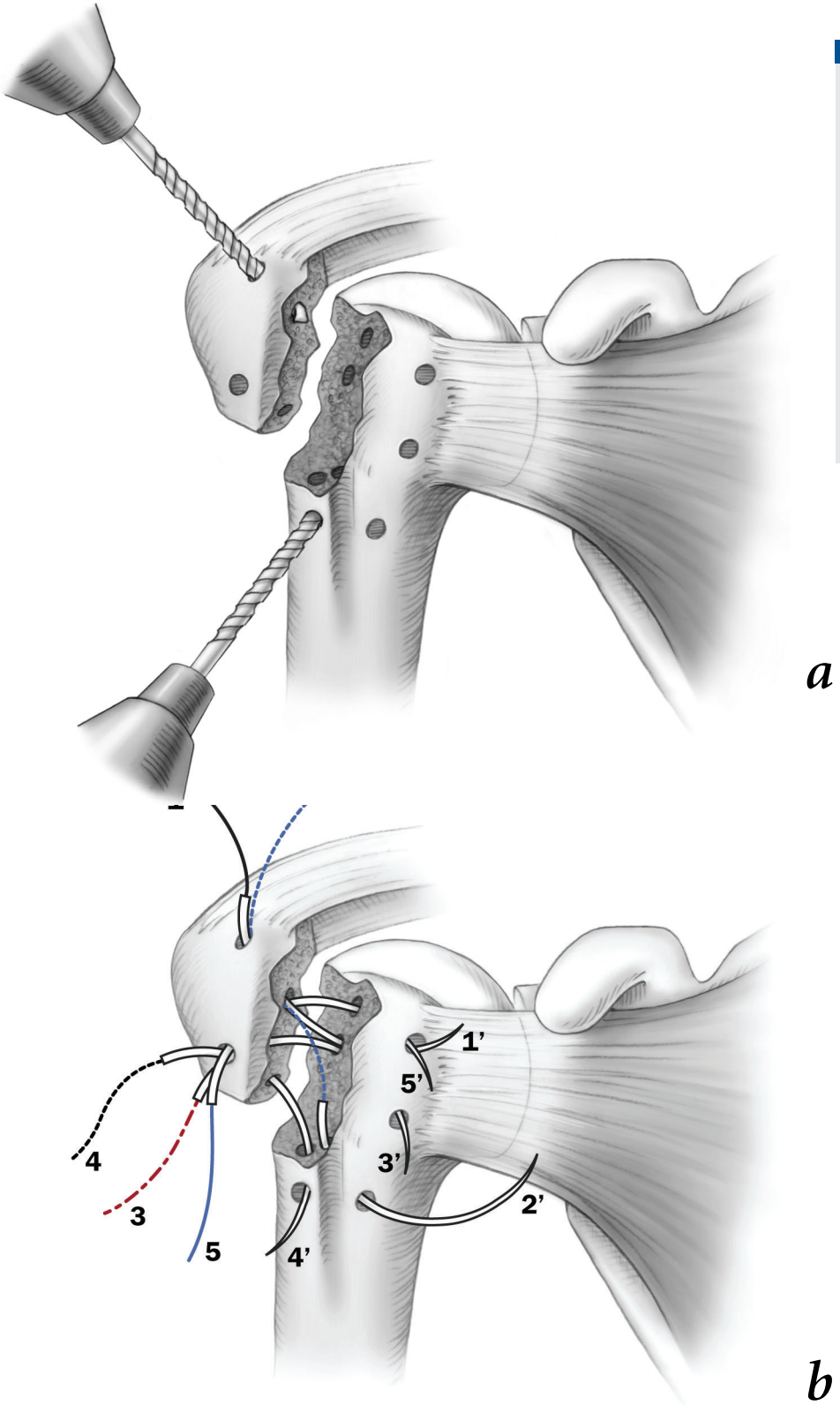


c



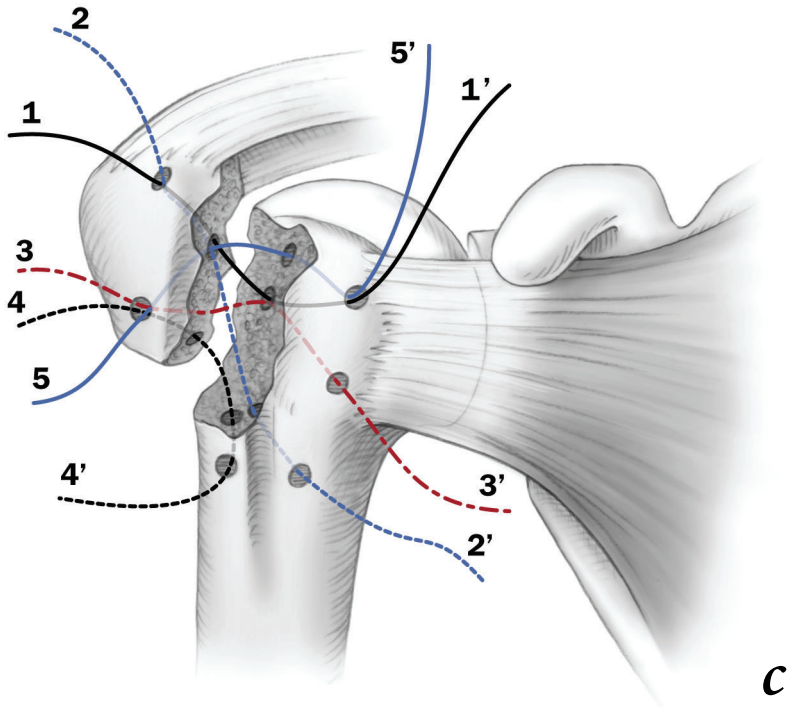
d

FIG. 9 (CONTINUED)



A two-part fracture of the proximal part of the humerus. *a:* Drawing showing the drilling of the greater tuberosity and the humeral metaphysis. *b:* The sutures are passed through the holes as illustrated following the order of the numbers. *c:* The sutures are in place prior to knot-tying. *d:* The postreduction appearance after tightening of all of the sutures.

FIG. 10



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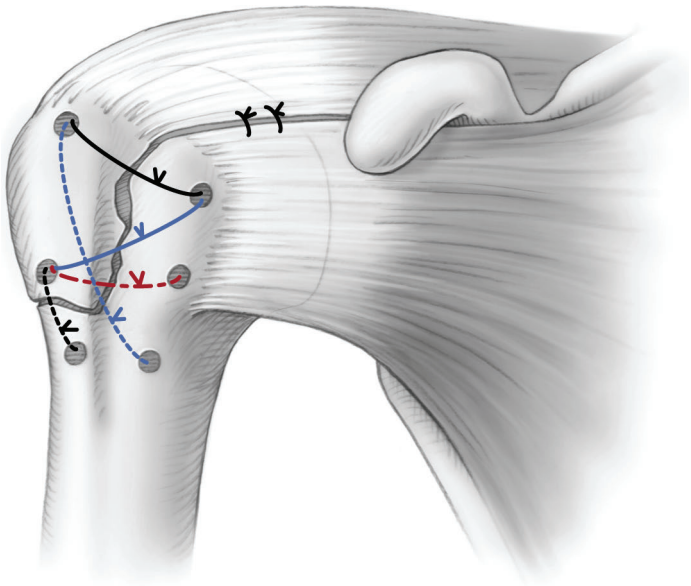

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FIG. 10 (CONTINUED)

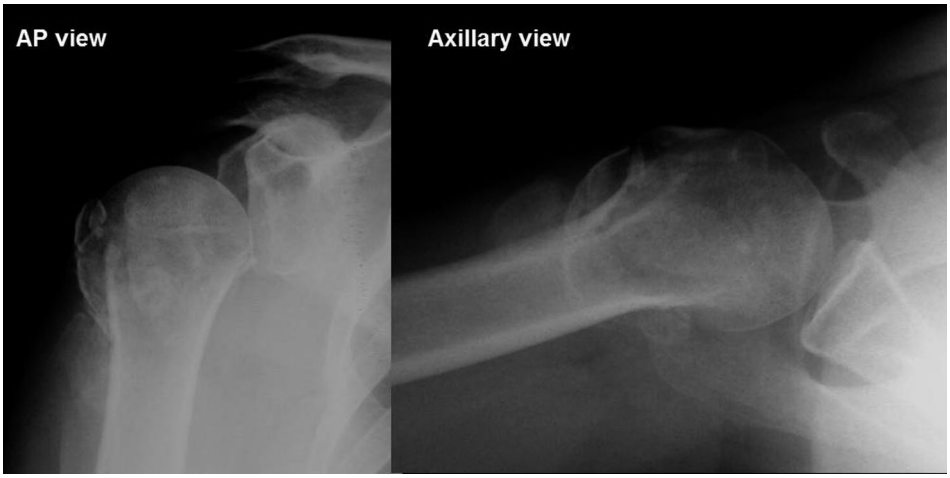

FIG. 11

Postoperative radiograph of the same four-part valgus impacted fracture as seen in Figure 1. The humeral head remains in its valgus position, and both of the tuberosities have been secured below the articular margin of the head. AP = anteroposterior.

CRITICAL CONCEPTS

INDICATIONS:

According to the classification of proximal humeral fractures proposed by Neer[4], the following types of fractures are appropriate for transosseous suture fixation:

- Two-part fractures of the greater tuberosity with or without an associated shoulder dislocation
- Three-part fractures or three-part fracture-dislocations
- Four-part valgus impacted fractures (with no more than 45° of rotational deformity and <6 to 7 mm of lateral displacement of the head on the anteroposterior radiograph)

CONTRAINDICATIONS:

- Displaced four-part fractures or four-part fracture-dislocations
- Two-part surgical neck fractures (relative contraindication)
- Head-splitting or anatomical neck fractures

POTENTIAL RISKS AND PITFALLS:

- The axillary nerve, which is the major anatomical structure in danger, is located approximately 5 to 6 cm distal to the tip of the acromion. With the transdeltoid approach, the deltoid split ends well proximal to the nerve since only 1 to 2 cm of metaphyseal exposure is required to place the drill holes in the shaft fragment. We believe that the main advantage of the lateral approach compared with the more standard deltopectoral approach is the preservation of the remaining blood supply of the humeral head, especially in four-part valgus impacted fractures[5].
- From a technical point of view, the passage of all sutures prior to fracture reduction is essential, as doing so can balance the deforming forces of the rotator cuff tendons and facilitate mobilization of the tuberosity fragments. The sutures are always tied in a cruciate fashion with use of a specific order of knot-tying. Loosening of the knots because of fracture compression is mitigated by tying additional knots between the free sutures also in a cruciate manner. We prefer heavy number-5 nonabsorbable sutures passed through 2.7-mm drill holes. The sutures are cut at the end of the procedure only

continued

CRITICAL CONCEPTS

POTENTIAL RISKS AND PITFALLS (CONTINUED):

after a stable construct has been achieved. With osteoporotic or severely comminuted tuberosity fragments, the sutures are passed near the musculotendinous junctions.

- The displaced tuberosities in four-part valgus impacted fractures are always pulled down below the top of the head fragment with the shoulder in the adducted position and are sutured not only to each other but also to the head fragment as well as to the medial and lateral aspects of the diaphysis in a manner that we believe neutralizes the deforming muscular forces. We avoid disimpacting the head fragment from its valgus impacted position, thus minimizing the risk of further disruption of the vulnerable blood supply of the posteromedial hinge. Despite this "incomplete" fracture reduction, it seems that the residual disturbance of normal anatomy does not affect shoulder joint mechanics. The moment arm of the rotator cuff muscles is preserved by suturing the tuberosities below the top of the impacted head. Use of this approach is supported by the very low rate of early degenerative arthritis seen in our series.
- In three-part fractures of the greater tuberosity, the sutures are passed through the intact lesser tuberosity. This provides a stable construct and restores the normal functional balance of the involved tendons, thus allowing for early shoulder joint motion. In isolated two-part fractures of the greater tuberosity, the displaced tuberosity is reduced to its anatomical position, thus avoiding a mechanical block to abduction of the shoulder or obstruction of external rotation because of posterior displacement of the greater tuberosity. Our preference is for suture fixation of the greater tuberosity fragment in patients with associated dislocation of the shoulder, regardless of the extent of its postreduction displacement[6]. Our decision to internally fix the greater tuberosity in its anatomical position is based on the nature of the injury rather than the degree of postreduction displacement. Recently proposed guidelines of 5 or 10 mm of greater tuberosity displacement as an indication for internal fixation cannot be followed because displacement often exceeds 20 mm at the time of dislocation. Associated tears of rotator cuff tendons, noted in the majority of our patients, are an additional indication for early surgical intervention.
- Regarding two-part surgical neck fractures, we believe that the optimal treatment is with plate-and-screw osteosynthesis. We do not recommend transosseous suture fixation in this type of fracture as rotational instability between the large proximal fragment and the narrow diaphysis can often be problematic. In such patients, stable fixation can be achieved only if the humeral head fragment is impacted to the diaphysis.
- Finally, integral to obtaining the optimum outcome is completion of the full rehabilitation program. An important variation of our current regimen over previous protocols is the early initiation of pendulum exercises on the second postoperative day and their continuation for the first three to four weeks. A full range of motion is restored in this manner without exerting stress on the fixation.

AUTHOR UPDATE:

No changes or modifications of the original technique have been made since its publication.

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The line drawings in this article are the work of Joanne Haderer Müller of Haderer & Müller (biomedart@haderermuller.com).

REFERENCES

1. Hawkins RJ, Bell RH, Gurr K. The three-part fracture of the proximal part of the humerus. Operative treatment. J Bone Joint Surg Am. 1986;68:1410-4.

2. Park MC, Murthi AM, Roth NS, Blaine TA, Levine WN, Bigliani LU. Two-part and three-part fractures of the proximal humerus treated with suture fixation. J Orthop Trauma. 2003;17:319-25.

3. Banco SP, Andrisani D, Ramsey M, Frieman B, Fenlin JM. Tension band fixation for unstable two-part humeral fractures in patients with osteopenic bone (parachute technique). Tech Shoulder Elbow Surg. 2001;2:50-3.

4. Neer CS 2nd. Four-segment classification of proximal humeral fractures: purpose and reliable use. J Shoulder Elbow Surg. 2002;11:389-400.

5. Panagopoulos AM, Dimakopoulos P, Tyllianakis M, Karnabatidis D, Siablis D, Papadopoulos AX, Lambiris E, Kraniotis P, Sakellaropoulos G. Valgus impacted proximal humeral fractures and their blood supply after transosseous suturing. Int Orthop. 2004;28:333-7.

6. Dimakopoulos P, Panagopoulos A, Kasimatis G, Syggelos SA, Lambiris E. Anterior traumatic shoulder dislocation associated with displaced greater tuberosity fracture: the necessity of operative treatment. J Orthop Trauma. 2007;21:104-12.