Interlocked Intramedullary Nailing of the Humerus

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ABSTRACT: Indications for use of the intramedullary interlocked humeral nail are: pathologic fractures, including those with severe osteopenia alone; nonunions, especially those with bone atrophy and/or marked osteopenia; and humeral shaft fractures with comminution, bone loss, or other causes of instability not controlled by conventional treatment methods. In this series, eight patients were treated by intramedullary interlocked humeral nail. Follow up ranged up to 30 months, with an average of 12 months. Five of six patients in this series who had the potential to unite their fractures did so. The remaining patient had a painless fibrous union. While the two patients with pathologic fractures of the humeral shaft caused by malignant tumors did not unite their fractures, the pain relief, functional recovery, and lack of postoperative morbidity justified the operative procedure.

Introduction

Humeral shaft fractures account for less than 5% of all treated fractures. In older patients with osteopenic bone, humeral fractures may have an incidence as high as 20%. Conservative methods such as hanging arm casts, functional bracing, coaptive splinting, sling and swath, and traction are still the basic standards of treatment. Intramedullary fixation of the humeral diaphysis has been shown to have a high incidence of nonunion and complications due to inability to control rotation. This can be attributed to the round design of most contemporary intramedullary devices. Experience with multiple flexible intramedullary wires or nails has fared little better. Plates have failed to provide satisfactory osteosynthesis in osteopenic or other pathologic diaphyseal humeral fractures. A review of morbidly obese patients with humeral shaft fractures has shown the highest incidence of nonunion by conventional methods of treatment, both closed and open. Therefore, the addition of interlocking capability to intramedullary nails in the humerus has made this an ideal implant for pathologic fractures, including those with severe osteopenia alone, nonunions (especially those with bone atrophy and/or marked osteopenia), and humeral shaft fractures with comminution, bone loss, or other causes of instability not controlled by conventional treatment methods.

An additional advantage of the interlocking intramedullary nail is that it is superior to plating in the humeral diaphysis in terms of load sharing and controlling bending forces over a greater length. In addition, an intramedullary nail does not require lengthy incision or extensive soft tissue dissection. Interlocked intramedullary nailing, when used for the indications detailed above, can be expected to provide good and predictable pain relief, functional improvement of the injured extremity, and facilitation of nursing care. It can be used in concert with bone grafting when appropriate. Intramedullary nailing is not used as an initial treatment in open fractures, although the interlocking nail may be used as delayed primary treatment in grade I and II open fractures and for salvage of grade III open fractures after coverage has been achieved. The interlocked intramedullary nail is especially useful in impending

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pathologic fractures and was the authors' initial choice in recent pathologic fractures. This device is not used in infected fractures.

**Operative Technique**

Insertion of an intramedullary humeral rod requires reaming of the medullary canal to conform to the rod. The proximal two-thirds of the humeral shaft is round, while the distal one-third is triangular in shape and is more susceptible to fracture.\textsuperscript{7,9} Reaming should be done gently and should allow sufficient endosteal contact on both sides of the fracture in as far as possible. Interlocking the humeral nail overcomes any failure of the nail to control rotation where there is a minimum of contact with bone. The patient is placed supine on a radiolucent fluoroscopy table. The nailing may be done in either antegrade or retrograde fashion.

Antegrade nailing is used for most fractures and defects throughout the humerus with the exception of those at the very most proximal part of the humerus where an antegrade approach might extend an existing fracture or precipitate an impending pathological fracture. Antegrade nailing requires placing the hand of the injured arm across the chest and onto the opposite shoulder, thus placing the injured humerus in an adducted, flexed, and internally rotated position. An incision up to 4 cm in length is made just below the acromion. The deltoid muscle is split in line with its fibers, exposing the humeral head. Under fluoroscopic control, the point of an awl is inserted at the junction of the middle and lateral thirds of the humeral head. The fracture is reduced and sequentially reamed to the desired diameter. Reaming must be monitored by fluoroscopy in order to avoid leaving the intramedullary canal and, consequently, injuring the radial nerve. A minimum 2 cm of rod contact in the intramedullary canal of the humeral diaphysis is desired and 4 cm is preferred whenever possible. The canal is reamed 0.5 cm larger than the nail to be used.\textsuperscript{10}

Retrograde nailing is reserved for fractures and lesions of the proximal third and occasionally for those at the junction of the proximal and middle thirds of the humeral shaft, where fractures or lesions might be further damaged by an antegrade approach. An incision is made just proximal to the olecranon tip with the elbow flexed at least 90°. The incision is extended proximally 5 cm to 6 cm, and the triceps muscle is split in line with its fibers, exposing the posterior humeral cortex. Care must be taken to avoid or to protect the radial nerve. The distal end of the intramedullary canal is localized with an image intensifier, and a 4.5 mm hole is drilled into the center of the posterior cortex approximately 3 cm above the olecranon fossa. This hole is centered over the distal intramedullary canal of the humerus and is progressively enlarged with larger drills or a router to the size of the first cannulated reamer. Failure to ream and angulate sufficiently may lead to difficulty in entering the canal with the reamers and in driving the nail, or fracture of the distal fragment. Reaming is carried out with great care to ream anteriorly against the posterior cortex of the humerus to ensure preservation of as much of the humeral canal as possible. The distal 3 cm to 4 cm of the intramedullary canal must be overreamed by at least 1 mm diameter greater than the intended nail. The proximal humeral diaphysis is only reamed to its flare so that the nail may purchase as much cancellous bone as possible prior to interlocking.

The proper length of the nail to be used can be determined either by measurement of the uninjured contralateral humerus or by measuring the guide wire directly after insertion under fluoroscopic control.

When interlocking the humeral nail in the proximal aspect, one must direct the screws away from the glenohumeral joint. In the open slotted Kuntscher nail, the end having the extraction (eye) hole is utilized for one of the interlocking screw holes. In antegrade nailing, this hole will remain proximal while in retrograde nailing, the eye will remain distal. The authors have modified straight Kuntscher nails by drilling additional holes, one adjacent to the extraction hole and two on the opposite end using a 3/16 inch cobalt alloy or titanium nitride drill bit that will penetrate the stainless steel. Extreme care is taken to remove all drill fragments that would leave dissimilar metals, in order to avoid local corrosion. The 3/16 inch drill measures 4.8 mm and allows the passage of the 3.2 mm drill bit, followed by the 4.5 mm tap and the appropriately measured 4.5 mm screws.

The interlocking screw holes are located in full relief under the image intensifier. Small incisions are made over the holes in the skin and carried through the muscle to the bone. A 3.2 mm drill bit is centered over the interlocking hole on the image screen and drilled through the bone and the intramedullary nail.
### TABLE
PATIENTS TREATED WITH KÜNTSCHER INTERLOCKING INTRAMEDULLARY NAILS

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Diagnosis</th>
<th>Contributing</th>
<th>Prior Treatment</th>
<th>Operation</th>
<th>Bone Graft</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>61</td>
<td>Nonunion 24 Months</td>
<td>Osteoporosis</td>
<td>Rush Rod x4</td>
<td>IM Rod Proximal/ Distal Interlock</td>
<td>Yes</td>
<td>Union Restoration of Motion</td>
</tr>
<tr>
<td>2</td>
<td>44</td>
<td>Nonunion 6 Months</td>
<td>Trauma</td>
<td>AO Plate</td>
<td>IM Rod Proximal/ Distal Interlock Cerclage</td>
<td>Yes</td>
<td>Fibrous Union Restoration of Shoulder Elbow Function</td>
</tr>
<tr>
<td>3</td>
<td>61</td>
<td>Pathologic Fracture 1 Month</td>
<td>Malignant schwannoma</td>
<td>Closed</td>
<td>IM Rod Proximal/ Distal Interlock</td>
<td>No</td>
<td>Return to Function Patient Died 5 Months Postoperatively</td>
</tr>
<tr>
<td>4</td>
<td>67</td>
<td>Nonunion 22 Months</td>
<td>Osteoporosis</td>
<td>Closed</td>
<td>IM Rod Distal Interlock Cerclage</td>
<td>Yes</td>
<td>Union Resolved Anterior Interosseous Nerve Lesion</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>Nonunion 6 Months</td>
<td>Alcoholism</td>
<td>Closed</td>
<td>IM Rod Proximal/ Distal Cerclage</td>
<td>Yes</td>
<td>Union Return to Function</td>
</tr>
<tr>
<td>6</td>
<td>67</td>
<td>Nonunion 5 Months</td>
<td>None</td>
<td>Closed</td>
<td>IM Rod Proximal/ Distal Interlock</td>
<td>Yes</td>
<td>Union Return to Function</td>
</tr>
<tr>
<td>7</td>
<td>40</td>
<td>Delayed Union 3 Months With Bone Loss</td>
<td>Gunshot wound</td>
<td>Closed</td>
<td>IM Rod Distal Screws</td>
<td>No</td>
<td>Union Return of Function</td>
</tr>
<tr>
<td>8</td>
<td>48</td>
<td>Multiple Myeloma Impending Fracture</td>
<td>Multiple myeloma</td>
<td>Interlock rod</td>
<td>IM Rod Interlock Distal Screw Cerclage</td>
<td>No</td>
<td>Stabilized Fracture Return of Function</td>
</tr>
</tbody>
</table>

The 3.2 mm drill bit is then removed from the drill and allowed to remain in the hole. Its position in the interlocking screw hole is checked with the fluoroscopy unit. The drill bit is removed and the depth gauge measures the length of the screw necessary. The hole is then threaded with the 4.5 mm tap. One or two 4.5 mm screws are then inserted above and below the fracture or lesion. This prevents collapse of the humerus and also controls rotation (Fig. 1).

In nonunions, the fracture site is treated with appropriate bone grafting. The nail is driven under fluoroscopic control and interlocked above and below without exposing the fracture site in pathologic metastatic lesions.

Hemovac drains are left in place for 24 to 48 hours. The arm is wrapped with bias cut stockinette and a sling is used for comfort. Depending on the type of lesion, the patient begins active assisted motion to the shoulder on the second or third postoperative day. The arm is placed in a sling for comfort during recovery and extreme internal and external rotation of the arm is avoided for 4 to 6 weeks. When clinical or radiographic evidence of union is seen, the patients are allowed to begin resistive exercises which are increased as tolerated. Unrestricted activity is allowed when the fracture is healed, usually 8 to 12 weeks after surgery. Patients with pathologic lesions are allowed guarded activity within the limits of pain tolerance.

**Clinical Data**

Eight patients were treated by the above method of modified Kuntscher interlocking intramedullary nailing (Table). Six were women and two were men. Ages ranged from 40 to 67 years, with an average of 57 years. There were five established nonunions, three of which had been treated by closed methods, that had failed due to inability to control the fracture. In addition, these patients had severe osteopenia. Two of the patients had been treated by a total of five operative procedures with a failure to achieve union. One patient had an open fracture with comminution and bone loss secondary to a gunshot wound which was unstable and had shown no clinical or radiographic progress toward union 3 months after injury. The remaining two patients had malignant tumors, a multiple myeloma and a malignant metastatic schwannoma.
Results

Each of the above patients was treated by a modified Kuntscher intramedullary interlocking humeral rod. Four of these patients had additional fixation with cerclage wires and two had adjunctive screw fixation. Each of the five nonunions was treated with simultaneous autogenous bone grafting. Four of these patients united their fractures and the remaining patient had a painless fibrous union. The patient with comminution and bone loss secondary to gunshot wound was slightly shortened and stabilized with the modified Kuntscher interlocking intramedullary nail; her fracture united. Although the two patients with pathologic fractures due to malignant tumor were not bone grafted and did not unite their fractures, they had substantial pain relief and functional recovery. The only significant complication of surgery in this series was a transient anterior interosseous nerve palsy in one patient.

Case Reports

A 61-year-old woman fell and sustained an oblique fracture at the junction of the proximal and distal
thirds of the right humerus. The fracture was treated nonoperatively for 13 months at which time a Rush rod was inserted and remained for an additional 14 months. Three Rush rods were interchanged for control of pain and motion, with each rod being successively larger. Continued instability of the fracture necessitated open reduction and attempted rigid internal fixation using a plate and screws 4 months after the Rush rods had been applied. This failed within 1 week and another Rush rod was inserted accompanied by allograft cancellous bone. With continued instability and nonunion, the patient was referred to the authors’ institution (Fig. 2), where static interlocked nailing and autogenous cancellous bone grafting were performed. The bony union of the fracture was not well defined radiographically (Fig. 3), but the patient has had an uneventful postoperative course with no pain and near normal function at 2½ years postoperatively (Fig. 4).

Another 61-year-old woman with recurrent malignant schwannoma of the jaw received radiotherapy and chemotherapy, but developed multiple sites of metastasis, including a site in the proximal diaphysis of the right humerus (Fig. 5). She experienced pain with abduction and rotation of the shoulder. She was treated with a static interlocking nail (Figs. 6-7). This eliminated all symptoms of pain and allowed func-

Fig. 4: Postoperative functional performance.

Fig. 5: AP view. Preoperatively malignant schwannoma to the proximal humerus.
tion of her extremity until her death 5 months postoperatively.

**Discussion**

While simple humeral fractures are usually best managed nonoperatively, those with complex configuration, nonunion, impending or frank pathologic fracture due to tumor, or those humeral fractures with osteopenia that require fixation may be treated with a minimum of morbidity and reasonable reliability to achieve union or stability using an interlocking intramedullary nail. Adjunctive bone grafting is used where indicated in cases of complex configuration and nonunion. Rush pins and other intramedullary devices used without locking have not been reliable.

Osteopenia and bone atrophy at the fracture site prevents the use of plates and screws due to inadequacy of bone purchase. Similarly, comminution and bone loss may prohibit the use of plates and screws due to the extent of the bone involvement. Although the technique of application of the intramedullary interlocked humeral nail is demanding, there have been few complications.

**Conclusion**

The interlocking intramedullary nail provides an excellent means for stabilizing humeral fractures which cannot be controlled by closed or other types of open methods. When comminution, bone loss, or nonunion are present, interlocked intramedullary
nailing along with appropriate bone grafting provides reasonably reliable salvage and achieves union and functional recovery in most cases. It is particularly useful where other methods of internal fixation have failed to achieve union and in uncontrolled fractures or nonunions with osteopenic bone. It is an excellent method of stabilizing pathologic fractures or impending fractures secondary to malignant metastatic or primary bone tumors and provides stability, pain relief, and functional improvement. There usually is minimal associated morbidity.

References


Editorial Discussion

ORTHOPEDICS: The advent of the interlocked intramedullary nail truly allows us to address problems of humeral fracture stabilization and healing where previous remedial efforts held little hope of success. Drs Ward and White have laid a foundation for what we feel will be an expanding number of successful humeral reconstruction and salvage procedures. It is noteworthy that this implant device is especially suitable for achieving both stability and preservation of blood supply in the situation where vascularity has often been an important component of previous failure of osteosynthesis.