Original Article

SEIDEL INTRAMEDULLARY NAILING OF HUMERAL DIAPHYSEAL FRACTURES: A PRELIMINARY REPORT

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ABSTRACT

Forty-two humeral diaphyseal fractures in 41 patients were treated at three centers between April 1988 and November 1989. There were 28 acute fractures; four were open. Average time to union was 8 weeks. There were no infections. Six patients with seven pathologic fractures due to metastatic disease died during the course of this study, but the nail had allowed them to be functional with minimal surgical dissection. Five of six nonunions united with one procedure. There was one residual nonunion in a patient with a wide canal and an arthrodesed shoulder above the nonunion. There were three preoperative radial and two preoperative axillary nerve palsies, and no iatrogenic nerve palsies. In all patients with anterior deltoid incisions, shoulder motion returned reliably, but took as long as 6 months. Four rods were left prominent in the rotator cuff and the patients had symptoms of impingement until rod removal. Six patients had restricted shoulder function, one due to a fracture of the humeral head and five from a lateral deltoid incision. This incision was used in 12 cases. There were no stiff shoulders when using an anterior deltoid incision.

The primary treatment for diaphyseal humeral fractures is clearly nonoperative. Options include hanging casts, coaptation splints, sling and swathe, traction, and functional bracing, the preferred method of treatment. Union rates are high, and the few subsequent nonunions are easy to correct. Shoulder and elbow motion and humeral shortening have not been clinical problems. Minor deformities resulting from this treatment have, likewise, not been significant clinical problems.1 4 There are, however, several indications for internal fixation. Absolute indications include pathologic fractures, "floating elbows," and fractures associated with vascular deficits. Relative indications include nonunions, fractures involving the metaphyses, and obese and polytrauma patients. Open fractures in selected cases also may be included. In addition, some patients cannot tolerate the painful motion of their fracture within a functional brace. Some fractures are of such high energy that they cannot be held adequately within a brace. Patients with radial nerve palsies and bilateral humeral fractures, or multiple upper extremity fractures, frequently require operative stabilization.5 22

Polytrauma patients sustaining high energy fractures are of particular interest to us and make up the bulk of our patient population. The polytrauma setting has two considerations regarding humeral fractures. The first is bringing the arm away from the chest for pulmonary care and patient mobilization. The second is the necessity to walk on crutches, as many of these patients will have pelvic or lower extremity injuries.6 It is with these last two considerations that we have developed an interest in intramedullary nailing of the humerus. A closed nailing technique allows more rapid patient mobiliza-
tion and ambulation on crutches. Our previous experience with flexible nailing of the humerus mirrors others in the literature, where early patient mobilization is possible but difficulties with union are encountered.6,10,11 Even in the polytrauma setting when weightbearing on the arm is necessary, many of our patients have been treated well with functional bracing.

Plate fixation of the humeral diaphysis is an excellent technique for achieving union and shoulder motion.16,17,22 Necessary dissection of the arm, however, is considerable, coupled with increased operative time and possible increased infection rates. Patients cannot ambulate with crutches on a humeral plate. Metal removal and reoperation for nonunion place the radial nerve in considerable danger.23 Cortical atrophy due to circulatory compromise and stress protection under a plate make plate and screw removal dangerous.

It is, therefore, with considerable interest that we view the Seidel nail, a load-sharing device, as a means of a closed, intramedullary technique which would stabilize very complex fractures without the difficulties of union encountered with flexible nails, and with less dissection and more rapid weight bearing than plate fixation.

MATERIALS AND METHODS

Between April 1988 and November 1989, 42 humeral diaphyseal fractures in 41 patients were treated with Seidel intramedullary fixation. Indications for surgery were 7 nonunions (8 through 36 months duration), 7 pathologic fractures in six patients with metastatic carcinoma, and 28 acute fractures. Of the acute fractures, 2 were due to close-range shotgun blasts, 4 from high-energy isolated humeral fractures, and 22 from blunt trauma patients. Twenty-four fractures were closed, 3 were open grade 3B, and 1 was a grade 2 open fracture.

Six patients with metastatic cancers died during the course of this study, but their function prior to their death was well-documented. One patient with an acute fracture moved out of state 2 months postinjury. One 85-year-old patient died of unrelated health conditions 4 months postinjury. These last two patients had their courses documented prior to their death. All other patients were available for review.

Twelve cases were performed with a deltoid incision extending laterally from the tip of the acromion. This procedure has sometimes allowed the surgeon to insert the nail too far posteriorly and laterally. It brought the rotator cuff incision close to the greater tuberosity. Thirty cases were performed through an anterior deltoid incision that allowed the rotator cuff incision to be in a better substance of rotator cuff and allowed a more linear access to the shaft of the humerus.

Intraoperatively, the patient is positioned on a radiolucent surgical table (Fig 1). A pacemaker insertion table will suffice in most current operating rooms. The patient is placed at the side of the table opposite the surgeon. The contralateral arm is fully abducted. The limiting factor of many fluoroscopy set-ups is the length of arc of the C-arm. With the patient positioned at the opposite side of the table and the opposite arm fully abducted, the C-arm can come in through the opposite axilla and across the patient’s chest and easily reach the fractured humerus. In this position the surgeon can place long guide rods and reamers through the shoulder and not have to abduct the operative arm. The arm can remain at the patient’s side while the surgeon operates.

To obtain a lateral view, approximately 30° of obliquity can be obtained in either direction by rotation of the C-arm. The position of guide rods and implant on the lateral view can be further ascertained by rotation of the patient’s arm. Care must be taken to be certain that the guide rods are not directly posterior to the humerus and that the rotating bone is overlapping a stationary guide rod. As an additional check under fluoroscopy, the arm is stressed into varus and valgus throughout the case so the guide rods are not overlapping the cortex as an indication of their being extraosseous.

A roll is placed behind the operative scapula to elevate the operative shoulder off the bed (Fig 1). This extends the shoulder approximately 20° to 30°. This extended position of the shoulder brings the anterior half of the humeral head out from under the acromion.

A 2 cm incision is made anterior to the mid portion of the acromion (Fig 2). A longitudinal incision is made through the deltoid muscle.
The deltoid muscle is not elevated from the acromion. The claviculo-pectoral fascia is incised, exposing the rotator cuff. An incision beginning approximately 1 cm medial to the greater tuberosity and 1 cm in length is made in line with the fibers of the rotator cuff. Care is taken not to enter the greater tuberosity area, as this is the most avascular and poorest-healing area of the rotator cuff. An awl is inserted into the head of the humerus.

The decision whether to ream or not ream is based on the canal diameter in the preoperative radiographs. In questionable cases, reaming is safer. If reaming is to be performed, an appropriate guide system is used. A 2 mm rod is inserted into the humerus. The spreading screw is inserted into the end of the Seidel nail, and the nail is driven into the canal of the bone. The spreading screw provides a rounded tip for easy nail insertion. The apex of the bend of the nail faces anteriorly. The nail is inserted until the proximal end of the nail is within the head of the humerus. Minimal protrusion of the nail is associated with significant impingement symptoms. The spreading screwdriver is then inserted through the upper end of the nail into the spreading screw and turned counter-clockwise until tight. When inserted unreamed, the spreading screwdriver sometimes cannot be turned, and this does not represent a clinical problem. In these cases, bone enters the interstices of the phalanges of the nail and provides excellent stability. The upper locking screws have guides. When inserting the upper locking screws, a longitudinal skin incision is made, and a curved hemostat is inserted to the bone. With the lateral screw a longitudinal spread is made, and with the anterior screw a transverse spread, to remove the axillary nerve or biceps tendon, respectively, from the drill point and screw. In osteopenic bone, locking screws should be drilled under fluoroscopic control, as the bone can be very soft and there is sometimes not a good feel of the opposite cortex, and over-penetrating with the drill bit is easy and dangerous. From the anatomic dissections of Kellam, it is apparent that there is a significant risk of axillary nerve damage in the quadrilateral space when over-penetrating with the anterior-posterior drill point and screw. We, therefore, prefer to use only the medial-lateral proximal screw.

Reaming the humerus is unlike reaming other bones. There is no distal flap of the medullary canal, and, therefore, no place for debris to run. The bone is very hard and reaming can be very difficult. Furthermore, the distal fragment is often very short. If a reaming guide rod backs out a couple of inches, it may exit the fracture site and rest in the soft tissues, making the next stage dangerous. When reaming was necessary, we initially reamed to 11 mm and inserted the nail by hand. This did not give very good rotational control, and we now ream most of the bone to 11 mm but only ream the distal portion of the canal where the spreading screw is designed to have fixation to 10 mm.

The rotator cuff is not repaired, or repaired with a nonabsorbable suture, so the rotator cuff incision can be found at nail removal. With the nail buried, the rotator cuff often lies in position without a gap. The deltoïd is repaired loosely, and the skin is closed in the usual fashion. Shoulder motion is begun early. Unless fixation is precarious, patients can walk on crutches as soon as comfortable, generally in 2 to 7 days. The Seidel nail can be used when there is bone stock 2 cm below the surgical neck of the humerus and 5 cm above the end of the medullary canal. These are the necessary fixation areas for the proximal locking screws and distal spreading device, respectively. We have stabilized some fractures beyond the standard fixation areas, but these have been exceptional cases. Because of the fair distal rotation control with the spreading device, we do not believe that two proximal screws are necessary for proximal fixation, except where proximal screw purchase is precarious.

The Seidel nail was developed in Hamburg, Germany, by Dr Hartmut Seidel. It is stainless steel with a closed section, presently available in only a 9 mm diameter. It has two transverse proximal locking screws, one AP and one medial-lateral. Distal locking is accomplished internally to avoid the problem of screws and power tools potentially damaging neurovascular structures near the bone in the distal humerus. Three longitudinal splits are made in the distal nail wall. A 9 mm ball with a reverse screw is
inserted into the distal end of the nail and is reached by a screwdriver inserted through the proximal end of the nail. When this 9 mm ball is retracted, it expands the phalanges of metal between the longitudinal cuts in the distal nail against the endosteal cortex. Through Kellam's biomechanical studies, it is apparent that this gives, at best, fair rotational control but excellent axial control.26

A "cap washer" is also available in Europe. This does not, at the time of publication, have FDA approval. The "cap washer" screws into the proximal end of the Seidel nail. It has five malleable phalanges used to grip fractures of the humeral head. Insertion of the "cap washer" requires an acromioplasty and early removal. As it is not FDA approved, it has not been analyzed in this study.

RESULTS

For acute fractures, the average time to union was 8 weeks (range: 6 to 16). This result excludes one gunshot wound, which united in 24 weeks and is an exceptional case (Fig 5).

Twenty-two patients had excellent shoulder mobility, within 15° of normal forward flexion, and abduction with no complaints of shoulder discomfort. Five patients had adequate shoulder motion, losing between 15° and 30° of forward flexion and abduction, without complaint. These five were done through lateral incisions, which, again, place the rotator cuff incision in an avascular area of the cuff. One patient with a significant fracture of the humeral head had a resultant 90° of abduction, with stiffness due to impingement from bony prominences. The nail did an excellent job of holding a split humeral head on the humeral shaft.

Shoulder motion, especially with the anterior incision, has returned reliably, but slowly. Some cases have required up to 6 months to see shoulder motion reach a plateau. For unclear reasons, some patients regained their shoulder motion literally on their first postoperative day. The slow return of shoulder motion has been a greater clinical problem than the ultimate function of the shoulder joint itself.

Four rods were left proud. In two cases, this was due to an old design insertion device that broke during nail insertion. This defect has been redesigned and has not occurred again. All four patients impinged due to their proud rods but regained shoulder motion and function upon rod removal.

Of the seven nonunions, six healed with one operation. Three underwent bone grafting at the time of their operative stabilization. All nonunions significantly improved their shoulder motion and comfort postoperatively. The exact increase in range of motion is difficult to ascertain because preoperatively it was difficult to tell if they were moving at the shoulder or at their nonunion site. The residual nonunion occurred in a twice-operated humeral nonunion in a very large patient with a wide canal and an arthrodesed shoulder. He originally injured his arm weightlifting. The distal fixation device of the Seidel nail did not adequately hold in rotation in the wide canal. Furthermore, the arthrodesed shoulder placed great stresses on
the hold of the spreading phalanges in the bone.

Although all of our patients with pathologic fractures died during the course of this study, they had been able to achieve, with minimal surgical dissection, excellent function of their arms in a very short time. The Seidel nail appeared to be an excellent treatment in these patients.

Nine patients had significant pelvic or lower extremity fractures. All were able to ambulate on their arms with crutches or on a bed-to-chair regimen without external support of a brace. No patients had difficulty with elbow mobility or function. There were three cases of iatrogenic comminution with the lateral deltoïd incision, and none with the anterior deltoïd incision.

There were no infections. There were three preoperative axillary nerve and three preoperative radial nerve palsies. There were no iatrogenic nerve or vascular injuries. The authors believe serious consideration should be given to direct visualization of the radial nerve in a patient who presents with a partial or complete radial nerve palsy preoperatively, to be certain the nerve will not be damaged by closed manipulation.

As these nails were of an early design, there were five breakages of the insertion equipment. This hardware problem has been resolved, and in over 40 subsequent cases there have been no further breakages. During the course of this study we saw one distal spreading screw back out of the end of the nail. We have now seen this in approximately 10% of our patients, including patients outside this study. This problem has not led to clinical failures, but is being investigated (Figs 3-5).

All fractures have healed within 12° of their normal axis. No patients had deformities that have caused functional difficulties. The humerus does not have to be perfectly straight to function normally. The medial-lateral upper locking screw is inserted in proximity to the distal end of the axillary nerve. The AP proximal locking screw is inserted in proximity to the biceps tendon, but immediately behind the bone is the axillary nerve in the quadrilateral space. There were no instances of iatrogenic nerve palsies or tendon injuries. Preoperatively, we documented two axillary and three radial nerve palsies. Care is taken with screw insertion to

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**Fig 4A:** Severely comminuted distal humerus fracture in a 7-foot tall laborer.

**Fig 4B:** Fixation with humeral locking nail. The longest available nail barely crosses the fracture site.

**Fig 4C:** Fracture has united uneventfully. Patient with head injury thrashed for 2 weeks postoperatively. Fixation held despite patient's size, combativeness, and the fact that the distal spreading screw backed out the end of the nail.
move important structures out of the path of power tools and locking screws. Six nails have been removed. In each case fluoroscopy was used to find the proximal end of the nail so as not to make multiple holes in the rotator cuff, and precautions were taken to protect the biceps tendon and axillary nerve with screw removals. There were no infections in this series. Only four of our fractures were open, however, but they were both associated with significant trauma and soft tissue loss.

**DISCUSSION**

Excellent results can be obtained with good functional brace treatment of many humeral diaphyseal fractures. When faced with difficult clinical problems of fixation, the Seidel has proven a useful addition to our operative armamentarium. It is a means of stabilizing complex and pathologic fractures with minimal soft tissue trauma, has held well in osteopenic bone where plate and screw fixation would be precarious, and has stabilized comminuted fractures outside the realm of flexible nailing with much less dissection than plate fixation. Union has occurred reliably and rapidly. Patients have been able to weight bear early on their arms. It has thus been an excellent device for early mobilization of the polytrauma patient.

As the nail is inserted through the rotator cuff, shoulder motion has to be a concern. With the anterior deltoid incision, our shoulder motion has returned reliably. All patients have achieved within 15° of their preoperative shoulder motion. It is important to note that patients do not have significant functional complaints regarding the shoulder, as long as the nail is inserted deep enough into the substance of the humeral head and adequate therapy is employed. The greatest concern relative to shoulder motion is the time needed to reach a plateau. This has sometimes been an uncomfortably long interval of up to 6 months. This has been a greater clinical problem than the ultimate shoulder function itself.

Slow return of shoulder function is clearly not the sole result of violation of the rotator cuff. Other authors have noted the same clinical concern when treating humeral fractures with flexible nails without violation of the rotator.
cuff. As fractures have healed, shoulder motion has returned, and ultimate shoulder function has been satisfactory. An exact interval to return of shoulder function is difficult to analyze because a number of these patients have had head injuries that have precluded their cooperation in physical therapy for their immediate post-injury period. It is clear, however, that in some patients without head injuries, shoulder motion can take as long as 6 months to plateau. It is also clear that when the rod is left proud in the rotator cuff as a technical error of nail insertion, until rod removal, the patient will experience significant shoulder difficulties. It is imperative that the nail be inserted adequately into the substance of the humeral head.

All of our ultimate shoulder problems and iatrogenic comminutions have been seen in cases where an incision off the lateral border of the acromion was used. This method allows a too posterior and lateral positioning of the insertion point of the nail. The nail is so strong relative to the humerus that any eccentric positioning of the nail can fracture the humerus. Furthermore, the incision in the rotator cuff should be made in good vascular tissue. The area of the greater tuberosity exposed with the lateral incision is the most avascular portion of the rotator cuff and should be avoided. We now routinely use an incision over the anterior half of the acromion. This allows a direct longitudinal axis to the diaphysis of the humerus and makes it easy to place our rotator cuff incision in good substance of tendon tissue.

Our starting point clearly violates the articular surface of the humeral head. It is the most lateral portion of the superior part of the head articular surface involved. This area will only articulate with full abduction of the shoulder, which is cause for very little clinical concern. Most of our patients come within 15° of their contralateral shoulder motion. They do not notice this difference in mobility, but its source
may be this loss of the edge of their articular surface.

As this is a new device, there have been difficulties with the equipment. Many have been resolved at the time of this writing. The only remaining difficulty is loosening of the distal spreading screw, and this aspect of the Seidel nail design is under study. We have not seen clinical failures associated with these mechanical failures (Figs 4,5). We have used this nail in three fractures open grade 3B and one fracture open grade 2. None has become infected. This is far too small a sample to advocate the use of the nail routinely in open fractures. Further data is necessary.

The Seidel nail has been an excellent means of stabilizing humeral fractures when internal fixation is necessary. Ultimate shoulder motion is satisfactory. Our greatest clinical problem with the Seidel nail has been the rate of return of shoulder motion. When fracture problems are complex, the Seidel nail has been a very efficient means of achieving stabilization. In these cases the tradeoff of slow but reliable return of shoulder motion for minimal surgical dissection and good fixation makes the Seidel nail very attractive. The ability to immediately weight bear on the fractured humerus is, likewise, an obvious advantage. Whether the Seidel nail will perform more reliably than plate fixation or flexible nailing in fractures of simple geometry that require internal fixation is yet unclear.

CONCLUSION

The Seidel humeral nail has been an excellent adjunct to our other forms of treatment for humeral fractures, especially when fixation problems are difficult, due to either the complexity of the fracture or bone quality. The nail has routinely been useful within 2 cm of the surgical neck and 5 cm of the distal end of the humeral canal. Ultimate shoulder function has not been a significant clinical problem. Slow return of shoulder function has been a concern. Early extremity function and weight bearing have been achieved reliably in both traumatic and pathologic fractures. When humeral diaphyseal fixation is necessary, and especially when the fixation is potentially precarious, the Seidel nail has proved extremely effective.

REFERENCES