Clavicular fractures account for approximately 4% of all fractures, and 80% occur in the middle third.\textsuperscript{1,2} Surgery is rarely indicated except for neurovascular compromise, skin compromise, multiple injuries, and open fractures. Various modes of treatment have been proposed, but are associated with complications.\textsuperscript{3} Increased nonunion rate and unaesthetic scar were the most important factors resulting in poor satisfaction.

This article describes a technique using closed reduction and percutaneous intramedullary fixation for midclavicular fractures.

**SURGICAL TECHNIQUE**

A surgical table with radiographic transparency is used, and head-tail position of the table is reversed to provide sufficient working space for the C-arm image intensifier.

The patient is placed in a semi-sitting position with the back elevated approximately 30°. General anesthesia is recommended. A rolled towel approximately 15 cm in diameter is placed obliquely under the back to allow the affected shoulder to hang free at a 30° elevation. The resultant position makes the S-shaped clavicle lie flat in a horizontal plane. To perform the operation precisely, the C-arm should visualize the clavicle in two views in 90° crossover. The base of the C-arm should be placed at the sound side, with the rotation axis passing through the affected clavicle. Hence, the S-shaped view and I-shaped view can be switched easily by rotation of the C-arm (Figure 1).

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The area is disinfected and draped with the entire clavicle, acromion, and upper half of scapula exposed. The bony structures, including the clavicle, fracture site, scapular spine, and acromion, are palpated and marked with a marking pen (Figure 2). A straight line is drawn along the axis of the distal fragment, and a small incision is made on the line 2 cm posterior to the clavicle. The incision is extended from medial to lateral, approximately 1.5 cm in length. A
Kelly hemostatics is used to dissect the soft tissue bluntly to the bone.

The ideal inlet locates along the axis of the medullary canal on both the S-shaped view and I-shaped view (Figure 3A). This point is critical because a malpositioned inlet may result in malalignment, poor purchase of the bone and screw, or iatrogenic fractures.

A 1.2-mm Kirschner wire combined with a 2.7-mm cannulated reamer is used to create the inlet and open the medullary canal. The cannulated reamer may act as a sleeve to control the position of the thin K-wire. The K-wire is anchored on the bone at the appropriate position. The C-arm is used to verify the position on both the S-shaped view and I-shaped view; the K-wire is driven into the bone (Figure 3B). The canal is opened by the cannulated reamer (Figure 3C). The K-wire and reamer must be carefully aligned to prevent K-wire breakage. This reamer should be used only to make an opening to the canal, and should be advanced no more than 1 cm to prevent excessive propagation of the K-wire.

Figure 3D and 3E). For a thinner clavicle, a Knowles pin can be used. After the distal fragment and inlet are prepared, the fracture is then reduced. In most circumstances, the distal fragment migrates medially, and the proximal fragment displaces upward and backward. The distal fragment usually is small and difficult to control. A cannulated tap engaged on the distal fragment is used to assist with fracture reduction.

With the guide pin in place, the cannulated tap is inserted to hold the distal fragment and a traction force is applied. The proximal fragment is pushed downward and forward to align with the distal fragment (Figure 3F). Usually, the fracture site can be palpated and the reduction appreciated because the clavicle is a subcutaneous bone. C-arm images may be needed for obese patients or patients with substantial soft-tissue swelling. Reduction should be carried out gently with attention to the neurovascular bundle and lung lying just under the clavicle.

After reduction is achieved, the guide pin is advanced into the proximal canal (Figure 3G). Bony alignment and guide pin position are checked with the C-arm. The tap is removed with care to keep the guide pin in place. Another guide pin with identical length can be used to measure the optimal screw length. A cannulated screw is inserted through the guide pin (Figure 3H). The isthmus of the medullary canal usually locates laterally, and reaming of the proximal fragment is not required. The screw head should abut against the bone as closely as possible to reduce screw head protrusion and irritation. However, a screw tip penetrating the anterior cortex may also cause prominence and irritation and should be avoided. The wound is closed.

Postoperative care includes sling support for 1-2 weeks for comfort and progressive range of motion.

**CASE REPORT**

A 41-year-old man presented with a left midclavicular fracture with marked displacement, skin tenting, and bony comminution (Figure 4). Closed reduction and intramedullary fixation with a 7-mm cannulated screw was performed. Anatomical alignment was achieved, and the fixation was stable (Figure 4). On postoperative day 2, pain according to visual analog score was <2 points. Radiographs at 10-week follow-up showed stable fixation and bone healing (Figure 4C). The patient had full range of motion, and the Constant-Murley Score was 88 points.

**DISCUSSION**

Intramedullary fixation of midclavicular fractures via an open method with various implants such as the Rush pin, Kirschner wire, and Knowles pin has been widely used. We present a standardized, reproducible technique for measurement on radiographs. In a male adult, a 6.5-mm cannulated screw is used in the clavicle. A 2-mm, blunt-tip guide pin is inserted into the canal, and the canal is reamed to appropriate size (Figures 3D and 3E). For a thinner clavicle, a Knowles pin can be used.
closed reduction and fixation of these fractures that avoids the technical problems of imaging, the optimal location of the inlet, and reduction. The entire procedure resembles closed nailing for long bones. It may be the simplest of all because the clavicle is small, palpable, and easy to manipulate.

This technique has some limitations and disadvantages. First, this technique was designed for fresh fractures. It has not been applied to fractures >7 days old or fractures with nonunion because difficulty in closed reduction is anticipated. Second, not all fractures classified as midclavicular fractures are suitable for this procedure. In a long oblique fracture or small distal fragment fracture, the bone may be inadequate to hold the screw securely. Third, no implant specifically designed for the clavicle exists. The cannulated technique is safer and easier, but the 6.5-mm size is inappropriate for small bones. Knowles pins or smaller diameter cannulated screws may be required. In severely comminuted fractures, a partially threaded screw may slide in the distal fragment when the fracture site collapses and screw head protrusion may result. A double barrel threaded screw may provide more stable fixation but is not available currently. Fourth, radiation exposure is the main disadvantage. Although the radiation dose can be substantially reduced after a learning curve, it is a major concern.

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Operative treatment is only indicated for open fractures, widely displaced fractures, neurovascular compromise, skin compromise, multiple injuries, and nonunions. However, recent studies reported unacceptably high nonunion rates with conservative treat-
Grassi et al., in a comparative study, reported a similar 25% unsatisfactory rate in both the nonoperative group and operative group. The major factors resulting in poor satisfaction were unaesthetic deformity in the nonoperative group and unsightly scars in the operative group. Increased cases of high-energy injuries and altered fracture pattern distribution may have contributed to these changes.

Our technique has several advantages. It provides relatively stable fixation and rapid pain relief and restores anatomical alignment—all of which cannot be achieved by nonoperative treatment. It also avoids soft-tissue stripping and unsightly scars that complicate open reduction and internal fixation.

Due to the unsatisfactory experiences in our patients with conservative treatment or open reduction and internal fixation, we first performed intramedullary fixation by closed reduction in August 2001, and have since operated on 25 patients. Some complications occurred in the pilot cases, including 2 time-consuming reductions converted to open reduction and 2 intraoperative comminutions. In the later cases, standardized procedures were established and followed, and all operations went smoothly without immediate or short-term complications. Nevertheless, long-term evaluation is required to confirm its value.

REFERENCES