ABSTRACT

Background: Fracture of the scaphoid bone can be treated with cast immobilization or surgery. Historically, surgery was reserved for displaced fractures. However, because weeks of cast immobilization may result in stiffness, loss of strength, loss of bone density and an inability to work or participate in recreational activities for a prolonged period, operative treatment of non-displaced fractures has become increasingly common. Several surgical techniques for fixation have been described, but their risks and benefits have not yet been clearly elucidated. In a study in cadavers, we investigated whether one approach—volar percutaneous fixation—might pose a risk of injury to surrounding structures.

Methods: In 15 cadaver upper limbs with the wrist structures intact, a K-wire was inserted in a volar percutaneous manner under fluoroscopic guidance, distal to proximal and through the scaphoid waist into the center-center position. The volar aspect of the wrist and hand were then dissected around the K-wire, with isolation of surrounding structures. The distance between the K-wire and several individual structures was then measured with a digital caliper.

Results: The K-wire was at least 4 mm from the superficial radial nerve, the first dorsal extensor compartment, the recurrent motor branch of the median nerve, and the radial artery (RA) in all specimens. However, the K-wire had penetrated the flexor carpi radialis (FCR) tendon in four specimens and was directly adjacent to it in another four. In one specimen, the K-wire was directly adjacent to the superficial volar branch of the RA.

Conclusions: The K-wire may penetrate the FCR tendon and the superficial volar branch of the radial artery during volar percutaneous scaphoid fixation. The possible long-term clinical implications of this finding require investigation.

Clinical Relevance: Our findings indicate that modification of the volar percutaneous approach to scaphoid fixation may be advisable to avoid damage to adjacent structures. We suggest use of a “mini-open” percutaneous procedure.

INTRODUCTION

Scaphoid fracture, the most commonly fractured carpal bone, frequently results from a fall on an outstretched hand with the wrist in extension. Most scaphoid fractures occur in active men, often athletes, in their twenties or thirties. The annual incidence is about 30 to 43 fractures per 100,000 people. Approximately 70% of scaphoid fractures occur at the waist (middle third) of the bone.

The scaphoid bone has unique characteristics that require special consideration when planning treatment of fractures. Normal carpal alignment depends partly on an intact scaphoid. The scaphoid spans both the proximal and distal carpal rows and is exposed to marked stress; therefore, immobilization is important in achieving union after fracture. About 70% to 80% of the intraosseous blood supply and the entire proximal pole of the scaphoid receives blood flow in a retrograde manner from branches of the radial artery (RA) that enter at the dorsal ridge. The remaining 20% to 30% is provided by the volar RA branches at the distal tuberosity. A scaphoid fracture may disrupt this tenuous blood supply, leading to delayed union, nonunion, or avascular necrosis and, ultimately, post-traumatic arthritis and carpal collapse.

Early treatment of scaphoid fractures is important in preventing these complications. The principal treatment methods are cast immobilization and surgery. There is general agreement that unstable and displaced fractures require operative treatment, but the optimal treatment for stable, non-displaced fractures remains
somewhat controversial. Both cast immobilization and screw fixation have high, similar union rates (about 85% to 100%\(^2,8,9\)), although some studies have found that the long-term complication rate is higher in patients who undergo surgery\(^9-11\). In patients given a cast, however, fracture healing may require 12 or more weeks, during which time loss of muscle strength and bone density occurs, as does stiffness of the wrist, elbow, and hand\(^2,8,12\). In addition, the young, active patients who are most likely to sustain a scaphoid fracture may find a cast particularly burdensome because it restricts recreational and occupational activities. Surgical treatment (screw fixation) of non-displaced fractures has therefore become increasingly common, and the mean time to union and return to work have been found to be significantly shorter in patients who have undergone surgery compared with those given a cast\(^12,13\).

Several surgical procedures for treating scaphoid fractures have been described, including open and percutaneous volar or dorsal techniques. Because open fixation involves dissection that damages the volar radiocarpal ligaments or dorsal capsular structures\(^8\), surgeons may choose a percutaneous approach.

Studies comparing the dorsal and volar percutaneous approach to screw fixation of scaphoid fracture have found little difference between the two procedures with respect to screw position, union rate, or functional outcomes\(^14,17\). However, with any percutaneous technique, there is a risk of injury to anatomical structures during guide wire placement and screw advancement. This risk has been addressed in several cadaver studies. For example, investigations by Adamany et al\(^18\) and Weinberg et al\(^19\) found that dorsal percutaneous scaphoid fixation can damage the posterior interosseous nerve and the extensor indicis proprius, extensor pollicis longus, extensor carpi radialis, and extensor digitorum tendons. Kamineni and Lavy\(^20\) observed that the volar percutaneous approach risks injuring the superficial volar branch of the RA (SVBRA). In a study of screw positioning using the volar method, Vaynrub et al\(^21\) noted articular damage affecting an average of 7% of the articular surface in 6 of 10 wrists and “fraying” of 5% of the ulnar-most fibers of the abductor pollicis longus (APL) in one specimen and 10% of the radial-most fibers of the flexor carpi radialis (FCR) tendon in another specimen. Little other information on anatomical structures that may be at risk during volar percutaneous fixation is available.

**METHODS**

Fifteen fresh-frozen cadaveric upper limbs (Science Care, Phoenix, AZ) were used in this study (mean age, 41 years [range, 27-54 years]). Seven (four male and three female) were matched pairs, and one was a single right arm (male). All structures in the wrist of the specimens were intact at the beginning of the study, and no specimen showed evidence of wrist trauma or prior surgery.

The specimens were placed in a supine position on a flat table with a bump to maintain wrist extension (Figure 1). Ulnar deviation was obtained by using manual traction through the thumb. A completely percutaneous procedure was then performed under direct mini-fluoroscopic guidance. A 1.58-mm (0.062-in) K-wire was advanced through the skin and thenar muscles into the scaphoid tuberosity in line with the first metacarpal in the coronal plane and positioned at a 45° angle in the sagittal plane. A starting point just radial to the distal pole of the scaphoid was attained within the scaphotrapezial joint. The K-wire was advanced through the scaphoid waist and into a central position in both the sagittal and coronal planes of the proximal pole (Figure 2A and Figure 2B).

The volar aspect of the wrist and hand in each specimen was then dissected around the K-wire, with isolation of the following anatomical structures: the RA, SVBRA, recurrent motor branch of the median nerve (RMBMN), superficial radial nerve (SRN), first dorsal extensor compartment (FDEC), and FCR tendon. The distance between the K-wire and the nearest portion of each anatomical structure in each specimen was measured to the nearest 0.1 mm by using a digital caliper. If the structure had been penetrated by the K-wire, a value of 0 was assigned. If the K-wire was directly adjacent to the structure, a value of 0.1 mm was assigned. Data were expressed as the mean ± SD distance between the K-wire and structure of interest and the number and percentage of specimens with 0 and 0.1-mm values for each structure.
RESULTS

Table 1 shows the results of the measurements of the distance between the K-wire and structures in the 15 specimens. The K-wire was at least 4 mm from the SRN, FDEC, RMBMN, and main RA in all specimens and directly adjacent to the SVBRA in one specimen. In four specimens, the FCR had been penetrated by the K-wire (Figure 3). In another four, the K-wire was directly adjacent to the FCR (Figure 4). Therefore, for 8 of the 15 specimens (53%), the FCR is considered to be at risk of injury from the surgical procedure.

DISCUSSION

Both the dorsal and volar percutaneous approaches to scaphoid fixation have a low complication rate and allow an earlier return to normal activities than does cast immobilization. However, advantages and disadvantages...
have been described for both methods. With the dorsal approach, central placement of the screw in the long axis of the scaphoid may be easier to achieve. Disadvantages of the dorsal technique include a risk of fracture displacement because of the maximal wrist flexion it requires and possible iatrogenic injury to the dorsal blood supply and radiocarpal joint. The volar approach does not require wrist hyperflexion. Disadvantages of this technique include the risk of iatrogenic injury to the scaphotrapezial joint, the difficulty of obtaining a central-axis screw position because of the anatomical hindrance of the trapezium, and the potential for volar ligament instability.

Although the clinical results of the two percutaneous approaches have generally been satisfactory, the findings of our study and previous cadaver investigations that identified structures at risk with each method raise questions about possible avoidable injury to surrounding structures during this procedure. For the volar approach, our findings and those of Kamineni and Lavy suggest that the SVBRA is at risk, and indeed, at least one injury of this vessel has been observed in a patient who underwent volar percutaneous scaphoid fixation. In contrast, Vaynrub et al observed no visible damage to vascular structures. The reason for this discrepancy in results among the three studies is unclear. None of the three studies detected a risk to nerves.

Injury to a tendon was observed only in our study and that of Vaynrub et al. Vaynrub et al reported “minor” damage to the APL and FCR. We found penetration of the FCR tendon with the K-wire in 27% of specimens and direct adjacency in another 27%. These results are concerning, especially in light of the fact that a cannulated screw is then advanced over the K-wire further increasing the diameter of the affected region. A case of a patient in whom FCR tenosynovitis and, eventually, FCR tendon rupture occurred after volar percutaneous scaphoid fixation has been described. At reoperation, irritation and inflammation of the FCR tendon, scar tissue, and pieces of metal in the tendon fibers were observed. Either K-wire placement, screw advancement, prominent hardware, or a combination of these factors may have been responsible for this outcome. The implications of damage to the FCR tendon require further investigation. The tendon is often harvested for grafting to treat common conditions, including osteoarthritis of the thumb carpometacarpal joint. Varitimidis et al reported no compromise in wrist function after FCR harvest. On the other hand, Naidu et al showed that wrist-flexion extension torque ratio and fatigue resistance decreased when the entire tendon was harvested. Our study had the usual limitations of a cadaver investigation in that the anatomical findings could not be correlated with outcomes in patients, including union rates, development of arthritis, or function. Moreover, the cadaver wrists we used had not sustained a fracture. Our results suggest that the usual “blind” volar percutaneous approach to scaphoid fixation may not be optimal. Therefore, like Kamineni and Lavy, we recommend use of a “mini-open” percutaneous technique to enhance the safety of the procedure. The mini-open method includes blunt dissection down to the scaphotrapezial joint through a 1-cm incision to allow direct visualization of the distal scaphoid. This modification may prevent injury to the FCR tendon and SVBRA during K-wire placement and screw advancement.

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DECLARATION OF CONFLICTING INTERESTS

Each author certifies no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

REFERENCES


