The vascularity of the scaphoid bone

The extraosseous and intraosseous vascularity of the carpal scaphoid was studied in 15 fresh cadaver specimens by injection and clearing techniques. The major blood supply to the scaphoid is via the radial artery. Seventy to eighty percent of the intraosseous vascularity and the entire proximal pole is from branches of the radial artery entering through the dorsal ridge. Twenty to thirty percent of the bone, in the region of the distal tuberosity, receives its blood supply from volar radial artery branches. There is an excellent collateral circulation to the scaphoid by way of the dorsal and volar branches of the anterior interosseous artery. An explanation for the cause of scaphoid necrosis on the basis of the vascular anatomy is proposed. The volar operative approach would be least traumatic to the proximal pole’s blood supply.

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The high frequency of avascular necrosis of the proximal pole of the carpal scaphoid following fracture has been noted by several authors. Scaphoid fractures account for less than 2% of all fractures, but the scaphoid is second only to the femoral head in its incidence of posttraumatic avascular necrosis. Whereas several factors have been related to scaphoid avascular necrosis, the only consistent finding has been a correlation of fracture location and avascular necrosis of the proximal pole. Thirty percent of middle third fractures and almost 100% of proximal fifth fractures have been associated with avascular necrosis of the proximal pole of the scaphoid.

The first study designed to determine the anatomical basis for avascular necrosis of the scaphoid was performed by Preiser and Lexer in 1910. They investigated the scaphoid’s vascularity in an experiment which utilized vascular injection and dissection techniques. The most recent of a group of studies using injection and clearing techniques was performed by Talesnik and Kelley in 1966. They injected the radial artery with India ink and barium sulfate and dissected the scaphoid’s blood vessels under magnification. They then cleared the bone by the Spalteholz method and visualized the internal vascularity. Despite the contribution of this study, considerable differences of opinion have persisted about the origin and relative contribution of the scaphoid’s nutrient arteries, and the orientation and clinical significance of the intraosseous vascular patterns.

The purpose of this study is to demonstrate the external and internal vascularity of the carpal scaphoid by nondissection techniques. The radial, ulnar, and interosseous arteries were injected to define the precise contribution of the major blood vessels supplying the scaphoid and determine the extent of its collateral circulation. The entry vessels and internal vascularity were studied to provide a better understanding of scaphoid avascular necrosis and to help determine the least de-
Fig. 2. Schematic drawing of the dorsal blood supply of the scaphoid. (S, scaphoid; 1, radial artery; 2, dorsal scaphoid branch; 3, dorsal division of the anterior interosseous artery; 4, intercarpal artery.)

Intraosseous vascularity. After observations on the external vascularity had been made, the scaphoids were removed. The number and location of the entry vessels were recorded. The scaphoids were then cleared by a modified Spalteholz technique. They were fixed in formalin for 12 to 18 hours, washed for 1 hour in running water, and decalcified in 30% formic acid. The solution was changed two to three times with the process taking approximately 1 week. The scaphoids were again washed in running water and then immersed in hydrogen peroxide for 3 days. They were dehydrated in 70% and 95% ethanol overnight, followed by 100% ethanol for 1 week in a vacuum. The specimens were immersed in chloroform for 3 days and then placed in oil of wintergreen until the bones were completely transparent. Photographs of the internal vascularity were taken with the specimens immersed in a mixture of oil of wintergreen and benzyl benzoate 50.

Results

External vascularity. The scaphoid receives its blood supply primarily from the radial artery. Two
major blood vessels enter the scaphoid, one through its dorsal surface and one through its volar surface. All of the vessels entered the bone through nonarticular surfaces in areas of ligamentous attachment.

The volar vascular supply to the scaphoid accounts for 20% to 30% of the internal vascularity of the bone, all in the region of the distal pole. The volar aspect of the scaphoid is concave, ending distally in a rounded elevation called the tubercle. The tubercle is the area of entry for the volar distal blood supply of the scaphoid. The radial artery lies between the brachioradialis and the flexor carpi radialis at the wrist before coursing dorsally to enter the palm through the first dorsal interosseous space. At the level of the radial-scaphoid joint the radial artery gives off its superficial palmar branch (Fig. 1). Just distal to the origin of the superficial palmar branch, several smaller branches course obliquely and distally over the volar aspect of the bone to enter the scaphoid through the region of the tubercle. These branches, the volar scaphoid branches, divide into several smaller branches just prior to penetrating the bone. In 75% of the specimens these arteries arose directly from the radial artery. In the remaining specimens they arose from the superficial palmar branch of the radial artery. Consistent anastomoses were noted between the volar division of the anterior interosseous artery and the volar scaphoid branch of the radial artery when the latter arose from the superficial palmar branch of the radial artery (Fig. 1). There were no apparent communicating branches from the ulnar artery to the volar branches of the radial artery supplying the scaphoid. There were several very small vessels seen running over the volar scapholunate ligament, but they did not penetrate the bone and did not contribute to the vascularity of the scaphoid in that region. The volar cartilaginous areas of the scaphoid were devoid of any blood vessels.

On the dorsum of the scaphoid, there is a ridge which lies obliquely between the articular surfaces for the radius and for the trapezium and trapezoid. The major dorsal vessels to the scaphoid enter the bone through small foramina located on this dorsal ridge (Fig. 2). At the level of the intercarpal joint the radial artery gives off the intercarpal artery which immediately divides into two—a transverse branch to the dorsum of the wrist and a branch that runs vertically and distally over the index metacarpal (Fig. 3). Approximately 0.5 cm proximal to the origin of the intercarpal vessel at the level of the styloid process of the radius, another vessel is given off which runs over the radiocarpal ligament to enter the scaphoid through its waist along the dorsal ridge. In 70% of the specimens the dorsal vessel arose directly from the radial artery. In 23% the dorsal branch had its origin from the common stem of the intercarpal artery. In 7% the scaphoid received its dorsal blood supply from branches off both the intercarpal artery and the radial artery directly. There were consistent major anastomoses between the dorsal scaphoid branch of the radial artery and the dorsal branch of the anterior interosseous artery in each specimen (Figs. 2 and 3).

There were no vessels seen entering the proximal-dorsal region of the bone through the dorsal scapholunate ligament, and there were no vessels entering through dorsal cartilaginous areas.

Both the dorsal and volar blood vessels entered the scaphoid through the distal half of the bone. The anterior interosseous artery appeared to significantly enhance the blood supply of the scaphoid through its communication with both the dorsal and volar scaphoid branches of the radial artery.

**Internal vascularity.** In 79% of specimens, one to two dorsal vessels entered the scaphoid through foramina located on the dorsal ridge at the level of the
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In 7% the vessels entered proximally, and in 14% just distal to the waist. In one specimen four separate vessels entered the waist, two of which ran in a horizontal direction supplying the waist and two of which extended into the proximal pole. In most specimens the dorsal vessels divided into two to three branches soon after entering the bone. These branches ran volarily and proximally, dividing into smaller branches supplying the proximal pole as far as the proximal subchondral region (Figs. 4 and 5). In two speci-

Fig. 4. Photograph of a cleared specimen showing the internal vascularity of the scaphoid. [1, dorsal scaphoid branch of the radial artery; 2, volar scaphoid branch (The vessels in the dorsal and volar scapholunate ligaments do not penetrate the bone.).]

Fig. 5. Photograph of a specimen showing the internal vascularity of the scaphoid. (1, dorsal scaphoid branch of the radial artery; 2, volar scaphoid branch.)
Fig. 6. The proximal 70% to 80% of the bone is supplied by dorsal vessels (shaded area). The distal 20% to 30% is supplied by volar branches of the radial artery (white area).

Discussion

The proximal 70% to 80% of the scaphoid is supplied by branches of the radial artery entering along the narrow, oblique dorsal ridge (Fig. 6). The distal scaphoid is supplied by direct branches of the radial artery or its superficial palmar branch. Those branches enter the tuberosity and supply the distal 20% to 30% of the bone. While the ulnar artery makes no apparent contribution to the scaphoid’s vascularity, the dorsal and volar branches of the anterior interosseous artery make significant contributions. The dorsal branch of the anterior interosseous artery anastamosed with radial branches prior to their entering the bone in each specimen. In 33% of the specimens there was a similar communication between the volar branch of the anterior interosseous and the volar radial branches.

Our review of the literature yielded conflicting reports on the vascularity of the scaphoid. In Talesnik and Kelley’s study of 11 cadaver specimens, three major vessels to the scaphoid—the laterovolar, dorsal, and distal vessels—were found. They concluded that the laterovolar vessels were the largest and provided most of the blood supply to the proximal two thirds of the bone. The intraosseous vascular patterns in their study were particularly well demonstrated, due to the use of freshly amputated limbs. On studying the major vessels of their cleared specimens, it was apparent that their lateral-volar vessels were analogous to our dorsal ridge vessels, and their distal vessels similar to our tuberosity vessels. They thought that the lateral-volar vessels entered the bone just proximal to the tubercle on the volar surface of the bone, however, whereas we consistently found the major vessels entering the ridge on the dorsal surface of the scaphoid. Barber studied the internal vascularity of eight specimens by injecting barium sulfate and clearing by the Spalteholz technique. He noted three groups of vessels entering at various intervals along the dorsal ridge and branching to supply the tuberosity and the proximal pole. He did not find any vessels entering the scaphoid through its volar surface. Grettve, based on a study of five specimens, stated that there were small vessels entering the scaphoid through the radiovolar aspect. He concurred with our findings, however, and those of Barber that the major blood supply came from the dorsum. We confirmed our orientation several times, recorded our findings with the scaphoid in situ, and photographed each specimen prior...
to dissection. Using this method we were able to identify two consistent entry vessels—the dorsal ridge vessels and the volar tubercle branches of the radial artery. The dorsal nutrient vessels consistently provided the vascularity to the proximal portion of the bone.

Lutzeler \(^7\) described vessels entering the scaphoid through the volar and dorsal scapholunate ligaments supplying the proximal pole directly. Travaglini \(^8\) also noted vessels entering the proximal pole through the scapholunate ligament, and Barber \(^9\) noted a tiny vessel directly supplying a small area of the proximal cortex. We studied the proximal cortex for any direct vessel entry and, although we consistently found vessels in both the volar and dorsal scapholunate ligaments, none of these vessels penetrated the cortex. The proximal segment always received its vascularity from vessels entering through the dorsal ridge.

In a study of scaphoid nutrient foramina by Obletz and Halbstein, \(^9\) 13% of 297 scaphoids were lacking foramina proximal to the waist. In 14% of our specimens the dorsal vessels entered distal to the waist. In 27% the vessels entered just proximal to the waist but within 2 to 3 mm of the midsection of the bone, and in the remaining 59% entered directly over the waist. Avascular necrosis of the proximal pole of the scaphoid is due to an interruption of the proximal intraosseous vascularity, which in our specimens was noted to enter along the dorsal ridge. Fourteen percent of our specimens would have had a significant interruption and 59% a partial interruption in the proximal pole's vascularity following a fracture through the waist. The more proximal the fracture the higher the incidence of total avascularity.

These findings may have clinical importance in other areas. It appears that a volar operative approach to the scaphoid would injure less of the vascularity to the proximal pole than would a dorsal approach. This concurs with the observations of Böhler \(^11\) and Russe \(^10\), who recommend grafting through a volar operative approach. The bone grafts would theoretically be vascularized and incorporated more quickly by preservation of the dorsal ridge vascularity. Finally, the consistent rich collateral circulation to the scaphoid by way of the dorsal and volar branches of the anterior interosseous artery would ensure the scaphoid's vascularity in the event of a segmental loss of the radial artery at the wrist. It is unlikely that a simultaneous injury to the radial artery and a fracture of the scaphoid would cause any increased incidence of scaphoid avascular necrosis over the fracture occurring alone.

**Conclusions**

1. The major blood supply to the scaphoid is from the radial artery. The proximal pole and 70% to 80% of the bone receives their blood from vessels entering through the dorsal ridge.

2. The tuberosity and the distal 20% to 30% of the bone are supplied by volar branches of the radial artery and its superficial palmar branch. There were no significant intraosseous anastomoses between dorsal and volar branches.

3. The collateral circulation to the scaphoid is by way of the dorsal and volar branches of the anterior interosseous artery anastomosing with dorsal and volar branches of the radial artery.

4. The vascularity of the proximal pole of the scaphoid would be traumatized least by a volar operative approach.

**REFERENCES**