Chapter 1
Scaphoid Anatomy

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The human scaphoid bone has a unique and complex shape that allows it to function as a critical element in proper wrist biomechanics. It is the only carpal bone that links the proximal and distal carpal rows. Its irregular anatomic shape and high percentage of coverage with articular cartilage lead to low tolerances during bony remodeling after injury. The scaphoid's ligamentous attachments, osseous anatomy, and complex biomechanics predispose this bone to certain ligamentous dysfunctions that lead to osteoarthritis, and certain fracture patterns that lead to malunion or nonunion. It also has a retrograde blood supply that leads to relatively high rates of avascular necrosis following fracture, particularly those closest to its most proximal end or pole. Injury to the scaphoid and its surrounding ligaments may significantly limit wrist function in the short term and can predispose patients to severe pain and osteoarthritis with concomitant long-term dysfunction.

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Scaphoid Injury/Incidence

The scaphoid is the most commonly fractured carpal bone and accounts for nearly 70 % of all carpal fractures [1, 2]. The most common injury mechanism is a fall onto an outstretched hand. Wolf and coauthors in 2009 studied 14,704 scaphoid fractures in a military population. They reported the unadjusted incidence of scaphoid fracture to be 121/100,000 person-years. Young males in the 20 to 24 year-old age group had the highest scaphoid fracture incidence at 164/100,000 person-years [2]. The same group studied the National Electronic Injury Surveillance System, which is a database of injuries presenting to emergency rooms in the USA. Over a 4-year period, 507 scaphoid fractures were identified in the database. When extrapolated, this corresponded to an estimated 21,481 scaphoid fractures nationally over the same time period with an estimated incidence of 1.47/100,000 person-years. They estimate that scaphoid fractures account for 2.4 % of all wrist fractures, again with young males representing the highest risk for fracture [3].

Vascular Supply

The blood supply of the scaphoid predisposes it to avascular necrosis and nonunion following injury, particularly to the proximal pole. The radial artery provides the primary blood supply to the scaphoid [4]. In 1980, Gelbermann characterized the blood supply of the scaphoid by injecting latex into 15 cadaveric scaphoid bones. Approximately 70–80 % of the intraosseous vascularity and the entire proximal pole are supplied from branches of the radial artery entering through the dorsal ridge [5] (Fig. 1.1). The large volume of bone dependent on a single intraosseous vessel poses a great risk to develop avascular necrosis following fracture [6]. Further studies showed that the scaphoid is the carpal bone at highest risk for avascular necrosis following injury [7]. The

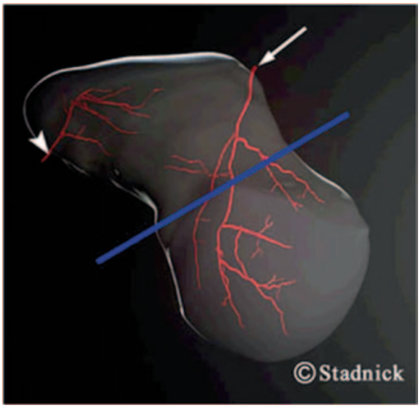

Fig. 1.1 Depiction of the typical blood supply to the scaphoid showing the larger distal dorsal branch supplying the proximal pole. (From http://rad-source.us/scaphoid-fracture/ with permission.)

remaining 20–30 % of the bone in the region of the distal tuberosity is supplied from volar radial artery branches [5] (Fig. 1.2). There is no apparent palmar-to-dorsal anastomosis. Venous drainage is via the dorsal ridge into the venae comitantes of the radial artery [7].

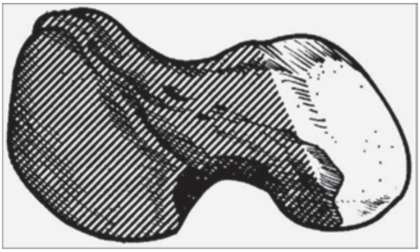

Fig. 1.2 Proximal 70–80 % of the scaphoid is supplied by the dorsal vessels (shaded) and the distal 20–30 % is supplied by the volar branches of the radial artery. (From ref. [5], with permission.)

Osseous Anatomy

The anatomy of the scaphoid presents a unique challenge when dealing with injury. Its anatomy has been described in detail by many authors [8]. The scaphoid is the only carpal bone to cross the proximal and distal rows and acts as a strut between them. It is the largest bone in the proximal carpal row, is oriented on an oblique long axis, and is concave volarly and ulnarly. Approximately 75 % of the scaphoid is covered with articular cartilage, with only the volar surface being partially uncovered [9, 10]. Four distinct anatomic regions of the scaphoid have been described: (1) the tubercle, (2) the distal pole, (3) the proximal pole, and (4) the waist. (Fig. 1.3) In a study of 24 morphological and 11 morphometric scaphoid parameters, at least one morphometric feature was missing in 200 specimens. The scaphoid tubercle and dorsal sulcus were present consistently, with the greatest differences in waist circumference, size of the tubercle, and sulcus width [11]. A statistical model of scaphoid CT scans suggests that variations in morphology represent extremes of a normal distribution and not distinct subtypes [12]. The tubercle is directed radially and volarly and serves as an attachment point for the scaphotrapezoidal and the scaphotrapezial ligaments where it is also partially covered by the flexor carpi radialis tendon. At its distal end, the scaphoid articulates with both the trapezoid and the trapezium. However, a ridge along the scaphoid separating these articulations is not routinely identifiable [13]. At its proximal end, the scaphoid

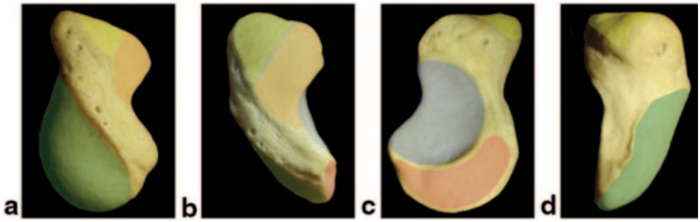

Fig. 1.3 Representative views of the scaphoid bone. Bottom of the image is proximal and the top of the image is distal. **a** Radial. **b** Dorsal. **c** Ulnar. **d** Volar. Colors represent articulations with other carpal bones: distal radius (green), trapezoid (orange), trapezium (yellow), capitate (blue), and lunate (red). (From ref. [8], with permission)

articulates with the scaphoid fossa of the distal radius. Along its ulnar border, the scaphoid articulates with the lunate proximally and the capitate distally [14].

Several studies have quantified the anthropometry of the human scaphoid. In 2007, Heinzelmann measured 30 cadaveric scaphoid bones with calipers. They found that male scaphoids were significantly longer than scaphoids in females (31.3 mm ± 2.1 vs. 27.3 mm ± 1.7). The male scaphoids were significantly wider than the female specimens when measured perpendicular to the long axis 2 mm from the proximal pole (4.5 mm ± 1.4 vs. 3.7 mm ± 0.5) and at the waist (13.6 mm ± 2.6 vs. 11.1 mm ± 1.2). This has significant implications in fracture fixation as diameters of many commercially available standard headless compression screws are close to the size of the proximal pole of female scaphoids. They suggest that the usual countersunk screw length will be 27 mm for males and 23 mm for females [15]. In a study that evaluated the scaphoid using three-dimensional computed tomography scans, Pichler showed that the scaphoid had a mean length of 26.0 mm and a mean volume of 3389.5 mm^3, again with a gender difference where length-adjusted female scaphoids are thinner [16]. Kivell showed that the female scaphoid body proximal-to-distal length is longer than that of males when size-adjusted; thus, as carpal size increases, female scaphoids are longer [17]. Lee characterized the osseous microstructure of the scaphoid. Articular regions showed the highest bone strength parameters (bone mineral density and trabecular density) and had thicker subchondral bone, especially at the articulations with the capitate and radius. The lowest number of trabeculae were found along the midcarpal side of the waist. Overall, the waist has thick subchondral and trabecular bone leading to a high moment of inertia against bending stresses[18].

Ligamentous Attachments

Numerous controversies exist within the literature regarding the ligamentous attachments to the scaphoid bone. The ligaments that attach to the scaphoid play an integral role in proper wrist biomechanics and function. A recent anatomic study by Jupiter analyzed eight cadaveric wrists with computed tomography and an imaging cryotome. Three-dimensional reconstruction showed ligamentous attachment consists of approximately 9% of total scaphoid surface area. The ligaments are divided into volar, dorsal, and scapholunate interosseous ligaments. The volar ligamentous complex connects the scaphoid to the distal radius and the adjacent of the carpal bones. The volar ligaments attaching to the scaphoid are made up of the radioscaphocapitate, scaphocapitate, scaphotrapezoidal, scaphotrapezial, transverse carpal, and radioscapholunate. The scaphocapitate ligament covers 40% of the volar ligament attachment surface area and covers nearly the entire ulnar scaphoid tubercle. Only one ligament attaches to the dorsal scaphoid; the dorsal intercarpal ligament originates from the dorsoradial aspect of the triquetrum and inserts on the proximal and waist areas of the dorsoradial ridge of the scaphoid. The scapholunate interosseous ligament is a single C-shaped ligament with a volar, dorsal, and proximal bundle dominated by the proximal portion of the ligament. These bundles are difficult to differentiate and can be viewed more as thickenings rather than discrete bundles [19] (Fig. 1.4).

All of these ligaments function to allow the scaphoid to serve a vital role in the complex biomechanics that are in play during normal wrist motion. Unfortunately, these interconnections also contribute to the abnormal and pathologic biomechanics that occur

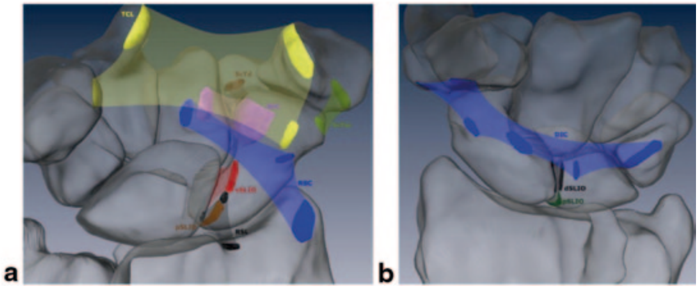

Fig. 1.4 Three-dimensional representation of the wrist showing the scaphoid ligaments and their attachments. Paths and attachments are based on cadaveric data. **a** Volar view. **b** Dorsal view. (From ref. [19], with permission.)

during injury to the scaphoid and/or its structural attachments. The following chapters of this text provide a detailed review of injuries to the scaphoid and the various treatment options that are currently available.

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