Vascular Insufficiency of the Upper Extremity

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Vascular insufficiency of the upper extremity can be due to acute vascular injury, chronic vasospastic disease, and occlusive disease. Its treatment requires a thorough understanding of the vascular anatomy of the upper extremity, diagnostic modalities, and medical and surgical management options. Promising advances continue to be made in surgical treatment and medical therapy. *(J Hand Surg 2010;35A:1545–1553. © 2010 Published by Elsevier Inc. on behalf of the American Society for Surgery of the Hand.)*

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ANATOMY

The vascular anatomy of the upper extremity is well defined. Knowledge of the intricacies of collateral vessel flow and anatomic anomalies serve the hand surgeon well in the assessment and treatment of vascular problems in several areas along the course of major arteries.

As the brachial artery descends through the medial brachium anterior to the intermuscular septum en route to the antecubital fossa, it serves as the dominant blood supply to the distal extremity. Just distal to the antecubital crease, it bifurcates into the major vessels of the forearm. From this point forward, the dominant vessels serve the hand with the vascular reserve and compensation inherent to a duplicative system. An occlusion or transection of the brachial artery proximal to this bifurcation can result in catastrophic ischemia to the distal limb. There are 3 major sources of collateral flow across the elbow, including the deep brachial artery, which passes posterior and lateral to the humerus in tandem with the radial nerve and joins the radial artery distally; the superior ulnar collateral artery, which passes posterior to the medial epicondyle in tandem with the ulnar nerve to join the ulnar artery distally; and the inferior ulnar collateral artery, which passes anterior to the medial epicondyle to join the ulnar artery distally. These vessels can serve as a means of continued profusion of the limb despite occlusion of the brachial artery at or above the elbow.

The radial artery is more superficial than the ulnar artery in the proximal forearm, coursing deep to the bicipital aponeurosis and brachioradialis and superficial to the biceps tendon, pronator teres, flexor digitorum superficialis, and flexor pollicis longus sequentially. Along this course, it reaches the wrist flexion crease between the flexor carpi radialis and brachioradialis tendons. The ulnar artery is deeper in the forearm, beneath the pronator teres, median nerve, and flexor digitorum superficialis muscle bellies. Shortly after its departure from the brachial artery, it branches off the common interosseous artery before migrating onward to the superficial surface of the flexor digitorum profundus muscle to join the ulnar nerve at the junction of the middle and proximal thirds of the forearm. These 2 structures run in tandem to reach the wrist flexion crease immediately deep and radial to the flexor carpi ulnaris tendon.

Variance in the path or source of the radial artery is reported in up to 30% of patients. The most common variation is the high origin of the radial artery rising from the brachial or axillary artery proximal to the antecubital fossa. This is estimated to occur in 2.4% to 14.3% of extremities. Substantially less common variations include absence of the radial artery, duplication of the radial artery, and superficial passage of the radial

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artery above the tendons of the snuffbox. Variation in the ulnar artery pathway or position is much less commonly seen (3% to 5%).[1]

Substantial investigative efforts have been focused on determining which of these 2 vessels is of greater import to perfusion of the hand. Although the ulnar artery is larger in the proximal forearm, the radial artery is more often larger at the level of the wrist. It has been speculated that this is because the ulnar artery branches throughout the forearm axis, whereas the radial artery passes with relatively less division to its destination at the hand. The size dominance of the radial artery at the wrist has been demonstrated in both cadaveric studies and duplex ultrasound findings.[2,3] Although the ulnar artery serves as the source vessel for the superficial palmar arch and the radial artery serves as the source vessel for the deep palmar arch, there are myriad anastomotic interconnections between these 2 systems. Because the common digital arteries to the fingers arise from the superficial palmar arch, it might seem logical that this would serve as the dominant source of perfusion to the hand. Early data from studies of pulse volume plethysmography indicated that the radial artery was more often critical for maintaining pulsatile digital blood flow.[4,5] There are additional data pertaining to the compensatory effects of radial artery harvest (ie, radial forearm flap or radial artery conduit harvest) on blood flow dynamics to the hand, demonstrating increased size and flow velocities across the remaining vessels.[6] These data would indicate that the vascular bed of the hand is a complex anatomic and physiologic entity that might preclude the assignment of vessel dominance.

The blood vessels in the hand communicate via 3 major arches—2 palmar and one dorsal (excluding carpal arches). A great number of studies have elucidated the extreme anatomic variance in this network of vessels, particularly on the radial side of the hand. The superficial palmar arch is a source of 3 or 4 common digital arteries, whereas the deep palmar arch gives rise to 3 to 4 palmar metacarpal arteries. The dorsal arch, likewise, is the source vessel for the anatomically diverse dorsal metacarpal artery system. These 3 systems communicate at the level of the arches themselves, as well as along the pathway of the longitudinally oriented palmar and dorsal metacarpal arteries and common digital arteries. Studies of the anatomic variability of this network demonstrate that the superficial palmar arch is complete in more than 80% of patients, whereas the deep palmar arch is complete in more than 90% of patients.[1] A complete arch is defined as one that demonstrates anastomoses between the vessels that constitute it. The superficial palmar arch has been the focus of the greatest number of studies in this area, and a wide variety of classification systems have been created based on differences in the anatomic makeup of the arch. The most commonly encountered arch is one in which a superficial arch is "complete" via communications between the superficial volar branch of the radial artery and the superficial branch of the ulnar artery in Guyon's canal. A clinically relevant anatomic variant is the presence of a communication between a persistent median artery (an embryologic remnant that normally undergoes apoptosis during upper limb development) and the superficial palmar arch, which serves to complete the arch. This was seen in 15.5% of specimens in a well-performed cadaveric study.[7]

An overview of the areas of greatest scientific inquiry in upper extremity vascular anatomy in the last 10 years should include the multitude of studies examining the radial aspect of the hand. All of these studies demonstrate a great deal of variability in the first web space as to the source vessels serving the thumb and index finger, as well as their communications with the ulnar-sided structures.

EDUCATIONAL OBJECTIVES

- Describe the vascular anatomy of the upper extremity.
- Discuss the concept of vessel dominance with reference to the radial and ulnar arteries.
- State the factors to consider when deciding to repair or ligate a single vessel injury at the wrist.
- List the long-term changes in the ulnar artery following radial artery harvest.
- Discuss the long-term effects of radial artery harvest.
- Compare and contrast the various types of vascular conduits.

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ACUTE VASCULAR INJURY

Acute vascular injury from penetrating trauma is a common cause of ischemia with less diagnostic uncertainty than chronic vaso-occlusive disease. Debate in the literature regarding the indications for repair of noncritical vessels, however, warrants discussion.

Repair or ligate?

The decision to repair a damaged vessel is clear when critical ischemia is evident. However, in the setting of adequate perfusion via collateral vessels, the decision is more difficult. Intraoperative indicators that perfusion is adequate include the following:

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