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# 7

## The Blood Vessels of the Upper Extremity

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## ARTERIES OF THE UPPER EXTREMITY

### The Importance of the Collateral Circulation when Ligating Arteries of the Upper Extremity

The arteries of the upper limb may be damaged by penetrating wounds or may require ligation in amputation operations. Because of adequate collateral circulation around the shoulder, elbow, and wrist joints, ligation of the main arteries of the upper limb is not followed by tissue necrosis or gangrene, provided, of course, that the arteries forming the collateral circulation are not diseased and that the patient's general circulation is satisfactory. Nevertheless, it may take days or weeks for the collateral vessels to open up sufficiently to provide the distal part of the limb with the same volume of blood as previously provided by the main artery.

At the time of the injury, where there is a complete interruption of the main arterial supply, the collateral flow

may be sufficient to prevent the signs of ischemia; it is rare, however, for the physician to be able to palpate the distal pulse at the initial examination.

### Anatomy of Arterial Injuries in the Upper Extremity

Many of the injuries are directly related to the anatomy of the upper limb. The extreme mobility of the limb at the shoulder joint permits the forearm and hand to be raised as a shield to ward off an attack. This position of the arm commonly results in laceration of the blood vessels.

#### Penetrating Arterial Injuries

Arterial injuries of the upper limb are common and may occur from guns, knives, automobile accidents, and iatrogenic causes. Basically, three types of arterial injury are possible, and the structure of the artery determines the signs and symptoms as well as the type of treatment instituted.

1. In a **completely severed artery** the circular smooth-muscle fibers of the tunica media contract, immediately slowing the bleeding. In addition, the elastic fibers and longitudinal smooth-muscle fibers of the media contract,

causing the ends of the artery to retract. The contraction and retraction of the arterial ends usually slow the blood flow to such an extent that bleeding ceases spontaneously, and a firm blood clot plugs both ends of the severed artery. The loss of distal pulses is immediate.

2. In a **partially severed artery** the vessel is unable to contract and retract; in fact, any retraction that does occur causes the arterial wound to gape, resulting in serious bleeding. Hemorrhage into the surrounding tissues may produce an enlarging pulsatile hematoma that may slowly expand along fascial planes to reach the surface and cause a severe hemorrhage. Another possibility is that the damaged arterial wall gives way, leaving only the tunica adventitial intact. In these circumstances, a **pseudoaneurysm** is formed.

Since with partial arterial injury the arterial wall is still intact, blood flow continues into the distal end, and a distal pulse is usually recognizable.

3. In an artery with **intimal damage only** secondary to external blunt trauma, excessive stretching, or internal damage from a catheter, there is a reduction in blood flow and an absence of external hemorrhage. Later, as a result of progressive thrombosis or bleeding into the wall at the site of injury, the blood flow becomes diminished and the distal pulses disappear.

### Injuries to the Axillary Artery

These are often caused by penetrating wounds in the pectoral region, fractures of the surgical neck of the humerus, or excessive stretching following anterior dislocations of the shoulder joint (see text Fig. 7-7). Damage to the branches of the brachial plexus may be an added complication.

### Injuries to the Brachial Artery

These may follow supracondylar fractures of the lower end of the humerus (especially in children), a site where the artery is close to the shaft of the humerus as it lies on the brachialis muscle (see text, Fig. 7-9). Damage to the adjacent median nerve may also occur. Severe dislocations of the elbow joint may damage the artery in the cubital fossa. Since the brachial artery is located superficially in the upper part of the arm, it is a common site for arterial catheterization. Frequently the tunical intima is damaged on the wall opposite the penetration site, and arterial thrombosis may follow.

### Allen Test

This test may be used to determine the patency of the ulnar and radial arteries. With the patient's hands resting in his or her lap, the radial arteries are compressed against the anterior surface of each radius. The patient then tightly clenches his or her fists, which closes off the superficial and deep palmar arterial arches. When he or she opens his or her hands,

the skin of the palms is at first white, and then normally the blood quickly flows into the arches through the ulnar arteries, causing the palms to promptly turn pink. This establishes that the ulnar arteries are patent. The patency of the radial arteries can be established by repeating the test, only with the ulnar arteries compressed where they lie lateral to the pisiform bone

### Injuries to the Radial Artery

These are common and occur in the lacerations of the front of the forearm. The close relation of the artery to the radial nerve and the forearm tendons means that these structures are also commonly damaged (see text Figs. 7-12 and 7-13). Catheter injuries are also common just proximal to the wrist joint.

### Injuries to the Ulnar Artery

These are relatively common and occur in lacerations in the front of the wrist and flexor retinaculum. Here the artery is superficial and easily cut in glass or knife wounds (see text Figs. 7-12 and 7-13). The closely related ulnar nerve is frequently involved also.

### Intraarterial Injections by Drug Users

In cases of intraarterial injection by drug abusers, the patient presents with a swollen and extremely painful hand. The drug is often injected into the radial or ulnar arteries. The pharmacologic agent and its diluent causes damage at the arteriole level as the result of blockage by crystal, chemical necrosis of the tunica intima, or vasospasm of the smooth muscle in the tunica media. Extensive tissue necrosis or gangrene may occur in the area of anatomic distribution of the artery injected.

### Arterial Venous Fistulas

Arteriovenous fistulas are common complications of arterial injuries in the upper limbs. This results from the close relationship that exists between the arteries and veins in the limbs. The axillary artery has the axillary vein on its medial side; the brachial, radial, and ulnar arteries have venae comitantes running alongside.

Arteriovenous fistulas occur when the penetrating arterial injury also perforates the accompanying vein. Bleeding from the artery follows the path of least resistance, and therefore an arteriovenous communication is established with resulting venous hypertension, varicosities, and edema distal to the communication site.

## Anatomy of the Procedure of Arterial Puncture

The brachial, radial, and ulnar arteries are commonly used for arterial puncture.

## Brachial Artery

The brachial artery is usually cannulated as it descends into the cubital fossa on the medial border of the biceps brachii muscle (see text Fig. 7-11). Unfortunately, the brachial artery has been associated with a higher incidence of post-catheterization thrombosis than the radial artery. This is probably because of the motility of the brachial artery associated with movements at the elbow joint.

## Radial Artery

With the radial artery it is first essential to determine the adequacy of the collateral circulation of the hand by performing the Allen test. This precaution is necessary in case thromboid occurs during or after cannulation. The forearm is then supinated and the wrist joint is extended to an approximately 50° angle (CD Fig. 7-1). The radial artery can then easily be palpated as it lies anterior to the distal end of the radius.

## Needle Approach

The needle is passed through the arterial wall at an angle of about 25° to the anterior surface of the wrist (see CD Fig. 7-1). The catheter can then be advanced into the arterial lumen and the needle withdrawn.

## Cutdown Approach

A transverse incision is made over the radial artery just above the proximal transverse skin crease at the wrist. The artery is gently mobilized on the anterior surface of the radius and the cannula is introduced.

Some physicians make a vertical incision for the radial artery cutdown to lessen the risk of cutting a nerve and also to avoid giving the patient a horizontal cut that could potentially be misinterpreted (as a suicide attempt) on the anterior surface of the forearm.



## SUPERFICIAL VEINS OF THE UPPER EXTREMITY

## Finding the Superficial Veins of the Upper Extremity

The cephalic, basilic, median cubital, median cephalic, median basilic, and median veins of the forearm can all be used for venipuncture and blood transfusion. These veins are fairly large and relatively constant in position. Unfortunately, in

obese persons the veins cannot always be seen. The surface anatomy of the superficial veins is given on text page 209.

## Anatomy of Basilic and Cephalic Vein Catheterization

The median basilic or basilic veins are the veins of choice for central venous catheterization, because from the cubital fossa until the basilic vein reaches the axillary vein, the basilic vein increases in diameter and is in direct line with the axillary vein (see text Fig. 7-19). The valves in the axillary vein may be troublesome, but abduction of the shoulder joint may permit the catheter to move past the obstruction.

The cephalic vein does not increase in size as it ascends the arm, and it frequently divides into small branches as it lies within the deltopectoral triangle. One or more of these branches may ascend over the clavicle and join the external jugular vein. In its usual method of termination, the cephalic vein joins the axillary vein at a right angle. It may be difficult to maneuver the catheter around this angle.

## Thrombosis of the Superficial Veins

Prolonged intravenous infusion and, rarely, bacterial cellulitis of the superficial fascia can produce thrombosis of the superficial veins. In both cases injury to the tunical intima is the initiating factor.

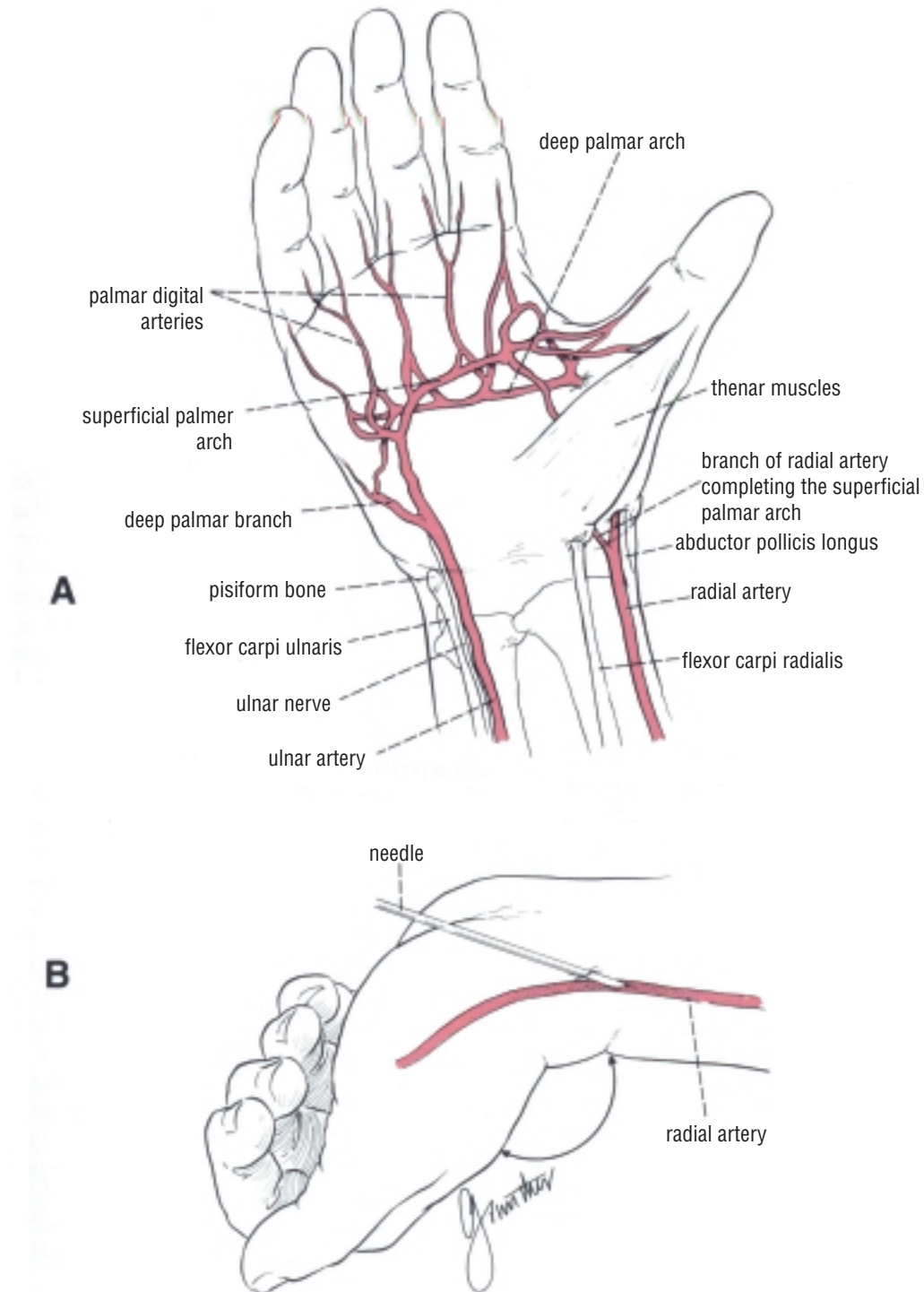
## Anatomy of Arteriovenous Shunts and Fistulas in the Upper Limb for Hemodialysis

Vascular access for hemodialysis can be provided by the construction of an external arteriovenous shunt or an internal arteriovenous fistula. Most methods can be performed under local anesthesia.

### External Arteriovenous Shunt

This is commonly used when a short period of treatment is required. The shunt is constructed if possible in the non-dominant limb. The radial artery or the ulnar artery, and the cephalic vein or the basilic vein may be used. The procedure is as follows:

- The branches of the lateral and medial cutaneous nerves of the forearm are blocked with a local anesthetic.
- A midline incision is made on the anterior surface of the distal part of the forearm.
- The cephalic vein or the basilic vein is located in the superficial fascia as it winds around from the dorsum of the



**CD Figure 7-1** **A.** The positions of the radial and ulnar arteries in front of the wrist. Note that the superficial palmar arch is formed mainly from the ulnar artery and the deep palmar arch receives its major contribution from the radial artery. **B.** The wrist joint is extended during cannulation of the radial artery.

hand to ascend the front of the forearm (see text Figs. 7-18 and 7-19).

- The deep fascia is incised and the artery is located. The radial artery can be palpated (see text Fig. 7-13) as it lies anterior to the distal third of the radius and between the tendons of flexor carpi radialis (medially) and the brachioradialis (laterally). The ulnar artery can be felt just lateral to the pisiform bone and can be traced proximally into the forearm (see text Fig. 7-13).
- The appropriate artery and vein are then connected to the dialyzer.

In those patients in whom the distal vessels have been previously used, the same vessels can be cannulated at a more proximal site.

In children, if the distal arteries and veins are too small, a shunt can be constructed between the brachial artery and cephalic vein just proximal to the cubital fossa.

### Internal Arteriovenous Fistula

This procedure is most often used when it is necessary to have a prolonged period of hemodialysis. The procedure is as follows:

- The branches of the lateral and medial cutaneous nerves of the forearm are blocked with a local anesthetic.
- A midline incision is made on the anterior surface of the distal part of the forearm.
- The cephalic vein is located in the superficial fascia.
- The deep fascia is incised and the radial artery is located in front of the distal end of the radius, as described in the previous section.
- A side-to-side anastomosis is performed between the radial artery and the cephalic vein. Alternatively, an end-to-end or end of vein-to-side of artery anastomosis can be constructed. The peripheral circulation is maintained by the extensive anastomoses from the ulnar artery around the wrist and through the palmar arches.
- The vein quickly becomes arterialized and distended and can be easily punctured with a cannula. The cannula

from the dialyzer is inserted into the distended vein, and the cannula to the dialyzer is inserted into the fistula to enter the radial artery.

A similar arrangement can be made using the ulnar artery and the basilic vein.



## DEEP VEINS OF THE UPPER EXTREMITY

### Axillary-Subclavian Vein Thrombosis

Spontaneous thrombosis of the axillary and or subclavian veins occasionally occurs following excessive and unaccustomed use of the arm at the shoulder joint. The close relationship of these veins to the first rib and the clavicle and the possibility of repeated minor trauma from these structures is probably a factor in its development.

Secondary thrombosis of axillary and/or subclavian veins is a common complication of an indwelling venous catheter.

### Anatomy of Subclavian Vein Catheterization

#### Venous Tone and Hypovolemic Shock

In extreme hypovolemic shock, excessive venous tone may inhibit venous blood flow and thus delay the introduction of intravenous blood into the vascular system.

## Clinical Problem Solving Questions

**Read the following case histories/questions and give the best answer for each.**

A young secretary, running from her office, had a glass door swing back in her face. To protect herself, she held out her left hand, which smashed through the glass. On admission to the hospital, she was bleeding profusely

from a superficial laceration in front of her left wrist. She had sensory loss over the palmar aspect of the medial one and a half fingers but normal sensation of the back of these fingers over the middle and proximal phalanges. She had difficulty in grasping a piece of paper between her left index and middle fingers. All her long flexor tendons were intact.

1. The following statements concerning this patient are correct **except** which?
  - A. The radial artery was cut in front of the flexor retinaculum, and this accounted for the profuse bleeding.
  - B. The loss of skin sensation on the palmar aspect of the medial one and a half fingers was caused by the severance of the ulnar nerve as it crossed in front of the flexor retinaculum.
  - C. The normal sensation on the back of the medial one and a half fingers over the proximal phalanges was caused by the fact that the posterior cutaneous branch of the ulnar nerve arises about 2.5 in. (6.25 cm) proximal to the flexor retinaculum and was spared.
  - D. The inability to hold the piece of paper was caused by the paralysis of the second palmar interosseous muscle, which is supplied by the deep branch of the ulnar nerve.
  - E. There was no sensory loss on the palm of the hand because the palmar cutaneous branch of the ulnar nerve was not cut.
2. A middle-aged man with a history of chronic duodenal ulcer was seen in the emergency department in a state of severe shock. He was pale, restless, and sweating, and his blood pressure was 80/60 mm Hg. The resident made a diagnosis of internal hemorrhage, probably due to the erosion of the gastroduodenal artery or one of its branches, and decided to set up a blood transfusion immediately. Based on your knowledge of anatomy, into which superficial vein of the upper limb would you perform the transfusion: in the elbow region or in the forearm? If the veins were too collapsed to be identified, where, in an emergency, could you cut down on a superficial vein in the upper limb?
3. Palpation of the radial artery at the wrist can provide the experienced medical professional with considerable insight into the state of the patient's circulatory system. The degree of hardness of the arterial wall can be appreciated by the examining finger; the pulse rate and quality of the rhythm can be determined; and the amount of pressure required to occlude the vessel can be used to assess the blood pressure. What are the relations of the radial artery at this site where the pulse is taken?
4. An 8-year-old boy fell off a swing and sustained a supracondylar fracture of his left humerus. Following the reduction of the fracture, a suitable splint was applied and the child was sent home. A few hours later, the child complained of pain in the forearm, which persisted. Four hours later, the parents decided to return to the hospital, since the child's left hand looked dusky white and the pain in the forearm was still present. On examination, there was found to be a complete loss of skin sensation of the hand. After removal of the splint, the pulse of the radial and ulnar arteries could not be felt. Every possible effort was made to restore the circulation of the forearm, without avail. What has happened to this child's circulation in the forearm? What deformity would you expect this child to have 1 year later?
5. Why is the radial artery chosen in preference to the ulnar artery or brachial artery for direct blood pressure monitoring? Why are the upper limb arteries used in preference to the dorsalis pedis artery of the foot? What are the important anatomic relations of the radial artery at the site of cannulation? Why is it necessary to extend the wrist joint when the canula is introduced?
6. During an emergency procedure it is sometimes necessary to monitor central venous pressure via peripheral access. Why is the basilic vein more often used to establish a central venous pressure line than the cephalic vein?
7. A 29-year-old woman was seen in the emergency department complaining of severe pain and discoloration of the fourth and fifth fingers of both hands. She said that she had had similar symptoms before and that they always occurred in very cold weather. Initially, her fingers turned white on exposure to cold and then became deep blue in color. The color change was confined to the distal half of each finger and was accompanied by an aching pain. Placing her hands in hot water was the only treatment that relieved the pain. As the pain disappeared, she said, her fingers became red and swollen. Using your knowledge of anatomy, make the diagnosis.
8. A 23-year-old medical student decided to assist his father in building a garden shed. Unfortunately, much of the wood had to be cut to length by using a hand saw. He noticed on the third day that his right arm felt heavy and that his right hand was swollen. At the emergency department, a diagnosis of right subclavian vein thrombosis was made. Can you explain the possible anatomic reasons why thrombosis occurred in this vein in a healthy individual?

# Answers and Explanations

1. **A** is the correct answer. The radial artery does not enter the palm by passing in front of the flexor retinaculum; it does so by passing forward between the two heads of the first dorsal interosseous muscles between the first and second metacarpal bones (see text Fig. 7-14). It was the ulnar artery that was cut with the ulnar nerve in front of the flexor retinaculum.
2. The cephalic, basilic, and median cubital veins, and their tributaries, are located in front of the cubital fossa and may be used for transfusion (see text Fig. 7-19). In the forearm, the cephalic and basilic veins can be seen as they wind around the lateral and medial borders of the forearm, respectively. The cephalic vein lies in a constant position behind the styloid process of the radius (see text Fig. 7-18), and it is here that it may be exposed through a small skin incision.
3. The radial artery lies in front of the distal third of the shaft of the radius; it is directly in contact with the front of the bone (see text Fig. 7-11). On its lateral side lies the tendon of the brachioradialis, and on its medial side is the tendon of the flexor carpi radialis muscle. The artery is covered anteriorly by skin and fascia.
4. At the time of sustaining the supracondylar fracture of the humerus or the application of the splint, the brachial artery went into spasm in the distal third of the upper arm. This effectively shut off the blood flow through the radial and ulnar arteries, including the collateral circulation around the elbow joint (see text Fig. 7-8). During the following hours, when the child was complaining of severe pain, avascular necrosis of the tissues of the forearm was taking place. Later this was followed by Volkmann's contracture.
5. The radial artery has a lower incidence of arterial thrombosis than the brachial artery, possibly because the tunica intima of the brachial artery is more likely to be damaged by the point of the catheter, since the brachial artery is more difficult to immobilize because of the movements at the elbow joint. The dorsalis pedis artery can be easily cannulated. It has a higher incidence of thrombosis, however, and sometimes the circulation of the foot is compromised by the inadequate collateral circulation. The radial artery is usually cannulated 2 to 3 cm proximal to the distal transverse crease of the wrist. Here the artery lies anterior to the distal third of the shaft of the radius, medial to the tendon of the brachioradialis and lateral to the tendon of flexor carpi radialis. It is covered anteriorly by skin and fascia. The forearm is supinated, and the wrist is extended to an approximately 50° angle (see CD Fig. 7-1). Extension stretches and stabilizes the artery during the process of introducing the needle and the catheter.
6. The basilic vein is used more often than the cephalic vein for the following reasons: (a) The basilic vein increases progressively in diameter from the cubital fossa to the axillary and subclavian veins, whereas the diameter of the cephalic vein increases only slightly as it ascends the upper extremity; (b) the basilic vein is in line with the axillary vein (see text Figs. 7-19, 7-22, and 7-23), whereas the cephalic vein opens into the axillary vein at a right angle; and (c) the basilic vein is directly continuous with the end of the axillary vein, whereas the cephalic vein may bifurcate into several small veins near its termination or may join the external jugular vein.
7. This patient had Raynaud's disease. The initial pallor of the fingers is due to spasm of the digital arterioles. The cyanosis that follows is due to local capillary dilatation caused by an accumulation of metabolites. Since there is no blood flow through the capillaries, blue deoxygenated hemoglobin accumulates within them. It is during this period of prolonged cyanosis that the patient experiences severe aching pain. On exposing the fingers to warmth, the vasospasm disappears, and oxygenated blood flows back into the very dilated capillaries. Reactive hyperemia is responsible for the swelling of the affected fingers.
8. The subclavian vein is closely related to the upper surface of the first rib and to the posterior surface of the medial third of the clavicle (see text Fig. 7-3). Repeated minor trauma to the vein wall by these bones during the movements of the right shoulder while sawing resulted in damage to the tunica intima, followed by thrombosis. This problem is particularly likely to occur in an individual who is not used to this type of excessive movement of the shoulder. Usually there is some preexisting compression.



