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CANNULATION INJURY OF THE RADIAL ARTERY: DIAGNOSIS AND TREATMENT ALGORITHM

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Cannulation of the radial artery can result in complications ranging from arterial thrombosis, arterial aneurysm, compartment syndrome, infection, nerve injury, and skin necrosis to possible thumb or even hand necrosis if not recognized and treated early. The anatomy of the radial artery, the diagnosis of injury, and a treatment algorithm are presented so that potential devastating hand complications can be avoided. (American Journal of Critical Care. 2004;13:315-319)

Arterial cannulation allows continuous monitoring of blood pressure, repeated acquisition of blood samples for arterial blood gas analysis, and access to blood for other quantitative assays. Critically ill patients and patients undergoing major surgery, such as cardiovascular or neurosurgical procedures, often require arterial cannulation. Commonly, the radial artery is the vessel of choice; it is readily accessible, and the hand usually has extensive collateral circulation.

Arterial cannulation is not without risk. Fortunately, the risk of serious complications is less than 0.2%. Formation of hematomas, infection of the surrounding skin and subcutaneous tissue, acute carpal tunnel syndrome, compartment syndrome, nerve injury, arterial thrombosis, formation of aneurysms, and ischemia leading to necrosis of tissues including the thumb, fingers, and even the extremity have been reported.

Anatomy of the Radial Artery
The radial artery arises at the bifurcation of the brachial artery, most commonly just distal to the antecubital fossa, and then traverses distally along the radial side of the volar forearm under the brachioradial muscle and the radial flexor muscles of the wrist (flexor carpi radialis). Of note, the brachial artery may bifurcate more proximally in the arm and give off anastomotic branches. The radial artery gives off multiple fasciocutaneous perforators until it reaches the wrist, where it courses over the dorsum of the first web space and forms the deep palmar arch. The radial artery contributes to the principal artery of the thumb and the radial artery of the index finger. In addition, the radial artery often anastomoses with the deep branch of the ulnar artery system.

At the wrist, the radial artery gives off a volar carpal branch that joins the ulnar artery. Often, a distal branch in the volar aspect of the wrist forms part of the superficial palmar arch, and it also contributes to the blood supply of the skin over the thenar region. The superficial arch is complete in about 80% of patients, and the predominant blood supply is thought to be from the ulnar artery, although the results of a recent study suggest otherwise. The contributing blood supply of the arch has several variations, including ones in which the superficial arch is incomplete (Figure 1).

The ulnar artery may not provide the major blood supply to the hand in all instances.

Case Report
A 61-year-old man with a history of insulin-dependent diabetes mellitus, hypertension, peripheral vascular disease, coronary artery disease, and renal cell
cancer that required a right nephrectomy came to the hospital 2 weeks after he had had 2-vessel coronary artery bypass surgery. He was admitted to the intensive care unit in septic shock and was treated with broad-spectrum antibiotics and vasopressors. He had monitoring catheters inserted, including a radial artery cannula that was inserted without difficulty on the first attempt in his dominant left hand.

When ischemic changes to the hand were noted approximately 12 hours after the initial cannulation, the radial artery cannula was removed. The patient also had some ischemic changes in both lower extremities, including mottling of the skin; no skin mottling was evident in his right hand. No vascular studies were done at this time; however, a vascular surgeon was consulted. Because of the patient's poor condition, noninterventional treatment was recommended.

The ischemia of the lower extremities fluctuated with changes in the patient's overall condition but reversed completely once treatment with vasopressors was tapered off during the ensuing week. However, tissue necrosis developed over the radial dorsal aspect of the left hand, thumb, and tips of the index and long fingers (Figure 2). A plastic surgeon was consulted 1 week after the initial event. The treatment plan recommended at this late stage included splinting the hand in an intrinsic-plus position and observation to allow definitive demarcation of the involved parts of the left hand.

The patient's left thumb was amputated at the level of the metacarpophalangeal joint, and the wound was closed primarily. The tips of the left long finger, index finger, and thenar eminence improved and did not require any debridement. A dry eschar on the radial dorsal aspect of the hand was debrided and was covered with a split-thickness skin graft. The hand healed without further complications.
Risk factors for complications associated with radial artery cannulation

- Previous upper extremity surgery
- Previous upper extremity trauma
- Congenital anomalies of the upper extremity
- Peripheral vascular disease
- Diabetes
- Collagen vascular disorders
- Blood dyscrasias
- Active upper extremity infection
- Current use of medications
  - Heparin
  - Warfarin
  - Aspirin
  - Vasopressors

Discussion

Obtaining a patient’s medical history before insertion of a radial artery cannula is important. Some risk factors (see Table), including previous injury, such as from trauma or burns, and surgery performed on the extremity, may lead to complications associated with radial artery cannulation. For instance, previous harvesting of the radial artery for coronary artery bypass surgery or for radial or ulnar artery pedicled or free flaps may have left only 1 vessel for perfusion of the hand. Preaxial or postaxial congenital deformities, such as in radial club hand, can result in anomalous vasculature to the extremity. A history of diabetes, hypertension, peripheral vascular disease, active infection in the extremity, collagen vascular disorders, and blood dyscrasias may affect the decision to place the arterial catheter, because all these conditions have been associated with an increased risk of complications.

Anticoagulant medications such as heparin, warfarin, and aspirin increase the risk of bleeding; therefore, in patients taking these medications, a hematoma can develop at the puncture site, a situation that in turn may cause ischemia of the hand. Other medications that increase the risk include vasopressor agents. Unfortunately, many critically ill patients require these agents and so the use of the medications cannot be discontinued.

After a patient’s medical history is reviewed, a physical examination should be done (Figure 3). The radial and ulnar arterial pulses should be assessed. Some researchers suggest that an Allen test should be performed to determine the dominant filling artery to the hand; others think that the test is unreliable and that the results are poorly predictive of ischemic hand damage. Still, some clinicians prefer to evaluate the extremity by using a Doppler probe, pulse oximetry, or digital plethysmography, mapping out the radial and ulnar arteries and using modifications of the Allen’s test. In addition, hand dominance should also be determined; cannulation of the dominant hand should be avoided to limit the potential for injury and loss of function to this part of the upper extremity.

Some experts recommend the Allen test; others think the results of the test are a poor predictor of ischemic hand damage.
A number of factors may increase the risk of cannulation injuries of the radial artery. Use of a 20-gauge or smaller cannula may decrease the risk of complications. Long-term use of an indwelling catheter can also increase the risk. In one study, patients who required radial artery cannulation for more than 20 to 40 hours had a 50% occlusion rate; however, all of the arteries eventually became patent.

**Using a 20-gauge or smaller cannula may decrease risk of complications.**

If contraindications exist, alternative options include using other vessels for cannulation, such as the opposite radial artery, the dorsal artery of the foot, the femoral artery, the brachial artery, the axillary artery, and the temporal artery. The dorsal artery of the foot is an uncommon site because the anatomy may be unpredictable; this vessel is congenitally absent in 12% of patients. Use of the dorsal artery of the foot should be avoided in patients who do not have a posterior tibial pulse or who have peripheral vascular disease.

The femoral artery often is the first option when a radial artery is unavailable. The femoral artery is a large vessel that is easily palpable. Percutaneous puncture should be performed distal to the inguinal ligament. Potential complications at this site include retroperitoneal hematoma and perforation of a viscus. Ischemia of the lower extremity is unusual with this approach. However, use of the femoral artery should be avoided in patients who have peripheral vascular disease or who have had previous vascular procedures in the groin.

The brachial artery is yet another option when other vessels are not available; it is usually not used because it has little collateral circulation to the forearm and hand. The axillary artery has better collateral circulation than does the brachial artery. Use of axillary artery may result in a pneumothorax or brachial plexus injury. The temporal artery has a rich collateral circulation, but the vessel may be very small and tortuous, making the artery difficult to cannulate.

If ischemia of the hand develops after placement of a cannula in the radial artery, the cannula should be removed and the patient should be monitored for improvement of signs and symptoms (Figure 3). Patients who are being treated with vasopressors should be weaned off the medications if possible. However, in most instances, discontinuing use of vasopressors is unlikely. If arterial spasm is suspected, a sympathetic block can be performed to induce vasodilatation and improve circulation. For critically ill patients, the block can be done at the bedside.

Arterial duplex Doppler sonography is a noninvasive procedure that can be done at the bedside to delineate areas of occlusion and flow through the artery. Angiography to evaluate the extent of the injury to the radial artery may also be helpful.

**Arterial duplex sonography can be used at the bedside to delineate areas of occlusion and flow.**

Operative intervention may be necessary to remove a clot from a thrombosed radial artery, repair a lacerated radial artery, or perform a bypass graft or use a vein graft for a damaged artery. In critically ill patients who cannot tolerate surgery, selective thrombolytic therapy may be beneficial.

Observation and splinting may be the only choice in patients who cannot tolerate any of the treatments described. The subsequent definitive treatment may be delayed until demarcation of the involved parts, and then amputation or debridement can be performed when the patient's condition is stable.

Complications of radial artery cannulation are fortunately very rare. However, delay in diagnosis and treatment can lead to marked debility and should be avoided. Often, the cause of ischemia in a critically ill patient is multifactorial. For instance, in the patient described in the case report, a combination of hypotension, use of vasopressors, radial artery cannulation, and the patient's underlying medical conditions, including peripheral vascular disease and insulin-dependent diabetes mellitus, may have contributed to the necrosis of the thumb.

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Cannulation of the radial artery can be performed in most patients without any untoward effects, and in many instances, the radial artery can be sacrificed without clinical consequences. Even in patients who have thrombosis of the radial artery, the outflow spontaneously recanalizes. However, when complications do occur, they are severe because of the functional importance of the affected areas of the thumb and hand.

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