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Research Article

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Radial Artery Cannulation: A Review Article

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Abstract

Percutaneous radial artery cannulation is a well established procedure that is commonly used in the operating room and intensive care units. Relevant anatomy and attention in detail during cannulation and maintenance are important aspects of the technique that enhance patient safety. Access to the arterial circulation will remain important for hemodynamic monitoring and access to arterial blood. This article reviews the current indications, contraindications, pre-procedure assessment, technique, complications, and monitoring of the site.

Keywords: Radial artery, Arterial catheterization, Arterial circulation, Anatomy, Indications, Complications

Abbreviations: PPV: Pulse Pressure Variation; SPV: Systolic Pressure Variation; SVV: Stroke Volume Variation; CDC: Center for Disease Control and Prevention; HICPAC: Healthcare Infection Control Practices Advisory Committee; ICU: Intensive Care Unit; Ga: Gauge

Introduction

Percutaneous radial artery cannulation is a well established procedure that is commonly used in the operating room and the intensive care unit. Physicians performing vascular access procedures require an understanding of the relevant anatomy and awareness of potential complications. This article will review the current indications, contraindications, pre-procedure assessment, technique, complications, and site monitoring.

History of Arterial Cannulation

Although it is unclear when the first radial artery cannulation was performed, the first recorded cannulation of an arterial blood vessel was performed in 1714 by the English Reverend, Stephen Hales [1]. The first description of arterial cannulation in a human occurred in 1856, when the blood pressure was measured in the femoral artery [2]. More recently, cannulation of the radial artery by surgical cut-down has been described in Cuba [3], and by Radner [4] in Sweden (1948).

Continuous recording of arterial blood pressure during the perioperative period with small plastic catheters was first described in 1949 by Peterson et al. [5] who inserted them into the brachial artery through a metal needle.

In 1951, Peirce described the percutaneous catheterization of large arteries in animals [6] and humans [7] using polyethylene catheters. In 1953, the Swedish radiologist Sven Seldinger described the now widely used *catheter-over-wire* technique [8]. Improvements to both catheter design and pressure transducing systems led to an increase in arterial line use beginning in the 1960's. By 1990, approximately 8 million arterial catheterizations were performed annually in the United States; the vast majority of these catheters being placed within the radial artery [9].

There are several reasons for the popularity of the radial artery. These include, ease of access, high success rate, [10,11] and they are easy for the nursing staff to care for. Given the rich collateral circulation of the human hand, and the fact that most humans are ulnar artery dominant, the risk of radial artery thrombosis with the development of distal ischemia is low. In 1929, Allen [12] described a method to assess the presence of collateral circulation, which was later modified to

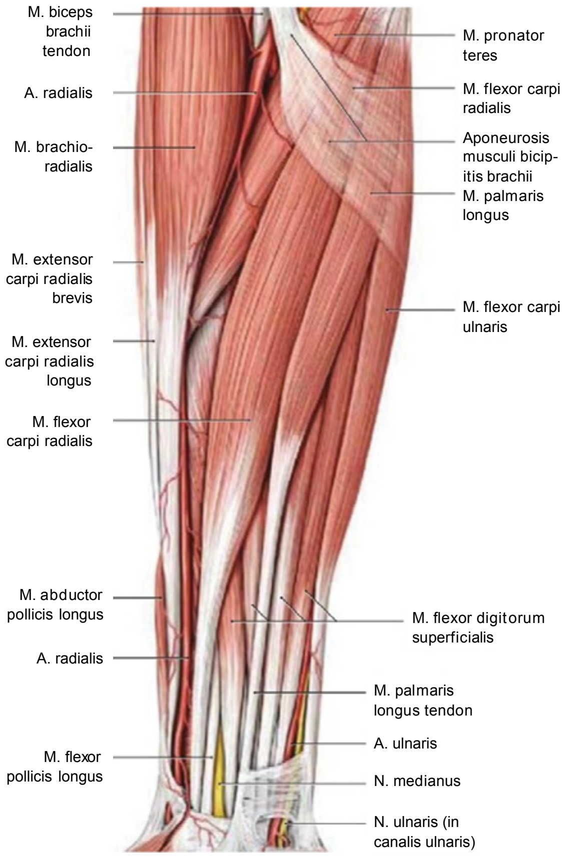

Figure 1: Arterial circulation of the forearm. (reproduced with permission from Atlas of Anatomy, Gilroy AM, MacPherson BR, Ross LM (2009) Thieme Medical Publishers, New York, NY)

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the current "Allen" test [13]. Caution however must be exercised with patients who are more likely to have vascular disease and those who are radial artery dominant.

Anatomy

The increased use of the radial artery in coronary artery bypass grafting has generated new interest in its anatomy. In most patients, the artery originates just below the elbow as a branch of the brachial artery. The radial artery courses passes along the lateral margin of the forearm until it reaches the level of the wrist [14]. In the upper forearm the vessel is deep to the body of the supinator longus muscle. In the mid forearm, down to the level of the wrist, it lies between the tendons of the supinator longus and the flexor carpi radialis (Figures 1 and Figure 2). Variations in both the origin and course are well described [15]. The most common variant involves the artery originating just superior to the elbow, although it may originate much higher in the arm. High origination from the brachial artery has been reported in up to 12% of cases [14-17] while 5% of humans have its origination within the axilla [18]. There have been described cases of patients with dual radial arteries [17,19-21] or absence of radial artery [22-26].

The radial artery is usually smaller than the ulnar artery at their origins [17,27], but is equal or larger at the wrist as the ulnar artery gives off numerous branches in the forearm [28]. Together the two arteries create a dense anastomotic network of 4 arches, providing arterial blood flow to the hand. Three of these arches occur on the palmar side of the hand and include the palmar carpal arch, the deep palmar arch, and the superficial palmar arch (Figure 3). The arterial network on the dorsal side consists of the dorsal palmar rete. The palmar arches can be divided into 2 types: complete and incomplete [29]. The superficial palmar arch (formed from the terminal part of ulnar artery) and deep palmar arch (formed from the terminal part of radial artery) [14,30] are the most clinically significant arches because they provide blood flow to all the digits of the hand.

The majority of individuals have either a complete superficial or a deep palmar arch, which makes radial artery occlusion well tolerated. When radial artery occlusion occurs in a patient with 2 incomplete arches the risk for digital ischemia is substantially increased [31]

Indications for Cannulation

Intra-arterial cannulation with continuous blood pressure transduction is considered the most accurate method for blood pressure monitoring by most clinicians. Arterial cannulation is most often performed when either continuous blood pressure measurement is needed and/ or frequent arterial blood gas sampling is required. Recently, functional hemodynamic parameters derived from the arterial waveform–pulse pressure variation (PPV), systolic pressure variation (SPV) or pulse contour analysis–stroke volume variation (SVV) to better predict the physiologic response to fluid resuscitation or fluid removal have been described. [32,33]

Other uses for arterial cannulation are related to inability to use/inaccurate regular blood pressure monitoring (e.g., severe burns, morbid obesity, and severe peripheral vascular disease).

Contraindications

Absolute contraindications to radial artery cannulation include inadequate circulation to the extremity, Raynaud syndrome, thrombo-

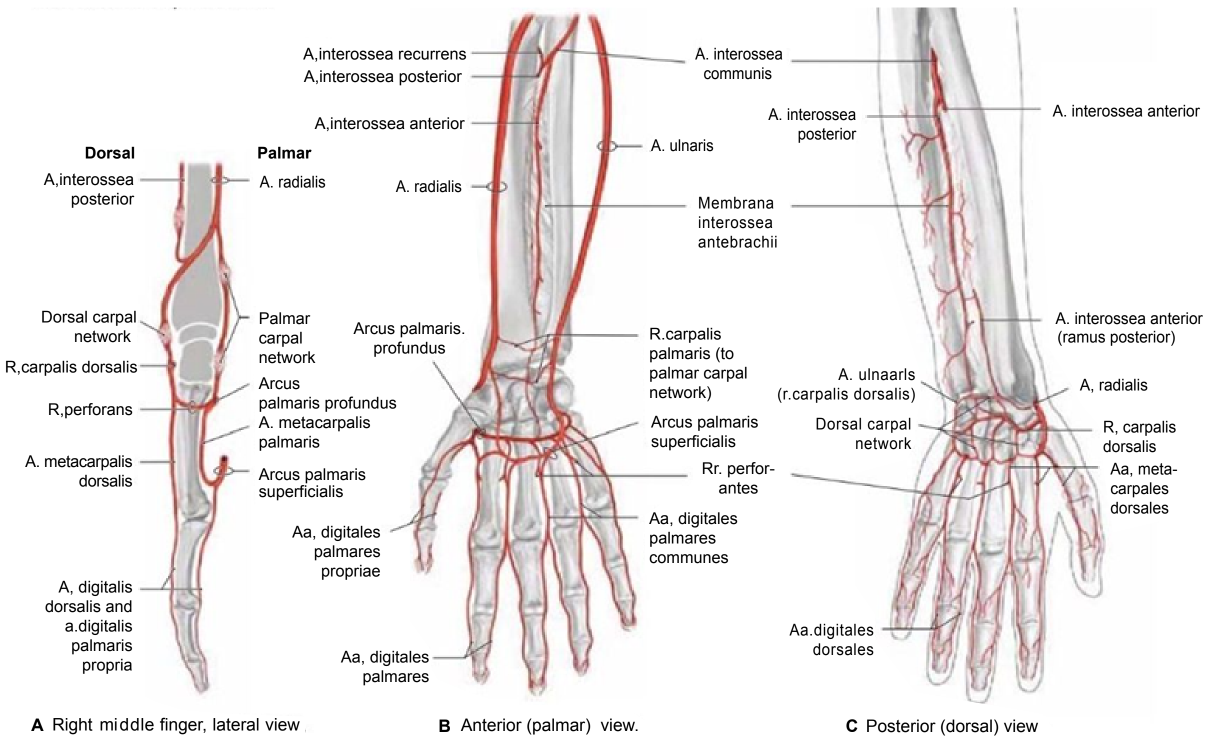

Figure 2: Arterial circulation of the hand. A. right middle finger, lateral view. B. Anterior (palmar) view. C. Posterior (dorsal) view. (reproduced with permission from Atlas of Anatomy, Gilroy AM, MacPherson BR, Ross LM (2009) Thieme Medical Publishers, New York, NY)

angiitis obliterans (Buerger disease), and full-thickness burns or skin infection over insertion site.

Other contraindications are relative, such as uncontrolled coagulopathy, systemic anticoagulation, inadequate collateral flow from ulnar artery on Allen test, or atherosclerosis [34,35].

Complications

In a review by Scheer et al. [36], the most common complications were temporary radial artery occlusion (19.7%), and hematoma (14.4%) followed by infection at the arterial site (0.72%), hemorrhage (0.53%) or bacteremia (0.13%), and very rarely permanent ischemic damage or pseudoaneurysm (0.09% each).

Local injury (e.g., intimal damage and proliferation) and scarring have been found even after short term catheterization. Long-standing or permanent radial artery occlusion has also been described. In some cases (particularly after vascular procedures) the radial artery occlusion may be delayed several days of the procedure or removal of catheter [37].

Rare complications include paralysis of the median nerve [38-40] air embolism [41], compartment syndrome, and carpal tunnel syndrome [42-44]. Rarely, intravascular catheter fragments have occurred [45-48].

Larger catheter diameter [37,49,50], presence of vasospasm [37,51-53], female sex [52,54] (probably related to smaller vessel diameter) [37,50,54,55] increase the risk of ischemic complications. Inadequate experience placing catheters *(high number of attempts, multiple arterial sticks and hematoma formation)* may influence the complication rate [37,51-53].

Pre-Procedure Assessment

Step 1

Consider indications for arterial catheterization, anticipated catheter duration and presence of risk factor.

Step 2

Inspect potential areas of cannulation looking in particular for signs of infection, skin breakdown, accessibility, and importantly the presence of the radial pulse. The physical examination should include at least a bilateral evaluation of pulse quality and of the blood pressure in both arms. The quality of the pulse and noting whether a blood pressure differential exists will provide important clues to both the ease of arterial cannulation as well as the accuracy of the measurement.

Step 3

In the case of radial arterial cannulation, one must assess for the presence of an ulnar dominant blood flow to the hand. Numerous studies have investigated the use of the Allen's test [12], the modified Allen's test [13], pulse oximetry, and Doppler ultrasound.

Allen described a method to assess the collateral circulation of the hand in patients with thromboangiitis obliterans. The test consists of the compression of either the radial or ulnar artery while the patient clenches the fist for approximately 1 minute [12]. The patient then unclenches the fist while pressure over the vessels (radial or ulnar) is maintained and return of color to the hands and fingers is noted. Normally the pallor quickly disappears if the circulation is intact [56].

Performing the modified Allen's test requires compression of both

Figure 3: Wrist is hyperextended with the use of an arm board and a roll.

"the ulnar and radial arteries at the wrist for greater than 30 seconds to induce hand ischemia, while the hand is drained of blood by tight clenching. The test vessel is released and the hand relaxed. The time to adequate perfusion of the tips of the fingers and thumb noted. The vessel is said to pass or fail the test as follows: pass (<5 seconds); equivocal (6 -10 seconds); fail (>10 seconds)" [57].

Erroneous results can arise if the test is performed incorrectly with the hand hyperextended or wide spreading of the fingers [58,59]. Both tests suffer from inter-observer reliability issues and have not been validated to be predictive of hand ischemia after radial artery cannulation [29], therefore the use of Allen's or modified Allen's test is not widely accepted.

When performed, any failure of the tested vessel should prompt the provider to document the abnormal finding and to use an alternate site for cannulation.

Pulse oximetry was used to make the interpretation of modified Allen's test more reliable, but results were not promising [60-62].

The utilization of ultrasound or Doppler ultrasound to facilitate both cannulation and integrity of collateral circulation is promising, but has not been rigorously evaluated [29].

Technique

The procedure should be explained to the patient and informed consent should be obtained when possible. Appropriate sedation and analgesia are important for patient cooperation and comfort.

The needed equipment and supplies (Table) should be gathered. The patient's wrist is hyperextended and held in place with an arm board and gauze dressing so that the wrist is exposed (Figure 3). Positioning of the patient's arm and wrist is one of the most important preparatory steps as hyperextension of the wrist brings the radial artery more superficial and increases success rate [35].

The Center for Disease Control and Prevention (CDC) and the Healthcare Infection Control Practices Advisory Committee (HICPAC) updated guidelines [63] for the prevention of intravascular catheter-related bloodstream infections in 2011, suggest the use of a cap, mask, sterile gloves and a small fenestrated drape (as a minimum) to help reduce the risk of infection.

Once the wrist is extended and fixed to an arm board with tape or gauze, a chlorhexidine (> 0.5%) or iodinated wash is performed (Figure 4) and a large sterile field is applied over the wrist area (Figure 5). The artery is then palpated between the first and second fingers (Figure 6). Alternatively the use of ultrasound to find the radial artery increases success, decreases procedure time [64-68], and minimizes the number of needle passes.

Figure 4: Chlorhexidine washing of the skin.

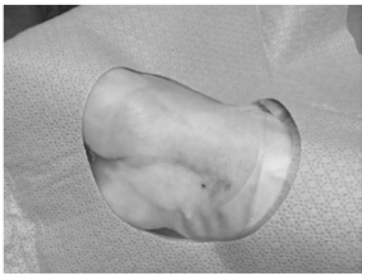

Figure 5: A large enough drape is applied over the prepped area.

Figure 6: Radial artery is palpated with first and second fingers.

Figure 7: Catheter needle assembly is held at 45 degrees, while artery is palpated in between the first and second fingers, stabilizing the artery.

Figure 8: Guide wire is advanced in the artery after blood is seen advancing in the catheter needle assembly.

The entry site is typically 1-1.5 cm cephalad from the junction of the arm and the hand. Typically the best approach is to find the area of maximal arterial pulsation. A 20-gauge or smaller catheter over the needle cannulation is typically used with or without a guide wire (Figure 7). Once pulsatile blood flow is noted the catheter should be gently slipped into the artery with a slight rotation while holding the needle perfectly still. If a guide wire is to be used at this point, it should now be inserted through the needle into the vessel and the catheter advanced over it (over-the-wire technique) (Figure 8). Occasionally the back wall of the artery is penetrated. In this circumstance, the pulsatile flow will be transient. Simply backing the needle catheter assembly out slowly and assessing for the return of pulsatile blood flow will often locate the vessel in this situation. Patency of radial artery catheters is enhanced by placing the catheter close to the bend of the wrist [69].

The catheter should then be hooked up to the pressure tubing, quickly flushed and the adequacy of the arterial trace assessed for optimal damping. The catheter should be secured using tape, or other securing devices such as Stat Lock [70]. The 2011 CDC guidelines recommend against the suturing of catheters [63].

If cannulation fails, there may be anatomic or technical problems why the vessel cannot be entered. Radial artery cannulation is associated with a very high success rate, thus several failed attempts should prompt the provider to try another site. The use of ultrasound has been shown to increase the success of first cannulation attempt from 27% to 43% [67].

Monitoring of site / Care of the arterial site

Special care should be exercised after successful insertion of the arterial catheter to assure that the site, flushing device, and infusion system is free of contamination [71-73]. The risk of arterial catheter infection appears to be lower than that of central venous catheters, although the rate of colonization is the same [74]. Current CDC guidelines recommend against routine replacement of arterial catheters [63], although immune compromised patients may benefit from routine catheter change every 4 days [75].

Although there is some advantage to the use of heparin (in different concentrations) versus heparin-free flushing solutions in preventing catheter occlusion [76-78] many ICUs have moved away from using heparinized solutions due the risk of heparin induced thrombocytopenia [79-82] and falsely abnormal coagulation profiles [83-85].

The arterial access should be removed as soon as it is no longer needed or when there is evidence of circulatory compromise or clot formation (e.g. cyanosis in fingers tips, dampening pulse waveform on monitor). The catheter should not be flushed in an attempt to remove clots. Vigorous flushing of the catheter should be avoided, as rare cases of cerebral embolization have been reported [86,87].

After removal of catheter, hemostasis is usually achieved with compression over the arterial site. Although there are commercially available compression devices (i.e. RadStat, Radistop, Adapty, TR band, etc) [88], simple manual site compression with gauze secured with tape is sufficient.

Summary

Radial artery catheterization is a common, safe and important procedure in the care and management of both the critically ill and the high risk surgical patient. Relevant anatomy and attention to detail during cannulation and maintenance of the catheter are important aspects of the technique which enhance patient safety. Although minimally invasive and non-invasive techniques for the measurement of blood pressure and arterial oxygenation abound, intra-arterial cannulation remains vital to the care and management of both critically ill patients in the ICU and those going to the operating theater.

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Dr. Bloomstone: review and editing

Dr. McGee: concept, review, and editing

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