Detection of collateral circulation of the palmar arcade: Comparison of results with use of the Doplette-10®, the modified Allen’s test and finger photo-plethysmography

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A comparison is made by the authors of the accuracy of the Doplette-10®, the modified Allen’s test and photo-plethysmography in determining the presence and extent of collateral circulation in the hand before radial artery cannulation. All prove to be accurate means of assessing circulation.

Percutaneous radial artery catheterization is used extensively in the management of patients undergoing major surgery and in critically ill patients in intensive care units. The information obtained by radial artery catheterization is of unquestionable value to the patient. It allows for close and precise monitoring of both the acid-base balance and the pulmonary alveolar gas exchange by arterial blood gas analysis. The continuous monitoring of cardiovascular function by direct measurement of arterial blood pressure is advantageous to the patient with cardiovascular instability, and is essential in the patient receiving vasoactive drug therapy where severe and rapid changes in blood pressure are possible.1

The radial artery is the most logical artery to use for prolonged arterial catheterization since it is easy to reach and the hand usually has abundant collateral circulation from the ulnar artery. The connection between the radial and ulnar arteries in the hand is formed of nearly perfect free anastomoses.2 The anastomoses occur on the front and back of the wrist through the palmar and dorsal carpal arches, and in the hand through the superficial and deep palmar arches. The deep palmar arches and the dorsal arch are fed primarily by the radial artery, while the superficial palmar arch is usually a continuation of the ulnar artery, which joins the superficial palmar branch of the radial artery. The fingers are supplied predominantly from the superficial palmar arch via the palmar digital arteries.

Unfortunately, this collateral circulation cannot be assumed; it must be proven in every patient. The incidence of an incomplete superficial palmar arch was found by Mozersky et al to be 1.6%;3 by Coleman and Anson to be 7.5%;2 the incidence of absent ulnar pulses bilaterally was found by Friedman to be 3.4%.4

Assessing collateral circulation

Collateral circulation from the ulnar artery can easily be assessed by performing the modified Allen’s test.5 This test requires only adequate lighting and a conscious, cooperative patient who is able to flex his hand. The examiner first compresses with his fingers both the radial and ulnar arteries at the patient’s wrist. The patient is asked to clench and relax his hand several times. He then passively relaxes it; the examiner removes the pressure from the ulnar
artery, and notes the time taken for the blanched thenar area to become flushed. If the hand is completely flushed in one to seven seconds, collateral circulation is considered normal and the test is considered negative. If flushing takes from 7 to 15 seconds, collateral circulation is considered slow but is not a contraindication to cannulation of the radial artery. If flushing takes longer than 15 seconds, collateral circulation is considered inadequate (that is, the test is positive for inadequate circulation) and another site for cannulation should be found. It is important that unclenching of the fist before the ulnar pressure is released be passive and that the hand remain relaxed while open. The radial artery is often an end-artery to the thenar area of the palm, and if the fingers are hyperextended and held separated, this area of the palm will remain blanched indefinitely. If the results of the modified Allen’s test are questionable, another method of determining ulnar artery patency and distribution is photo-plethysmographic measurement of the volume of blood passing through the index finger. A finger-pulse transducer is placed over the index finger and the resulting contour is recorded on an electrocardiographic monitor. The examiner then simultaneously compresses both the radial and ulnar arteries, causing a loss of the pulse contour. He then releases the pressure over the ulnar artery and notes: (1) how quickly the pulse returns, and (2) how similar the ulnar pulse wave contour is to the radial and ulnar flow contours recorded before compression of the arteries. If collateral circulation in the hand is adequate, the pulse wave contour should return almost instantaneously with release of the ulnar artery pressure and the volume beneath the curve should approximate that of the radial and ulnar flow combined.

A third, noninvasive method of assessing collateral circulation in the hand became possible with the introduction of Doppler flow detectors. Alterations in the ultrasonic energy reflected from the moving blood are transmitted back through the muscles and skin to the Doppler sensors, which amplify the sound. Flow is measured before, during, and after ulnar artery compression, as with plethysmography. The obvious advantages of plethysmography and ultrasonic flowmeter measurements are that they are noninvasive and do not require the cooperation of the patient.

The purpose of this study was to compare these three methods of bedside determination of ulnar artery collateral circulation, particularly to determine whether the newer Doppler technique is as reliable as the modified Allen’s test and finger photo-plethysmography.

The Doppler used in this study was the Doplette-10®, a new, unidirectional, 10-megahertz Doppler, comparable in size to an ink pen. It connects to ordinary stethoscopic tubing (Figure 1). Ten megahertz has proven to be a satisfactory frequency for recording blood pressure and peripheral vascular flow.

Practice was necessary to determine how much pressure was required in applying the Doplette-10® over the vessel being studied and at what angle to hold the device. Experience in determining the amount of pressure necessary was gained with practice over large pulsating arteries. Experience in determining the proper angle showed us that the Doplette-10® works best in determining collateral circulation in the hand when it is held at an angle of 30 to 45 degrees with the skin of the palm. The angle directs the signal toward the palmar vessels in the intermetacarpal spaces (Figure 2).

Method

Flow in 100 hands of healthy subjects was measured with the modified Allen’s test, finger photo-plethysmography, and the Doplette-10®. The following procedures were performed in se-
The modified Allen's test was performed and the time until flushing of the palm occurred was recorded. A photo-plethysmograph** was then placed on the index finger and both the radial and ulnar arteries were compressed. Pressure on the ulnar artery was then released and the interval until a pulse wave contour returned was recorded. In addition, the height of the pulse wave from ulnar artery flow alone was compared grossly to that of the pulse wave of the radial and ulnar arteries combined. The Doplette-10® was then placed over the palmar arch in the thenar area of the palm; the radial and ulnar arteries were again compressed to occlusion; the pressure on the ulnar artery was again released; and the interval until blood flow returned was recorded.

**Hewlett-Packer Model #1430A digital photo-plethysmograph sensor
These observations correlated with marginal flow demonstrated by the photo-plethysmograph.

Discussion

The complication rate of catheterization of the radial artery is low. The incidence of systemic or local infection from cannulation is reported to be no greater than from venous cannulation. Serious complications, which imply the presence of significant ischemia of the hand, with or without gangrene, are very rare. The most common complications result from occlusion of the artery and the formation of emboli. Both are a consequence of deposition of thrombotic material on the cannula while it is in situ. Minor complications include necrosis over the tip of the cannula, vasospasm, and Osler’s nodes. Despite these potential complications, the information gained from radial artery catheterization justifies their risk in the care of major surgical and critically ill patients.

The more serious sequelae secondary to radial artery occlusion post-decanalulation may be prevented or markedly reduced if cannulation of the radial artery is done only after an adequate collateral circulation is confirmed.

Conclusion

The Doppler is a versatile tool which has value in many areas of medicine, particularly in vascular studies. The Doppler device used in this study (Doplette-10®) proved to be as accurate as the modified Allen’s test and finger photo-plethysmography in assessing the adequacy of collateral circulation in the hand when radial artery flow was blocked. This assessment is essential before radial artery cannulation can be done. The Doplette-10® is small, inexpensive and portable, and it can be used at the bedside or in the operating room on an anesthetized or unconscious patient. Therefore it is a suitable alternate method for assessing collateral circulation to the hand when the modified Allen’s test cannot be performed or if the results of the modified Allen’s test are equivocal.

REFERENCES

AUTHORS

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