Comparison of Axillary Artery or Brachial Artery Pressure With Aortic Pressure After Cardiopulmonary Bypass Using a Long Radial Artery Catheter

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Arterial pressure measured in a peripheral artery may significantly underestimate central arterial pressure after discontinuation of cardiopulmonary bypass (CPB). Arterial pressure measured with a 50 cm radial artery catheter advanced into the brachial or axillary artery was compared to ascending aortic pressure in 31 patients before and after discontinuation of CPB. The radial artery catheter extended proximally into the brachial artery in 8/31 patients, and into the axillary artery in 23/31 patients. The patient’s age, pre-CPB cardiac ejection fraction, and surgical procedures were similar in both groups. The systolic arterial pressure measured in the ascending aorta was found to be significantly different from that in the axillary artery after CPB, whereas the mean and diastolic pressures were not. The average aorta-to-axillary artery systolic pressure gradient was $-3.0 \pm 4.0$ mmHg, with no patient having a gradient greater than 10 mmHg. The

ACCURATE MEASUREMENT of arterial pressure is necessary for optimal patient management during cardiac surgery. Several studies have determined that arterial pressure measured in a peripheral artery may significantly underestimate the central arterial pressure after discontinuation of cardiopulmonary bypass (CPB). The large central-to-peripheral arterial pressure gradients may necessitate measurement of femoral or ascending aortic pressure if a peripheral artery is being used to monitor arterial pressure. Alternatively, a femoral arterial catheter or a long radial arterial catheter advanced into the subclavian artery can be placed in the preoperative period. Both techniques have been shown to provide an accurate estimate of central aortic pressure in the post-CPB period.

The purpose of this study was to compare arterial pressure measured with a long radial artery catheter advanced proximally into the axillary artery with ascending aortic pressure after CPB. In addition, a method for placement of a long radial artery catheter using the Seldinger technique is described.

METHODS

After institutional review board approval, 35 consecutive adult patients undergoing cardiac surgery with CPB were studied. Surgical procedures included coronary artery bypass grafting (20 patients), aortic valve replacement (6 patients), mitral valve replacement (2 patients), and combined valve replacement and by-pass grafting (7 patients) performed by two cardiac surgeons. The left radial artery was preferentially cannulated in 25/35 patients. Patients were excluded from the study if the long radial artery catheter could not be advanced proximally due to anatomic deformity of the extremity or apparent obstruction in the artery.

Arterial tubing to a transducer, was placed by the surgeon into the ascending aorta before and after CPB for direct arterial pressure sampling. Anesthesia consisted of sufentanil, midazolam, and up to 50% nitrous oxide. Skeletal muscle relaxation was obtained with vecuronium, pancuronium, or both drugs. The long radial artery catheter was a 50-cm, 18-gauge polyethylene angiographic catheter (No. C-PSY 401, Cook Corp, Bloomington, IN). The technique for placement was as follows: The skin overlying the wrist was cleansed with povidone iodine and draped with sterile towels. After infiltration with 1% lidocaine, the radial artery was cannulated with a 20-gauge, 16-cm catheter (Jelco No. 4050, Critikon Corp, Tampa, FL). Then using the Seldinger technique, the 32 cm catheter was exchanged over a 65-cm J-wire. The 50 cm catheter was advanced proximally, and the J-wire was removed. The insertion site was dressed with povidone iodine ointment and noncircumferential adhesive tape.

The aortic pressure sampling needle and the long radial arterial catheter were connected to identical 0.050 inch internal diameter, 84 inch length sterile disposable pressure tubing (No. 91117, Mallinkrodt Co, Utica, NY) and disposable transducers (Dix Plus, Viggo-Spectromed, Oxnard, CA), which were zeroed at the level of the right atrium. Simultaneous arterial pressures were recorded before CPB and within 5 minutes after discontinuation of CPB with all patients in the supine position at end-expiration with controlled ventilation.

All patients were monitored clinically for postoperative complications related to arterial cannulation. Postoperative chest x-rays were used to confirm the catheter position (Fig 1).

Standard descriptive statistics were used for data analysis. The paired differences were evaluated by the paired Student’s t-test. Gradients were calculated by subtracting the pressure measured in the long radial arterial catheter (mmHg) from the corresponding ascending aortic pressure (mmHg). The unpaired Student’s t-test was used to compare the aorta-axillary artery gradients with the aorta-brachial artery gradients.

RESULTS

The long radial arterial catheter was successfully advanced its full length in 32 of 35 patients. Two patients had severe peripheral vascular disease and one patient had an
anatomic deformity at the elbow prohibiting full extension such that the catheters would not advance their full length. These patients were excluded from the study. One additional patient was excluded because the long radial arterial catheter became nonfunctional during chest wall retraction.

Arterial pressure was measured simultaneously with the long radial arterial catheter and in the ascending aorta before institution of CPB, and within 5 minutes after CPB was discontinued. Postoperative chest x-rays documented that the position of the long radial arterial catheter tip extended proximally into the axillary artery (LRC/AX) in 23 of 31 patients, and into the brachial artery (LRC/BR) in 8 of 31 patients. This correlated clinically with patient size. Each patient group was similar with regard to surgical procedures and cardiac function (Table 1). The arterial pressure measured in the LRC/AX and LRC/BR was not significantly different from the aortic pressure pre-CPB. This was not the case after CPB. The mean post-CPB pressures with corresponding standard deviations are shown in Table 2. The post-CPB pressures measured in the LRC/AX were similar to the aortic pressures, however, the LRC/BR pressures had larger standard deviations.

Statistical analysis using the paired Student's t-test showed systolic pressure measured in both the LRC/AX and LRC/BR to be different from that in the ascending aorta after CPB. The mean pressure in the LRC/BR was significantly different from the aortic mean pressure, but the LRC/AX was not. The diastolic pressures measured in the aorta, LRC/AX, and the LRC/BR were not significantly different.

The blood pressure gradients post-CPB between the ascending aorta and the long radial arterial catheters are shown in Table 3. The aorta-LRC/BR gradients are larger than the aorta-LRC/AX gradients for systolic pressure, whereas the mean and diastolic gradients are smaller and similar. Analysis with the unpaired Student's t-test showed the aorta-LRC/BR systolic gradient to be significantly different from the aorta-LRC/AX systolic gradient. This can be clearly seen in Fig 2, which graphically shows the LRC/BR catheter to underestimate the aortic pressure, whereas the LRC/AX catheter tends to slightly overestimate the aortic systolic pressure after discontinuation of CPB.

**DISCUSSION**

Central-to-peripheral arterial pressure gradients have been well described in the post-CPB period. Prior studies have shown systolic arterial pressure gradients greater than 10 mmHg in 52% to 77% of patients immediately post-CPB. Furthermore, systolic arterial pressure gradients of 20 to 60 mmHg were observed in 15% of these patients. In the post-CPB period the lower pressures were consistently measured in the peripheral arteries. The gradients persist
for up to 60 minutes after discontinuation of CPB. Rulf et al recently demonstrated that a long arterial catheter placed in the radial artery and advanced proximally to the subclavian artery accurately estimates central aortic pressure. They found a mean systolic arterial pressure gradient of only 2.2 mmHg or 2.2% in 28 patients with the subclavian artery pressure exceeding the aortic pressure. In addition, they placed both short radial catheters and long radial catheters in 47 patients. The systolic radial artery pressure was less than the systolic subclavian artery pressure in 77% of the patients. The mean gradient was 7.6 ± 9.8 mmHg, with the lowest pressure measured in the radial artery.

The present data confirm these observations. When the long radial arterial catheter extended into the axillary artery, the aorta-LRC/AX post-CPB systolic pressure gradient was not significant, and no patient had a gradient greater than 10 mmHg. The systolic axillary artery pressure was greater than the systolic aortic pressure in most patients in the post-CPB period with gradients similar to those reported by Rulf et al for the aorta-subclavian artery. However, when the long catheter extended only into the brachial artery, the aorta-LRC/BR systolic pressure gradient was +6.9 ± 6.9 mmHg with three of the eight patients having a gradient greater than 10 mmHg. As was the case in the Gravlee study, the systolic and mean arterial pressures were significantly different in the aorta and brachial artery.

The LRC/BR had a tendency to underestimate the aortic pressure after CPB. Thus, the axillary artery appears to be the most distal site in the upper extremity at which arterial pressure can be measured to consistently provide an accurate estimate of central aortic pressure after CPB.

Percutaneous cannulation of the radial artery is considered to be a generally safe procedure when standard catheters are used. The most frequent complication is temporary arterial occlusion, which is typically asymptomatic and resolves spontaneously with no clinical evidence of distal ischemia or embolization. Larger catheters may have a higher incidence of vessel occlusion resulting from more damage to the artery. In addition, there is likely a time-related increase in the incidence of arterial occlusion with a significant increase in arterial occlusion after 24 hours. To date, the authors have placed more than 100 long radial arterial catheters in patients undergoing cardiac surgery. All patients were followed prospectively with no apparent clinically significant complications related to the long catheters. These findings are consistent with those reported by others. Rulf et al reported no significant complications with 68 long radial arterial catheters observed prospectively after placement for cardiac surgery. Gardner et al reported no significant complications in more than 2,500 patients who had 100 cm long radial arterial catheters advanced into the subclavian artery. In a follow-up prospective study,
Gardner et al monitored 531 patients with indwelling long radial arterial catheters and found the incidence of complete arterial occlusion to be 0.56%. Their reported risk factors included: catheter in place for more than 6 days, hypotension, and severe peripheral vasoconstriction.

Another potential risk with a LRC is cerebral emboli from catheter flushing. Though not previously reported with LRCs, cerebral emboli have been reported with flushing of peripheral arterial catheters. Due to close proximity of the LRC to the origin of the common carotid arteries, there is a significant theoretical risk for this to occur, and meticulous care should be undertaken when flushing the LRC. Though the LRC appears to have morbidity similar to other arterial catheters, evaluation is in progress to further identify risks.

In conclusion, common arterial pressure monitoring sites in patients undergoing cardiac surgery include the radial artery, brachial artery, femoral artery, and ascending aorta. The radial artery is often the preferred site because it is readily accessible, technically easy to cannulate, and normally has good collateral circulation. The radial artery, however, underestimates the central arterial pressure in a significant number of patients in the post-CPB period. The brachial artery offers no advantages to the radial artery, and it has been shown that it may underestimate the central aortic pressure in the post-CPB period. The femoral artery is the less-preferred site even though it will more accurately estimate central arterial pressure and has no overall increased morbidity associated with its use than the radial artery. Possible reasons include limited intraoperative accessibility, a high prevalence of aortofemoral occlusive disease in this patient population, prior femoral artery surgery, or a greater local infection risk. Another alternative site is the ascending aorta. This site provides accurate arterial pressure measurements; however, the cannula must be placed by the surgeon, can be easily dislodged, and must be removed prior to closure of the chest. A final option is the long radial arterial catheter. Using the Seldinger technique as described, the catheter can be easily placed in most patients, and provides an accurate estimate of central arterial pressure when the proximal tip extends into the axillary artery. Longer catheters (55 cm to 65 cm) are available for larger patients to assure adequate length for advancement of the proximal catheter tip into the axillary artery. Though these catheters were not included in this study, unpublished data suggest similar performance when they are advanced into the axillary artery. The long radial artery catheters can be placed at the beginning of surgery, or a short radial artery catheter can be exchanged for a long radial artery catheter after heparin reversal in those patients in whom a clinically significant central-to-peripheral arterial pressure gradient exists.

REFERENCES