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The impact of two arterial catheters, different in diameter and length, on postcannulation radial artery diameter, blood flow, and occlusion in atherosclerotic patients

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Abstract

Purpose. Arterial cannulation is a common intervention in anesthesia practice. However, the success rates and complications of radial arterial cannulation with 20-G or smaller catheters in patients with atherosclerosis have been underevaluated. The aim of this prospective randomized study was to compare the efficacy of and complications with 20- and 22-G catheters for radial arterial cannulation in atherosclerotic patients.

Methods. Thirty patients with atherosclerosis, American Society of Anesthesiologists (ASA) III-IV, undergoing general anesthesia were enrolled in the study. Radial artery cannulation was performed in group 20G ($n = 15$) with a 20-gauge ($20 \times 1.1 \times 33$ mm; flow, 61 ml·min^{-1}) catheter and in group 22G ($n = 15$) with a 22-gauge ($22 \times 0.9 \times 25$ mm; flow, 36 ml·min^{-1}) catheter. Radial artery systolic blood flow (SBF) and radial artery diameter (RAD) were assessed by a Doppler ultrasound probe before cannulation and 24 h after decannulation for vascular complications. The number of puncture attempts, arterial blood gas samples, and manual flushes; total heparinized solution consumption; duration of cannulation; decannulated radial arterial systolic blood flow; postcannulation RAD; and vascular complications such as occlusion, hematoma, pseudoaneurysm, bleeding, and thrombosis were noted. The Mann Whitney U-test, χ^2 test, and one-sample t-test were used. Values are expressed as medians and quartiles and $P < 0.05$ was considered as significant.

Results. The number of puncture attempts was greater in group 20G (range, 1 to 4) than in group 22G (range, 1 to 2; $P = 0.02$). In group 20G patients, postoperative RAD was larger than preoperative RAD ($P = 0.02$) and postoperative SBF was lower than preoperative SBF ($P = 0.03$). In group 22G patients postoperative SBF was higher than preoperative SBF ($P = 0.03$), while there was no significant difference between preoperative and postoperative RAD. The occlusion rate of atherosclerotic radial arteries was 6% with the 22-gauge catheter and 26% with the 20-gauge catheter ($P = 0.02$).

Conclusion. A 22-gauge catheter for radial arterial cannulation in patients with atherosclerosis provides unchanged postcannulated radial artery diameter, decreases postcannulation complications, and improves the first-attempt success rate.

Key words Catheter · Diameter · Blood flow · Atherosclerosis

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Introduction

In atherosclerotic patients undergoing major surgical interventions, arterial cannulation is commonly performed for continuous monitoring of systemic blood pressure and intermittent assessment of arterial blood gases [1]. The radial artery is the preferred artery, with its well-documented low complication rate and easy access [2]. However, radial artery cannulation is sometimes time-consuming, and may even associated with complications as a result of repeated attempts for successful cannulation [3].

Atherosclerosis is a systemic phenomenon, and structural changes attributable to atherosclerosis, such as luminal narrowing, intimal hyperplasia, and reduction in distensibility occur frequently throughout the arterial tree [4]. The radial arterial diameter in atherosclerotic patients is relatively small and occlusion of the radial artery increases as more of the arterial lumen is occupied by a catheter [4,5].

Failure in atherosclerotic radial artery cannulation commonly results from tortuosity of the artery, vasospasm, and a reduction in internal diameter [6]. The use of a small-diameter short catheter may reduce the number of attempts required to achieve successful arterial cannulation, as well as reducing insertion times and the overall incidence of complications such as hematoma, bleeding, vasospasm, and thrombosis.

Arterial cannulation with 20-gauge catheters is a common practice in anesthesia management [7]. However, the ease of insertion and complications with radial arterial cannulation with smaller catheters in patients with atherosclerosis have not been studied before. In this study it was hypothesized that the use of a smaller-diameter shorter catheter in an atherosclerotic radial artery with a narrowed internal lumen would have less effect on structural changes of the radial artery and fewer related subsequent complications, and as well, would provide a superior cannulation success rate. This blinded prospective randomized study was planned to compare the impact of two different arterial catheters, differing in diameter and length, on postcannulation radial artery diameter, blood flow, subsequent complications, and the cannulation success rate in atherosclerotic patients.

Patients and methods

The study group consisted of 30 patients with atherosclerotic heart disease who were scheduled for elective major surgery with an indication for radial artery cannulation. Atherosclerotic patients in this study were defined as those patients with 60% narrowing of coronary arteries who had been treated with coronary bypass surgery or stent placement, followed by medical therapy, ordered according to the protocol of the cardiology department of the institution. The local ethics committee approved the study protocol and all patients gave their written informed consent to participate. Exclusion criteria included a positive class D modified Allen's test result, the presence of known or suspected upper-extremity peripheral arterial disease, and dialysis fistula. Patients were assigned randomly to two groups, by the sealed envelope technique, for radial artery cannulation with either a 20-gauge or a 22-gauge catheter (see details below).

Demographic data, medical history, and physical examination and blood test results were recorded for all patients. Demographic data included age, blood pressure, height, and weight. Blood samples were drawn to determine total high- and low-density lipoprotein (HDL and LDL) cholesterol, triglyceride, and glucose levels. Coronary risk factors were defined as follows: hypertension as systolic blood pressure of 140 mmHg or more, diastolic blood pressure of 90 mmHg or more, or taking antihypertensive medication; hyperlipidemia as total serum cholesterol more than 193 mg/dl, LDL cholesterol more than 116 mg/dl, triglycerides more than 177 mg/dl or taking lipid-lowering medication; diabetes as fasting serum glucose more than 110 mg/dl or taking oral hypoglycemic agents or insulin; smoking; and familial tendency. The American Society of Anesthesiologists (ASA) classification was stratified by patients' controlled or uncontrolled coronary risk factors and whether the underlying disease was controlled by medications. According to the protocol, ASA III patients were defined as patients with atherosclerotic heart disease associated with underlying disease controlled by medications, and ASA IV patients were defined as patients who had atherosclerotic heart disease associated with limitations of activities and underlying disease poorly controlled by medications.

Patients in both groups were evaluated by using a commercially available color Doppler ultrasonography unit (Japan Standart, Shiki City, Japan) with a 12.0-MHz linear array transducer before and 24 h after cannulation of the radial artery. The patients were examined in a supine position with extended arm supported on a trolley at heart level. Vessel compression was avoided by using ultrasound gel between the transducer and skin surface. Anterior-posterior internal diameter measurements of the radial artery were made in the transverse plane within 2 cm of the cannulation site, peak systolic velocity was measured directly from a Doppler spectral waveform using an angle correction of 60° or less, the volume flow was obtained from the velocity and the surface area, and the presence of stenosis or occlusion of the radial artery at two sites for each patient was examined by the same blinded physician who had 10 years of experience in color Doppler ultrasonography.

On arrival at the operating room, patients were assigned randomly by the sealed envelope technique for radial artery cannulation with either a 20-gauge or a 22-gauge catheter (see group details below). Demographic data and baseline characteristics were recorded before a modified Allen's test was performed. The nondominant hand was placed in extension, using a towel roll, and taped to an arm board for immobilization. Arterial punctures were performed under local anesthesia with 1 ml 2% lidocaine, and cannulation was done by an anesthesiologist who had experienced more than 200 cannulation cases. The first anesthesiologist was replaced by another anesthesiologist after two consecutive unsuccessful attempts. Success was defined as cannulation at the first attempt.

In group 20G, a 20-gauge ($20 \times 1.1 \times 33$ mm; flow, 61 ml·min^{-1}; Eastern Medikit, Gurgaon, India) polytetrafluoroethylene catheter and in group 22G, a 22-gauge ($22 \times 0.9 \times 25$ mm; flow, 36 ml·min^{-1}; Eastern Medikit) polytetrafluoroethylene catheter was inserted into the radial artery.

The catheter was inserted at an angle of 30° to 45° and then advanced over the needle as soon as there was arterial blood return through the needle puncture. The inserted catheter was connected to a closed blood withdrawal device (Safedraw; Becton Dickinson, Singapore) and a pressure transducer set (DTX plus; Becton

Dickinson). During the perioperative period, patency of the arterial catheter was maintained by using heparinized (50 IU·ml^{-1}) manual flushing solution (1 ml every 5 min). The procedure was watched by an independent observer who recorded the overall number of separate arterial punctures, the number of anesthesiologists that repeated an attempt, and the overall success rate. Successful placement of the catheter was confirmed by observing the transduced arterial waveform on the monitor.

The number of puncture attempts, number of anesthesiologists involved, number of arterial blood gas samples that were withdrawn from the system, number of manual flushes, and total heparinized solution volume were recorded. The duration of the arterial catheter onsite and the surgery time were also noted.

The arterial catheters were removed in the intensive care unit on the first postoperative day. The site was manually compressed for 3–5 min until the bleeding stopped. Twenty four hours after decannulation, all patients were assessed by the same blinded physician, using Doppler ultrasonography for radial arterial diameter, flow velocity, and vascular complications such as occlusion, hematoma, pseudoaneurysm, bleeding, and thrombosis.

Statistics

A preliminary study was conducted in five patients to determine the median and quartile values of the radial artery diameter. The number of patients needed to be enrolled in the study to find at least a 0.5-mm difference in radial arterial diameter was calculated as 14 per group with an alpha error of 0.05 and beta error of 0.20. Statistical analyses were performed using the SPSS 10.0 statistical package program (Statistical Program for Social Sciences, version 10.0; SSPS, Chicago, IL, USA). The Mann Whitney *U*-test and χ^2 tests were performed to test for statistically significant differences among groups. Success of the attempt was analyzed with the one-sample *t*-test and success was regarded as successful catheterization at the first attempt. Values are expressed as medians and quartiles and $P < 0.05$ was considered as statistically significant.

Results

Demographic data, baseline characteristics, and the duration of atherosclerotic heart disease were similar in the two groups. The number of patients treated for hypertension was 8 (53%) in group 20G and 9 (60%) in group 22G; 33% (5/15) of the patients in each group had diabetes mellitus and were treated with insulin. The number of patients with hyperlipidemia was 9 (60%) in group 20G and 13 (86%) in group 22G, and 60% (9/15) of the patients in each group had a smoking addiction (Table 1). The differences between baseline heart rate and the systolic, diastolic, and mean arterial pressure measurements in the two groups were also insignificant (Table 2).

The number of anesthesiologists involved with the cannulation, the duration of cannulation onsite and duration of surgery, number of times blood was withdrawn from the system, number of manual flushes, and total heparinized solution consumption were similar in the two groups. The number of puncture attempts was greater in group 20G (range, 1 to 4) than in group 22G (range, 1 to 2; $P = 0.02$; Table 3) and the success rate of cannulation was 60% in group 20G and 73% in group 22G. The configuration and amplitude of the arterial-pressure wave did not show any significant change in either group, nor was there a damping pattern, and there was no difficulty in obtaining arterial blood samples during the study period.

The postoperative radial artery diameter (RAD) of patients in group 20G was wider than the preoperative

Table 1. Demographic data and baseline characteristics of patients enrolled in the study

	Group 20G (*n* = 15)	Group 22G (*n* = 15)
Age	66 ± 7	62 ± 8
Sex (F/M)	13/2	12/3
Weight (kg)	76.1 ± 7.8	76.2 ± 12.9
Height (cm)	168 ± 10	173.5 ± 9.2
ASA (III/IV)	10/5	12/3
AHD duration (years)	5.7 ± 2.8	7.3 ± 5.4
HT (*n*)	8/15	9/15
DM (*n*)	5/15	5/15
Hyperlipidemia (*n*)	9/15	13/15
Smoking (*n*)	9/15	9/15

Data are expressed as means ± SD, except where shown
AHD, atherosclerotic heart disease; DM, diabetes mellitus

Table 2. Baseline hemodynamic measurements of patients enrolled in the study

	Group 20G ($n = 15$)	Group 22G ($n = 15$)
HR (bpm)	84 ± 16	87 ± 14
SBP (mmHg)	140 ± 24	147 ± 29
DBP (mmHg)	75 ± 13	76 ± 16
MAP (mmHg)	93 ± 14	96 ± 22

Data are expressed as means ±SD
HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure

Table 3. Number of puncture attempts, duration of cannulation and surgery, and data related to the maintenance of arterial catheter patency

	Group 20G ($n = 15$)	Group 22G ($n = 15$)	P value
Number of puncture attempts	2 (1–4)	1 (1–2)	0.02*
Number of anesthesiologists who repeated the puncture technique	1 (1–2)	1 (1–2)	0.44
Duration of cannulation onsite (min)	371 (165–380)	351 (135–345)	0.89
Duration of surgery (min)	222 (155–315)	210 (120–290)	0.76
Number of times blood was withdrawn	1 (0–2)	1 (1–2)	0.84
Number of manual flushes	13 (8–20)	11 (5–16)	0.35
Total volume of heparinized solution used	24 (16–36)	23 (14–30)	0.84

* $P < 0.05$; between groups
Data are expressed as medians and quartiles (25–75)

Table 4. Preoperative and postoperative radial artery diameter and systolic blood flow

	Group 20G	Group 22G
Preop RAD (mm)	3. 39 (3–3.6)	3, 31 (3–3, 6)
Postop RAD (mm)	3, 62 (3,3–4)[1*]	3, 35 (3–3, 5)
Preop SBF ($ml \cdot min^{-1}$)	63, 76 (45–79,7)	52, 82 (42, 6–61,8)
Postop SBF ($ml \cdot min^{-1}$)	52,93 (47–62, 3)[2*]	68, 16 (50–99, 9)[3*;4*]

[1*] $P < 0.05$, compared with preoperative value; [2*] $P < 0.05$, compared with preoperative value; [3*] $P < 0.05$, compared with preoperative value; [4*] $P < 0.05$, between groups
Data are expressed as medians and quartiles (25–75)
RAD, radial artery diameter; SBF, systolic blood flow

RAD ($P = 0.02$) and the postoperative systolic blood flow (SBF) was lower than the preoperative SBF ($P = 0.03$). In group 22G patients postoperative SBF was higher than the preoperative SBF ($P = 0.03$), while there was no significant difference between the preoperative RAD and postoperative RAD (Table 4).

Twenty-four hours after decannulation, the occlusion rate of atherosclerotic radial arteries was 6% with the 22-gauge catheter and 26% with the 20-gauge catheter ($P = 0.02$). Hematoma development was seen in five patients in group 20G and in one patient in group 22G, although coagulation tests were in the normal range; all these six patients had undergone at least two puncture attempts for radial arterial cannulation. Bleeding was seen in one patient in group 20G and thrombosis occurred in one patient in group 22G, although the thrombosis was clinically asymptomatic and no sign of ischemia occurred.

Discussion

In this study we compared the efficacy of and complications with 20- and 22-gauge catheter placement for radial artery cannulation in atherosclerotic patients. Our results lead us to emphasize that a 22-gauge catheter is preferable; as compared with the 20-gauge catheter, it reduced postcannulation complications related to repeated puncture attempts, improved the success rate at the first puncture attempt, and had potentially fewer intraoperative monitoring problems.

The anesthetic plan in atherosclerotic patients undergoing major surgery usually entails performing radial arterial cannulation before anesthesia induction, and in general, 20-gauge catheters are applied [7]. In the normal population, failure to cannulate the radial artery using a 20-gauge catheter occurs in fewer than 5% of patients when done by experienced hands [2]. However, in atherosclerotic patients who generally have vessels of small diameter with tortuous structure, a high incidence of unsuccessful attempts, resulting in periarterial hematoma, vasospasm, and loss of a palpable pulse, can be expected [8,9].

Changes in the internal diameter of an artery induce modifications in the arterial wall properties and influence the velocity of arterial blood flow. Velocity in the narrowed or dilated segment of an artery is determined by the following equation:

$u = \Delta V. E. h / 2\pi r^3 pC_o$ (where u is the velocity of blood flow; ΔV is the intraarterial volume change; E is the vessel elasticity; h is the arterial wall thickness; r is the internal diameter; p is the blood density; and C_o is the constant) [10].

This equation shows a strong and inverse relation between the velocity of blood flow and the internal diameter of the artery, i.e., velocity increases due to reduction in the vessel-lumen diameter. In the present study, the postcannulation radial artery diameter (RAD) was increased significantly in group 20G. This was considered to be a result of local arterial damage or edema formation following repeated cannulation attempts. As estimated from the equation, a decrease occurred in measured velocity. In group 22G, no significant difference in arterial diameter following decannulation was observed in comparison with the precannulation measurements, and this result suggests the superiority of cannulation with smaller-gauge catheters. Although the diameter of the radial artery lumen did not change in this group, blood flow velocity was increased following decannulation. The velocity change cannot be explained by the flow hemodynamics of the radial artery and was probably secondary to clinical factors such as changes in the cardiovascular status of the patient after the operation. Also, ultrasound examination is operator-dependent and this is especially true when one deals with a small structure such as the radial artery; small variations in measurement can occur and this may have influenced the outcome and created a limitation of the present study, in addition to its small sample size.

The diameter of the radial artery, besides exerting an effect on velocity, is as important a predictor of the cannulation success rate and incidence of occlusion as the catheter size and the ratio of the catheter diameter to the vessel-lumen diameter [2]. In one study, the success rate of radial artery cannulation at first puncture attempt with a 22-gauge, 3.1-cm, polyethylene catheter was 64.4% in 45 nonatherosclerotic patients [11]. However, atherosclerotic radial arteries have structural changes attributable to atherosclerosis, such as irregulation, tortuosity, and fragility, as well as the actual disappearance of muscle and elastic fibers and replacement by fibrous tissue [12]. Although these structural changes cause an expectation of difficulty in cannulation, the success rate at first puncture attempt in our study was 73% in group 22G and 60% in group 20G, with a total success rate of 66.6%.

The ratio of the diameter of the arterial sheath to the radial artery was studied by Saito et al. [13], and they found that incidence of occlusion was 4% in patients with a ratio of less than 1, while the incidence was 13% in those with a ratio of greater than 1. These results indicated a linear increase between the incidence of radial occlusion and the ratio of catheter diameter to vessel-lumen diameter. Thus, using a smaller-diameter and shorter catheter in patients with atherosclerosis to minimize the ratio of the catheter diameter to the arterial diameter could show an increase in the success rate of cannulation, decreasing the incidence of arterial occlusion, as supported by our study results.

In the normal population, the occlusion rate of the radial artery following cannulation ranges from 1.5% to 35%. Bedford [5] evaluated radial arterial function 24 h after cannulation, using arteriography and Doppler ultrasound examination, and reported an 8% incidence of radial-artery occlusion following cannulation with 20-gauge catheters, compared with a 34% incidence of occlusion with 18-gauge catheters. In our study, the occlusion rate of atherosclerotic radial arteries was 6% with 22-gauge catheters, whereas it was 26% with the 20-gauge catheters. The higher rates of radial occlusion with 20-gauge catheters in our study were probably the result of the relatively small diameters of the atherosclerotic radial arteries, the elevated ratio of the catheter diameter to the vessel-lumen diameter, and the greater number of puncture attempts required for successful cannulation.

In our study, another subsequent complication of cannulation was hematoma formation, with an incidence of 33.3% in group 20G; this may be attributed to the number of puncture attempts, which was greater when the larger (20-gauge) catheter was inserted. This supports the observations that the use of a small (22-gauge) catheter leads to a very low, 6%, incidence of hematoma formation. The difference could be the result of many factors, particularly catheter size and intraluminal length. For minimizing hematoma formation, due to injury to blood vessels in cannulation, the small-diameter short catheters were found to be most satisfactory and led to a preference for 22-gauge catheters for cannulation in very small or tortuous arteries.

A limitation of the present study, in addition to its small sample size, is that the vascular complications were assessed only in the early period of decannulation, and control measurements were not performed to demonstrate whether structural changes were present in the arteries. However, this study confirmed that the shorter smaller-diameter catheters did not change the postcannulated radial artery diameter in atherosclerotic patients, and these catheters decreased the incidence of postcannulation complications related to repeated puncture attempts.

In conclusion, we found that the incidence of postcannulation complications was proportional to the number of puncture attempts for successful catheter placement, and the incidence of such complications was decreased by using 22-gauge catheter insertion, with the internal radial artery diameter being unchanged. Therefore, we recommend the routine use of 22-gauge catheters in the cannulation of atherosclerotic arteries.

References

1. Wilkins RG. Radial artery cannulation and ischemic damage: a review. Anaesthesia. 1985;40:896–9.
2. Martin C, Saux P, Papazian L, Gouin F. Long-term arterial cannulation in ICU patients using the radial artery or dorsalis pedis artery. Chest. 2001;119:901–6.
3. Rigatelli G, Magro B, Maronati L, Tranquillo M, Oliva L, Panin S, Bedendo E. An improved technique for gaining radial artery access in endovascular interventions. Cardiovasc Revasc Med. 2006;7:46–7.
4. MacKay AJ, Hamilton CA, McArthur K, Berg G, Tropeano A. Radial artery hypertrophy occurs in coronary atherosclerosis and is independent of blood pressure. Clin Sci. 2001;100:509–16.
5. Bedford RF. Radial arterial function following percutaneous cannulation with 18- and 20- gauge catheters. Anesthesiology. 1977; 47:37–9.
6. Bazemore E, Mann JT. Problems and complications of the transradial approach for coronary interventions: a review. J Invasive Cardiol. 1999;83:180–6.
7. Scheer BV, Perel A, Pfeiffer UJ. Clinical review: complications and risk factors of peripheral arterial catheters used for haemodynamic monitoring in anaesthesia and intensive care medicine. Crit Care. 2002;6:198–209.
8. Giannattasio C, Mangoni AA, Failla M, Carugo S, Stella ML, Stefanoni P, Grassi G, Vergani C, Mancia G. Impared radial artery compliance in normotensive subjects with familial hypercholesterolemia. Atherosclerosis. 1996;124:249–60.
9. Mangar D, Thrush DN, Connell R, Downes JB. Direct or modified Seldinger guide wire-directed technique for arterial catheter insertion. Anesth Analg. 1993;76:714–7.
10. Milnor WR. Properties of the vascular wall. In: Collins N, editor. Hemodynamics, 2nd ed. Baltimore: Williams & Wilkins; 1982. p. 95–101.
11. Karacalar S, Ture H, Baris S, Karakaya D, Sarihasan B. Ulnar artery versus radial artery approach for arterial cannulation: a prospective, comparative study. J Clin Anesth. 2007;19:209–13.
12. Allen EV, Baker NW, Hines EA. Peripheral vascular disease. 3rd ed. Philadelphia: WB Saunders; 1962. chapter XI.
13. Saito S, Ikei H, Hosokawa G, Tanaka S. Influence of the ratio between radial artery inner diameter and sheath outer diameter on radial artery flow after transradial coronary intervention. Cathet Cardiovasc Intervent. 1999;46:173–8.