Original Article

Does the resistive index of the radial artery change after arterial cannulation in patients undergoing abdominal surgery? A prospective observational study

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ABSTRACT

Background and Aims: To evaluate the flow at the cannulation site in the radial artery, the resistive indices (RIs) before cannula insertion and 6 h after decannulation were measured (primary outcome). The secondary outcomes were measurement of the artery size by anteroposterior (AP) diameter at the insertion site, RI and AP diameter at a point 4 cm proximal and in the ipsilateral ulnar artery before insertion and 6 h after cannula removal. **Methods:** In 96 patients requiring an arterial line during surgery, peak systolic velocity (PSV) and end-diastolic velocity (EDV) were measured to derive RI using a linear ultrasound transducer. The RI was measured at R1 (insertion point), R2, 4 cm proximal to R1, and U1 on the ipsilateral ulnar artery. The AP diameter of the arteries at baseline $R1_0$, $R2_0$ and $U1_0$ was measured and repeated 6 h after removal of the cannula, $R1_6$, $R2_6$ and $U1_6$. **Results:** RI or AP diameter in R1 or R2 did not differ pre- and post-cannulation. Mean $R1_0$ 1.143 [standard deviation (SD: 0.239)] versus $R1_6$ 1.181 (SD: 0.260) m/sec [mean difference (MD): –0.0372 (95% confidence interval (CI): –0.098, 0.023), *P* = 0.230]. Mean AP diameter at baseline versus 6 h decannulation 0.177 (SD: 0.042) versus 0.172 (SD: 0.045) cm [MD: 0.005 (95% CI: 0.003, 0.013), *P* = 0.222] was also similar. The mean PSV in $U1_0$ versus $U1_6$ was higher: 0.480 (SD: 0.178) versus 0.528 (SD: 0.316) m/sec [MD: 0.120 (95% CI: –0.185, –0.054), *P* = 0.002] and AP diameter was also higher than baseline (*P* = 0.001). **Conclusion:** The flow in the radial artery did not change following cannulation. The PSV and AP diameter in the ulnar artery increased after decannulation, suggesting a compensatory increase in flow.

Keywords: Cannulation, end-diastolic velocity, peak systolic velocity, radial artery, resistive index, ulnar artery

INTRODUCTION

Cannulation of the radial artery is routinely carried out perioperatively and in critical care settings. Although invasive, it provides arterial blood pressure with a beat-to-beat accuracy. This allows the clinician or anaesthesiologist to assess the response, execute appropriate treatment rapidly and collect arterial blood samples for blood chemistry, blood gas analysis and coagulation management.

The radial artery is the most commonly preferred site for arterial cannulation due to its anatomy, ease of access and low rate of complications. Although rare, several complications are known to occur.[1] The impact of cannulation on the artery and changes in

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flow parameters following prolonged cannulation in the artery is poorly understood. The resistive index (RI) (Pourcelot Index) is the simplest ultrasound measure of vascular flow. RI depends upon vessel resistance and compliance and is measured from the peak systolic velocity (PSV) and the end-diastolic velocity (EDV).

We hypothesised that any change in the resistance to blood flow after cannulation would manifest as an increase in RI. The primary objective was to evaluate RI in the radial artery before cannula insertion and 6 h after decannulation to assess the impact of arterial blood flow at the cannulation site. Secondary objectives were comparing the anteroposterior (AP) diameter at the radial artery insertion site, RI and AP diameters 4 cm proximal to the insertion points, and the ulnar artery.

METHODS

This prospective observational study was conducted after obtaining approval from the Institutional Ethics Committee (vide approval number IEC-AIMS-2021-ANES-045, dated 12 March 2021) and registration with the Clinical Trials Registry-India (CTRI/2021/05/033610, accessible at www.ctri.nic.in). The study was conducted between May 2021 and April 2022. Patients aged 18–75 years undergoing major elective surgery requiring arterial line and 1–2 days stay at the intensive care unit (ICU) after surgery and belonging to the American Society of Anesthesiologists Physical Status I-III were included in the study. Written informed consent was obtained in the local vernacular or English to participate in the study and use their medical data for research and educational purposes. The study was conducted in compliance with the 2013 Declaration of Helsinki and Good Clinical Practice guidelines.

The radial artery was cannulated using a landmark cannulation technique, as is the practice at our institution. Patients with difficulty in cannulation, described as requiring more than two cannulation attempts, known peripheral vascular disease or carpal tunnel syndrome were excluded. A standard technique using landmark palpatory method for cannulation with 20 G BD Insyte (Becton Dickinson Infusion Therapy Systems Inc, Sandy, UT, USA) was used. Standard guidelines in cannulation, including the modified Allen's test, were followed to ensure safety in radial artery cannulation. In addition, a doppler of the ulnar artery was done, and the flow was confirmed before radial artery cannulation. Consultant anaesthesiologists or trainees with more than one year of experience in invasive arterial cannulation performed the cannulation. As per the operator's technique, either transfixation or direct puncture was employed.

All measurements were taken using Mindray ultrasound machine M7 (Shenzhen Mindray Bio-Medical Electronics Co., Ltd) with a 5–20 MHz frequency linear probe. Before placement of an arterial line, the radial artery's RI was measured in the operating room. To measure PSV (m/sec) and EDV (m/sec), the linear transducer was positioned along the long axis of the artery. The flow was confirmed by colour Doppler, and values of RI were derived by the formula (PSV-EDV)/PSV. These measurements were used to determine the RI corresponding to the baseline ($R1_0$). A similar measurement was made at a point 4 cm above the proposed site of puncture ($R2_0$). The ulnar artery flow was also measured at a point opposite to the radial arterial flow ($U1_0$). The radial and ulnar arteries' AP diameters at $R1_0$, $R2_0$ and $U1_0$ were also measured. At the end of the surgery, patients were shifted to the ICU, and the arterial line was removed, according to the intensivist's decision. The RI and AP diameter were measured 6 h post-decannulation in both radial and ulnar arteries ($R1_6$, $R2_6$, $U1_6$). The readings were taken by the research consultant, junior consultant or the researcher after training with 20 patients under supervision. All readings were counterchecked by a radiologist involved in the study by sharing acquired images.

The sample size was calculated based on the sample of 30 patients as part of a pilot study, wherein the mean RI in the radial artery before cannulation was 1.171 [standard deviation (SD): 0.27] and 6 h after decannulation was 1.043 (SD: 0.28). With an effect size of 0.49, a correlation of 0.1, 90% power and 95% confidence interval, the minimum sample size was calculated as 86 patients. We included 96 patients in our study. Statistical Package for the Social Sciences statistics software version 21.0 (International Business Machines Corporation, Armonk, NY, USA) was used for analysis. Descriptive statistics were represented as mean (SD) for continuous variables [(age, weight and body mass index (BMI)] and number and percentage for the categorical variable (gender). The Kolmogorov–Smirnov test was applied to check the normality of the data. To test the statistical significance of the change in the mean values of PSV and EDV in the artery before and after decannulation, a paired *t*-test (Gaussian data) was applied. Wilcoxon signed-rank test for skewed data, namely AP diameter and RI, was applied. In subgroup analysis, the Wilcoxon signed-rank test was also used to test the change in the values of all parameters. A *P* value of <0.05 was considered to be statistically significant.

RESULTS

One hundred twenty patients were screened for inclusion in our study, and 96 were included. [Figure 1]. The mean age of the patients was 51.1 (SD: 17.1) years, mean weight was 67.5 (SD: 10.6) kg and mean BMI was 24.7 (SD: 2.2) kg/m^2. Among the 96 patients studied, 47 were aged 60 years and above. The distribution of comorbidities was as follows: hypertension ($n = 35$), diabetes ($n = 32$) and documented coronary artery disease ($n = 10$). In the group, 59 were male and 37 were female. The surgeries included hepatectomy (donor and resection) ($n = 41$), colonic surgeries ($n = 28$), urological surgery ($n = 13$), Whipple and pancreatic surgery ($n = 8$) and oesophageal and gastric surgery ($n = 6$).

RI in the radial artery before and after decannulation at the cannulation site ($R1_0$ vs. $R1_6$) was not statistically different [Table 1]. RIs at the radial artery 4 cm proximal to the site of insertion ($R2_0$ vs. $R2_6$) and at the ulnar artery ($U1_0$ vs. $U1_6$) were also comparable. PSV, EDV, and AP diameters were similar at both radial artery points before and after decannulation. PSV and AP diameter in the ulnar artery were significantly higher after decannulation ($U1_0$ vs. $U1_6$) [Table 1].

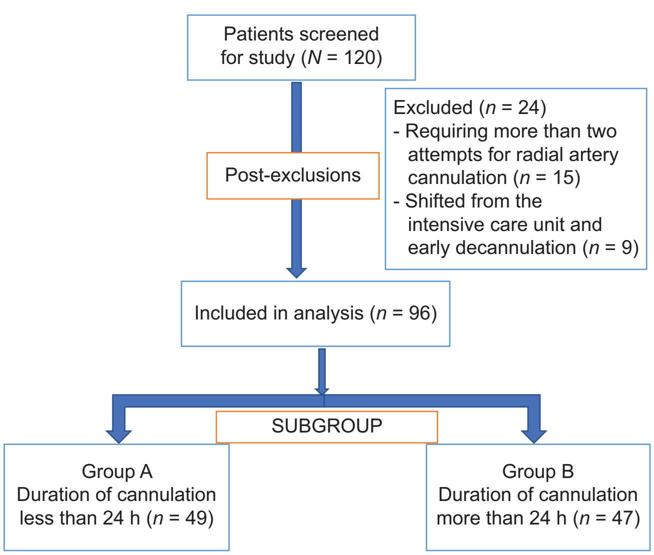

Figure 1: Study participants' flow diagram

A subgroup analysis among the 96 patients who underwent radial artery cannulation was performed based on the duration of cannulation as Group A with a duration of cannulation less than 24 h ($n = 49$) and Group B with a duration of cannulation more than 24 h ($n = 47$). In Group A, RI at $R1_6$ was significantly higher following decannulation than the preinsertion value $R1_0$ ($P = 0.024$). There was an increase in EDV at 6 h post-decannulation at $R1_6$ compared to preinsertion EDV, $R1_0$ ($P = 0.029$) [Table 2]. In Group B, the AP diameter at U1 increased at 6 h post-decannulation, $U1_6$, compared to the preinsertion diameter, $U1_0$ ($P = 0.006$). PSV at 6 h at $U1_6$ post-decannulation compared to the preinsertion velocity U10 was statistically significant ($P = 0.015$) [Table 3].

Two patients in our study had Doppler evidence of thrombus when evaluated 6 h after decannulation.

DISCUSSION

Our study did not find any differences in RI of the radial artery before and after cannulation. However, a subgroup analysis showed increased EDV in the radial artery at the insertion site in patients with indwelling cannulas for less than 24 h. The ulnar artery showed an increase in PSV and AP diameter when the cannula was retained for more than 24 h.

Different techniques of radial arterial cannulation have been described. However, we did not perceive any increase in complications based on the technique employed. Sung *et al.*[2] have shown that dynamic needle placement guided by ultrasound for radial arterial cannulation was superior to the longitudinal in-plane approach, having fewer attempts, better success rates and lower incidence of haematoma formation. Thailamuthu *et al.*[3] have presented similar findings. A study in children by Yu *et al.*[4] showed that a modified in-plane radial artery cannulation was superior to dynamic tip placement in children undergoing radial artery cannulation.

We included patients over 60 years of age, but excluded those who needed more than two attempts. This could have eliminated patients with significant atherosclerotic diseases in this group. Krishnaprasad *et al.*[5] have shown that the dorsal radial artery at the anatomical snuff box can be a viable alternative for difficult arterial cannulation at the wrist, but suggest using a smaller cannula and a semi-prone hand position for the same.

Table 1: Preinsertion and post-decannulation comparison of flow (*n*=96)

	PSV m/sec				EDV m/sec			
	0 h Mean (SD)	6 h Mean (SD)	MD (95% CI)	*P**	0 h Mean (SD)	6 h Mean (SD)	MD (95% CI)	*P**
R1	0.430 (0.188)	0.440 (0.251)	-0.010 (-0.064, 0.0440	0.744	-0.059 (0.123)	-0.087 (0.121)	0.028 (-0.005, 0.062)	0.115
R2	0.396 (0.142)	0.433 (0.266)	-0.036 (-0.090, 0.016)	0.600	-0.040 (0.120)	-0.060 (0.121)	0.020 (-0.013, 0.055)	0.144
U1	0.408 (0.178)	0.528 (0.316)	-0.0120 (-0.185, -0.054)	0.002	-0.066 (0.157)	-0.068 (0.154)	0.002 (-0.041, 0.045)	0.620
	RI m/sec				AP cm			
	0 h Mean (SD)	6 h Mean (SD)	MD (95% CI)	*P**	0 h Mean (SD)	6 h Mean (SD)	MD (95% CI)	*P**
R1	1.143 (0.239)	1.181 (0.260)	-0.0372 (-0.098, 0.023)	0.230	0.177 (0.042)	0.172 (0.045)	0.005 (-0.003, 0.013)	0.222
R2	1.099 (0.277)	1.115 (0.308)	-0.016 (-0.096, 0.063)	0.683	0.184 (0.043)	0.185 (0.046)	-0.001 (-0.009, 0.007)	0.797
U1	1.146 (0.265)	1.111 (0.292)	0.0344 (-0.029, 0.098)	0.287	0.149 (0.0370)	0.162 (0.038)	-0.013 (-0.021, -0.005)	0.001

**P*-value for PSV and EDV using paired *t*-test, for RI and AP using Wilcoxon signed-rank test. 0 h=baseline, 6 h=6 h after decannulation, AP=anteroposterior, CI=confidence interval, EDV=end-diastolic velocity, MD=mean difference, PSV=peak systolic velocity, R1=radial artery at insertion, R2=radial 4 cm proximal to insertion, RI=resistive index, SD=standard deviation, U1=ulnar artery

Table 2: Preinsertion and post-decannulation comparison of PSV and EDV with cannulation <24 h (*n*=49)

Site	PSV m/sec				EDV m/sec			
	0 h Mean (SD)	6 h Mean (SD)	MD (95% CI)	*P**	0 h Mean (SD)	6 h Mean (SD)	MD (95% CI)	*P**
R1	0.409 (0.178)	0.372 (0.166)	-0.058 (-0.148, 0.030)	0.309	-0.049 (0.126)	-0.092 (0.103)	0.013 (-0.042, 0.069)	0.029
R2	0.399 (0.151)	0.394 (0.151)	-0.080 (-0.167, 0.007)	0.590	-0.048 (0.122)	-0.070 (0.110)	0.020 (-0.035, 0.075)	0.345
U1	0.378 (0.152)	0.462 (0.233)	-0.157 (-0.269, -0.045)	0.090	-0.039 (0.155)	-0.054 (0.143)	-0.011 (-0.079, 0.057)	0.583
	RI m/sec				AP diameter cm			
	0 h Mean (SD)	6 h Mean (SD)	MD (95% CI)	*P**	0 h Mean (SD)	6 h Mean (SD)	MD (95% CI)	*P**
R1	1.135 (0.243)	1.207 (0.257)	0.000 (-0.094, 0.094)	0.024	0.176 (0.041)	0.173 (0.042)	0.007 (-0.005, 0.020)	0.576
R2	1.116 (0.276)	1.173 (0.290)	0.025 (-0.105, 0.156)	0.132	0.184 (0.039)	0.182 (0.045)	-0.005 (-0.017, 0.008)	0.396
U1	1.134 (0.275)	1.081 (0.299)	0.053 (-0.041, 0.148)	0.327	0.155 (0.038)	0.164 (0.042)	-0.018 (-0.030, -0.007)	0.082

**P*-values calculated using Wilcoxon signed rank test in both the groups. 0 h=baseline, 6 h=6 h after decannulation, AP=anteroposterior, CI=confidence interval, EDV=end-diastolic velocity, MD=mean difference, PSV=peak systolic velocity, R1=radial artery at insertion, R2=radial 4 cm proximal to insertion, RI=resistive index, SD=standard deviation, U1=ulnar artery

Table 3: Preinsertion and post-decannulation comparison of flow variables >24 h (*n*=47)

Site	PSV (m/sec)				EDV (m/sec)			
	0 h Mean (SD)	6 h Mean (SD)	MD (95% CI)	*P**	0 h Mean (SD)	6 h Mean (SD)	MD (95% CI)	*P**
R1	0.452 (0.197)	0.511 (0.302)	0.036 (-0.025, 0.099)	0.646	-0.068 (0.121)	-0.0826 (0.139)	0.042 (0.002, 0.083)	0.897
R2	0.393 (0.133)	0.473 (0.310)	0.004 (-0.058, 0.067)	0.208	-0.031 (0.11)	0.051 (0.132)	0.021 (0.021, 0.065)	0.343
U1	0.439 (0.198)	0.597 (0.375)	-0.083 (-0.157, -0.009)	0.015	-0.094 (0.15)	-0.083 (0.165)	0.015 (-0.040, 0.070)	0.940
	RI				AP			
	0 h Mean (SD)	6 h Mean (SD)	MD (95% CI)	*P**	0 h Mean (SD)	6 h Mean (SD)	MD (95% CI)	*P**
R1	1.152 (0.238)	1.153 (0.264)	-0.073 (-0.154, 0.008)	0.835	0.178 (0.441)	0.170 (0.048)	0.003 (-0.009, 0.015)	0.216
R2	1.081 (0.279)	1.081 (0.279)	-0.057 (-0.155, 0.042)	0.900	0.184 (0.047)	0.189 (0.047)	0.002 (-0.001, 0.015)	0.610
U1	1.157 (0.257)	1.143 (0.257)	0.053 (-0.004, 0.148)	0.923	0.142 (0.034)	0.161 (0.035)	-0.009 (-0.020, 0.002)	0.006

**P*-values were calculated using the Wilcoxon signed-rank test for both groups. 0 h=baseline, 6 h=6 h after decannulation, AP=anteroposterior, CI=confidence interval, EDV=end-diastolic velocity, MD=mean difference, PSV=peak systolic velocity, R1=radial artery at insertion, R2=radial 4 cm proximal to insertion, RI=resistive index, SD=standard deviation, U1=ulnar artery

In their evaluation of 120 patients, Liu *et al.*[6] documented an increase in ulnar artery diameters 5 min and 24 h after cannulation, which returned to normal at 7 days. Kim *et al.*[7] evaluated flow in the radial artery and ulnar artery before anaesthesia, 5 min after intubation, immediately after and 5 min after cannulation of the radial artery and also looked at flows comparing 20 G and 22 G cannulas. They concluded that the flow reduced in the radial artery immediately after cannulation, but recovered in 5 min, while ulnar arterial flow increased in 1 min and remained elevated at 5 min. The authors did not find differences between the sizes of cannula studied.

We are uncertain about the impact of induction on flow at 1 and 5 min in the radial artery when the brunt of haemodynamic responses is usually seen. In addition, we felt that the presence of cannula could affect the probe placement and RI measurements, which Kim *et al.*[7] had not mentioned in their study.

We documented the increase in ulnar flow following decannulation, but did not appreciate flow changes in the radial artery at the time points studied.

We found that the RI and AP diameter at the radial artery, both at the point of insertion and at the point proximal to the site of insertion, were comparable at 6 h following decannulation. This corroborated with comparable values of PSV and EDV at these points. Contrarily, PSV and AP diameter in the ulnar artery were higher after decannulation than before cannulation, suggesting a compensatory increase in ulnar artery blood flow following radial artery decannulation. Other researchers have endorsed this finding.[8] We found a compensatory increase in the ulnar PSV and AP diameter of the ulnar artery when the radial cannula was retained for longer than 24 h. The group with a cannula for less than 24 h showed a rise in RI and EDV of the radial artery (R1) at 6 h following decannulation.

A consensus statement from the Society of Vascular Medicine and Society for Vascular Ultrasound has defined waveform characteristics commensurate with arterial narrowing.[9] Very minimal flow disruption may increase PSV slightly while maintaining the early diastolic flow reversal. The multiphasic wave can change to monophasic patterns when the flow obstruction increases. Continuous increase in obstruction to flow can manifest as increases in PSV and EDV. Our studies showed that when PSV and EDV were on opposite sides, RI was higher, and it was lower when they were on the same side [Figure 2a and b].

Although the systemic vascular RI is supposed to correlate with the radial resistance index measured by Doppler at the radial artery, Rodríguez Aparicio *et al.*[10] have shown the correlation was poor and cannot be used as a surrogate for the systemic vascular resistance index.

Radial artery occlusion (RAO) after transradial catheterisation is well known. Among the factors predisposing to its occurrence are female gender, low BMI, diabetes mellitus, dyslipidaemia and reduced renal function.[11] The use of a larger sheath, reduced dose of heparin and repeat cannulations are also associated with RAO. In these instances, denudation of the endothelial lining with exposure of the underlying matrix and the release of inflammatory vasoconstrictor substances have been postulated as the cause of thrombus formation. We did not find any differences in the RIs between the female and male genders in our study group. Bigler *et al.*[12] have proposed a novel finding that RAO will likely occur after transradial catheterisation in those with well-developed collateral circulation or a well-developed palmar arch.

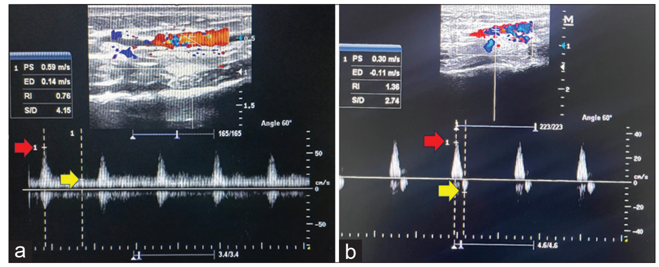

Figure 2: (a) Lower resistive index with systolic and diastolic flows on the same side (b) Higher resistive index with systolic and diastolic flows on the opposite side. The red arrow indicates PS, the yellow arrow indicates ED. PS = peak systolic, ED = end diastolic, RI = resistive index, (PS-ED)/PS.

Overall, the incidence of complications was very low in our patients, and this is similar to the results of the analysis by Nuttall *et al*.,[13] who reported a complication rate of 2.7 per 10,000 cannulations using a 20 G cannula. In an observational study of 509 patients, Hou *et al.*[14] reported haematoma formation in 31% and median nerve injury in 8% of them.

We acknowledge the limitations of our research. Most strikingly, when we encountered decreased pulsatility of the radial pulse on palpation, we could not document this on an ultrasound Doppler. This was due to the study design, which selected the RI only at any point with documented flow. We did not include patterns of vascular flow as biphasic versus monophasic, but relied on values of RIs for flow documentation. We did not follow up with the patient beyond 6 h of decannulation. The earlier design of this study included measurements at the time of hospital discharge. We could not follow up on these patients during the first follow-up due to logistic issues in patient shifting for flow assessment. A prospective trial evaluating the flow patterns at decannulation and extending the measurement period beyond immediate decannulation may provide valuable information to intensivists and anaesthesiologists in their practice.

CONCLUSION

Radial artery flows assessed by resistive index did not change following cannulation at the insertion site or proximally, and the size of the radial artery measured by anteroposterior diameter was also similar. After decannulation, the ipsilateral ulnar artery documented increased peak systolic velocity and anteroposterior diameter, suggesting a compensatory flow adjustment to the radial arterial flows.

Study data availability

De-identified data may be requested with reasonable justification from the authors (email to the corresponding author) and shall be shared after approval as per the authors' institution policy.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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