Journal of Anesthesia (2025) 39:41–48
https://doi.org/10.1007/s00540-024-03419-0

ORIGINAL ARTICLE

Margin of safety for needle puncture of a radial artery in children: Recommendation for ultrasound-guided cannulation

Kazuyoshi Furuta[1] · Takashi Asai[1] · Hiroaki Suzuki[1] · Shunsuke Saima[1] · Yasuhisa Okuda[1]

Received: 29 July 2024 / Accepted: 12 October 2024 / Published online: 10 November 2024

Abstract
Background The radial artery is commonly selected for arterial puncture and cannulation, but radial nerve palsy may occur. To minimize possible damage to the nerve, needle puncture should be made within the margin of safety (between the wrist to the distal end of the radial artery and the radial nerve running in parallel). In adults, the margin of safety for radial artery puncture is approximately 6.8 cm from the wrist in men and approximately 5.4 cm in women, but the margin of safety is not known in children of different age groups.
Methods Using an ultrasound device, we measured the margin of safety in 100 anesthetized patients aged 0 months to 15 yr. Polynomial quadratic regression models were made, and the lower limit of the prediction interval was regarded as the margin of safety. These results were then compared with the results obtained in adults.
Results The margin of safety became wider as a child grows older, and the height, weight, and age were all suitable explanatory variables to predict the margin of safety, providing fairly a constant predicted margin of safety from a few millimeters in neonates to approximately 4 cm in adolescents (much narrower than in adults).
Conclusions In children and adolescents, the margin of safety for radial artery puncture is much narrower than in adults, and these findings support the recommendation to use ultrasound guidance during radial artery puncture in children and adolescents, to minimize the risk of associated complications.
Clinical trial registration jRCT1032230243.

Keywords Arterial cannulation · Radial artery · Radial nerve · Nerve injury · Children

Introduction

The radial artery is regarded as a suitable site for needle puncture or cannulation, to take arterial blood or to monitor the direct blood pressure [1]. In addition, the radial artery is now regarded as the main access for endovascular angiography and interventional procedures in adults [2, 3] and it has increasingly been selected in children [4–7].

Nerve injury is one of the rare complications associated with needle puncture or cannulation of the radial artery [8, 9]. The incidence could be increased to 1.8% in adults when cannulation of the radial artery is performed for endovascular angiography and interventional procedures [10]. The exact mechanism for the injury is not clear [10], but one possible reason is damage to the radial nerve by needle puncture [10, 11]. There have been no studies which indicated the incidence of this complication in children, but because of smaller sizes of the artery and the nerve, the incidence may be similar to, or higher than, the incidence in adults.

The radial nerve bifurcates centrally in the forearm into the deep and superficial radial branches. While the deep radial branch separates from the radial artery, the superficial branch runs parallel with the radial artery (behind the brachioradialis muscle) and then separates from the radial artery in the distal part of the forearm. Therefore, to avoid injury to the radial nerve, needle puncture should be made in the area where the radial nerve is not running near the radial artery, between the radial styloid process and the distal edge of the parallel segment of the artery and the nerve.

In our previous study [12], we have reported that the margin of safety for radial artery puncture is approximately 6.8 cm from the wrist in male adults and approximately

✉ Takashi Asai
asaita@dokkyomed.ac.jp

1 Department of Anesthesiology, Dokkyo Medical University Saitama Medical Center, 2-1-50, Minami-Koshigaya, Koshigaya, Saitama 343-8555, Japan

5.4 cm in female adults. We predicted that the margin of safety would be narrower in children, but no studies have confirmed this. Therefore, the main aim of our study was to decide the margin of safety for radial artery puncture in children.

Methods

The research ethics committee of Dokkyo Medical University Saitama Medical Center approved the study (ID: 22,091). We registered the study in a publicly accessible database (the Japanese clinical trial register, on 19th July 2023) before recruitment of the first subject (iRCT; 1,032,230,243). Written informed consent was obtained from the patient or their guardians; for children who were able to communicate, informed assent was also obtained from the children after explaining the study protocol in simple language with pictures. The study was carried out from July to December 2023.

We studied 100 Japanese patients aged 0 month to 15 yr, who were scheduled for elective surgeries under general anesthesia. Patients were excluded if they underwent emergency surgery, their parents or guardians declined to, or were unable to, provide written informed consent, or withdrew consent.

In an operating room, an electrocardiogram, a non-invasive blood pressure cuff, and a pulse oximeter were attached. General anesthesia was induced either with intravenous propofol or with inhalation of sevoflurane, and a clear airway was secured either by tracheal intubation or by insertion of a supraglottic airway.

One of us (KF) measured the following two distances, with the method used in adults in our previous study [12]. Before starting a formal study, we assessed if it was feasible to use the methods used in adults [12], in children (including infants), and confirmed that there was little difficulty in using this method to identify the radial artery and radial nerve. In addition, correct identification of the radial nerve using the ultrasound echograph was confirmed by locating the entire course of the nerve in the forearm, by confirming that the course of the nerve was in agreement with the course illustrated in anatomical textbooks, and by asking orthopedic surgeons to confirm that the nerve shown on the ultrasonography was the radial nerve.

Briefly, each patient's upper extremity was abducted and externally rotated, the wrist joint was mildly dorsiflexed, and the position was fixed using adhesive tape. Using an ultrasound echograph (linear-type ultrasound probe, Sonosite PX, FUJIFILM Medical Co., Ltd, Tokyo, Japan), point A (the styloid process), point B (the distal edge of the parallel segment of the radial artery and the radial nerve) and point C (the proximal edge of the parallel segment of the artery and the nerve) were located (Fig. 1), and the distances between A and B, and A and C, were measured. The distance between A and B was regarded as the margin of safety for needle puncture of the radial artery. If there was difficulty in locating the radial artery or the radial nerve, or if there was uncertainly in identifying the radial artery or the radial nerve, the patient was withdrawn from data analysis.

Statistical analysis

We predicted (and confirmed after obtaining the data) that the multivariate regression model would not be suitable for the outcome variable (the margin of safety) with explanatory variables (patient's age, height and weight), as there were strong linear relations between the explanatory variables in children and multicollinearity was present (detailed reasonings are provided in Supplementary Methods). Therefore, we planned to use a single regression model. We considered that the patient's height would be the most practical and useful

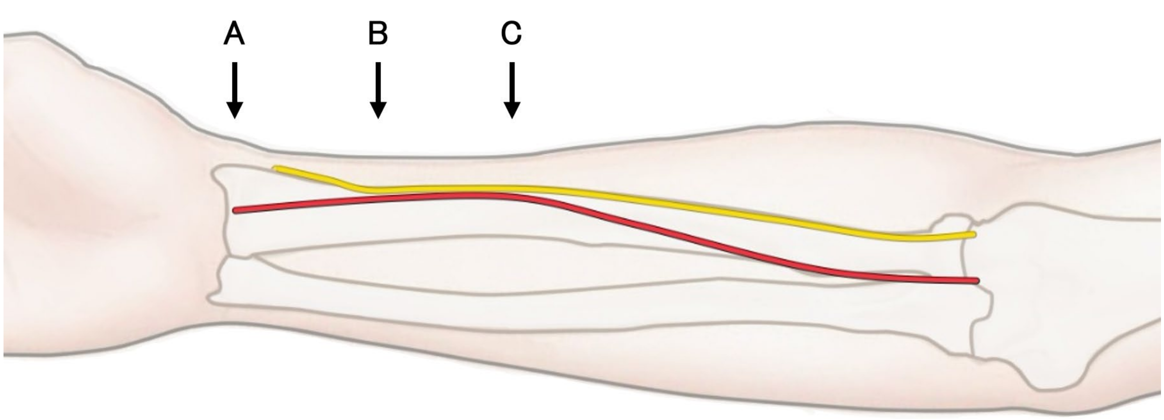

Fig. 1 Measurement of the margin of safety for needle puncture of the radial artery. Point A (the styloid process), point B (the distal edge of the parallel segment of the artery and the radial nerve), and point C (the proximal edge of the "run side-by-side" segment)

predictor of the margin of safety (distance A–B), and thus we regarded this analysis as the primary outcome analysis.

We also predicted that a possible difference in the margin of safety between male and female children would be less than a clinically meaningful difference. In fact, a confidence interval for the difference between the slope of a regression line for males and the slope for females [13] indicated that these two groups are likely to be from the same population (detailed reasonings are provided in Supplementary Methods). Therefore, we analyzed pooled data of all 100 children, including males and females.

After obtaining the data, the suitability of linear regression analysis was assessed by plotting residuals against an explanatory variable (height, weight or age), and it was judged that linear regression would not be a suitable model, even after log transformation of the data (Supplementary Methods). Therefore, we decided to construct a polynomial quadratic regression model.

The main aim of our study was to decide the margin of safety for radial artery puncture in children of different age groups, by first applying correlation analysis to confirm if there was a relation between the height and the distance A–B. *F* test was used to assess if the model explains a significant amount of variance in the outcome variable. The coefficient of determinations (R^2) was calculated to indicate the proportion of the variation in the outcome variable that is predictable from the explanatory variable. The 95%prediction intervals for distance A–B were calculated and the lower limit of prediction intervals was regarded as the margin of safety for radial artery puncture.

After obtaining the data, we have also found that there were considerable differences in the margin of safety, between older children and adults. We speculated that this might be the reason for non-linear relation between the children's height and the margin of safety, and thus we added the data of adults obtained previously [12] and constructed a new polynomial regression model. Mann–Whitney *U* test was used to compare the distance A–B (together with the distance B–C and the distance A–C) between large children (with a height taller than the minimum height of adults) and adults. The 95%confidence interval for the median differences in the distance A–B was also calculated.

Continuous variables were expressed as the means and the standard deviations when the data were normally distributed, whereas they were expressed as the medians, interquartile ranges, and ranges when they were not normally distributed. $P < 0.05$ were considered significant for the primary outcome measure, whereas $P < 0.0001$ were considered significant for the secondary outcome measures.

Power analysis was performed before the start of the study, for the primary outcome measure (relation between the height and the distance A–B). We defined the null hypothesis for a regression analysis that the slope of the linear regression (b) is 0 (that means that there is no linear relation (b_0)). As it was impractical to define the minimum clinically meaningful value for the slope of the regression line (b and b_0), we used the medium effect size defined by Cohen ($R^2 = 0.13$ or $f^2 = 0.15$) [14]. Fifty-three participants would be required to detect this effect size, with a power of 0.8, and $P = 0.05$. In addition, to obtain a reasonably small uncertainty for the estimate for the primary outcome measure (the margin of safety for each height range), a minimum of several patients would be required in each height range (from approximately 60 cm to approximately 170 cm in 5-cm increments). Therefore, we decided to study 100 patients.

SPSS version 29.0.1.0 was used for the statistical analysis, and manual calculation was carried out to confirm the validity of the results. G*Power version 3.1.9.6 was used to carry out power analysis.

Results

We enrolled 100 children (patients' characteristics in Table 1) and because there was no difficulty in identifying the radial artery and radial nerve in all the children (including infants), we included all the children for data analysis.

Height vs the margin of safety

A polynomial regression model showed a significant positive relation between the patient's height and the distance A–B ($F = 164.8$, $P < < 0.0001$) (Fig. 2a). The coefficient of determinations (R^2) was 0.773, indicating that 77.3% of the variability of the distance A–B can be explained by the height.

The lower 95%prediction intervals for the distance A–B indicated that the taller the patient, the wider the margin of safety for radial artery puncture, and the predicted margin of safety ranged from 0.2 cm (for the lowest height of 57.4 cm) to 4.2 cm (for the highest height of 173 cm) (Fig. 2a, Table 2). Nevertheless, there were a few children (whose heights were between 110 to 150 cm) in whom the margin of safety was markedly narrower than the predicted values (Fig. 2a).

Table 1 Patients characteristics (medians [interquartile ranges] (ranges))

Males/ females	73 / 27
Age (yr)	5.5 [1.8–10.0] (0.16–15.9)
Height (cm)	109 [84–139] (57.4–173)
Weight (kg)	18 [12–36] (4.7- 74)

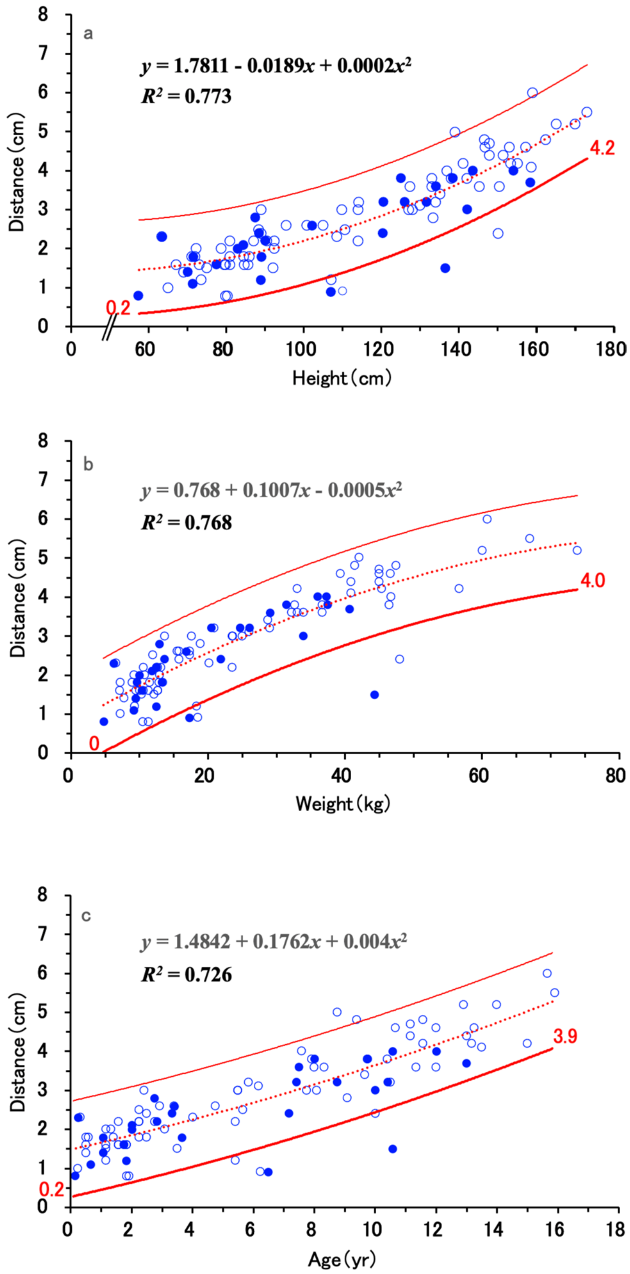

Fig. 2 **a** Regression model for the distance A–B (the margin of safety for needle puncture of the radial artery) with children's height as an explanatory variable; **b** Regression model for the distance A–B with patient's weight as an explanatory variable; and c) Regression model for the distance A–B with patient's age as an explanatory variable. Individual values of children (males (○), females (●)), polynomial quadratic regression lines (dotted curve lines) with their equations and the coefficient of determination (R^2), and 95%prediction intervals (solid curve lines) are shown. The minimum and maximum values of the lower boundaries of 95% prediction intervals, which indicate the margin of safety for the needle puncture of the radial artery, are also indicated

Table 2 Predicted margin of safety (cm) for radial artery puncture for different heights, weights, and age categories of children

Explanatory variables	Margin of safety
Height	0.3–0.6 cm
60–80 cm	0.3–0.6 cm
80–100 cm	0.6–1.0 cm
100–120 cm	1.0–1.7 cm
120–140 cm	1.7–2.5 cm
140–160 cm	2.5–3.5 cm
160–170 cm	3.5–4.1 cm
Weight	
5–10 kg	0.1–0.5 cm
10–20 kg	0.5–1.4 cm
20–30 kg	1.4–2.1 cm
30–40 kg	2.1–2.8 cm
40–50 kg	2.8–3.3 cm
50–60 kg	3.3–3.7 cm
60–70 kg	3.7–4.0 cm
Age category	
Infants (0.2–1 year)	0.2–0.4 cm
Small children (1–6 years)	0.4–1.4 cm
School-aged children (6–12 years)	1.4–2.9 cm
Adolescents (12–15 years)	2.9–3.7 cm

Weight or age vs the margin of safety

There was a significant positive relation between the patient's weight and the distance A–B ($F = 160.8$, $P < < 0.0001$), with R^2 of 0.768 (Fig. 2b). The predicted margin of safety ranged from 0 cm (for the lightest weight of 4.7 kg) to 4.0 cm for the heaviest weight of 74 kg) (Fig. 2b, Table 2).

There was a significant positive relation between the patient's age and the distance A–B ($F = 128.3$, $P < < 0.0001$), with R^2 of 0.726 (Fig. 2c). The predicted margin of safety ranged from 0.2 cm (for the youngest of 0.16 yr) to 3.9 cm for the oldest of 15.9 yr) (Fig. 2c, Table 2).

Large children vs adults

When the scatter plot of the data from both children and adults [12] was made, it became clear that the relation between the patient' height and the distance A–B was strongly curved at the patient's height of approximately 150 cm (Fig. 3). This was confirmed by the fact that a polynomial regression line for both children and adults ($F = 373.0$, $P < < 0.0001$) was more strongly curved than the regression line for children only (Fig. 3).

When the data of male and female adults [12] were pooled, the median and range of the distance A–B in adults were 8.8 (5.6 – 16.8) cm (Fig. 4). The minimum height of adults was 148 cm, in whom the shortest A–B

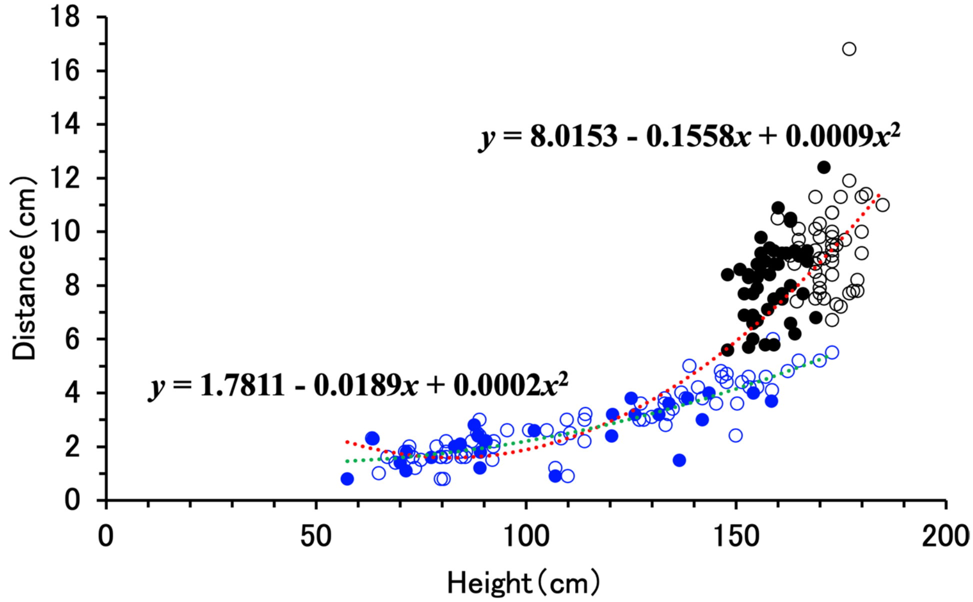

Fig. 3 Regression model for the distance A–B with both children's and adults' height as an explanatory variable. Individual values of children (males (○), females (●)) with a polynomial quadratic regression line (green dotted curve line) for children, together with individual values of adults (males (○), females (●)) with a polynomial quadratic regression line (red dotted curve line) for both children and adults

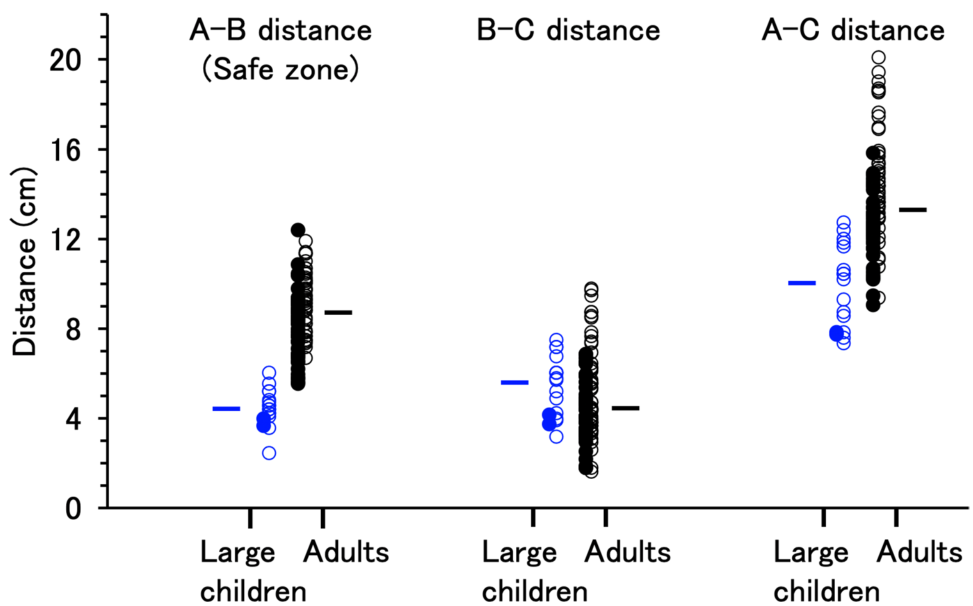

Fig. 4 Individual values of children (males (○), females (●)) and of adults (males (○), females (●)), with the medians for the distance A–B, B–C and A–C in large children (with their heights 148 cm or taller)

(5.6 cm) was observed. There were 17 children whose heights were 148 cm or taller. In these large children, the median and range of the distance A–B was 4.4 (2.4–6.0) cm, and in only one of 17 children, the distance A–B was longer (6.0 cm) than the shortest A–B in adults (5.6 cm) (Fig. 4). The distance A–B was significantly shorter in the large children than in adults ($P < <0.0001$). The median difference between adults and large children was 4.3 cm, with 95%confidence interval for the median differences of 3.6–4.9 cm.

Distance A–B, B–C and A–C

To elucidate the reasons for the marked difference in the margin of safety between adults and large children, we compared the distance B–C (parallel segment of the artery and the nerve) and the distance A–C (the margin of safety plus the parallel segment) between these two groups of patients (Fig. 4). The distance A–B or the distance A–C was significantly shorter in the large children than adults ($P < <0.0001$), whereas there was no significant difference in the distance B–C between the large children and adults ($P = 0.12$).

A scatter plot of the ratios of distance A–B to distance B–C for all the children and adults (Fig. 5) indicated that the A–B/B–C ratio was fairly constant between the children of different heights (median: 0.8; interquartile range: 0.7–0.9). In contrast, in adults, the A–B/B–C ratio (median: 2.0) was much larger than in children, and there was a much larger variability (interquartile range: 1.4–2.7). These indicate that the relative length of distance A–B to distance B–C would markedly increase during the transition from adolescence to adulthood.

Discussion

We have shown that the margin of safety for radial artery puncture would become wider as a child grows up, and have found that the height, weight, and age of children are all suitable explanatory variables to predict the margin of safety. The regression models with the height, weight, and age, provided fairly a constant predicted margin of safety from a few millimeters to approximately 4 cm (Fig. 2). One major unpredicted finding is that the margin of safety for radial artery puncture was much narrower in large children (or children of adult size) (approximately 4.0 cm) than in adults (6.8 cm in men and 5.4 cm in women). In addition, the margin can be less than 2.5 cm in a child with height of approximately 150 cm.

The exact reasons are not clear for the apparent discrepancy in the margin of safety between adults and large children. One possibility is that the ratio of the arm length to the height may be relatively smaller during adolescent growth, as it is known that the legs are the first to grow, then the arms [15, 16]. Nevertheless, the growth of the arms ends 0.25 yr after the end of the growth of the legs [15]. Therefore, this possibility would not be the main reason.

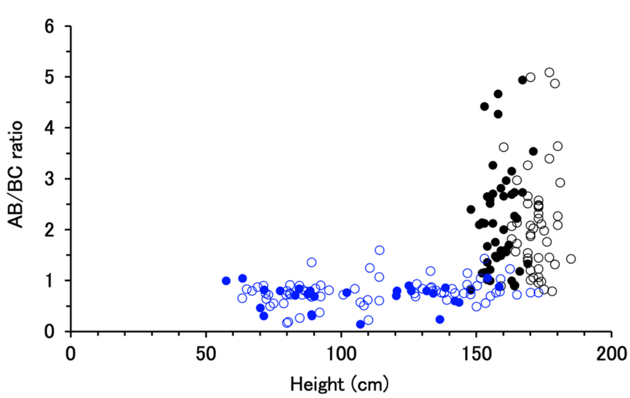

Fig. 5 Individual AB/BC ratios of children (males (○), females (●)) and of adults (males (○), females (●)) over the height

Another possible reason may be related to the difference in the growth rate between the distal part and the middle part of the forearm. Longitudinal growth of the radius and ulna occurs at the cartilaginous growth plates (or epiphyseal plates) located near both ends of the bones until the plates are ossified (epiphyseal closure or growth plate fusion) in late puberty. For the radius and ulna, approximately 80 to 90% of growth occurs at the distal growth plate [17], and thus the degree of longitudinal growth is greater near the distal growth plate than the middle or the proximal part of the bones [18]. This possibility is supported by our results that there was no significant difference in the distance B–C (located in the middle part of the forearm) between adults and large children, whereas the distance A–B was significantly shorter (hence the A–B/B–C ratio smaller) in large children than in adults (Fig. 4). Therefore, it would be reasonable to assume that the margin of safety has become wider by the growth of the distal part of the forearm during the transition from adolescence to adulthood.

Limitations of this study include that all the patients we studied were Japanese, whose size and the growth rate of the forearm may be different from the other ethnic groups [19, 20]. In addition, there may be differences in the branching and innervation pattern of the radial nerve in the forearm between different ethnicity (such as Asians or Caucasians) [21], or between different people [22]. Therefore, the margin of safety may be wider in taller populations or in people in whom skeletal maturity occurs earlier.

Another limitation of this study is that we analyzed the data obtained from children up to 15 yr of age and the data of adults reported previously, [12] and thus there were relatively few or no data of children of middle or late adolescence. Therefore, we could not obtain sufficient data to confirm possible reasons for the discrepancy in the margin of safety between adults and large children. In our previous study of adults, there seemed to be a difference in the margin of safety for radial artery puncture between males and females (6.8 cm from the wrist for men, and 5.4 cm from the wrist for in women) [12]. In contrast, in this study of children, there was no significant difference in the margin of safety between male and female children. This apparent dissociation between adults and children may also be explained by the insufficient data from children of middle or late adolescence.

Clinical implications of the study include that the margin of safety for radial artery puncture is much narrower in children than in adults, and it may be less than 2.5 cm in large children. Therefore, we should regard that even children of adult size are at an increased risk of radial nerve injury during attempts at radial artery puncture.

Systematic reviews and meta-analyses have shown that, compared with palpation or Doppler auditory assistance, the use of ultrasonography reduces repeated attempts at insertion of a cannula to the radial artery, and also reduces the incidence of hematoma in children [23, 24], so that it may be recommended to use ultrasonography routinely during cannulation to the radial artery in children. Nevertheless, ultrasonography may not be routinely used during cannulation of the radial artery either in adults or in children. In our previous study, we concluded that, in adults, routine use of ultrasound guidance would not be mandatory to minimize possible damage to the radial nerve, as far as needle puncture of a radial artery is attempted within 5 cm from the wrist in adults [12]. In contrast, our current study in children supports the recommendation to use ultrasound guidance during radial artery puncture in children and adolescents, to minimize the risk of associated complications.

Conclusions

In conclusion, the margin of safety for radial artery puncture ranges from a few millimeters in neonates to approximately 4 cm in adolescents, and this range is much narrower than in adults, and these findings support the recommendation to use ultrasound guidance during radial artery puncture in children and adolescents, to minimize the risk of associated complications.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00540-024-03419-0.

Authors' contributions Conception of the study: TA, SS. Design of the study: TA, KF, HS, SS, OY. Acquisition of data: KF, HS, SS. Data analysis and interpretation: TA, KF, HS, SS. Initial manuscript drafted: KF.

Funding None.

Data availability Data are available from the authors.

Declarations

Conflict of interest TA is an Associate Editor-in-Chief of the Journal of Anesthesia. The other authors have no conflicts to declare.

References

1. Brzezinski M, Luisetti T, London MJ. Radial artery cannulation: a comprehensive review of recent anatomic and physiologic investigations. Anesth Analg. 2009;109:1763–81.
2. Levine GN, Bates ER, Blankenship JC, Bailey SR, Bittl JA, Cercek B, Chambers CE, Ellis SG, Guyton RA, Hollenberg SM, Khot UN, Lange RA, Mauri L, Mehran R, Moussa ID, Mukherjee D, Nallamothu BK, Ting HH. 2011 ACCF/AHA/SCAI guideline for percutaneous coronary intervention: a report of the American college of cardiology foundation/american heart association task force on practice guidelines and the society for cardiovascular angiography and interventions. Circulation. 2011;124:e574-651.
3. Jolly SS, Mehta SR. Coronary intervention: radial artery access comes of age. Lancet. 2015;385:2437–9.
4. Irving C, Zaman A, Kirk R. Transradial coronary angiography in children and adolescents. Pediatr Cardiol. 2009;30:1089–93.
5. Srinivasan VM, Hadley CC, Prablek M, LoPresti M, Chen SH, Peterson EC, Sweid A, Jabbour P, Young C, Levitt M, Osbun JW, Burkhardt JK, Johnson J, Kan P. Feasibility and safety of transradial access for pediatric neurointerventions. J Neurointerv Surg. 2020;12:893–6.
6. Lee SB, Cho YJ, Kim SH, Lee S, Choi YH, Cheon JE. Transradial cerebral angiography: Is it feasible and safe for children? Cardiovasc Intervent Radiol. 2022;45:504–9.
7. Cox P, Riveros R, Torres F, Venegas A, Carvajal Y. Transradial access for pediatric teenage neurointervention: A single-center case series. Interv Neuroradiol. 2022;28:381–5.
8. Sandoval Y, Bell MR, Gulati R. Transradial artery access complications. Circ Cardiovasc Interv. 2019;12: e007386.
9. Ul Haq MA, Rashid M, Kwok CS, Wong CW, Nolan J, Mamas MA. Hand dysfunction after transradial artery catheterization for coronary procedures. World J Cardiol. 2017;9:609–19.
10. Jang HJ, Kim JY, Han JD, Lee HJ, Kim JS, Park JS, Choi RK, Choi YJ, Shim WH, Kwon SW, Kim TH. Numbness after transradial cardiac catheterization: the results from a nerve conduction study of the superficial radial nerve. Korean Circ J. 2016;46:161–8.
11. Hickman J, Chekairi A. Superficial branch of the radial nerve injury: A case for conscious perioperative arterial cannulation. J Perioper Pract. 2018;28:99–100.
12. Saima S, Asai T, Okuda Y. Margin of safety for needle puncture of a radial artery. J Anesth. 2021;35:459–63.
13. Altman DG, Gardner MJ. Regression and correlation. In: Altman DG, Machin D, Bryant TN, Gardner MJ, eds. Statistics with confidence. Confidence intervals and statistical guidelines. 2nd edn. Bristol: BMJ Books, 2000;73–92.
14. Cohen J. Multiple regression and correlation analysis. In: Statistical power analysis for the behavioral sciences. 2nd ed. New York: Psychology Press; 1988;407–65.
15. Attallah NL, Louis D. Growth of the limbs and their segments during childhood and adolescence: a photogrammetric study. Adv Res J Public Health Epidemiol. 2019;4:38–64.
16. Kvist O, Luiza Dallora A, Nilsson O, Anderberg P, Sanmartin Berglund J, Flodmark CE, Diaz S. A cross-sectional magnetic resonance imaging study of factors influencing growth plate closure in adolescents and young adults. Acta Paediatr. 2021;110:1249–56.
17. Pritchett JW. Growth plate activity in the upper extremity. Clin Orthop Relat Res. 1991;268:235–42.
18. Mainard N, Langlais T, Soubeyrand M, Vialle R, Creze M, Rougereau G. The interosseous tuberosities of the forearm exist from 1-year-old: a pediatric radiological study describing the ages of appearance of the different forearm reliefs. Surg Radiol Anat. 2023;45:593–602.
19. Kepley AL, Nishiyama KK, Zhou B, Wang J, Zhang C, McMahon DJ, Foley KF, Walker MD, Guo XE, Shane E, Nickolas TL. Differences in bone quality and strength between Asian and Caucasian young men. Osteoporos Int. 2017;28:549–58.
20. Cole TJ, Rousham EK, Hawley NL, Cameron N, Norris SA, Pettifor JM. Ethnic and sex differences in skeletal maturation among the birth to twenty cohort in South Africa. Arch Dis Child. 2015;100:138–43.
21. Chou P-H, Shyu J-F, Ma H-L, Wang S-T, Chen T-H. Courses of the radial nerve differ between Chinese and Caucasians: Clinical applications. Clin Orthop Relat Res. 2008;466:135–8.
22. Sawyer FK, Stefanik JJ, Lufler RS. The Branching and innervation pattern of the radial nerve in the forearm: Clarifying the literature

and understanding variations and their clinical implications. Diagnostics (Basel). 2020;10:366.
23. Raphael CK, El Hage Chehade NA, Khabsa J, Akl EA, Aouad-Maroun M, Kaddoum R. Ultrasound-guided arterial cannulation in the paediatric population. Cochrane Database Syst Rev. 2023. https://doi.org/10.1002/14651858.CD011364.pub3.
24. White L, Halpin A, Turner M, Wallace L. Ultrasound-guided radial artery cannulation in adult and paediatric populations: a systematic review and meta-analysis. Br J Anaesth. 2016;116:610–7.