Ultrasound study of forearm arteries in patients undergoing cardiac catheterization, and assessment of predictors of arterial vessel caliber

Estudo ultrassonográfico de artérias do antebraço de pacientes submetidos a cateterismo cardíaco e avaliação de preditores de calibre arterial

¹ Department of Interventional Cardiology, Instituto Dante Pazzanese de Cardiologia, São Paulo, SP, Brazil.

² Department of Interventional Cardiology, Instituto de Cardiologia de Santa Catarina, São José, SC, Brazil.

³ Department of Interventional Cardiology, Santa Casa de Marília, Marília, SP, Brazil.

Roberto Léo da Silva^{1ID}, Ozir Miguel Londero Filho², Pedro Beraldo de Andrade³, Alexandre Antonio Cunha Abizaid¹, Rodrigo de Moura Joaquim², Paulo Felipe Romandini Britto², Filipe Barcelos Filippini², Renata Mirelli de Melo Viana¹, Amanda Guerra de Moraes Rego Sousa¹, Fausto Feres¹, José de Ribamar Costa Júnior¹

DOI: 10.31160/JOTCI201927A20190019

ABSTRACT – Background: The radial approach has been increasingly used worldwide for diagnostic and therapeutic cardiac catheterization. The radial artery caliber is one of the limitations of its use. The objective of this study was to describe the anatomy of the radial and ulnar arteries, as well as to develop a radial artery diameter prediction score using clinical and anthropometric criteria. **Methods:** Using vascular ultrasound with bilateral radial and ulnar artery measurements, 1,180 patients who underwent cardiac catheterization or angioplasty procedures were prospectively evaluated. Using the patients' variables, a radial artery diameter prediction score was developed in a cross-sectional fashion, using half of the sample. The score was validated with the half not used for deriving the model. **Results:** A total of 1,180 patients were evaluated. The mean internal diameter of the right and left radial arteries was 2.69 ± 0.69 mm and 2.53 ± 0.64 mm ($p < 0.01$), and the mean internal diameter of the right and left ulnar arteries was 2.09 ± 0.59 mm and 2.10 ± 0.60 mm ($p = 0.76$), respectively. The factors that positively correlated with arterial size were male sex, previous catheterization, height, weight, and body surface area. The risk score developed using clinical and anthropometric variables had unsatisfactory discriminatory capacity (c-statistics 0.64). **Conclusion:** The right radial artery is the largest forearm artery in most cases. Men and patients who had previously undergone catheterization have a larger mean radial artery diameter. The artery diameter prediction score has modest accuracy for clinical use.

Keywords: Radial artery/imaging diagnosis; Anatomy; Ultrasonography, doppler; Cardiac catheterization

RESUMO – Introdução: A via de acesso transradial tem crescido em utilização mundialmente para cateterismo cardíaco diagnóstico e terapêutico. O calibre da artéria radial é um dos limitadores de seu uso. O objetivo deste estudo foi descrever a anatomia das artérias radiais e ulnares, bem como desenvolver um escore de predição de diâmetro da artéria radial, utilizando critérios clínicos e antropométricos. **Métodos:** Usando ultrassonografia vascular, com mensuração de artérias radiais e ulnares, bilateralmente, foram prospectivamente avaliados 1.180 pacientes, que foram submetidos a procedimentos de cateterismo cardíaco ou angioplastia. Usando as variáveis dos pacientes, foi transversalmente elaborado um escore de predição de diâmetro de artéria radial, utilizando-se metade da amostra. O escore foi validado com a metade da população não utilizada para a formulação do escore. **Resultados:** Foram avaliados 1.180 pacientes. O diâmetro interno médio das artérias radiais direita e esquerda foram $2,69 \pm 0,69$ mm e $2,53 \pm 0,64$ mm ($p < 0,01$), e das artérias ulnares direita e esquerda foram $2,09 \pm 0,59$ mm e $2,10 \pm 0,60$ mm ($p = 0,76$). Os fatores que se correlacionaram positivamente com o tamanho arterial foram sexo masculino, cateterismo prévio, altura, peso e área de superfície corporal. O escore de risco desenvolvido utilizando variáveis clínicas e antropométricas teve capacidade discriminatória não satisfatória (estatística-c 0,64). **Conclusão:** A artéria radial direita é a maior artéria dos antebraços na maioria dos casos. Homens e pacientes previamente

How to cite this article:

da Silva RL, Londero Filho OM, Andrade PB, Abizaid AA, Joaquim RM, Britto PF, et al. Estudo ultrassonográfico de artérias do antebraço de pacientes submetidos a cateterismo cardíaco e avaliação de preditores de calibre arterial. J Transcat Interv. 2019;27:eA20190019. <https://doi.org/10.31160/JOTCI201927A20190019>

Corresponding author:

Roberto Léo da Silva
Rua Adolfo Donato da Silva, s/n
Zip code: 88103-901, São José, SC, Brazil
E-mail: roberto.leo@ufsc.br

Submitted on:

Aug 30, 2019

Accepted on:

Dec 19, 2019

This content is licensed under a Creative Commons Attribution 4.0 International License.

submetidos a cateterismo têm diâmetro médio maior da artéria radial. O escore de predição de diâmetro de artéria apresenta modesta acurácia para uso clínico.

Descritores: Artéria radial/diagnóstico por imagem; Anatomia; Ultrassonografia doppler; Cateterismo cardíaco

INTRODUCTION

Transradial catheterization has gained popularity around the world, and many centers already use it as the preferred access for both diagnostic and therapeutic procedures.¹ This access is associated with a lower risk of vascular complications, lower bleeding rates and shorter hospital stay, and it corresponds with the patients' preference, when compared to the femoral access.²

However, its relatively small caliber and its propensity to spasm are limitations to its unrestricted use. And even more important, a possible complication of the procedure is the occurrence of radial artery occlusion after catheterization. An adequate use of heparin, the immediate removal of the introducer, and achieving patent hemostasis reduce the incidence of occlusion.^{3,4} The relation between the caliber of the artery and of the introducer is also a predictor of artery occlusion after the procedure. This combination limits the use of materials, such as introducers and catheters as small as possible for the proposed procedure.^{5,6}

With the increasing use of more complex therapies, such as rotational atherectomy or the simultaneous use of more than one balloon, which may require larger caliber catheters to effectively and safely perform the procedures, understanding the anatomical patterns in the population helps in planning the most appropriate access.⁷ The size of the artery can be easily measured by ultrasound, but not all services have the method available, so it is not routinely performed.

The objective of this study was to perform a population-based ultrasound evaluation of forearm arteries, assessing the diameter of the radial and ulnar arteries, as well as evaluating and determining the clinical and anthropomorphic artery caliber predictors that could be used when ultrasound is not available.

METHODS

This was a cross-sectional, descriptive and multicenter study conducted in two Brazilian centers. All patients provided informed consent, and the study was approved by the ethics committee of the participating institutions (protocol 4785/2017), CAAE 68678317.0.3001.5462.

All patients who underwent transradial catheterization, both for diagnostic and/or therapeutic procedures, from August 2017 to August 2019, were considered for inclusion. After patients' consent, prospective ultrasound measurements of the radial and ulnar arteries were performed. The internal diameter of the arteries was evaluated with the forearm supine, and measurements were taken 1 to 2 cm

proximal to the radial or ulnar styloid processes, bilaterally, according to the artery to be evaluated, using transverse sections, with 6 to 13MHz linear transducers on an M-turbo machine (FUJIFILM SonoSite, Bothell, USA), or a 7.5MHz linear transducer on a Power Vision 6000 machine (TOSHIBA, Tokyo, Japan). The ultrasound assessment was performed immediately before cardiac catheterization at room temperature.

Patients in continuous nitrate therapy or who were given nitrate in the one-hour period before the evaluation were excluded to allow the evaluation of the artery without the vasodilating effect of this medication.

Several clinical factors were considered for analysis: age, sex, race, weight, height, body mass index, calculated body surface area (Mosteller's formula), lateralization, risk factors for coronary artery disease, and previous use of radial artery as access for catheterization.

Statistical analysis

The Shapiro-Wilk test was performed to assess whether the variable had a normal distribution. Continuous variables were described as mean and standard deviation, and compared using Student's *t*-test for those with normal distribution, or Mann-Whitney test when the variables were not normally distributed. Categorical variables were described as frequencies or percentages and compared with the chi-square test. Potential predictors of radial and ulnar artery size were evaluated by calculating the correlation coefficients (r^2). The multiple linear regression model was performed to identify the independent factors of artery caliber. An artery size estimation score was developed from the coefficients indicated by the logistic model for each independent predictor, according to the previously described method,⁸ using 50% of patients in our sample. To validate the score, we tested the remaining 50% of sample. All analyses were conducted using the Statistical Package for Social Science (SPSS) software, version 22.0 (IBM Corp., New York, USA).

RESULTS

This study included 1,180 patients who underwent transradial catheterization in two Brazilian cath lab centers. Hydrophilic introducers were used in all procedures, 5F caliber in 742 procedures (62.9%), and 6F caliber in 37.1%. Eight catheterization procedures (0.7%) required conversion to another approach due to intense spasm, which made it impossible to complete the radial examination, and in 20 patients (1.7%), due to anatomical variations, an access conversion was also required. All exams that were not completed radially were changed to the femoral approach.

Demographic characteristics are presented in table 1. The mean internal diameter of the right and left radial arteries was 2.69 ± 0.69 mm and 2.53 ± 0.64 mm ($p < 0.01$), whereas the mean internal diameter of the right and left ulnar arteries was 2.09 ± 0.59 mm and 2.10 ± 0.60 mm ($p = 0.76$),

respectively. The diameter sample did not follow a normal distribution. The right radial artery was larger than the left radial artery in 71.6% of cases, larger than the right ulnar artery in 86.3% of cases, and larger than the left ulnar artery in 87.3% of cases; being the largest artery in 62.6% of sample. Immediate analysis of post-procedure occlusion in our sample was 2.7%, by means of antegrade radial artery flow assessment using Doppler ultrasonography, performed within the first 24 hours after removal of the hemostatic bracelet.

Using the Radifocus® II introducer (Terumo, Tokyo, Japan) as a reference, the right radial artery had a diameter smaller than the 5F introducer outer diameter (OD=2.29) in 27.3% of cases; smaller than the 6F introducer (OD=2.62) in 53.2% of cases; and smaller than the 7F introducer (OD=2.95) in 67.2% of cases, with an unfavorable artery/introducer ratio in these cases.

The right radial artery was larger in men compared to women (2.87 ± 0.68 mm vs. 2.41 ± 0.61 mm, respectively; $p < 0.01$), and in patients who had previously undergone right transradial catheterization (2.86 ± 0.68 mm vs. 2.65 ± 0.68 mm; $p < 0.01$). There was no difference in regard to lateralization (2.69 ± 0.69 mm in right-handed patients vs. 2.65 ± 0.58 mm in left-handed patients; $p = 0.57$). The presence of risk factors for coronary artery disease (hypertension, diabetes mellitus, dyslipidemia, and smoking) did not significantly alter the size of the artery. The correlations between the

variables and the right radial artery internal diameter are shown in table 2. Except for sex, all correlations were weak, and body mass index was not related to artery size. The fact that the radial artery was previously catheterized was poorly correlated with the current size ($r^2 = 0.126$; $p < 0.01$). Despite the weak correlation, it ranked second as the most important predictor of larger arteries in multivariate analysis, only behind the variable male sex.

For the development of a right radial artery size prediction score, the regression analysis generated a formula that included the following variables: constant (2.47); sex (0.43 if male); previous transradial catheterization (0.15 if present); height (0.06 if greater than 1.65m); right wrist circumference (0.01 if greater than 18cm) and body surface area (BSA) (0.01 if greater than 1.8m^2).

From this formula, the best simplified score was developed, which replaced the BSA with weight, and scored the variables as follows: sex (2 points) and height greater than 1.65m, wrist circumference greater than 18cm, previous catheterization and weight greater than 80kg (1 point each); varying the score from zero to 6 points. The c-statistics of this score was 0.64 in the prediction cohort, and 0.66 in the validation cohort, indicating unsatisfactory discrimination capacity. A score of 6 predicted an artery with an internal diameter greater than the 7F introducer outer diameter in 50% of cases. Values below 6 predicted that the artery was smaller than the 7F introducer diameter in 70% of cases. The comparison of predicted and mean real values (population analysis) is shown in table 3.

Table 1. Demographic characteristics and anatomical measurements

Characteristic	
Age, years	61.53 $\pm$ 10.57
Sex, male	60.8
Race, white	96.1
Weight, kg	76.65 $\pm$ 15.29
Height, cm	164.45 $\pm$ 9.21
BMI	28.30 $\pm$ 4.90
BSA*	1.86 $\pm$ 0.21
Lateralization, right-handed	95.7
Risk factors for CAD	
HTN	74.2
DM	33.9
Smoking	21.5
Dyslipidemia	59.9
Previous radial catheterization	20.8
Anatomical measurements	
Right radial	2.69 $\pm$ 0.69
Right ulnar	2.09 $\pm$ 0.59
Right wrist	17.26 $\pm$ 1.39
Left radial	2.53 $\pm$ 0.64
Left ulnar	2.10 $\pm$ 0.60
Left wrist	17.28 $\pm$ 1.39

Results expressed as mean $\pm$ standard deviation or %.

* Calculated by Mosteller formula.

BMI: body mass index; BSA: body surface area; CAD: coronary artery disease; HTN: hypertension; DM: diabetes mellitus.

Table 2. Correlations between internal diameter of the right radial artery and variables

Variable	r ²	p-value
Sex	0.321	<0.01
Weight	0.144	<0.01
Height	0.216	<0.01
BMI	0.022	0.45
BSA*	0.175	<0.01
Right wrist	0.181	<0.01
Left radial	0.786	<0.01

* Calculated by Mosteller formula.

BMI: body mass index; BSA: body surface area.

Table 3. Mean size of right radial artery, in millimeters, in prediction and validation samples

Score	T score	P measured	P formula	V measured	V formula
0	2.40	2.41	2.47	2.24	2.47
1	2.50	2.73	2.55	2.42	2.54
2	2.60	2.80	2.78	2.64	2.77
3	2.70	2.91	2.92	2.67	2.95
4	2.80	2.96	2.99	2.76	3.00
5	2.90	3.15	3.00	2.75	3.00
6	3.00	2.99	3.13	2.94	3.13

T: calculated size for simplified score; P: prediction sample; V: validation sample.

DISCUSSION

This study presents the ultrasound evaluation of radial and ulnar artery sizes of a large cohort of patients who underwent transradial catheterization, presenting data from the Brazilian population that may help the interventional cardiologist to plan the procedures, mainly because the relation between the size of the artery and the introducer diameter used is cited as a predictor of post-procedural arterial occlusion or stenosis.^{3,5} Only half of the patients in our study had a favorable relation (>1) to the use of 6F introducer, and a smaller portion (one third) to the use of 7F introducer. Nevertheless, our incidence of occlusion was low. The use of an adequate dose of heparin in all procedures and the use of hemostatic compression devices to achieve patent hemostasis may have influenced our occlusion rate.

The mean internal diameter of the right radial artery was 2.69mm. Previous studies showed that there may be a geographical variation in the size of the artery measured at the puncture site. In a study with a Chinese population of patients without previous catheterization, the mean diameter found was 2.37mm.⁹ Similar values were found in other Asian populations, with a diameter of 2.32mm in India;¹⁰ 2.25mm in Pakistan;¹¹ and 2.45mm in Singapore.¹² In Western populations, the sizes previously described are not much different and also smaller than those found in our study. A study of Texas volunteers in the United States showed a mean of 2.22mm;¹³ 2.17mm in European patients, and 2.44 mm in Canadians.^{7,14}

We found that the right radial artery was the largest forearm artery in most cases, being larger than the ulnar artery in 80% of cases, consistent with what has been shown in other studies.^{14,15} Previous studies showed similarities between right and left arteries, which were not observed in our study regarding radial arteries.^{14,16} In practice, the most indicated access in our population, by arterial size, is the right radial artery, and the best alternative is the contralateral radial artery.

The best predictor of radial artery size is sex, with larger arteries in men. Indeed, this was the only reasonable predictor ($r^2=0.32$) of larger arteries. The effect of the variable sex on arterial caliber has been demonstrated in previous studies.^{3,5,17} The other correlation coefficients found were weak predictors. One of the predictors found was previous catheterization, consistent with serial ultrasound analysis, which showed a sustained increase in the diameter of the catheterized radial artery up to 12 months after the procedure.¹⁴ No clinical variable, such as hypertension or diabetes, was correlated with arterial size.

This study also developed a radial artery size prediction score, to be used at the bedside, with anthropometric data. Despite a good population correlation, with mean predicted values close to the real values, its individual use is hampered by low sensitivity and specificity. Scores with discrimination similar to those predicted by our score, such as the CHA_2DS_2 -Vasc (c-statistics 0.61),¹⁸ have been used in clinical practice due to the lack of alternatives.

The low correlation of the variables and the large anatomical variation found impaired the score. A previous study developed a simplified score using only three variables in a population of 130 patients, and good accuracy was described.⁷ This score, when applied to our population, performed similarly to ours, with only reasonable accuracy in detecting patients with arterial diameters greater than 6F or 7F introducers. The fact that our sample size allowed for the division into prediction and validation cohorts allowed a broader and more general view of the score application.

Our analysis was limited because it excluded patients using nitrates. Saito et al. demonstrated larger arteries in a population that systematically received nitrates. The use of vasodilators (sublingually isolated nitrate or intraarterial verapamil nitrate) increases the average artery diameter by approximately 20%.^{19,20} The use of nitrate could increase the proportion of patients with favorable artery/introducer ratio in our population.

The use of ultrasound is the most reliable method for measuring arterial size. Clinical measures that could be used in the absence of ultrasound to predict larger arteries have a weak correlation with artery size. Given its noninvasive nature and easy execution, ultrasound remains the ideal tool for planning interventions using introducers and catheters of larger caliber.

CONCLUSION

The right radial artery is the largest forearm artery in most cases, being larger in men. Clinical variables do not predict arterial size. Anthropometric variables are weak predictors, and the developed score has modest accuracy in identifying larger radial arteries. Ultrasound evaluation is the ideal method for planning complex procedures using forearm arteries, and the size of the artery may influence the access selection.

SOURCE OF FINANCING

None.

CONFLICTS OF INTEREST

The authors declare there are no conflicts of interest.

CONTRIBUTION OF AUTHORS

Conception and design of the study: RLS, OMLF, PBA and JRCJ; data collection: RLS, OMLF, PFRB and FBF; data interpretation: RLS, OMLF, PFRB, FBF and JRCJ; writing of the text: RLS, OMLF and JRCJ; approval of the final version to be published: RLS, OMLF, PBA, AACAA, RMJ, PFRB, FBF, RMMV, AGMRS, FF and JRCJ.

REFERENCES

- Bertrand OF, Rao SV, Pancholy S, Jolly SS, Rodés-Cabau J, Larose E, et al. Transradial approach for coronary angiography and interventions. *JACC Cardiovasc Interv.* 2010;3(10):1022-31.

2. Bertrand OF, Blisle P, Joyal D, Costerousse O, Rao SV, Jolly SS, et al. Comparison of transradial and femoral approaches for percutaneous coronary interventions: A systematic review and hierarchical Bayesian meta-analysis. *Am Heart J*. 2012;163(4):632-48.
3. 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. *Catheter Cardiovasc Interv*. 1999;46(2):173-8.
4. Rao SV, Tremmel JA, Gilchrist IC, Shah PB, Gulati R, Shroff AR, Crisco V, Woody W, Zoghbi G, Duffy PL, Sanghvi K, Krucoff MW, Pyne CT, Skelding KA, Patel T, Pancholy SB; Society for Cardiovascular Angiography and Intervention's Transradial Angiography and Intervention: A Consensus Statement From the Society for Cardiovascular Angiography and Intervention's Transradial Working Group. *Catheter Cardiovasc Interv*. 2014;83(2):228-36.
5. Aminian A, Saito S, Takahashi A, Bernat I, Jobe RL, Kajiya T, et al. Impact of sheath size and hemostasis time on radial artery patency after transradial coronary angiography and intervention in Japanese and non-Japanese patients: A substudy from RAP and BEAT (Radial Artery Patency and Bleeding, Efficacy, Adverse event) randomized multicenter trial. *Catheter Cardiovasc Interv*. 2018;92(5):844-51.
6. Takeshita S, Asano H, Hata T, Hibi K, Ikari Y, Kan Y, Katsuki T, Kawasaki T, Masutani M, Matsumura T, Premchand RK, Rao SP, Suzuki T, Takahashi A, Takeda R, Tanaka S, Yamazaki S, Yin WH, Yoshimachi F, Saito S, NAUSICA Trial Investigators. Comparison of frequency of radial artery occlusion after 4fr versus 6fr transradial coronary intervention (from the Novel Angioplasty USIng Coronary Accessor Trial). *Am J Cardiol*. 2014;113(2):1986-9.
7. Kotowycz MA, Johnston KW, Ivanov J, Asif N, Almoghairi AM, Choudhury A, et al. Predictors of radial artery size in patients undergoing cardiac catheterization: Insights from the Good Radial Artery Size Prediction (GRASP) study. *Can J Cardiol*. 2014;30(2):211-6.
8. Sullivan LM, Massaro JM, D'Agostino RB Sr. Presentation of multivariate data for clinical use: The Framingham Study risk score functions. *Stat Med*. 2004;23(10):1631-60.
9. Nie B, Zhou Y, Yang Q, Cheng W, Wang Z, Wang J. Safety and feasibility of repeated percutaneous transradial coronary intervention in the same route. *Chin Med J (Engl)*. 2012;125(2):221-5.
10. Beniwal S, Bhargava K, Kausik SK. Size of distal radial and distal ulnar arteries in adults of southern Rajasthan and their implications for percutaneous coronary interventions. *Indian Heart J*. 2014;66(5):506-9.
11. Ashraf T, Panhwar Z, Habib S, Memon MA, Shamsi F, Arif J. Size of radial and ulnar artery in local population. *J Pak Med Assoc*. 2010;60(10):817-9.
12. Loh YJ, Nakao M, Tan WD, Lim CH, Tan YS, Chua YL. Factors influencing radial artery size. *Asian Cardiovasc Thorac Ann*. 2007;15(4):324-6.
13. Velasco A, Ono C, Nugent K, Tarwater P, Kumar A. Ultrasonic evaluation of the radial artery diameter in a local population from Texas. *J Invasive Cardiol*. 2012;24(7):339-41.
14. Peruga JP, Peruga JZ, Kasprzak JD, Krcki R, Jankowski , Zajc P, et al. Ultrasound evaluation of forearm arteries in patients undergoing percutaneous coronary intervention via radial artery access: results of one-year follow-up. *Kardiol Pol*. 2015;73(7):502-10.
15. Dharma S, Kedev S, Patel T, Rao SV, Bertrand OF, Gilchrist IC. Radial artery diameter does not correlate with body mass index: A duplex ultrasound analysis of 1706 patients undergoing transradial catheterization at three experienced radial centers. *Int J Cardiol*. 2017;228:169-72.
16. Yan Z, Zhou Y, Zhao Y, Zhou Z, Yang S, Wang Z. Anatomical study of forearm arteries with ultrasound for percutaneous coronary procedures. *Circ J*. 2010;74(4):686-92.
17. Nagai S, Abe S, Sato T, Hozawa K, Yuki K, Hanashima K, et al. Ultrasonic assessment of vascular complications in coronary angiography and angioplasty after transradial approach. *Am J Cardiol*. 1999;83(2):180-6.
18. Lip GY, Nieuwlaat R, Pisters R, Lane DA, Crijns HJ. Refining clinical risk stratification for predicting stroke and thromboembolism in atrial fibrillation using a novel risk factor-based approach: the euro heart survey on atrial fibrillation. *Chest*. 2010;137(2):263-72.
19. Chong AY, Lo T, George S, Ratib K, Mamas M, Nolan J. The effect of pre-procedure sublingual nitroglycerin on radial artery diameter and Allen's test outcome - Relevance to transradial catheterization. *Cardiovasc Revascularization Med*. 2018;19(2):163-7.
20. Boyer N, Beyer A, Gupta V, Dehghani H, Hindnavis V, Shunk K, et al. The effects of intra-arterial vasodilators on radial artery size and spasm: Implications for contemporary use of trans-radial access for coronary angiography and percutaneous coronary intervention. *Cardiovasc Revascularization Med*. 2013;14(6):321-4.