FREQUENCY OF RADIAL ARTERY ANATOMIC VARIATIONS IN PATIENTS UNDERGOING TRANSRADIAL HEART CATHETERIZATION

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SUMMARY – Over the last ten years, transradial cardiac catheterization has been increasingly applied, primarily because of its lower incidence of complications compared to the femoral approach. However, one of the greatest flaws of the transradial approach is a relatively high incidence of catheterization failure (1%-5%). Anatomic variations of radial artery are ranked second among the reasons for this. Previous studies have not provided unambiguous data on the frequency of these anomalies. It was therefore the aim of this study to determine the frequency of anatomic variations using routine angiographies of radial artery during left heart catheterization. This was a retrospective study involving examination of 602 images of routine angiographies of radial artery performed during cardiac catheterization. The frequency of anatomic variations of radial artery was 8.8%, exclusive of tortuosities with a frequency of 12.7%. The most frequent anatomic variation was the high origin of radial artery, found in 31 (5.1%) subjects. Radioulnar loops, being one of the potential contraindications for the procedure, were reported in 2% of cases. Regression analysis revealed that age ($p<0.001$), female sex ($p=0.015$) and high origin ($p=0.034$) considerably contributed to the development of tortuosity. The results indicated the incidence of tortuosity to increase linearly with age. Although it is not a contraindication for continuing with the procedure, we recommend that elderly patients have angiography of radial artery performed at the beginning of the procedure due to the higher frequency of tortuosity.

Key words: *Radial artery – radiography; Cardiac catheterization – classification; Cardiac catheterization – complications; Radial artery – abnormalities; PTCA/PCI*

Introduction

Clinical experience and studies have shown that cardiac catheterization using the radial artery approach is more beneficial that the femoral approach[1,2], especially in patients with ST elevation myocardial infarction[3,4]. It is believed that the reason for this is primarily the radial artery anatomy. To be precise, it is located just under the skin surface and is therefore easily accessible for hemostasis. This way, we have almost entirely avoided the complications pertinent to the femoral approach such as hematoma and pseudoaneurysm and arteriovenous fistulas[5,6]. Furthermore, if the above mentioned complications occur at any point, these do not require surgical intervention, but can rather be treated conservatively[7]. Another anatomic advantage is double blood irrigation of the hand in most cases through palmar arches that prevent hand ischemia after radial artery thrombosis, which occurs in 4%-10% of patients after transradial cardiac catheterization and depending on the manner of hemostasis[8].

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The downside of the radial approach is that radial artery has a significantly smaller diameter, 2.69±0.40 mm in men and 2.43±0.38 mm in women, compared to 6 mm of femoral artery diameter[9]. No wonder that according to the literature, the failed catheterization procedures amount to 1%-5% of cases[2,10].

Anatomic variations of radial artery are the second most frequent reason for such a failure rate[11]. The literature provides no unambiguous data as to the frequency of these; there are reports of frequencies from as low as 3% to as high as 20%[12,13].

It is precisely for this reason that the main aim of this study was to determine the frequency of anatomic variations of radial artery using angiographic images of patients that had routine transradial cardiac catheterization performed at the Interventional Cardiology Unit, Zagreb University Hospital Center in 2013.

Subjects and Methods

Subjects

This research was conducted as a retrospective study which involved patients that underwent transradial cardiac catheterization at the Interventional Cardiology Unit, Zagreb University Hospital Center in 2013. The study included patients that had elective coronarography performed in order to confirm or exclude coronary heart diseases; patients that had elective percutaneous coronary intervention (PCI); and patients with all forms of acute coronary syndrome that underwent urgent coronarography and/or PCI. All patients underwent routine angiography right after the introducer insertion into the radial artery. Seven hundred and forty-nine such cardiac catheterization procedures were carried out in the study period. All images were examined and, after selection, 602 remained for further research (414 men and 188 women). The process of selection required all patients to be of age and to have an accurate image of radial artery angiography. Correctly performed radial artery imaging involved imaging of the division of the brachial artery into the ulnar and radial arteries. It also implied visibility of at least half of the radial and half of the brachial artery. Of 147 subjects that were excluded from the study, 134 did not have a radial artery image at all and 13 had an image that did not cover a sufficiently long segment of radial artery for appropriate assessment of the potential anatomic variations to be made. Angiographies were done using radiologic and angiographic devices SIEMENS ARTIS (Siemens AG, Munich, Germany). The procedure of transradial catheterization was carried out using the recommended technique[14]. The puncture site was 1-2 cm proximal to the styloid process. Prior to puncture, the area was anesthetized with 1-2 mL of 2% lidocaine solution, and the puncture itself was performed using the Seldinger technique with a needle of 19-21 gauge size. After this, a short guide wire (0.018-0.035 inch) and then an introducer were introduced. Hydrophilic-coated introducer sheaths of 10 cm in length or 5-6 by French size were used. After introducing the introducer, 2.5 mg of verapamil was administered intra-arterially to prevent radial artery spasm. At the same time, a bolus injection of 5000 international units of heparin was administered intravenously. All subjects signed the informed consent for the mentioned procedure.

Definitions of radial artery anatomic variations

Anatomic variations are classified as the high origin of radial artery, radioulnar loops with superficial brachioradial artery (it is a 360º loop between the radial and ulnar arteries with an additional blood vessel that originates from the brachial and connects to the radial artery), radial artery loop (a 360º loop of the radial artery only), double radial artery (defined as the artery that originates from the brachial artery before normal bifurcation into ulnar and radial arteries and continues its way to the joint, in parallel with the normal radial artery), and high origin with double radial artery in accordance with the classification provided by Burzotta *et al*.[15]. The height which was taken to be the level of high bifurcation was the upper intercondylar process of the humerus. This line represents the upper edge of the cubital fossa. Tortuosities have been described as curvatures at more than 45° angle and have been analyzed as a separate anomaly, as they are, to a certain extent, acquired.

Statistical analysis

Results are shown in tables and figures. The continuous variable (age) was shown as median and standard deviation, and the Kolmogorov-Smirnov test proved normal data distribution. Other variables were

nominal, so these data were shown as frequencies and percentages. The χ^2-test or Fisher exact test was used in the analysis. In order to determine the relationship between the variables, multivariate analysis methods such as logistic regression, in which the dependent variable is dichotomous (there is or there is not tortuosity according to various criteria), were used. Statistical significance was set at 5%. A commercial statistical software, IBM SPSS version 20 (SPSS for Windows 20.0, SPSS, Chicago, IL, USA) was used on statistical analysis.

The investigation was performed in accordance with ethical standards laid down in the Declaration of Helsinki and was approved by the appropriate institutional review committees.

Results

In the total of 602 patients, 414 (68.8%) were men and 188 were women (31.2%) and all were Caucasian. The youngest patient was aged 18 and the oldest 87 (mean ± SD; 64±10.78), with normal distribution of subjects across age groups (Fig. 1).

In 538 (89.4%) patients, cardiac catheterization was performed through the right arm.

Anatomic variations, exclusive of tortuosities, were found in 53 (8.8%) subjects (Table 1). The most common anatomic variation was high origin of radial artery (Fig. 2), observed in 31 (5.1%) subjects. The next most frequent variation was radioulnar loop with superficial brachioradial artery (Fig. 3), reported in 12 (2.0%) subjects. A double radial artery was found in four (0.7%) subjects (Fig. 4). Radial loop was observed in three (0.5%) subjects (Fig. 5). Likewise, high origin of radial artery in combination with double radial artery (Fig. 6) was seen in three (0.5%) patients. There was only one accessory brachial artery, an anomaly not directly connected with radial artery (Fig. 7).

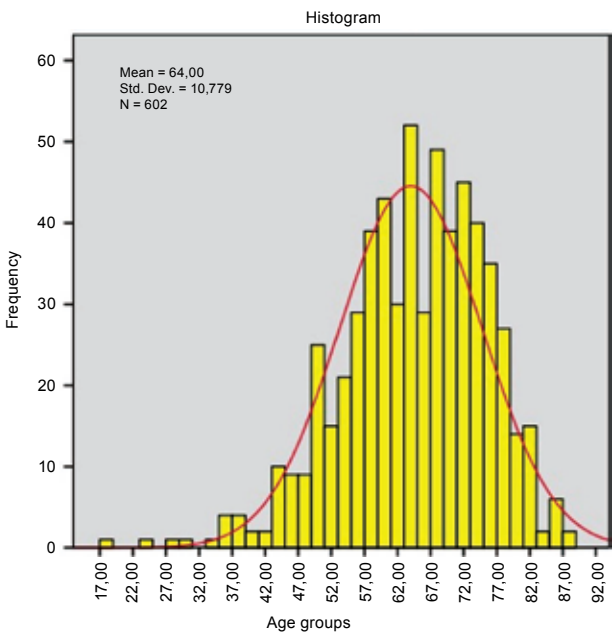

Fig. 1. Distribution of subjects across age groups.

Table 1. Frequency of anatomic variations

		Frequency n (%)
Gender	Male	414 (68.8)
	Female	188 (31.2)
Arm	Right	538 (89.4)
	Left	64 (10.6)
Normal anatomy	Yes	549 (91.2)
	No	53 (8.8)
High origin of radial artery	Yes	31 (5.1)
	No	571 (94.9)
Radioulnar loop	Yes	0 (0)
	No	602 (100)
Radioulnar loop with superficial brachioradial artery	Yes	12 (2)
	No	590 (98)
Radial loop	Yes	3 (0.5)
	No	599 (99.5)
Double radial artery	Yes	4 (0.7)
	No	598 (99.3)
High origin with double radial artery	Yes	3 (0.5)
	No	599 (99.5)
Accessory brachial artery	Yes	1 (0.2)
	No	601 (99.8)
Tortuosities	Yes	76 (12.7)
	No	526 (87.3)

Tortuosities were observed in 76 (12.7%) subjects.

Using the χ^2-test, no statistically significant relationship was observed between the left and the right arm and anatomic variations and tortuosities. Using the same test, no relationship between sex and anatomic variations was found except that tortuosities were observed more frequently in women than in men (p=0.001) (Table 2).

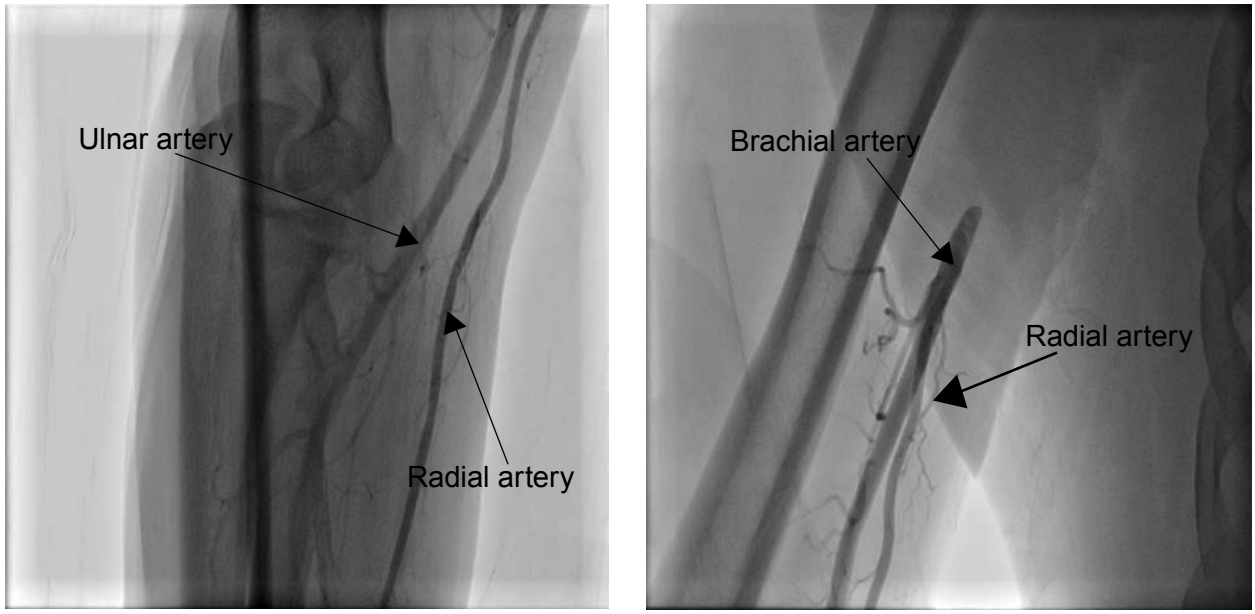

Fig. 2. High origin of radial artery: (left) radial and ulnar artery in cubital region; (right) high origin of radial artery in the middle of humerus bone.

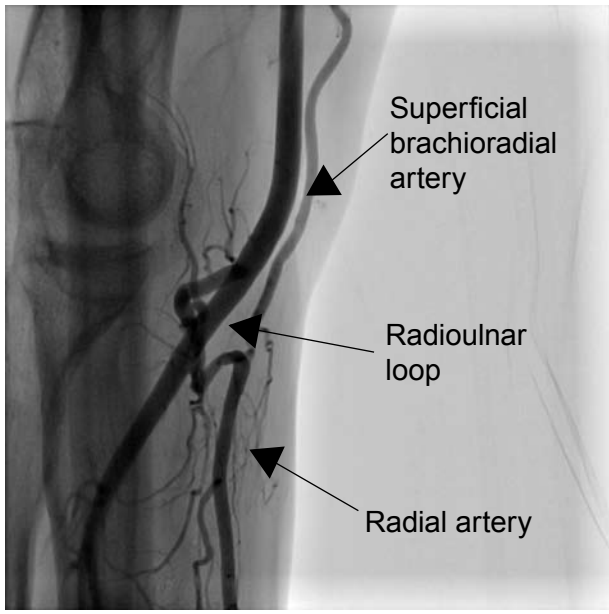

Fig. 3. Radioulnar loop with superficial brachioradial artery.

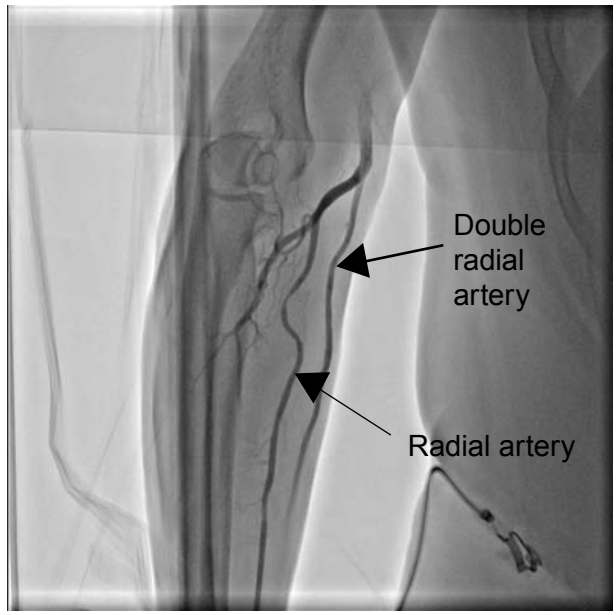

Fig. 4. Double radial artery.

In order to establish the relationship between tortuosities and the next variables (age, arm, normal anatomy and high origin of radial artery), we performed logistic regression in which tortuosities were considered as a dependent variable. The mentioned model showed statistical significance (χ^2=78.22; p<0.001). With this model, we could explain 12.2%-23.1% of variance. In other words, using this model it was pos-

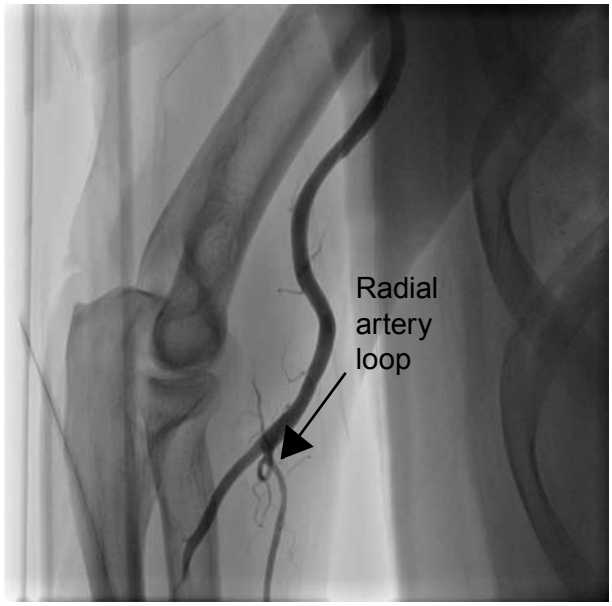

Fig. 5. Radial loop.

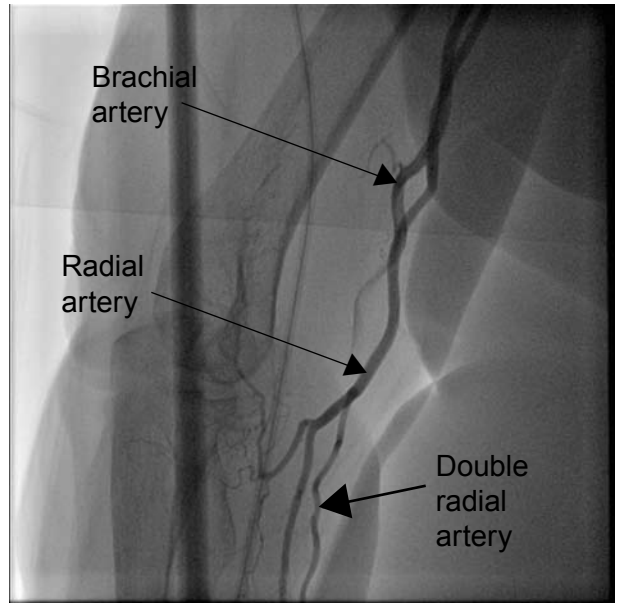

Fig. 6. High origin of radial artery with double radial artery.

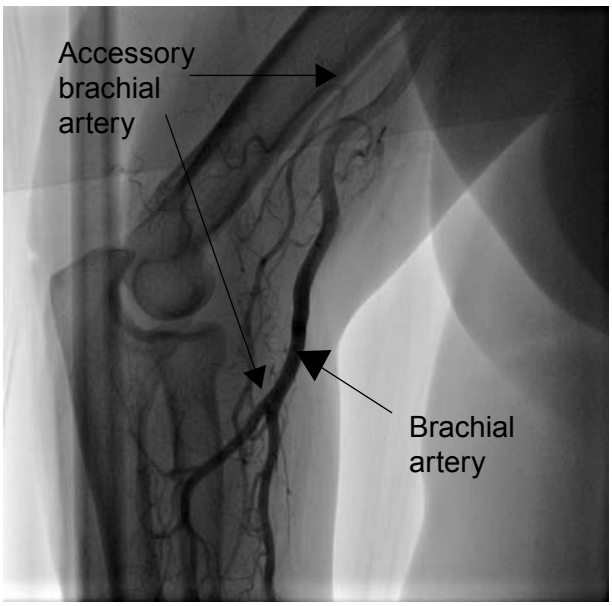

Fig. 7. Accessory brachial artery.

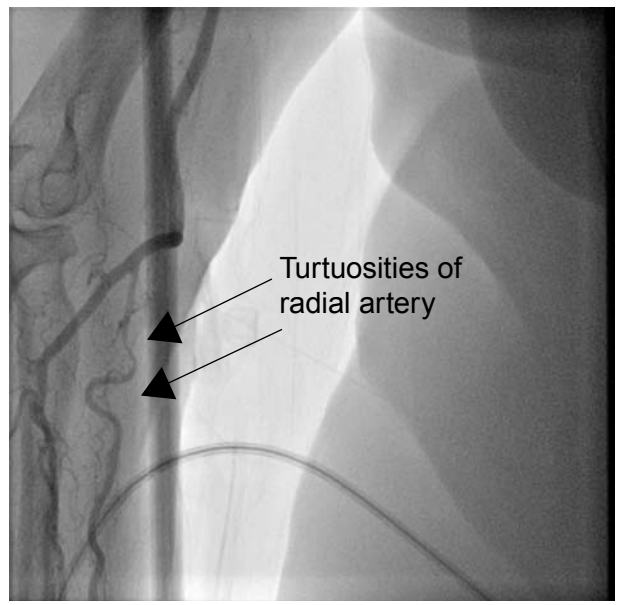

Fig. 8. Turtuosity.

sible to correctly qualify 88.2% of cases. When the effect of each variable on the dependent variable was analyzed, it was observed that age ($p<0.001$), female sex ($p=0.015$) and high origin ($p=0.034$) contributed significantly to tortuosity development. These are important to know, so the operators could prepare themselves for potentially more complicated interventions in these patients. We recommend that elderly female patients have angiography performed at the beginning of the procedure, in order to avoid complications.

Discussion

This research revealed that the frequency of angiographically verified anatomic variations of radial artery, exclusive of tortuosities, was 8.8%. This finding is similar to the findings of Yokoyama *et al.* (9.6%)[16], Karlsson and Niechajev (11%)[17], Burzotta *et al.* (12.6%)[15], and Uglietta and Kadir (9%)[18]. Unlike these results, Yoo *et al.* applied angiography of radial artery in 1191 subjects and obtained the frequency of variations of only 3.2%[12]. The reason for such a huge difference might be of racial nature. The highest frequency of anatomic variations has been reported by McCormark *et al.* (17%), but they only used post mortem samples[13]. The most likely reason for such a large deviation is the fact that the authors in question described the relationship between the radial and surrounding structures (such as veins and nerves) as anomalies, which, of course, cannot be determined by angiography. These studies have also shown that the most frequent anatomic variation is the high origin of radial artery, occurring in 3%-8% of cases, which corresponds to our results. Radioulnar loops as one of the potential contraindications for the procedure have been reported in 0.6%-2.0% of cases, the same as in the above mentioned studies. The prevalence of double radial artery, radial loop and high origin of radial artery in combination with double radial artery was less than 1%, similar to other studies. In our sample, we found no radioulnar loops without the superficial brachioradial artery. The studies conducted by Lanz and Wachsmuth[19], Rodriguez-Baeza *et al.*[20], and Yoo *et al.*[12] showed a difference in the variations with respect to the right and left arms, with greater frequency

Table 2. Relationship of anatomic variations with gender and arm used for catheterization

		Gender		χ^2-test	p	Arm		χ^2-test	p
		Men n (%)	Women n (%)			Right n (%)	Left n (%)		
Normal anatomy	Yes	377 (91.1)	172 (91.5)	0.029	0.864	48 (8.9)	5 (7.8)	0.088	0.767
	No	37 (8.9)	16 (8.5)			490 (91.1)	59 (92.2)		
High origin of radial artery	Yes	22 (5.3)	9 (4.8)	0.073	0.786	29 (5.4)	2 (3.1)	0.601	0.438
	No	392 (94.7)	179 (95.2)			509 (94.6)	62 (96.9)		
Radioulnar loop with superficial brachioradial artery	Yes	7 (1.7)	5 (2.7)	0.621	0.431	11 (2)	1 (1.6)	0.068	0.794
	No	407 (98.3)	183 (97.3)			527 (98)	63 (98.4)		
Radial loop	Yes	3 (0.7)	0 (0)	1.369	0.242	3 (0.6)	0 (0)	0.359	0.549
	No	411 (99.3)	188 (100)			535 (99.4)	64 (100)		
Double radial artery	Yes	4 (1.0)	0 (0)	2.290	0.130	3 (0.6)	1 (1.6)	0.466	0.495
	No	410 (99)	188 (100)			535 (99.4)	63 (98.4)		
High origin with double radial artery	Yes	0 (0)	3 (1.6)	6.639	0.010	2 (0.4)	1 (1.6)	1.636	0.201
	No	414 (100)	185 (98.4)			536 (99.6)	63 (98.4)		
Tortuosities	Yes	38 (9.2)	151 (80.3)	13.075	0.001	64 (11.9)	11 (17.2)	1.468	0.226
	No	376 (90.8)	37 (19.7)			474 (88.1)	53 (82.8)		

relative to the right arm. However, our results did not confirm this, possibly due to the insufficient number of subjects undergoing left radial artery catheterization. These results are scientifically important for two reasons. First, radial artery angiography is rarely performed in almost all patients undergoing cardiac catheterization procedure, and not just in cases where there are some complications, although in our opinion it can provide us with more accurate data. Another reason is that this is the first such study in the southeast Europe population.

A large difference in the results on the frequency of tortuosities is evident in all previous studies. Yoo *et al.* report on 4.2%[12], Yokoyama *et al.* 5.6%[16], Burzotta *et al.* 5.9%[15], and our study revealed 12.7% frequency. There are several possible reasons for this. First of all, there is no universal definition as to what we consider a tortuosity. Yoo *et al.*, for instance, describe tortuosity as two or more curvatures at more than 75° angle, while we used the definition provided by Burzotta *et al.* (a curvature at more than 45° angle)[15]. Such a large difference between these results could partially be attributed to an older population in our study. To be precise, similar to the previously mentioned studies, our results showed that the frequency of tortuosities increased almost linearly with age. We also showed that tortuosities were more frequent in high origin radial arteries than in normal anatomy. In our opinion, the reason for this lies in the length of the artery, which is considerably longer in case of anomaly.

In conclusion, anatomic anomalies of radial artery can be expected in 8.8% of patients undergoing transradial cardiac catheterization. It is important to underscore that the radioulnar loop as one of the potential contraindications for this procedure occurs in only 0.6%-2.0% of cases. Tortuosities are, based on our results, quite frequent and can be expected in 12% of patients. Although they are not a contraindication for continuing with the procedure, we recommend that elderly patients, due to the higher incidence of tortuosities, have angiography performed at the beginning of the procedure, with the purpose of avoiding complications. Since this was a retrospective study, we could not be entirely certain as to whether routine angiography of radial artery reduced the frequency of complications during transradial cardiac catheterization. In order to provide an answer to this interesting question, an appropriate prospective study should be conducted in the future.

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Sažetak

UČESTALOST ANATOMSKIH VARIJACIJA RADIJALNE ARTERIJE U BOLESNIKA PODVRGNUTIH TRANSRADIJALNOJ KATETERIZACIJI SRCA

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Posljednjih desetak godina kateterizacija srca transradijalnim pristupom sve se više koristi prvenstveno zbog rjeđih i lakših mogućih komplikacija u odnosu na femoralni pristup. Ipak, jedan od većih nedostataka transradijalnog pristupa je relativno visoka učestalost neuspjeha kateterizacije (od 1% do 5%). Na drugom mjestu uzroka iste nalaze se anatomske varijacije radijalne arterije (RA). Dosadašnji radovi nisu dali jednoznačne podatke o učestalosti ovih anomalija, stoga je cilj ovoga istraživanja bio odrediti učestalost anatomskih varijacija pomoću rutinskih angiografija RA prilikom PTCA/PCI. Radi se o retrospektivnoj studiji u kojoj su pregledane 602 snimke rutinskih angiografija RA učinjene prilikom kateterizacije srca. Učestalost anatomskih varijacija RA iznosila je 8,8%, ne uključujući tortuozitete učestalost kojih iznosi 12,7%. Najčešća anatomska varijacija je bila visoko polazište RA u ukupno 31 (5,1%) ispitanika. Radioulnarne petlje kao jedna od potencijalnih kontraindikacija za zahvat pojavile su se u 2% slučajeva. Regresijska analiza je pokazala da godine starosti ($p<0,001$), ženski spol ($p=0,015$) i visoko izlazište ($p=0,034$) značajno doprinose razvoju tortuoziteta. Rezultati ukazuju na to da se učestalost tortuoziteta s godinama linearno povećava. Iako isti nisu kontraindikacija za nastavak zahvata, preporučamo da se zbog veće učestalosti tortuoziteta kod starijih bolesnika na početku zahvata učini angiografija RA s ciljem izbjegavanja potencijalnih komplikacija zahvata.

Ključne riječi: *Radijalna arterija – radiografija; Kateterizacija srca – klasifikacija; Kateterizacija srca – komplikacije; Radijalna arterija – nenormalnosti; PTCA/PCI*