Should Technical and Anatomical Difficulties Discourage Operators From Embarking on Transradial Access for Percutaneous Coronary Intervention?

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ABSTRACT: Background. Use of the radial approach for PCI procedures is increasing due to lower rates of access-site complications/bleeding, and patient preference. However, femoral operators switching may be discouraged by the learning curve and by anatomical issues that may complicate the procedure. We aimed to define the frequency of anatomic variants and success rates during transradial access for PCI. **Methods.** We retrospectively analyzed 2588 cases of PCI attempted by the radial route; radial/brachial and subclavian angiography was performed when obstructions were encountered. Presence of anatomical variants, spasm, and ability to complete the procedure were noted. **Results.** Radial procedures were successfully completed in 2741/2588 cases (98.2%); in the remainder, switching to femoral approach was necessary. Local arteriography was performed in 221/2588 cases (8.5%) due to difficulties encountered; of these, 131/221 difficulties (59%) were due to problems at the radial arterial level, 58/221 (26%) were due to problems at the subclavian level, and 32/221 (15%) were due to problems at brachial arterial sites. Extreme radial tortuosity (18%) and radial loop (20%) had relatively lower rates of success followed by subclavian tortuosity (73%). Females had significantly higher incidences of radial spasm (6% vs 1.9% in men; $P<.001$), radial tortuosity (3.4% vs 1.7% in men; $P=.01$), and subclavian tortuosity (3.8% vs 1.8% in men; $P<.01$). **Conclusion.** Inability to successfully complete invasive procedures via the radial approach is uncommon. Even when encountered, most difficulties can be overcome with the use of vasodilators and hydrophilic wires. These data provide reassurance for would-be radial converts that the learning curve may not be as steep as envisaged.

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Radial access for percutaneous coronary intervention (PCI) is escalating owing to the benefits of decreased risk of bleeding complications, ie, easy ambulation and shortened hospital stay as compared to femoral approach.[1-3] Due to its superficial location, the radial artery allows easy hemostasis and hence reduces local access-site complications, especially when patients are on antiplatelet and antithrombotic agents during PCI.[1-6] Despite these benefits, the use of transradial access for PCI remains relatively low, especially in the United States as compared to most European countries.[7-16] Reports from the National Cardiovascular Data Registry in 2016 showed radial access for PCI was used in approximately 30% of cases; this number was even lower (12%) in cases of acute myocardial infarction.[8,9] Data from the British Cardiovascular Interventional Society demonstrated that radial access was used in 81% of cases in 2015.[16] Similarly, radial access for PCI is used in >70% of patients in most other European countries.[10-13] There are certain factors that have discouraged femoral operators from opting to use the radial approach; for example, the relatively longer learning curve, longer fluoroscopy times, anatomical obstacles, and the need for relatively increased catheter manipulation to intubate coronaries that may complicate or prolong the procedure.[17-19] Understanding the frequency and type of anatomical variations that may prolong the procedure or compel the operators to abandon the radial access site is important.[6,22-26] In addition, exploring the patient factors that may influence successful completion of the procedure can help anticipate any difficulties that might be overcome by adequate preparation.[25-28]

Previous studies have prospectively studied the incidence of radial and brachial artery anomalies by performing local arteriography prior to intubating the coronary arteries.[19,20] However, this custom is not the norm in the real world; in most centers, local arteriography is performed only when resistance is encountered while advancing the guidewire or catheter. In this study, we aimed to define the frequency of anatomical variants when the local arteriogram was performed in order to deal with the obstacle and to assess the factors influencing the successful completion of the intended procedure. We report the findings from our center's initial few years of experience using transradial access for PCI.

Methods

Our center had relatively limited experience with transradial access for PCI before 2008; it used to be mainly performed in patients who had difficulty with femoral access. Given the

Table 1. Number of percutaneous coronary intervention cases and transradial access per year (from 2009-2012).

Year	Total PCI Cases	Radial Access
2009	1977	175 (9%)
2010	2106	343 (16%)
2011	1890	801 (42%)
2012	2047	1269 (62%)

Data provided as number (%). PCI = percutaneous coronary intervention.

Table 2. Clinical characteristics.

Clinical Characteristics	(N = 2588)
Age (years)	64.8 ± 11.2 (range, 21-97)
Male	2031 (78%)
Body mass index (kg/m²)	28.8 ± 5.6 (range, 16-70)
Stable angina	1197 (46.2%)
Acute coronary syndrome	1391 (53.7%)
ST-elevation myocardial infarction	785 (30.3%)
Cardiogenic shock	32 (1.2%)
Previous myocardial infarction	863 (33.3%)
Previous PCI	540 (21.0%)
Previous coronary artery bypass graft surgery	113 (4.4%)
Hypertension	787 (30.4%)
Diabetes mellitus	633 (24.5%)
Dyslipidemia	1114 (43.0%)
Smoking (current and past)	1905 (74.0%)
Peripheral vascular disease	56 (2.2%)
Chronic kidney disease (creatinine >200 μmol/L)	246 (9.5%)

Data provided as mean ± standard deviation or number (%). PCI = percutaneous coronary intervention.

Table 3. Procedural characteristics and anomalies.

Characteristic	
Right radial access	2525 (97.5%)
Left radial access	63 (2.5%)
Local arteriography	221 (8.5%)
Success	2541 (98.2%)
Switched to femoral	47 (1.8%)
Radial spasm	72 (2.8%)
Minor radial tortuosity	42 (1.6%)
Extreme radial tortuosity	11 (0.4%)
Radial loop	15 (0.6%)
Recurrent radial	2 (0.07%)
High bifurcating radial	6 (0.2%)
Brachial spasm	2 (0.07%)
Brachial loop	30 (1.2%)
Subclavian tortuosity	56 (2.2%)
Subclavian stenosis	2 (0.07%)
Arterial complications	12 (0.5%)

Data provided as number (%).

Table 4. Anomalies/obstruction and success rates.

Anomalies/Obstruction	Numbers	Success Rate
Radial spasm	72	59 (82%)
Minor radial tortuosity	42	41 (98%)
Extreme radial tortuosity	11	2 (18%)
Radial loop	15	3 (20%)
Recurrent radial	2	2 (100%)
High bifurcating radial	6	6 (100%)
Brachial spasm	2	2 (100%)
Brachial loop	30	28 (93%)
Subclavian tortuosity	56	41 (73%)
Subclavian stenosis	2	2 (100%)

Data provided as number (%).

safety data on transradial access, we consciously began to use this approach in 2008; since then, our numbers consistently escalated. In 2009, only 9% of cases were performed via radial route, which increased to 62% in 2012 (Table 1).

Our routine practice is to perform fluoroscopy once the guidewire (0.35˝) is nearer the shoulder through to the aortic root. We do not routinely perform local arteriogram unless encountered with resistance while advancing the guidewire. All transradial cases received anxiolytics before the procedure and vasodilators (verapamil) through the arterial sheath after the radial access was gained. Additional vasodilators (nitroglycerin) were used if required, especially when encountered with radial or brachial spasms.

We retrospectively analyzed over 2500 cases of coronary interventions that were performed by the radial route and looked specifically for anatomical variants that compelled the operators to perform local arteriogram and methods adopted to overcome the obstacles.

Radial artery anatomical variations were classified using a modification of previous definitions by McCormack, Uglietta, and Rodriguez-Niedenfuhr.[22-24] A *radial artery loop* was defined as the presence of a full 360° loop of the radial artery distal to the bifurcation of the brachial artery. *Extreme radial tortuosity* was defined as the presence of a bend >90° in the contour of the vessel. *Minor radial tortuosity* was defined as a bend <90°. *Radial or brachial artery spasm* was defined as documentation of spasm on the arteriogram and inability to advance the guidewire requiring use of vasodilators and other techniques. *High bifurcating brachial artery* was determined with

Table 5. Male and female differences for anomalies/obstruction.

Anomalies/Obstruction	Male (n = 2031)	Female (n = 557)	*P*-Value
Radial spasm	39 (1.9%)	59 (6%)	<.001
Radial tortuosity	34 (1.7%)	19 (3.4%)	.01
Radial loop	10 (0.5%)	5 (0.9%)	.30
Recurrent radial	0 (0.0%)	2 (0.4%)	.50
High bifurcating radial	4 (0.2%)	2 (0.4%)	.50
Brachial spasm	2 (0.1%)	0 (0.0%)	.50
Subclavian tortuosity	37 (1.8%)	21 (3.8%)	<.01
Subclavian stenosis	1 (0.05%)	1 (0.1%)	.30

Data provided as number (%).

Table 7. Significant factors on multivariate model.

	Adjusted Logistic Regression Odds Ratio (95% CI)	*P*-Value
Age	1.065 (1.049-1.081)	<.001
Male gender	1.882 (1.364-2.596)	<.001
Diabetes	1.347 (0.973-1.864)	.07

CI = confidence interval.

reference to the intercondylar line of the humerus, which is a fixed line representing the proximal border of the antecubital fossa. Bifurcation of the brachial artery proximal to this line was considered a high bifurcation. *Recurrent radial (accessory radial)* is a small branch of the radial artery that connects to the brachial artery.

Success was defined as completion of the intended procedure through the initially selected radial access route. *Minor vascular complications* were defined as hematoma, vessel dissection without ensuing ischemia, pseudoaneurysm, and localized infection. *Major vascular complications* were defined as hematoma >5 cm, drop in hemoglobin due to access-site bleeding requiring transfusion, limb ischemia and/or compartment syndrome, and any other access-site complications that required surgical or radiological intervention.

Statistical analysis. Data are presented as mean ± standard deviation or median (interquartile range [IQR]) for continuous variables, and as counts and percentages for categorical variables. Differences in proportions were tested with Chi-square test or Fisher's exact test. A two-sided *P*-value of <.05 was considered statistically significant. To determine the independent predictors of endpoints, Cox's proportional hazards model was used, with all the variables showing $P \leq .20$ in the univariate analysis. Any factors previously associated with the event outcome in the literature were also incorporated in the final model. These results are reported as adjusted hazard ratio with associated 95% confidence interval (CI) and *P*-value. Analyses were carried out using SPSS for Windows, version 19.0 (SPSS, Inc).

Table 6. Demographical and clinical differences between those with obstacles and those without obstacles.

	Obstacle (n = 221)	No Obstacle (n = 2367)	*P*-Value
Age (years)	71.9 ± 10.9	64.1 ± 11.0	<.001
Male gender	138 (62.4%)	1893 (80.0%)	<.001
Height (cm)	167.7 ± 16.4	172.4 ± 10.3	<.001
Body weight (kg)	80.1 ± 19.9	86.0 ± 17.9	<.001
BMI (kg/m²)	28.2 ± 5.9	28.9 ± 5.6	.11
Clinical presentation			.38
Stable angina	96 (43.4%)	1101 (46.5%)	
ACS	125 (56.6%)	1266 (53.5%)	
Shock state	2 (0.9%)	29 (1.2%)	.68
Previous MI	84 (38.0%)	779 (32.9%)	.12
Previous CABG	14 (6.3%)	97 (4.1%)	.12
Previous PCI	44 (20.0%)	496 (21.0%)	.72
Hypertension	64 (29.0%)	723 (30.5%)	.62
Diabetes	68 (30.8%)	565 (23.9%)	.02
Dyslipidemia	107 (48.4%)	1007 (42.5%)	.09
Smoking history (current + past)	161 (72.9%)	1744 (73.7%)	.79
CKD (creatinine >200 μmol/L)	25 (11.3%)	221 (9.3%)	.34
PVD	6 (2.7%)	50 (2.1%)	.56
GP IIb/IIIa use	31 (14.0%)	360 (15.2%)	.85
Approach site			.23
Right radial	213 (96.4%)	2312 (97.7%)	
Left radial	8 (3.6%)	55 (2.3%)	
Success	174 (78.7%)	2367 (100%)	
Switch to femoral	47 (21.2%)	0 (0.0%)	
Radial spasm	72 (32.6%)	0 (0.0%)	
Radial tortuosity	53 (24.0%)	0 (0.0%)	
Minor tortuosity	42 (19.0%)	0 (0.0%)	
Extreme tortuosity	11 (5.0%)	0 (0.0%)	
Radial loop	15 (6.8%)	0 (0.0%)	
Accessory radial	2 (0.9%)	0 (0.0%)	
High bifurcation radial	6 (2.7%)	0 (0.0%)	
Brachial loop	29 (13.1%)	0 (0.0%)	
Brachial spasm	2 (0.9%)	0 (0.0%)	
Subclavian tortuosity	54 (24.4%)	0 (0.0%)	
Subclavian stenosis	2 (0.9%)	0 (0.0%)	
Arterial complications	4 (1.8%)	8 (0.3%)	<.01

BMI = body mass index; CABG = coronary artery bypass graft; CKD = chronic kidney disease; GP = glycoprotein; MI = myocardial infarction; PCI = percutaneous coronary intervention; PVD = peripheral vascular disease.

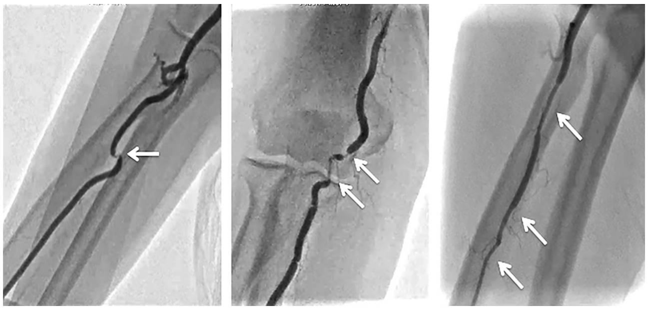

FIGURE 1. Radial spasm.

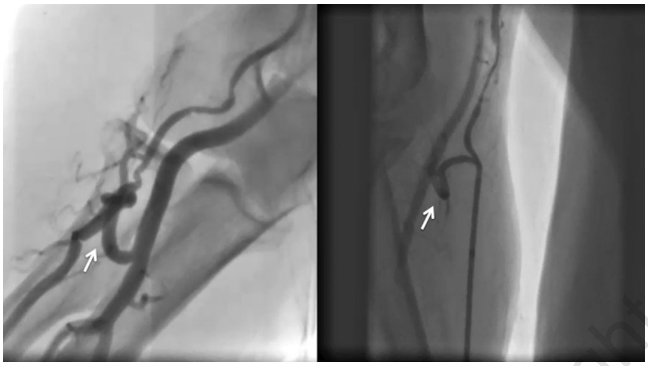

FIGURE 3. Extreme radial tortuosity.

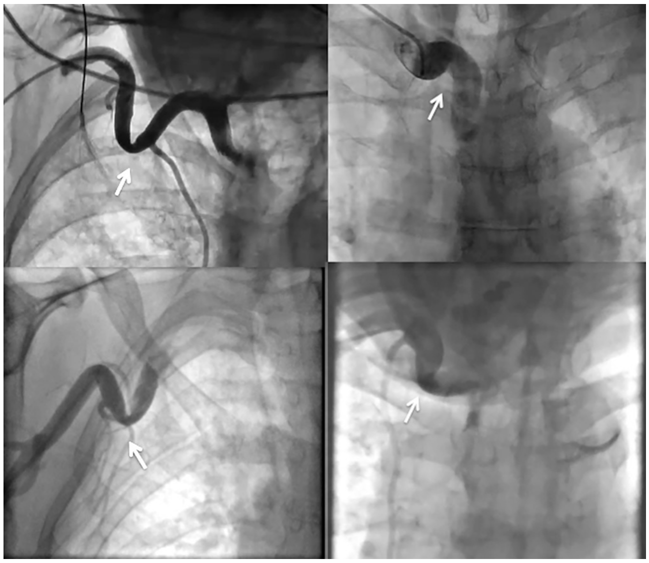

FIGURE 2. Subclavian tortuosity.

FIGURE 4. Radial loop.

Results

Between 2009 and 2012, we attempted 2588 cases of angioplasty through the radial approach. Details of the PCI procedures in relation to access sites from 2009 through 2012 are provided in Table 1. Use of radial access for PCI consistently increased at our center, with just 9% of cases performed radially in 2009, which rose to 62% by 2012.

The mean patient age was 64.8 ± 11.2 years (range, 21-97 years) with predominantly males (2031; 78%). The remaining demographics and clinical characteristics are provided in Table 2. Patients with acute coronary syndromes accounted for 54% of the total population. Diabetes was present in 25% of the population, while 30% had hypertension.

Procedural characteristics are provided in Table 3. Right radial was the predominant access site (97.5%). Local arteriography was needed in 8.5% of cases and was mostly at the radial artery level (131 cases; 59%) followed by the subclavian artery level (58 cases; 26%) and brachial artery level (32 cases; 15%). Although 8.5% of cases needed local arteriography, only 1.8% of cases required crossover to femoral access. Procedures were successfully completed in 98.2% of cases via the radial route.

Details of the obstacles/anomalies are provided in Table 3. Radial spasm was the most commonly encountered obstacle (n = 72; 2.8%) followed by subclavian tortuosity (n = 56; 2.2%) (Figures 1 and 2). Extreme radial tortuosity and radial loops were very uncommon (<1%) (Figures 3 and 4).

Success rates with individual obstacles/anomalies are provided in Table 4. Most of the obstacles/anomalies were successfully negotiated; however, extreme radial tortuosity and radial loops had relatively lower success rates (18% and 20%, respectively). Some of the radial loop and extreme radial tortuosity cases were negotiated successfully with the use of 0.35″ hydrophilic wires or 0.014″ angioplasty wires (Figure 5). Subclavian tortuosity and stenosis accounted for 58 cases (2.3%) (Figures 2 and 6). Of these, 73% were successively negotiated with the use of hydrophilic wires and/or breath-holding maneuvers, which helped in straightening the loop (Figure 7). Two of the subclavian tortuosity cases were arteria lusoria (retroesophageal course of the subclavian artery); in both cases, we failed to negotiate and had to switch to femoral access.

There were 12 cases of arterial complications (5 dissections and 7 hematomas). Only 1 patient required vascular surgery and blood transfusion. The remaining complications were managed conservatively. Complications occurred

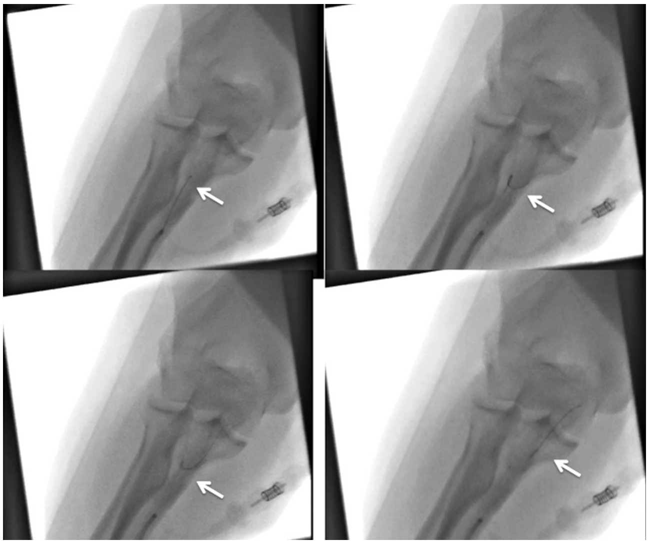

FIGURE 5. Straightening of radial loop.

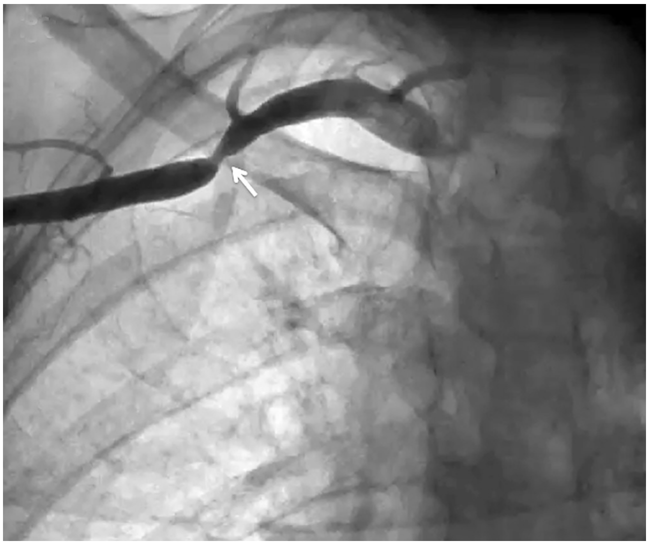

FIGURE 6. Subclavian stenosis.

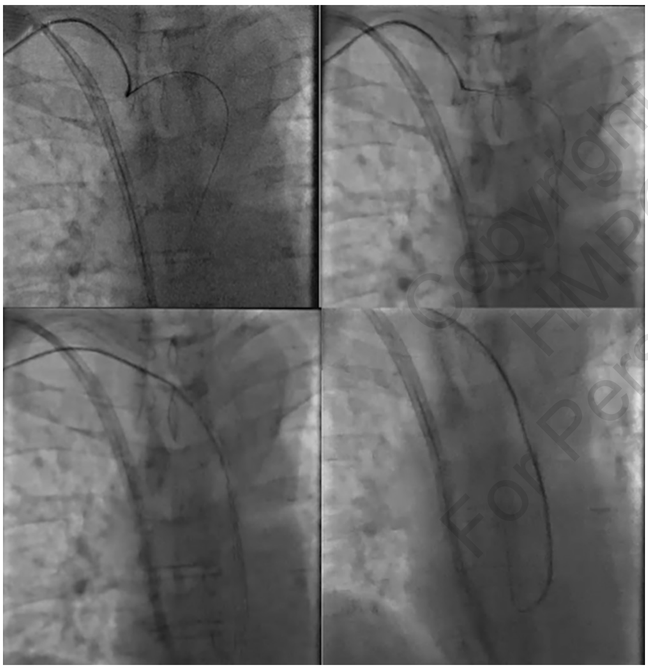

FIGURE 7. Straightening of subclavian tortuosity.

FIGURE 8. Radial loop unable to be straightened despite crossing with angioplasty wire.

significantly more often in patients who had obstacles (4 [1.8%] vs 8 [0.3%], respectively; $P<.01$).

We compared the occurrence of spasm and anomalies in males and females from the cohort (Table 5). Females had a significantly higher incidence of radial spasm (6% vs 1.9% in males; $P<.001$), radial tortuosity (3.4% vs 1.7% in males; $P=.01$), and subclavian tortuosity (3.8% vs 1.8% in males; $P<.01$).

We also compared various demographic and clinical characteristics between those who had obstacles requiring local arteriography and those who had no obstacles (Table 6). Older age, male gender, lower height, lower weight, and diabetes were significant on the univariate analysis, while age, male gender, and diabetes were the only independent predictors on the multivariate analysis (Table 7).

Discussion

The principal findings from this study are: (1) anatomical obstacles requiring local arteriography were encountered in 8.5% of cases and occurred mostly at the radial artery level (59%); (2) despite this, only 1.8% of cases required crossover to a different access site; (3) extreme radial tortuosity and radial loop had the highest failure rates as compared to other anomalies; and (4) females had significantly higher incidences of radial spasm and toruosity of the radial and subclavian arteries.

This study of over 2500 cases has been reported from our initial few years of experience with transradial access for PCI and provides insight into the details of the obstacles and difficulties encountered. Hence, it might be relevant to centers and/or operators embarking upon or in the initial phase of their experience with transradial access. Although there are previous studies[19-22] that have reported radial and brachial anomalies, this study is unique in that we evaluated these anomalies from a real-world practice where local arteriography was only performed when resistance was encountered during passage of the guidewire. We have also evaluated the success rates of individual anomalies.

Like most centers in the United Kingdom, our radial access for PCI has consistently increased ever since we began in 2008. Despite this, the use of radial access for PCI is variable across the globe. This may be due to a combination of relatively longer learning curve, anatomical obstacles that may discourage operators, and the need for relatively more catheter manipulations to intubate coronaries as compared to femoral access. Local arteriography was needed in 8.5% of our cases. Although most obstacles can be negotiated with hydrophilic wires, performing local arteriography will aid in understanding the nature of the obstacle, devising a strategy to overcome it, and minimizing the occurrence of arterial complications. We recommend having a low threshold for performing local arteriography, especially in the early phase of transradial access. Despite the need for local arteriography in 8.5% of our cases, <2% needed access-site crossover in a center that was relatively inexperienced with transradial access. These results should encourage operators planning to embark upon transradial access for PCI.

Although one could argue that we had lower failure rates, we were quite methodical during transradial access. This included the liberal use of anxiolytics before accessing the radial artery (especially in female patients) and a low threshold for obtaining local arteriograms when encountered with obstructions. For spasms and tortuosity, we gave a liberal dose of vasodilators and used Terumo or angioplasty wires for crossing the obstruction. These factors may have influenced our success rates.

Most of the obstacles were at the radial and subclavian levels. Radial spasm and minor radial tortuosity were negotiated in most cases with the use of vasodilators and/or hydrophilic wires. Although some of the radial loops and extreme radial tortuosities were successfully negotiated, these anomalies had relatively higher failure rates. Previous studies evaluating such radial anomalies have also shown higher failure rates in radial loops and extreme radial tortuosities.[19-23] In the learning-curve phase of the transradial approach, encountering these complex anomalies should encourage operators to switch the access site in order to preserve confidence (and more importantly, to avoid arterial complications).

Subclavian tortuosity had a 73% success rate; these vessels were negotiated using hydrophilic wires and/or breathing maneuvers (deep inspiration) that aided in straightening of the loop. Despite these successes, operators must be aware that catheter manipulation during intubation of coronary arteries can be challenging and may result in knotting of the catheters and entrapment, which can be quite difficult to extract and may even require surgical intervention.[29-33] If the tortuosity or loops do not straighten despite crossing, then the catheters are vulnerable to knotting during manipulation (Figure 8). Brachial tortuosity and spasms offered few problems, and most were negotiated with catheter manipulation, vasodilators, and hydrophilic wires.

Success rate also depends on the operator's skills and experience. Some operators prefer to be safe and have a low threshold for access-site crossover, whereas others may persist to achieve success, which may be influenced by their level of experience. A balance must be struck, especially during the learning-curve phase of transradial access for PCI.

The occurrence of radial spasm and tortuosity in the radial and subclavian arteries was significantly higher in female patients, indicating that certain anomalies are more common in females. Similar results have been reported in previous studies, and hence these findings may not be unique to this study.[27-29] Nevertheless, one can expect to encounter these difficulties in female patients and may prepare the case with the liberal use of vasodilators and anxiolytics prior to radial artery cannulation. Although radial spasms and tortuosities were higher in females, the overall occurrence of obstructions requiring local arteriography was significantly higher in males. In fact, male gender was one of the independent predictors along with diabetes and age.

Study limitations. Although this study assesses the anomalies at the radial/brachial and subclavian levels, it does not reflect the true incidence of these anomalies because local arteriography was only performed when encountered with resistance. It may be that some anomalies or spasms were negotiated with normal guidewires and thus went undetected. Nevertheless, we have explored these obstacles in a real-world practice. Finally, this study was from a single center that utilized radial access from 2009 onward; hence, these results may reflect a period of relative inexperience. However, this is the rationale for reporting this study, as it is relevant to centers beginning to utilize transradial access for PCI.

Conclusion

Transradial access for PCI is feasible with a very few cases that required access-site crossover. Most obstacles at the radial/brachial and subclavian levels were negotiated, except radial loops and extreme radial tortuosity, which had relatively lower success rates. These results should encourage operators and/or centers embarking upon transradial PCI programs.

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