Comparison of Right and Left Upper Limb Arterial Variants in Patients Undergoing Bilateral Transradial Procedures

Francesco Burzotta, MD, PhD; Marta Francesca Brancati, MD; Italo Porto, MD, PhD; Silvia Saffioti, MD; Cristina Aurigemma, MD, PhD; Giampaolo Niccoli, MD, PhD; Antonio Maria Leone, MD, PhD; Valentina Coluccia, MD; Filippo Crea, MD; Carlo Trani, MD

Background—Transradial approach (TRA), when compared with transfemoral, improves the safety of percutaneous coronary procedures. Arterial axis variants are known to hinder the performance of transradial approach percutaneous coronary procedures. Data on the occurrence of arterial axis variants in the right and left arm arterial axes of individual patients are lacking.

Methods and Results—From a single-center prospective registry, we selected all patients in whom bilateral upper limb arterial anatomy was assessed based on the performance of left and right radial catheterization obtained during the same or during repeat coronary diagnostic or interventional procedure(s). The occurrence of upper right and left limb arterial axis variants was classified according to the previously described operative ABC classification. A total of 610 patients were identified. An ABC upper limb arterial axis variant was detected in 156 (25.6%) patients. Variants were right-sided only in 65 (11.0%), left-sided only in 40 (6.6%), and bilateral in 46 (7.5%) patients. Thus, arterial axis variants were significantly more common in the right side (P=0.02). Bilateral arterial variants were significantly associated with age, female sex, and valvulopathy. Both A (radial/brachial) and B (axillary/subclavian/innominate) variants exhibited concordance across the 2 sides (odds ratio, 7.2; 95% confidence interval, 4.1–12.7 and 8.0; 95% confidence interval, 2.1–30.9, respectively).

Conclusions—The occurrence of an anatomic variant potentially hindering transradial approach coronary diagnostic or interventional procedures is bilateral in <8% of cases and is more common in the right arm. Such information may guide, during the clinical practice, the access selection in the case of repeat procedures or need for additional accesses. (Circ Cardiovasc Interv. 2015;8:e002863. DOI: 10.1161/CIRCINTERVENTIONS.115.002863.)

Key Words: catheterization ◼ coronary angiography ◼ percutaneous coronary intervention

Transradial approach (TRA) has been developed, as an alternative to transfemoral, to reduce vascular complications of percutaneous coronary (diagnostic and interventional) procedures (PCP). A major limitation of TRA is constituted by a higher failure rate compared with transfemoral1,2 and by the need of a dedicated learning curve.3,4 Both the right and the left radial artery may be safely selected for TRA, and usually, the side selection is a matter of operator or center preference, albeit recent evidence from randomized trials seems to suggest that duration and success of procedures may be facilitated by left-side approach.5,7 However, proficiency in both access routes is desirable, as specific conditions, such as the presence of an internal mammary graft, benefit from an ipsilateral access.

Importantly, a series of vascular anatomic variants or physiopathologic conditions of the radial/brachial arterial axis are known to increase the procedure complexity and the risk of TRA access failure in cardiac catheterizations and coronary interventions.5–13 In case of arterial variants in an arm, knowing the risk of finding a variant also in the contralateral arm is extremely useful in planning the access strategy, for the same or for subsequent procedures. Data on the comparison of upper limb arterial variants on the left and right sides in clinical patients are, however, completely lacking.

We herein present the results of a large, retrospective comparison of the anatomic variants encountered in right and left sides in individual patients undergoing TRA coronary diagnostic or interventional procedures through both radial arteries, in single or multiple stages.

Methods

During a 5-year period, consecutive patients admitted at our institution and undergoing percutaneous coronary diagnostic or interventional procedures by TRA as a first access were prospectively enrolled in our radial access registry. Demographic, clinical, and procedural data were collected on a dedicated database agreed on by all the operators of the center. The need for access crossover

Received June 4, 2015; accepted October 26, 2015.
From the Institute of Cardiology, Catholic University of the Sacred Heart, Rome, Italy.
Correspondence to Francesco Burzotta, MD, PhD, L.go Gemelli 1, 00168 Rome, Italy. E-mail f.burzotta@rm.unicatt.it
© 2015 American Heart Association, Inc.
WHAT IS KNOWN

• Transradial approach, when compared with transfemoral, improves the safety of percutaneous coronary diagnostic or interventional procedures. Arterial axis variants are known to hinder the performance of transradial procedures.
• Data on the occurrence of arterial axis variants in the right and left arm arterial axes of individual patients are lacking, and the selection of radial artery side (right or left) is usually just a matter of operator’s attitude.

WHAT THE STUDY ADDS

• We report the first comparison of upper limb arterial anatomy in a large series of patients who underwent cardiac catheterization through both forearms.
• The occurrence of an anatomic variant, potentially hindering transradial approach procedures, was found to be more common in the right arm and bilateral in <8% of cases.
• Such information may guide access selection in patients requiring repeat procedures or need for additional accesses.

Radial Technique

The Allen test was routinely used to screen the patient suitable for TRA. In the case of abnormal Allen test, the Barbeau test was performed. A dedicated arterial puncture kit (with plastic cannula and hydrophilic wire) including a 25-cm hydrophilic sheath (Radifocus Introducer II M Coat, Terumo, Japan) was used for radial artery catheterization. Details on drug regimen and postprocedural access management have been previously reported. Access site selection (right or left, radial or ulnar) was at operator’s discretion although right radial access is our preferred approach for all patients except for those with left internal mammary grafts that are usually approached by left radial access. Patients with renal failure requiring dialysis were not considered for radial approach. As a standard practice, we routinely perform retrograde arm angiography in case of any difficulty in the advancement or manipulation of guidewires or catheters. This selective strategy for angiography performance proved to be able to detect anatomic variants at a comparable rate of those observed in studies where systematic angiography was performed.

Arterial Variant Definition and Strategy for Troubleshooting

The arterial axis morphology of both arms has been previously classified by the operative ABC classification of the variants and pathophysiologic conditions potentially affecting TRA, which identifies 10 anatomic or physiopathologic variants grouped into 3 different levels. In particular,

• Type A variants identifying radial/brachial artery axis variants. This group includes radial occlusion, severe atherosclerotic radial/brachial disease, severe radial/brachial tortuosity, radial/brachial loop, radioulnar loop, and high origin of radial artery.
• Type B variants identifying axillary/subclavian/innominate axis variants. This group includes severe axillary/subclavian/...
innominate tortuosity and atherosclerotic axillary/subclavian/innominate stenosis.

- Type C variants identifying aortic arch variants. This group includes retroesophageal right subclavian artery and aortic arch elongation.

The exact definition for each of the specific arterial variant category has previously been reported, and each of these variants has been found to significantly increase the risk of procedure failure.13 Because C type variants are rare and located into the aorta, we decided to focus our analysis on A and B variants only to compare the upper limb vasculature across the left and right sides.

In the presence of arterial anatomic variants, a series of dedicated techniques were adopted to try to successfully complete the procedure through the same access. Such step-by-step approach has been previously detailed.17 Yet, briefly

- in type A variants, a 0.035″ hydrophilic wire, supported by a 5- to 6-F JR4 diagnostic catheter, was used in large arteries (>2.5 mm), whereas a 0.014″ wire (Choice PT XS, Boston Scientific) supported by a 4-F JR4 diagnostic catheter was used in smaller arteries.
- in type B variants, a 0.035″ wire supported by JR 4 diagnostic catheter was used to reach the ascending aorta, and in the case of extreme tortuosity limiting catheter rotation, coronary cannulation was performed by keeping the 0.035″ wire inside the catheter.

Statistical Analyses
Continuous variables were checked for normality using the Kolmogorov–Smirnov test and are presented as mean±SD. Categorical variables are presented as counts and percentages. Comparisons between left and radial axes have been performed using McNemar test with concordance odds ratio (OR) and 95% confidence interval estimation. Multivariate logistic regression analysis (with adjusted OR calculation) was performed to estimate the possible association between clinical characteristics and bilateral anatomic variants. A P value of <0.05 was established as the level of statistical significance for all tests. Statistical analyses were carried out using SPSS Statistics software package for Windows (version 19.0).

Results
A total of 610 patients (7.1% of the patients who underwent TRA during the study period), with known angiographic arterial anatomy of both arms, constituted the study population. They underwent PCP through both right and left radial approach, in either a single or staged procedures, during which angiography had been acquired on both sides. Clinical and procedural characteristics of the study population are summarized in Table 1. Angiography of the 2 arms was performed in a single procedure (either for crossover after failure of the first access or for the need of double arterial access) in 166 patients (27.2%), whereas in the remaining 444 patients (72.8%), the angiographies were separately acquired in different procedures (Table 1). Table 2 reports the access-related technical aspects. Right radial access, when compared with left one, was associated with higher failure rate and with similar vascular complication rate (Table 2). However, it should be noted that a higher incidence of right radial failure was expected because most of the patients enrolled in the study had right radial as the first approach,15 and crossover to left radial access has been a selection criteria for inclusion in this study.

In 156 (25.6%) patients, an AB vascular anatomic variant was found. The Figure shows examples of common A and B variants. About the level, 128 (21%) patients had type A variants (brachioradial level), 45 (7.4%) type B (axillary/subclavian/innominate level), and 5 (0.8%) type C (aortic arch level). Variants were isolated in the right side in 65 (11% of the overall population), isolated in the left side in 40 (6.6%), and bilateral in 46 (7.5%) cases. At multivariable linear regression analysis, age (P<0.001; OR, 1.9; 95% confidence interval, 1.3–2.6 for each increased decade), female sex (P=0.04; OR, 2.0; 95% confidence interval, 1.0–4.1), and valvulopathy (P=0.02; OR, 2.9; 95% confidence interval, 1.2–7.1) were found to be independently associated with the presence of bilateral arterial variants.

Arterial variants were significantly more common in the right side (P<0.02), and the excess of right radial variants was driven by a significant higher rate of both type A variants (9.3% versus 6.2%; P<0.001) and type B variants (3.9% versus 2.3%; P=0.01). To rule out the effect of a possible selection bias caused by the preferential use of the right radial approach as a first access (ie, knowledge of a right radial variant may have prompted the selection of left radial approach in a subsequent

<table>
<thead>
<tr>
<th>Table 2. Comparison of Access-Related Technical Aspects and Vascular Complications Between Right or Left Radial Access for Percutaneous Coronary Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Right, n=610 (%)</strong></td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td><strong>Arterial spasm requiring vasodilators</strong></td>
</tr>
<tr>
<td><strong>Need of 0.14″ coronary guidewire</strong></td>
</tr>
<tr>
<td><strong>Access failure</strong></td>
</tr>
<tr>
<td><strong>Radial access-related vascular complications</strong></td>
</tr>
<tr>
<td>Vessel perforation</td>
</tr>
<tr>
<td>Arterial venous fistula</td>
</tr>
<tr>
<td>Pseudoaneurysm</td>
</tr>
<tr>
<td>Arterial dissection</td>
</tr>
<tr>
<td>Hematoma (without documented vessel damage)</td>
</tr>
<tr>
<td>Compartmental syndrome</td>
</tr>
<tr>
<td>Any complication</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; and OR, odds ratio.
procedure), a confirmatory analysis was performed in patients without anticipated knowledge of right arm anatomy. To do this, we repeated the analysis in the subgroup of 210 patients in which the left approach was electively selected in the first procedure or in procedures requiring electively double arterial access. Of note, in keeping with the results obtained in the whole-study population, similar results were found confirming the excess of right radial variants ($P=0.04$).

Distribution of Variant Types and Patterns of Association

Among the 46 patients with bilateral arterial variation, 30 (65.2%) had the same-level variant on both right and left sides (type A or B), whereas 16 (34.8%) had asymmetrical variants (A type on one side and B type on the contralateral arm). The Figure shows 3 examples of associations found during the study. The prevalence of A and B variant types of their different combinations and of each subgroup of variants is reported in Table 3. The majority of individual arterial variants tended to be more common on the right side and exhibited a significant concordance across 2 arms (Table 3). The specific patterns of association between arterial variant types found in the right arm and the corresponding left side anatomy are detailed in Table 4. Overall, despite anatomic variant in the right arm, a contralateral normal anatomy allowing for a smooth transradial access was found in more than half of patients. Moreover, the chance of contralateral normal anatomy in patients with variant on the right side did not differ according to the type of variant encountered (normal left arm anatomy being found in 55.5% of A variant patients versus 64.5% of B variant patients versus 50.0% of A+B variant patients; $P=0.60$). Of note, in patients with a bilateral arterial variant, the level of variant location tended to be symmetrical between the 2 arms (60.6% of bilateral variants located at the same A or B level on both arms). Similarly, as shown in Tables 3 and 4, each of the specific anatomic variants detected in the right arm tended to be associated with the presence of the same specific variation in the contralateral arm (range, 12.5%–34.0%).

Discussion

The present large, retrospective study in a real-world sample of 610 patients who underwent TRA interventional or diagnostic coronary procedures and in whom bilateral angiographic arm anatomy was assessed shows that
• upper limb arterial variants are differently distributed across the 2 arms, but bilateral variants are encountered in <8% of cases.
• compared with the left, the right upper limb arterial vasculature is associated with a higher rate of anatomic variants.
• arterial variants seem to cluster, so that once a variant is encountered on one side, an increased probability of contralateral variant, often of similar type, exists.

During the last decade, TRA has emerged as a valuable option to increase the safety of percutaneous procedures in patients undergoing not only low-risk coronary angiography and intervention\(^1\)\(^2\) but also in high-risk patients presenting with acute myocardial infarction,\(^1\(^6\)\) cardiogenic shock,\(^1\(^9\)\) and peripheral artery disease.\(^2\(^0\)\)\(^2\(^2\)\) As a trade-off to the proven reduction in bleeding events, TRA is limited by a somewhat higher procedural complexity, which implies the need of a dedicated learning curve\(^3\)\(^4\) and may increase procedure failures.\(^1\)\(^2\) Indeed, compared with the lower limbs, upper limbs have smaller arteries with wider anatomic variations, which are relevant for clinical practice because they may hinder the performance of TRA.\(^4\)\(^5\)\(^1\(^3\)\)\(^1\(^4\)\) Moreover, although leg vasculature is basically symmetrical, the aortic take-off of vessels supplying the 2 arms is different and ascending aorta has an angulation that makes the approach to the coronary ostia different between the 2 arms. The meta-analytic summary of studies comparing left and right radial access for PCP has shown that left radial access is associated with a shorter procedural time (including fluoroscopy)\(^6\)\(^7\) and that it may be associated with higher success rates,\(^8\) especially during the learning phase.\(^2\(^3\)\)

This suggests that technical competence is needed to deal with more challenging anatomic features often encountered by right radial approach. In such context, this study may shed new light by providing a picture of the different anatomic conditions frequently associated with the side selection in real-world patients.

We compared the 2 sides in the same patients undergoing bilateral TRA PCP procedures. Such study design allows for adjustment of baseline characteristics (genetic, biometric, and clinical) that may theoretically influence the pattern of vascular anatomy. Moreover, to avoid any possible overestimation of anatomic features, we focused our attention on variants known to influence TRA procedures,\(^1\(^3\)\) by using a previously described, operative, classification of upper limb arterial axis variants\(^1\(^4\)\) that groups the main congenital or pathophysiologic variants in 3 different levels. The C variants (located at the aorta level), which are known to influence TRA procedures especially when performed by right side, have been reported but not included in the comparisons because of their centrality.

We documented that upper limb arterial variants are significantly more common on the right side. Such findings are in keeping with the aforementioned results of trials comparing left and right radial approach and help to explain why the operator experience reduces the effect of side selection during a first catheterization attempt.

Finally, a significant tendency toward symmetrical distribution of anatomic variants was observed. Indeed, the majority of bilateral variants were located at the same (A or B) level, and the specific anatomic categories detected in the right arm tended to be associated with the presence of the same specific variation in the contralateral arm. Thus, before attempting a contralateral radial access in patients with documented anatomic variant in the right side, operators, in light of their own radial experience, should carefully consider the significant chance of facing a similar scenario in the contralateral side. Increasing age, female sex, and valvulopathy were found to be significantly associated with increased probability to have bilateral variants. In the clinical practice, these considerations have to be taken into account in specific circumstances, such as the access selection in repeat PCP, the access selection after failure of the first one, or in cases of elective double arterial access, such as coronary interventions for chronic total occlusions.\(^2\(^4\)\)

### Table 3. Anatomic Variants Distribution in the Right vs Left Arm Arterial Axis

<table>
<thead>
<tr>
<th>Variants</th>
<th>Right, n=610 (%)</th>
<th>Left, n=610 (%)</th>
<th>P Value (McNemar test)</th>
<th>OR (95% CI) for Concordance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any anatomic variant</td>
<td>65 (10.7)</td>
<td>40 (6.6)</td>
<td>0.02</td>
<td>6.7 (3.8–11.4)</td>
</tr>
<tr>
<td>Arm arterial axis level variants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type A variant only</td>
<td>57 (9.3)</td>
<td>38 (6.2)</td>
<td>&lt;0.001</td>
<td>7.2 (4.1–12.7)</td>
</tr>
<tr>
<td>Type B variant only</td>
<td>24 (3.9)</td>
<td>14 (2.3)</td>
<td>0.01</td>
<td>8.0 (2.1–30.9)</td>
</tr>
<tr>
<td>Combined type A+B variants</td>
<td>10 (1.6)</td>
<td>6 (1.0)</td>
<td>0.42</td>
<td>13.2 (1.4–124.9)</td>
</tr>
<tr>
<td>Specific anatomic variants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radial occlusion</td>
<td>4 (0.7)</td>
<td>3 (0.5)</td>
<td>1</td>
<td>0.99 (0.98–1.01)</td>
</tr>
<tr>
<td>Severe atherosclerotic radial/brachial disease</td>
<td>5 (0.8)</td>
<td>6 (1.0)</td>
<td>0.09</td>
<td>19.9 (2.0–197.4)</td>
</tr>
<tr>
<td>Severe radial/brachial tortuosity</td>
<td>33 (5.4)</td>
<td>16 (2.6)</td>
<td>0.02</td>
<td>17.5 (8.1–37.7)</td>
</tr>
<tr>
<td>Radial/brachial loop</td>
<td>7 (1.1)</td>
<td>8 (1.3)</td>
<td>0.11</td>
<td>10 (1.2–96.5)</td>
</tr>
<tr>
<td>Radioulnar loop</td>
<td>13 (2.1)</td>
<td>8 (1.3)</td>
<td>0.02</td>
<td>11.3 (2.1–58.4)</td>
</tr>
<tr>
<td>High origin of radial artery</td>
<td>27 (4.4)</td>
<td>20 (3.3)</td>
<td>&lt;0.001</td>
<td>9.2 (3.8–22.2)</td>
</tr>
<tr>
<td>Severe axillary/subclavian/anomalous tortuosity</td>
<td>20 (3.3)</td>
<td>12 (1.96)</td>
<td>0.22</td>
<td>7.2 (1.9–27.5)</td>
</tr>
<tr>
<td>Atherosclerotic axillary/subclavian/anomalous stenosis</td>
<td>6 (0.98)</td>
<td>7 (1.1)</td>
<td>0.005</td>
<td>28.3 (4.9–165.5)</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; and OR, odds ratio.
Conclusions
Arterial variants potentially influencing PCPs are more commonly found in the right upper limb and are bilateral in <8% of cases. Such data provide further insights on the issue of side selection during the daily clinical practice of transradial coronary and interventional procedures.

Disclosures
None.

Table 4. Pattern of Associations Between Anatomic Variant Types Found in the Right Arm and Contralateral Arterial Side Anatomy

<table>
<thead>
<tr>
<th>Arterial Anatomic Variant</th>
<th>Detected in the Right Arm</th>
<th>Arterial Anatomy Found in the Left Arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm arterial axis level variants</td>
<td>Type A variant</td>
<td>55.5% Normal</td>
</tr>
<tr>
<td></td>
<td>34.4% Type A variant only</td>
<td>8.9% Type B variant only</td>
</tr>
<tr>
<td></td>
<td>2.2% Combined A+B variants</td>
<td>64.5% Normal</td>
</tr>
<tr>
<td></td>
<td>12.9% Type A variant only</td>
<td>12.9% Type B variant only</td>
</tr>
<tr>
<td>Type B variant</td>
<td>9.7% Combined Type A+B variants</td>
<td>50.0% Normal</td>
</tr>
<tr>
<td></td>
<td>30.0% Type A variant only</td>
<td>10.0% Type B variant only</td>
</tr>
<tr>
<td>Combined type A+B variants</td>
<td>10.0% Combined type A+B variants</td>
<td>50.0% Normal</td>
</tr>
</tbody>
</table>

Specific anatomic variants

Severe atherosclerotic 66.7% Normal
radial/brachial disease
16.7% Severe atherosclerotic radial/brachial disease*
16.7% Severe radial/brachial tortuosity
44.0% Normal
Severe radial/brachial tortuosity
4.0% Severe atherosclerotic radial/brachial disease
34.0% Severe radial/brachial tortuosity*
4.0% Radial/radial loop
Radial/radial loop
50.0% Normal
12.5% Radial/radial loop*
25.0% High origin of radial artery
Radial/radial loop
66.7% Normal
6.7% Severe atherosclerotic radial/brachial disease
13.3% Severe radial/brachial tortuosity
High origin of radial artery
61.1% Normal
2.8% Severe atherosclerotic radial/brachial disease
13.9% Severe radial/brachial tortuosity
2.8% Radial/radial loop
Severe axiality/ subclavian/ anonymous tortuosity
65.2% Normal
4.3% Severe atherosclerotic radial/brachial disease
21.7% Severe radial/brachial tortuosity
Atherosclerotic axiality/subclavian/ anonymous stenosis
62.5% Normal
12.5% Severe atherosclerotic radial/brachial disease
12.5% Severe axiality/subclavian/anonymous tortuosity

*Symmetrical variant.


Comparison of Right and Left Upper Limb Arterial Variants in Patients Undergoing Bilateral Transradial Procedures

Francesco Burzotta, Marta Francesca Brancati, Italo Porto, Silvia Saffioti, Cristina Aurigemma, Giampaolo Niccoli, Antonio Maria Leone, Valentina Coluccia, Filippo Crea and Carlo Trani

Circ Cardiovasc Interv. 2015;8:
doi: 10.1161/CIRCINTERVENTIONS.115.002863

Circulation: Cardiovascular Interventions is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2015 American Heart Association, Inc. All rights reserved.
Print ISSN: 1941-7640. Online ISSN: 1941-7632

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circinterventions.ahajournals.org/content/8/12/e002863

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation: Cardiovascular Interventions can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation: Cardiovascular Interventions is online at:
http://circinterventions.ahajournals.org//subscriptions/