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Vascular access: time development and contemporary practice

Acessos vasculares: evolução temporal e prática contemporânea

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DOI: 10.31160/JOTCI201927A20190018

ABSTRACT – The choice of the vascular access for coronary angiography or angioplasty is a function of the operator's experience, of the presence of arterial pulse at the chosen site, and of the clinical status of the patient. The femoral approach should still be preferable in cases of higher angiographic complexity that require large-bore guide catheters, while radial access should be the approach for elective coronary angiography and acute myocardial infarction, taking into consideration the reduction in overall events. When the standard radial approach is not possible, ulnar and distal radial access are appropriate alternatives.

Keywords: Angiography; Coronary angiography; Femoral artery; Radial artery; Ulnar artery; Brachial artery; Catheters

RESUMO – A escolha do acesso vascular para realização de coronariografia ou angioplastia deve passar pela experiência do operador, presença de pulso arterial no sítio preferencial e reconhecimento do cenário clínico do paciente. A técnica femoral ainda deve ser utilizada em cenários de maior complexidade angiográfica, que necessitem de cateteres-guia de maior diâmetro, enquanto o acesso radial deve ser o de escolha em cenários de coronariografia eletiva, além do cenário de infarto agudo do miocárdio, considerando a redução de eventos globais. As vias de acesso ulnar e radial distal constituem boas opções, na impossibilidade de uso da via radial tradicional.

Descritores: Angiografia; Angiografia coronária; Artéria femoral; Artéria radial; Artéria ulnar; Artéria braquial; Cateteres

BACKGROUND

There is a long path to consider in order to understand how the use of different vascular accesses revolutionized Interventional Cardiology. We start in the 1950's, with the contributions of Sven Ivar Seldinger, and then Frank Mason Sones Jr., who during the exam of a young female patient with rheumatic valvar disease, pulled back the catheter from the left ventricle to the aortic artery, and accidentally catheterized the right coronary ostium, shadowing and triggering temporary asystole, reverted by the patient coughing vigorously. That is how the selective coronary angiography technique began, conceived and improved by Sones.¹ In Brazil, the Sones' technique was introduced in the 1960's by José Eduardo Moraes Rego Sousa, at *Instituto Dante Pazzanese de Cardiologia*, in São Paulo, where the first coronary angiography was performed in the country.

Later, two American radiologists, Melvin Judkins and Kurt Amplatz, reported coronary angiography by femoral artery puncture, using pre-molded catheters for selective coronary artery angiography, which has been the most largely used technique worldwide over the past decades (Seldinger-Judkins or femoral puncture technique).²

In the 1990's, Lucien Campeau³ and Ferdinand Kiemeneij used radial puncture in the initial percutaneous coronary interventions (PCI).⁴ The novel technique showed major reduction in bleeding complication rates when compared to the femoral approach. Its safety is explained by the superficial course of the artery, allowing simple hemostasis by local compression. Additionally, the occurrence of thrombotic or vascular complications is largely asymptomatic, due to the dual arterial blood supply to hands.

The ulnar approach is a feasible, safe and efficient alternative for cases for which it is not possible to use the radial approach,⁵ and the more distal puncture of the

How to cite this article:

Maia F, Furtado R, Souza JB. Vascular access: time development and contemporary practice. J Transcat Interv. 2019;27:eA20190018. <https://doi.org/10.31160/JOTCI201927A20190018>

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Received on:

Jul 11, 2019

Accepted on:

Oct 10, 2019

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radial artery in the anatomical snuffbox, suggested by Kiemeneij,⁶ has been highlighted recently as an additional access alternative.

When deciding for a vascular access, it is essential to know the techniques involved in the procedure and the treatment of complications that might occur, and this is the first step in any diagnostic or therapeutic percutaneous procedure. The decision should be based on clinical and anatomic aspects, technique advantages, disadvantages and limitations, in addition to the proficiency of the operator.

MAJOR ACCESS ROUTES AND GENERAL ASPECTS

Femoral

The femoral artery is the most widely used access worldwide, it has a shorter learning curve, and enables the use of devices in more complex PCI cases, such as chronic total occlusions and bifurcations with multiple stents, because the diameter of the common femoral artery accepts large-bore introducers. Nonetheless, easier puncture enabled by the large diameter of the artery is counterbalanced by more likely bleeding complications, due to the difficulty of manual compression of the artery, which is enveloped by layers of muscles. The development of percutaneous devices for vascular hemostasis has decreased the incidence of hematoma at the puncture site, but has not shown impact in decreasing the incidence of major vascular events, such as pseudoaneurysms and arteriovenous fistulas.⁷ Femoral artery puncture above the inguinal ligament is associated with the emergence of retroperitoneal hematoma, since it is not possible to manually compress at the level of the abdominal cavity/retroperitoneum. On the other hand, low arterial punctures (below the bifurcation of the femoral common artery) can be more likely associated with the development of pseudoaneurysms and arteriovenous fistulas (Figure 1).

Figure 1. Entry zone at the common femoral artery (below inferior epigastric artery, and above bifurcation of common femoral artery). The lower inferior margin of the acetabulum is the anatomic landmark for the ideal entry point of the needle on the skin.

Radial

There has been a current increasing use in the radial technique because it enables early hospital discharge (because it does not require long bed recovery), and it is associated with a lower incidence of puncture site-related vascular and bleeding events when compared to the femoral approach. The fact that the technique requires longer training due to vessels that are smaller, more fragile and showing more tortuosity as the artery runs through the upper limb, should be remembered.⁸ The puncture is performed using a catheter or a dedicated needle, and should be performed 1 to 2cm proximal to the radius' styloid process. Manual compression and hemostasis are facilitated because the artery runs superficially and over a bone structure. The Allen test or the modified Barbeau test using oximetry can be performed to assess the patency of the radiopalmar arch, although without scientific evidence of the prognostic impact on the safety of radial artery use.

The development of curved catheter models dedicated to radial access, such as Barbeau (Cordis®) and TIG (Terumo®), has enabled performing coronary angiography with no need for catheter exchange, decreasing the likelihood of spasm, that has an incidence of approximately 2.6% to 14.3% reported in major published series.⁹ The noticeable variation can be explained by the difference in the expertise of centers, and by the difficulty to measure a subjective evaluation phenomenon. The administration of a spasmolytic mixture of heparin and nitrate or verapamil is crucial to reduce spasm, associated with a hydrophilic sheath introducer and appropriate local anesthesia to avoid pain stimulus. Radial spasm is more prevalent in specific groups, such as young patients and females, and is the second major cause for crossover to the femoral approach, while anatomic variations of the arterial course in the upper limb are the main cause (Figure 2), with a rate of approximately 7% in patients presenting ST-segment elevation acute myocardial infarction (STEMI).¹⁰

Source: translated from Hamon et al.¹¹

Figure 2. Anatomic variation of the radial artery (high take-off of radial artery/high bifurcation). Type 3 is associated with failure of radial access with spasm and with a high rate of conversion to femoral access.

Arterial occlusion is the major complication associated with transradial access, showing a wide-range from 1.5% to 33%. It is often asymptomatic due to the dual perfusion of the radial-palmar arch, and 50% of the occlusions evolve to spontaneous recanalization within 30 days.¹⁰ Among the measures with attested efficacy in preventing radial thrombosis are use of unfractionated heparin, patent non-occlusive hemostasis (compressive bands), smaller diameter sheaths, and reduction in the number of occasions the access is used during a single hospitalization.

Regardless of the difficulty to standardize a minimal cutoff for radial access to define proficiency in the radial approach, the European Society of Cardiology (ESC) has established that at least 50% of the case load of a center must be the radial artery, with a minimum of 80 procedures/year (Figure 3).¹¹

Source: Adapted from Hamon *et al.*¹¹

Figure 3. Steps to be followed to obtain high level proficiency in anatomic variations and different clinical and angiographic settings. Classification of the American College of Cardiology/American Heart Association: A – low, B – moderate, C – high complexity angiography. STEMI: ST-segment elevation myocardial infarction; NSTE-ACS: non-ST segment elevation acute coronary syndrome; PCI: percutaneous coronary intervention; CAG: coronary angiography.

Brachial

Sones' technique is virtually in disuse. It is used when the femoral or radial approaches present technical and anatomic difficulties to the operator, but are first choice route. Presently, a modified technique is proposed, with direct puncture, followed by manual compression for hemostasis.

SCIENTIFIC EVIDENCE

Femoral vs. radial

Transfemoral access is still considered the preferential route by some operators, due to the easy catheter handling

and control, immediate access to larger diameter devices and by the low rate of thrombotic events. Nonetheless, previous advantages are easily overcome by bleeding complications, longer hospital stay, high costs and the presence of limiting factors, such as peripheral artery disease.

Most publications before the current decade reported longer procedure time and higher exposure to radiation associated with the transradial access when compared to the transfemoral, although the studies were largely carried out in single centers, with reduced samples. Additionally, most of the centers, at the time these studies were published, were undergoing transradial access learning curves.^{12,13} Jolly *et al.*, in a sub-analysis of the RIVAL study, reported radiation exposure levels associated with the transradial and transfemoral approaches in 2,569 patients during coronary angiography and PCI, fluoroscopy time in minutes, air kerma (KA), and the product of the dose by the irradiated area (DAP). Fluoroscopy time was higher for the transradial group than for the transfemoral (9.3 vs. 8.0 minutes; $p < 0.0001$), and KA was also higher for the transradial group than for the transfemoral (1.046 mGy vs. 930 mGy; $p < 0.051$), and mean DAP showed no difference between the transradial and transfemoral groups (52.8 Gy.cm² vs. 51.2 Gy.cm²; $p < 0.83$). Most of the radiation measured by KA and DAP came from imaging recordings; thus, small increments of fluoroscopy for navigating the catheter across the upper limb do not lead to a considerable increase in radiation dose. The authors analyzed the results according to the transradial access proficiency of each center, and showed that fluoroscopy and KA do not differ when comparing high volume centers, recording >140 transradial PCI/year/operator; transradial 8.3 minutes vs. transfemoral 8.0 minutes of fluoroscopy time ($p < 0.059$; interaction $p < 0.021$); and KA measurement for transradial of 652 mGy vs. KA measurement for transfemoral 621 mGy ($p < 0.403$; interaction $p < 0.026$).¹⁴ In this study, the magnitude of the difference between low and high volume transradial centers was higher than what was described when the transradial and transfemoral approaches were directly compared, endorsing the relevance of adequate training for transradial access.

Hospital costs are also a significant aspect. When compared to transfemoral, the use of transradial access reduced costs,¹⁵⁻¹⁷ showed by less expenditures with medications, instruments and, most importantly, decreasing hospital length of stay, due to early ambulation and discharge, along with virtual absence of vascular complications.

These differences were not attenuated by the use of percutaneous closure devices for femoral access. In a registry-based prospective study, with 218 patients submitted to PCI, the use of the Perclose® device facilitated early ambulation after transfemoral access, but could not be used in 20% of cases due to peripheral artery disease, had a 10% failure rate, 3.7% of vascular complications, and consequent increase in costs.¹⁸

PCI via transradial access performed in the outpatient setting, followed by same-day hospital discharge, has been shown to be safe and efficient for patients with stable coronary artery disease, and it represents an additional factor for cost reduction.^{19,20} Thus, considering the aspects mentioned, higher quality of life indicators have been reported in questionnaires answered by patients submitted to transradial procedures, translating a clear preference for the technique.

Major bleeding and prognostic impact

The adverse prognostic effect of major bleeding after PCI procedure, mainly for patients presenting acute coronary syndrome, has been highlighted in the past decade in large trials, such as AQUIITY, showing a similar negative impact of major bleeding and re-infarction during 1-year follow-up.²¹ Approximately two-thirds of bleedings were attributed to puncture site complications,²²⁻²⁴ and once vascular complications are reduced, one might infer that using the radial access would promote concomitant reduction of ischemic events and mortality (Figure 4).

Source: Huff et al.²⁴

Figure 4. Bleeding rate of transradial approach for percutaneous coronary intervention in non ST-segment elevation acute coronary syndrome.

In order to test this hypothesis, Jolly et al.²⁵ conducted the RIVAL trial with 7,021 patients with acute coronary syndrome, with and without ST-segment elevation, randomized to transradial or transfemoral access. They did not find significant differences in the primary outcome (death, acute MI, stroke, and non-procedure related bleeding) between the groups (3.7% for transradial vs. 4.0% for transfemoral). However, the subgroup of patients with STEMI showed a 40% reduction in the risk of composite outcome and, more interestingly, a 61% reduction in the relative risk of death, due to the drop in hemorrhagic events. The results confirmed the findings of smaller sample stu-

dies in acute myocardial infarction settings, such as the RIFLE-STEACS study, which also supported the use of the transradial access, by showing a 47% decrease in bleeding events when compared to the transfemoral access, having a direct prognostic impact on the 30-day combined events rate.²⁶

Another large randomized trial comparing the vascular approaches in patients presenting acute coronary syndrome was the MATRIX study, with 8,404 patients randomized to the radial or femoral access for coronary angiography and ad hoc PCI. During the 1-year follow up, cardiovascular events did not differ among patients directed to the transradial access when compared to the transfemoral access (14.2% vs. 15.7%; OR 0.89; 95%CI 0.80-1.00; p=0.0526), but overall adverse clinical events, including type 3 and 5 bleeding, according to the Bleeding Academic Research Consortium (BARC) classification, were less frequent in the radial group when compared to the femoral group (15.2% vs. 17.2%; OR 0.87; 95%CI 0.78-0.97; p=0.0128).²⁷

As the reduction of overall cardiovascular events (efficacy and safety) in patients presenting acute coronary syndrome seems to be linked to less bleeding in the radial approach, there is an assumption that by using vascular closure devices, the transfemoral approach could achieve not inferior results to the transradial group. The recent reported SAFARI study tested this hypothesis, using contemporaneous practices of Interventional Cardiology in the primary PCI setting, with high use of new and more powerful antiplatelet drugs (91% ticagrelor), in addition to less use of IIb/IIIa glycoprotein inhibitors (6%). Vascular closure devices were used in 68% of transfemoral group patients treated for STEMI with onset of symptoms ≤ 12 hours. However, the study was aborted early, with approximately only 50% of the randomized sample, since no difference was shown between the transradial and transfemoral groups for the 30-day mortality rate (1.5% vs. 1.3%, respectively; p=0.69) and major and minor Thrombolysis in Myocardial Infarction (TIMI) bleeding criteria (1.8% vs. 2.1%; p=0.70). The study was terminated early due to futility, for the rate of deaths in the transfemoral group was well below the 4% postulated in the sampling calculation of the study, making conclusions drawn from the analysis merely speculative.²⁸

Due to the heterogeneity of patient samples in these studies comparing vascular approaches, meta-analyses were used, such as one by Andò et al.,²⁹ favoring radial access, establishing it as the preferential option in acute coronary syndrome, enabling a less restrictive use of antithrombotic agents, abiding with the updated recommendations of the guidelines on myocardial revascularization (class I-A),³⁰ and facilitating early ambulation and shorter hospital stays. Regarding acute coronary syndrome, evidence suggests that the radial access promotes more overall benefits and should be the preferable access (Figure 5).

Source: from Andò et al.²⁹

Figure 5. Forrest-Plot favoring transradial access in acute coronary syndrome.

Risk subgroups

Patients with certain demographic and clinical features present a higher risk of vascular complications during invasive coronary procedures. The elderly, women, underweight (<50kg), obesity, acute coronary syndrome, aggressive antiplatelet and anticoagulation regimens are common situations in our clinical practice, which facilitate a higher incidence of undesirable events.²⁸ In this scenario, radial or even distal radial access is a safe and effective alternative. Several studies compared radial and femoral approaches, specifically in subgroups of patients exposed to high complication rates.

The elderly

With increased life expectancy, elderly patients form a growing segment in our population. They have a high prevalence of coronary atherosclerotic disease and, in view of associated co-morbidities, percutaneous treatment becomes the preferred strategy. However, the presence of systemic atherosclerosis, pronounced calcification and tortuosity may limit the success and benefit of the procedure, considering the technical difficulties arising from these characteristics. Comparative studies between the radial and femoral approaches^{31,32} have shown that the radial access is associated with lengthier procedures, use of more guidewires and contrast volume, and requires changing the vascular access more frequently. Nevertheless, the radial technique shows a similar success rate, allows early ambulation and significantly reduces the rate of vascular complications, especially those related to the puncture site. Thus, a careful pre-procedure evaluation can help select which elderly patients can benefit from the radial access.

Female patients

Notwithstanding presenting a lower incidence of atherosclerotic disease and undergoing fewer PCI, women paradoxically have higher rates of in-hospital bleeding when compared to men. The higher prevalence of low weight, associated with relatively high doses of antithrombotic the-

rapy in respect to weight, is one of the determining factors that can explain the incidence of hemorrhage. Using radial access in this risk subgroup, although requiring a skilled interventional cardiologist due to the smaller diameter of the radial artery in women, promotes a significant reduction in both major and minor hemorrhages,³³ making the radial access an attractive option for coronary procedures.

Obese patients

Radial access is the main independent predictor of reduced risk of vascular complications after PCI in obese patients.³⁴ Difficulties in obtaining femoral access, performing proper hemostasis, and identifying early development of hematoma are major factors explaining the higher occurrence of bleeding with the use of this technique, especially in cases of morbid obesity. Therefore, radial access should be preferred in obese patients.

Anticoagulated patients

Studies have shown the radial access is feasible and safe to perform diagnostic and therapeutic coronary procedures in patients under oral anticoagulation (OAC), with no discontinuation of medication required, and preventing the risk of thromboembolic complications associated with the withdrawal of vitamin K antagonists, as well as the risk of hemorrhage from prophylactic antithrombotic therapy.^{35,36} When performing transfemoral access, OAC with coumarin derivatives approximately 5 days before the procedure should be discontinued in order to obtain an International Normalized Ratio (INR) <1.7 for a safer procedure. For patients on new anticoagulants (NOACs), discontinuation is usually done 48 hours before the procedure.

Comparing radial and ulnar access

The ulnar artery access has been presented as a viable alternative to perform coronary procedures in situations when the radial access is unavailable, which are estimated in 5% to 15% of cases, due to a negative Allen test, anatomical variations and occurrence of vasospasm.^{37,38} The ulnar access has technical characteristics essentially similar to radial approach, enjoys the same benefits provided by the latter, that is, reduced vascular complications and shorter length of hospital stay. A randomized study involving 431 patients undergoing diagnostic and therapeutic coronary procedures showed similar successful access rates, appropriate coronary contrast opacification, length of the procedure, fluoroscopy time, number of catheters used, PCI success, and puncture site-related complications.³⁹ Thus, in services with proficiency in the use of radial access, using the ulnar access in selected cases, becomes a tangible option to femoral access.

Distal radial access

There still are no large studies comparing distal radial access with other arterial approaches for coronary interven-

tions. Recently described,⁶ the distal radial artery puncture at the level of the anatomical snuffbox presents itself as a refinement of the traditional radial technique. The potential benefit is greater patient and operator comfort when using the left radial access, in addition to maintaining blood flow through the superficial palmar arch in case of artery occlusion, since the distal puncture is located after the emergence of the superficial palmar branch, minimizing the risk of hand ischemic injury (Figure 6). Moreover, by avoiding the usual puncture site and possible local complications reported by imaging methods such as negative arterial remodeling and arterial thrombosis, access would be preserved for possible new interventions, or as an option for coronary artery bypass graft. In Brazil, Andrade et al. showed proficiency for left distal radial access with mean fluoroscopy time (5.6 ± 4.5 minutes) slightly longer than traditional right radial access in a single-center study.⁴⁰

Source: Andrade et al.⁴⁰

Figure 6. Left distal radial artery puncture at the level of the anatomical snuffbox, with the operator positioned on the right side of the patient, the left upper limb over the abdomen, and pointing to the right inguinal region.

Both right and left distal radial arteries can be routinely used for diagnostic and therapeutic coronary procedures. Particularly noteworthy is the distal left radial access, since it enables greater patient comfort, due to the positioning of the patient's arm, especially in longer procedures, such as in bypass studies with more direct access to the left internal mammary artery graft.

However, large randomized studies, with adequate series and able to show reduction in morbidity events related to the distal radial access, are required to change the current clinical practice.

FINAL CONSIDERATIONS

The femoral access stands as the preferential technique for performing elective percutaneous procedures, such as graft studies for double mammary revascularization, com-

plex therapeutic interventions, like the left main coronary artery, chronic occlusions, bifurcations with the double stent technique. Furthermore, it is preferred for structural procedures, such as percutaneous transcatheter aortic valve implantation, which requires vascular access accommodating a large-bore arterial sheath. Although the incidence of vascular complications when using this technique has decreased noticeably in the past decade, they are higher than the virtual absence of bleeding associated with radial access. The radial technique in European and Asian countries, and in Brazil, has grown significantly in the past decade, and become the preferred access for diagnostic and therapeutic elective procedures. The early skepticism of some practitioners, envisaging technical difficulties, such as longer training time, was surpassed by the unequivocal demonstration of reduction in bleeding rates, prognostic impact on hard outcomes, as death and infarction in acute coronary syndrome cases, particularly in STEMI, and reduction in hospital costs. However, choosing one technique over the other should not abolish one of the techniques, so as to maintain appropriate proficiency in both techniques, as femoral access-related hemorrhagic complications tend to occur more frequently with default radial operators.

The ulnar approach is a viable and safe alternative when the radial approach cannot be selected (anatomic variations). The distal radial access represents a refinement of the standard radial technique, bringing more comfort during the procedure, mostly in the left radial artery, although further studies are required to determine the actual benefit of this new technique.

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: FM, RF and JBS; data collection: FM, RF and JBS; data interpretation: FM; text writing: FM; approval of the final version to be published: FM.

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