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CLINICAL MANAGEMENT

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Combined ultrasound and angiographic guidance to facilitate transradial access procedures

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Abstract

The introduction of transradial access for percutaneous coronary diagnostic and interventional procedures has led to a decrease in access site complications. The aim of this paper is to propose a combined stepwise technical approach where real time ultrasound ("echo-first" approach) can be used to select the best vascular access and, together with angiography, to manage the potential obstacles that may occur during transradial procedures. In each section, we summarize some tips and tricks based on both our experience and current literature that can be easily implemented in daily practice to increase the success of transradial procedures.

KEYWORDS

access site, multimodal imaging, radial

1 | INTRODUCTION

Transradial access (TRA) has become the recommended vascular approach for diagnostic and interventional coronary procedures.[1,2] Compared with transfemoral access (TFA), TRA is associated with significant reductions in bleeding,[3] access site complications,[4] hospital costs,[5] improved quality of life,[6] earlier mobilization,[3] and better clinical outcomes,[3,7] particularly in patients with acute coronary syndromes (ACS).[2] Nevertheless, important disadvantages of TRA compared to TFA remain the higher technical failure and the more frequent radial crossover or switch to femoral approach.[8] This is not desirable because it is associated with patient discomfort, increased radiation exposure and delayed revascularization (especially in the primary percutaneous coronary intervention (PCI) setting), thus abolishing the bleeding benefit when compared with a successful TRA.[9] Reported technical failure for TRA procedures ranges from 1% to 10%[8,10]: it is usually related to the inability to puncture the artery, the occurrence of spasms, and the presence of unfavorable vascular anatomy of the upper limb and aortic arch.[11] All these aspects highlight the importance of a meticulous access site selection. Recently, a novel, simple eight-item risk score (MATRIX score) was developed to predict radial crossover in patients with ACS.[12] In addition, real-time ultrasound (US) is already an invaluable tool in large vascular access (e.g., central veins and femoral arteries), and it has also been shown to increase TRA success, mainly by reducing the number of puncture attempts.[13] Its role in facilitating TRA could be further extended by identifying anatomic arterial variations, preventing them whenever possible, and helping in their

Abbreviations: ACS, acute coronary syndromes; AT, Allen test; DRA, distal radial access; LRA, left radial artery; RA, radial artery; RAO, radial artery occlusion; RAS, radial artery spasm; RRA, right radial artery; TFA, trans-femoral access; TRA, trans-radial access; TUA, transulnar access; UA, ulnar artery; US, ultrasound.

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management. The aim of this review is to propose a combined stepwise technical approach wherein real time US ("echo-first" approach) can be used to select the best vascular access and, along with angiography, to manage the potential obstacles that may occur during the different steps of transradial coronary procedures. In each section, we report some tips and tricks, based on our experience and current literature review, which could easily help operators in preventing and overcoming TRA challenges.

2 | CLINICAL EVALUATION OF ACCESS SITE

Careful assessment of access site is essential before proceeding with arterial puncture. The integrity and patency of the radial artery (RA) should be assessed by palpation of its entire course and not only at the distal site of arterial puncture, because radial artery occlusion (RAO) usually occurs at a more proximal site and a palpable pulse does not exclude its diagnosis. Indeed, palmar collateral blood flow, mainly through the anterior interosseous artery, may supply the periphery distal to the occlusion leading to RA patency misdiagnosis. In such a setting, the value of noninvasive tests is controversial, as neither the modified Allen test (AT) nor the Barbeau test has been shown to prevent clinically significant complications after TRA, even considering that the safety and feasibility of TRA has been demonstrated across the full range of AT results.[2,14] On the other hand, the "reverse" Barbeau test, where changes in plethysmography wave are assessed after simultaneous compression of the radial and ulnar arteries (UA) and subsequent decompression of the radial artery, has been shown to be helpful in the initial diagnosis of RAO.[15]

3 | ULTRASOUND ASSESSMENT BEFORE ARTERIAL PUNCTURE

The most reliable preprocedural method to assess the upper arm arterial vessels is a complete Doppler ultrasound examination, which is performed with high frequency (5–10 MHz or higher), linear array transducer. Costs, the need for a learning curve, set-up requirements, space limitations, and time all pose potential barriers to the widespread adoption of US in the Cath Lab. One strategy to overcome these difficulties is to utilize a variety of comfortable, inexpensive, and easy-to-use portable US devices. As previously described,[16] these options include wireless systems such as Freestyle™ (Siemens Healthineers, Erlangen, Germany), transducers that can be connected to an Android pad (Lumify; Philips Healthcare, Best, The Netherlands) and wireless portable transducers that can be connected to any Apple or Android pad (Clarius; Burnaby, BC, Canada). Imaging settings should be set for minimal penetration depth (until the radial bone is seen in the far field of the screen, usually 2–3 cm) and high gain. Radial and UA are imaged by holding the probe to visualize the vessel in the short-axis (or cross-sectional) view (Figure 1). Typically, arterial wall appears as an echo lucent circle surrounding the anechogenic lumen that pulsates with light pressure. Veins identification is often easy, as they completely disappear after compression. However, if there are difficulties in differentiating them (e.g., in atherosclerotic and/or calcified arteries), or in patients with a history of prior TRA, it is advisable to use pulsed Doppler (Figure 1, Panel B). Assessment of arterial size is paramount to evaluate its compatibility with radial sheaths commonly used in TRA procedures to avoid RAO. Once the radial and UA are identified, the entire course of the vessels should be scanned to highlight the presence of anatomic variants and/or acquired anomalies. This examination should trace their course as proximally as feasible, ideally until their origin from the brachial artery at the elbow level (Figure 1, Panel C). Long axis (longitudinal) view may be useful to confirm some anatomic variations (especially tortuosities and loops), especially if a high level of suspicion exists after the initial cross-sectional assessment.

4 | ACCESS SITE SELECTION AND US-GUIDED ARTERIAL PUNCTURE

After a complete clinical and US assessment of the arterial vessels of the upper arm bilaterally, in the absence of significant anatomic variants and/or acquired anomalies, we prefer right radial approach (RRA) by default for operator's comfort/ease of use and limitations of common cath-lab radiation equipment. However, left radial approach (LRA) is associated with less procedure time and radiation exposure than the RRA.[17] We suggest its use in elderly (≥80 years of age), in aortic dilation (due to the unfolding of the intrathoracic aorta), if catheterization of the left internal mammary bypass is required or when a PCI on the right coronary artery is expected (to increase support). Compared with the radial artery, the ulnar artery has a less favorable and deeper anatomic position and is associated with a less palpable pulse and with a more difficult hemostatic control.[2,18] Transulnar access (TUA) has been shown to be feasible and safe as a primary approach,[19] especially if the initial palpatory and ultrasonographic examination reveals a severely atherosclerotic narrowed or tortuous RA. Once a satisfactory puncture site has been selected, a subcutaneous anesthetic (5 mL) should be administered to avoid pain and the risk of spasm occurrence. In case of TRA the choice of single- or double-wall puncture technique is at operator's discretion, while in TUA we strongly suggest performing the single-wall technique with a strict US guidance to reduce postprocedural hematoma and/or other vascular complications. When puncturing the artery under US guidance, the vessel should be aligned with the centerline of the probe, inserting the needle with an angle of 30–45° (or less, especially for small arteries) and evidencing the tip (which appears as a hyperechoic dot) by briefly wiggling the needle (Figure 2, panel A and B). Once puncture is obtained, rotating the transducer 90° for longitudinal images can confirm proper vessel entry, particularly if off-center. This also ensures correct wire placement within the lumen and guides its advancement in cases of proximal tortuosity near the entry site (Figure 2, panel C).

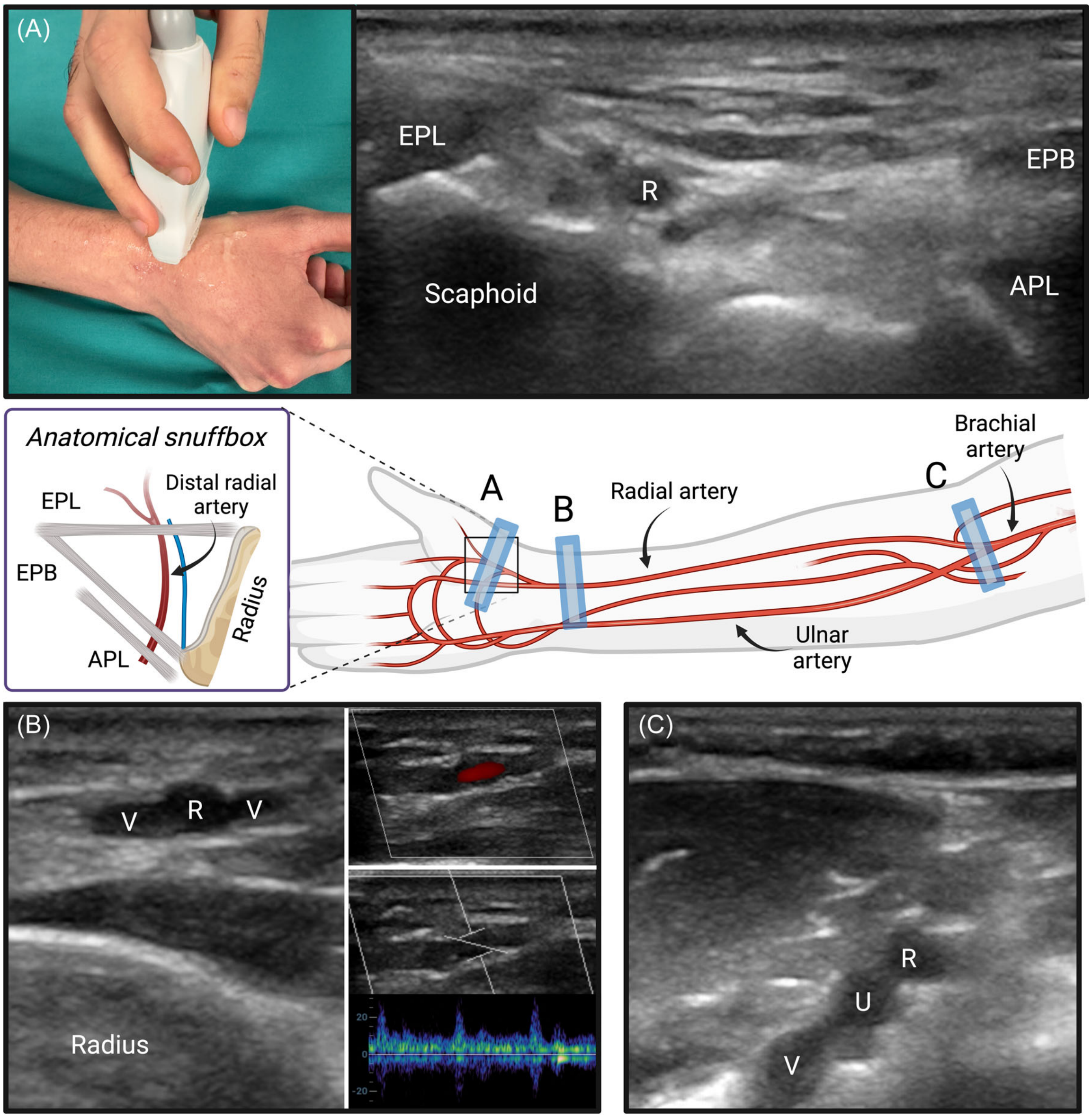

FIGURE 1 Ultrasound assessment of radial artery before arterial puncture. Radial artery (R) is imaged in the short-axis (or cross-sectional) view at the level of anatomical snuffbox (Panel A) and at the conventional site of puncture (Panel B). Discrimination between radial artery and veins (V) could be performed by compression or using Color/Pulsed Doppler (Panel B, white boxes). Once the radial and ulnar (U) arteries are identified, the entire course of the vessels should be scanned to highlight the presence of anatomic variants and/or acquired anomalies. This examination should trace their course as proximally as feasible, ideally until their origin from the brachial artery at the elbow level (Panel C). APL, abductor pollicis longus; EPB, extensor pollicis brevis; EPL, extensor pollicis longus; R, radial artery; U, ulnar artery; V, vein. [Color figure can be viewed at wileyonlinelibrary.com]

5 | SHEATH SELECTION

After a successful arterial puncture, the outer diameter of the hydrophilic-coated sheath should be smaller than the artery diameter (sheath-to-artery ratio <1). Indeed, the use of larger sheaths can lead to discomfort and vascular damage that favors the occurrence of RAS[20] and generates the prothrombotic milieu of RAO.[21,22] In some patients, such as females or those with a lower body mass index or smaller body surface area, the inner diameter of the radial artery could be smaller than the outer diameter of a 6 Fr sheath.[23] In such cases, downsizing to 5 or 4 Fr sheaths[24–26] or using slender introducers/sheathless techniques[27,28] may be appropriate (Figure 3). The recently developed Glidesheath Slender™ introducer (Terumo, Tokyo, Japan) has a thin-wall technology that enables a reduction in the outer diameter by 1 French size, while preserving a comparatively larger inner diameter. A sheathless guiding catheter system (Eaucath, Asahi Intecc, Aichi, Japan), that does not require an introducer, was developed to allow an increase in internal diameter, with a hydrophilic coating that covers the entire length

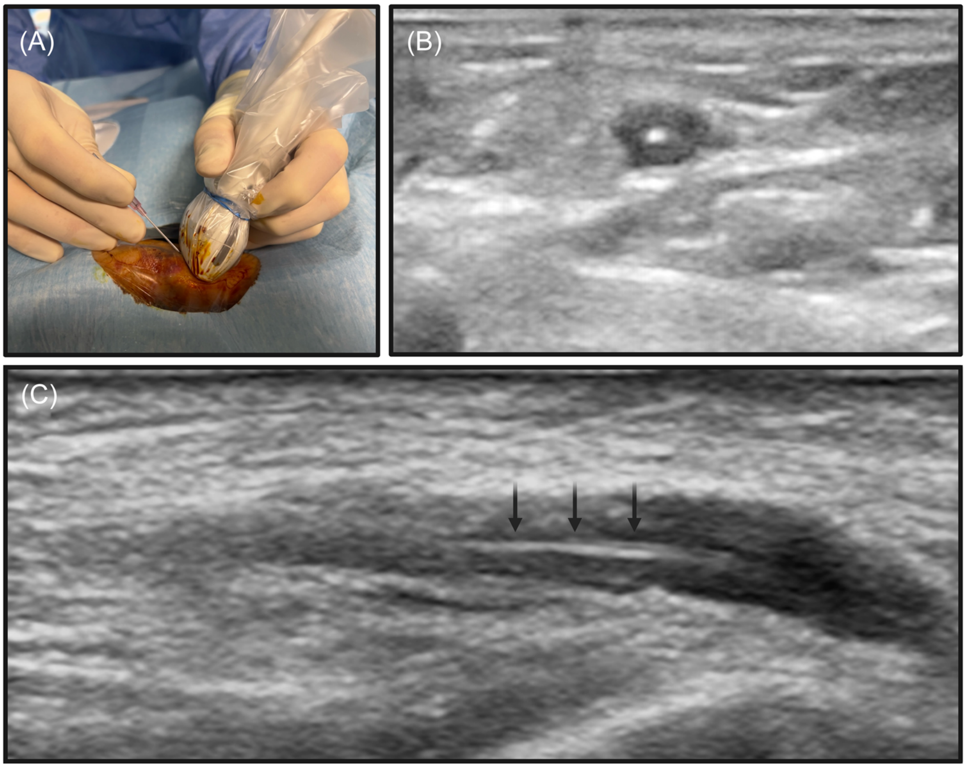

FIGURE 2 Ultrasound-guided transradial access technique. Axial position of the sterile draped ultrasound probe over the radial artery (Panel A). The needle is inserted just below the center of the probe when the artery is at the center of the screen. Visualization of the needle tip compressing and piercing the artery (Panel B). After the insertion, the wire is visible in a longitudinal view of the radial artery (black arrows, Panel C). [Color figure can be viewed at wileyonlinelibrary.com]

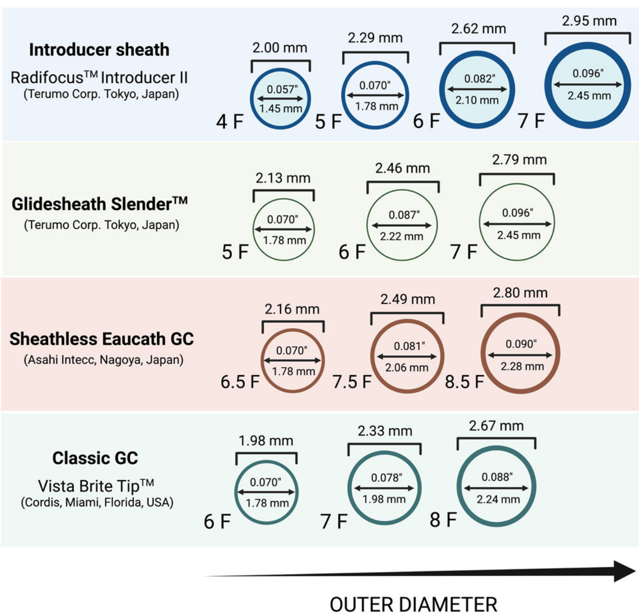

FIGURE 3 Inner and outer diameters of different device used in transradial procedures. Outer diameter is expressed in mm, inner diameter is expressed in mm and inches. GC, guide catheter; F, French. [Color figure can be viewed at wileyonlinelibrary.com]

of the device and reduces frictional forces.[29,30] This approach provides easier maneuverability through smaller, calcified, or tortuous vessels and minimizes the risk of radial artery trauma, thereby increasing procedural success rate and decreasing the likelihood of bleeding complications and RAO.[23–28,31] When performing coronary angiography with 4 or 5 Fr diagnostic catheters and anticipating a complex PCI that requires at least a 6 Fr guide catheter (GC) immediately afterward, the Railway Sheathless Access System™ (Cordis Cardinal Health, Santa Clara, CA, USA) may be a practical option. This device offers the flexibility to choose between two dilators that are compatible with either 0.021″ or 0.035″ guidewires, making it suitable for insertion into all currently available commercial 6- or 7-Fr GCs, essentially transforming them into sheathless GCs.[32,33] Once the device is prepared, the "dilator-in-wire" can be advanced either inside the conventional introducer or directly through the skin, providing access to the radial artery over the wire.[32] The safety and high success rate of this device has been previously demonstrated,[32,33] even in complex procedures performed via a distal radial approach.[34] In our experience, long sheaths (25 cm) are preferred to prevent difficult advancement of the catheters if spasm occurs during the procedure or in case of documented RA tortuosity and/or radio-ulnar loops. Short sheaths (16 cm) may be preferred when not multiple catheter exchanges are expected to be performed (e.g., during planned single vessel PCI).

6 | DISTAL RADIAL ACCESS

From an anatomical perspective, at the wrist the RA bends posterolaterally and crosses the scaphoid and trapezium in an area known as the anatomical snuffbox (Figure 1).[16,35,36] Puncture of the RA at this level (distal radial artery access, DRA) has been proposed as a possible alternative to conventional TRA[16,36,37] and has become increasingly popular since 2017, when Kiemeneij[38] published his first experience with left DRA (a setting associated with improvements in comfort for both the operator and the patient). To date, there is no conclusive evidence of the benefits of DRA in terms of reducing the incidence of RAO. Early studies found a lower RAO rate,[39,40] but on the other hand, the recent DISCO RADIAL trial[41] showed low RAO rates of both DRA and TRA without statistical significance by applying a rigorous patent hemostasis protocol. In addition, the DISCO RADIAL trial found no significant differences between the two groups in terms of overall bleeding events and vascular complications.[41] However, DRA was found to be associated with higher crossover but required a shorter time to achieve hemostasis.[41] US evaluation of the anatomical snuffbox is pivotal to discriminate between the distal radial artery and the surrounding structures (Figure 1, Panel A). DRA significantly benefits from US guidance, considering that blind puncture increases the risk of tendon injury, and the double-wall technique may irritate the underlying periosteum.[16] Furthermore, accessing the artery beyond the snuffbox heightens hematoma risk due to lack of bone support for hemostasis.[16] In addition, puncture of the vessel distal to the extensor pollicis tendon could inadvertently lead to access to a branch of the deep palmar arch.[16] Following the US assessment, achieving optimal positioning of the patient's arm is crucial for the success of the procedure.[35,36] Patients are instructed to either place their thumb under the other four fingers or hold a syringe or gauze roll. The choice of the sheath size should be based on the US assessment performed before the procedure. Although evidence regarding the size of the distal radial artery is limited, it is generally expected to have a smaller diameter compared to the wrist level.[16,36,37] Therefore, preferring a smaller diameter or slender introducer sheath is often a prudent initial choice.[35]

7 | RADIAL ARTERY SPASM (RAS)

The high vasoreactivity of the radial artery makes it susceptible to spasm (RAS) after local trauma, which is defined as a transient, sudden narrowing and constriction of the artery, occurring with an incidence from 4% to 20%.[42] It represents an important cause of patient discomfort and procedure failure because it can manifest during any procedural step, limiting puncture success, catheter manipulation, sheath removal and rarely leading to serious complications such as eversion atherectomy.[43] Risk factors for RAS are radial artery anomalies (i.e., high origin and tortuosity), small caliber, female gender, number of puncture attempts or catheters used, larger catheter size, long and difficult procedures with multiple catheter exchanges.[44]

7.1 | Tips and tricks

Adequate preprocedural analgesia has been shown to be helpful in reducing the risk of RAS,[45] in addition with strategies aimed at maximizing TRA with a single puncture.[46] Ultrasonography is useful to identify the best puncture site (especially if palpation reveals a small artery), to minimize arterial injury and to avoid repeated attempts. However, RAS cannot be completely ruled out, and if it occurs, it may hinder the success of TRA.[43] In the case of a severe RAS, some options may be applied, including puncture at a more proximal or distal site (only applicable in presence of local RAS) or the attempt to reverse it by administering exogenous vasodilators (systemic or local nitroglycerine or calcium channel blockers) and/or stimulating the release of endogenous vasodilators by manual compression of the ulnar artery or other maneuvers (e.g., forearm heating with the operator's palm, the Balbay maneuver).[43,46] After successful puncture of the radial artery, in case of any difficulty in advancing the standard 0.021"/.025" sheath guidewire, direct visualization of the artery is performed by careful angiography, injecting few millimeters of diluted contrast (to minimize or reduce patient discomfort) directly through the needle or the plastic cannula.[43] The radial angiogram should be performed in an anteroposterior (with additional rotation of the arm) or oblique view to separate the radial and ulnar bones and is essential to manage the possible encountered difficulties.[43] A standard workhorse 0.014" coronary guidewire, or preferentially, a more supportive and hydrophilic 0.014" wire (Choice PT Extra Support, Boston Scientific, Marlborough, MA, USA), may be used to cross the obstacle advancing its tip under road-mapping or fluoroscopic guidance (with caution to avoid arterial wall damage and/or perforation) proximally into the brachial or the subclavian artery to achieve sufficient support to allow at least partial placement of the hydrophilic-coated sheath[43] and subsequent intra-arterial vasodilators administration to completely resolve RAS.

8 | UPPER ARM ANATOMIC VARIATIONS

Historical post-mortem, angiographic and echographic classifications[47,48] of the upper arm arterial anatomy have some limitations, since they describe many variants not impacting the clinical practice (e.g., the anomalous course of radial and brachial arteries in relation to muscles and nerves) and exclude other situations that may affect TRA (e.g., tortuosity and atherosclerosis).[49] Based on these limitations, a simplified "operative" ABC classification[50] has been previously proposed, listing 10 possible angiographic variants of the radial-brachial axis, axillary-subclavian-anonymous axis, and the aortic arch (Figure 4). All these variants may be faced during TRA and are strictly associated with a significantly increased risk of access failure.[50,51] In a retrospective analysis of 610 patients,[52] RRA has been associated with a higher incidence of anatomic variants than LRA, and bilateral variants are encountered in <8% of patients, often of similar type and with symmetrical distribution.

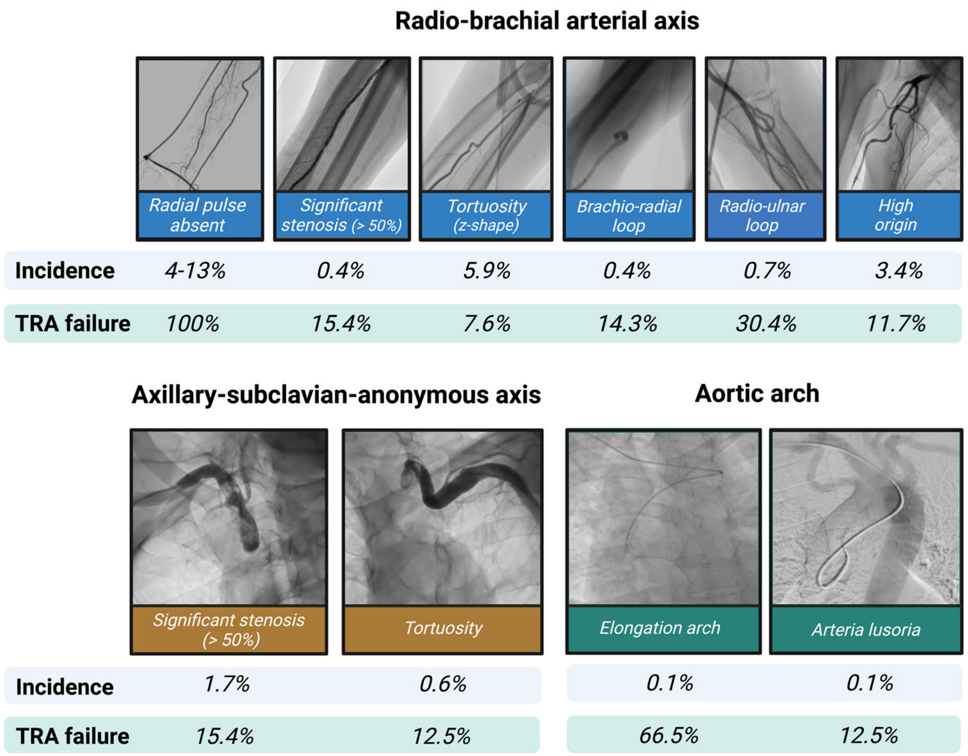

FIGURE 4 Upper limb vascular anomalies according to ABC classification. The incidence and impact on TRA failure are reported under each vascular anomaly.[50,51] TRA, transradial access. [Color figure can be viewed at wileyonlinelibrary.com]

9 | GROUP A: RADIO-BRACHIAL ARTERIAL AXIS

The main variants of the brachial-radial arterial axis are:

1. *Radial artery pulse absent*. The absence of RA pulse is classified as congenital[50] when there is a complete absence of the radial artery, supplied by the anterior interosseous or median artery (reported incidence <0.03%) or acquired (RAO), due to previous injury or atherosclerotic occlusive disease. RAO is the most common vascular complication of TRA, but rarely leads to serious clinical consequences because of the presence of a rich network of collateral circulation that provides a double blood supply to the hand. Because RAO is often undiagnosed, its true occurrence may be underestimated and, according to the current literature, it ranges between 1% and 10%.[53,54] RAO has been associated with several risk factors, such as baseline clinical (e.g., female sex, advanced age, diabetes, statin use, body weight, serum creatinine, and smoking) or procedural characteristics (high sheath-to-artery ratio, use or non-use of anticoagulants and/or vasodilators).[55] To reduce RAO, the SCAI Transradial Working Group and the Radialist Alliance Against RAO International Group recommend applying patent hemostasis in all patients undergoing TRA, usually through a hemostatic device.[56] Assessment and diagnosis of RAO, as previously described, is performed using a noninvasive test (the reverse Barbeau) together with a complete Doppler ultrasound assessment ("echo-first" approach) (Figure 5).
2. *Radial artery atherosclerosis*. The presence of a severely atherosclerotic and/or calcified radial artery (with a stenosis >50%) is rarely described,[48] with a high rate of TRA success (>85%), and in this setting the more frequent cause of TRA failure is due to the inability to insert the introducer sheath.[43]
3. *Anomalous, high origin of the radial artery*. Radial high origin is defined when the artery originates above the intercondylar line of the humerus, which represents the proximal border of the antecubital fossa[43,48] and it can be easily detected by US cross-sectional examination of the radial course to its origin from the brachial artery (Figure 6). Importantly, many of these anomalous vessels have small caliber and moderate to very tortuous anatomy and are more prone to develop a severe RAS.[43]
4. *Severe brachial and radial artery tortuosity*. Defined as the presence of a bend of more than 45° in the contour of the vessel, radial artery tortuosity has been reported with a mean incidence of 5.9% across different studies.[43,48] Brachial artery tortuosity is a rare anatomic variation, but it is easier to manage considering its large caliber.
5. *Radial and brachial artery loops*. Defined as a full 360° loop of the vessel, it may be located in the proximal radial artery below the brachial bifurcation or in the radioulnar anastomosis (radio-ulnar loop) (Figure 7). The presence of these anatomic variations is associated with the highest rate of TRA failure.[43,48,50,51,57] Complete loops of the brachial artery represent a very rare finding.[58]

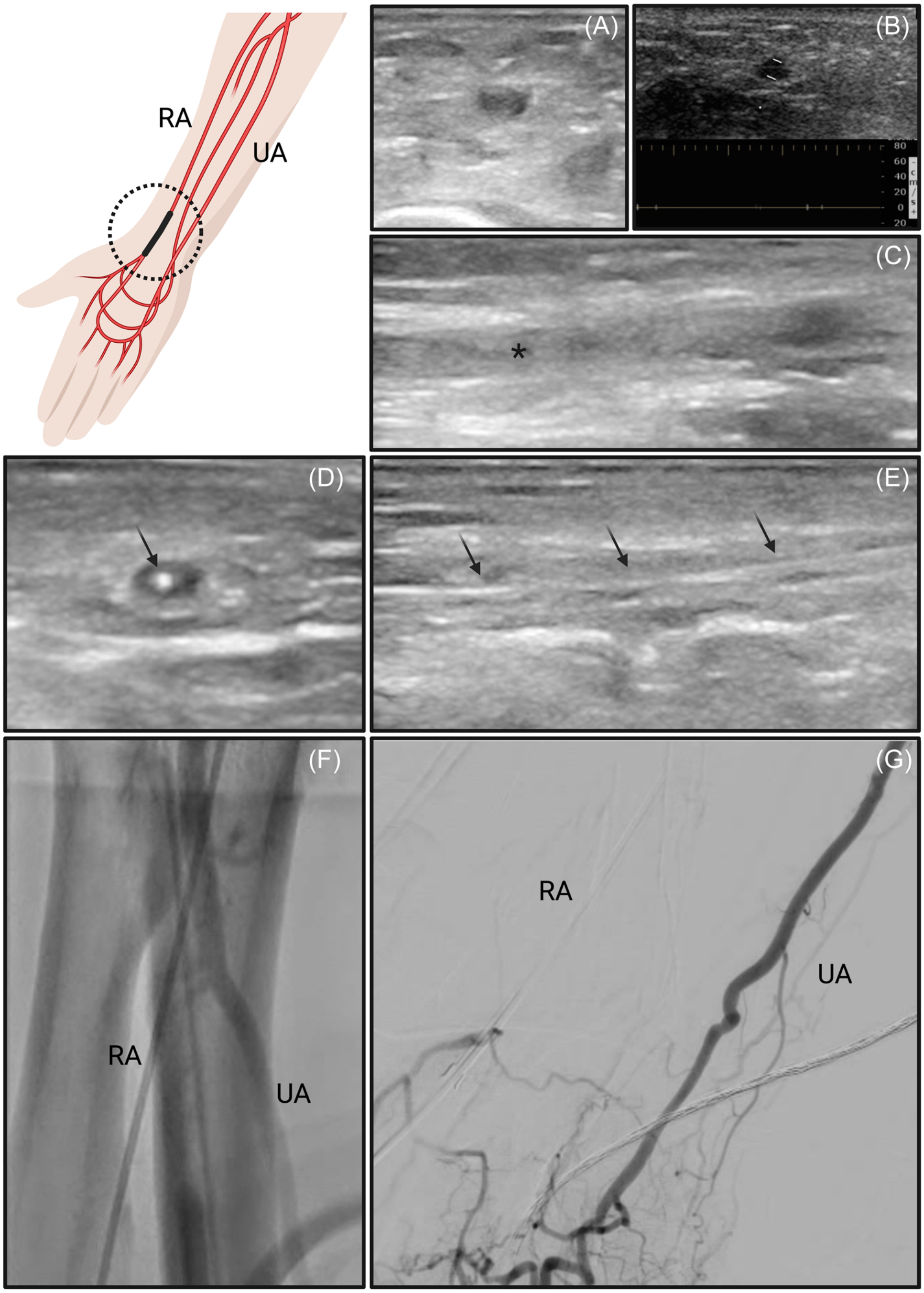

FIGURE 5 Ultrasound assessment of an apparently normal radial artery (panel A) showing a pattern consistent with occlusion at Pulsed Doppler examination (absence of pulsatile flow, panel B). Longitudinal echo assessment of radial artery showed hyperechogenic endoluminal material suggestive of thrombus (black asterisk, panel C). A successful attempt of recanalization was performed by inserting a 0.014" hydrophilic wire (Choice XS PT, Boston Scientific, MA, USA), visualized at cross-sectional (black arrow, panel D) and longitudinal (black arrows, panel E) views. Retrograde angiography performed by JR4 diagnostic catheter (panel F) and 6 F sheath (panel G) confirmed the occlusion of the radial artery. RA, radial artery; UA, ulnar artery. [Color figure can be viewed at wileyonlinelibrary.com]

9.1 | Tips and tricks

The previously described variants of the brachial-radial arterial axis can be easily diagnosed through a complete US assessment of both upper arms before the procedure, to select the best vascular access and, if possible, avoid their management. Anyhow, if any difficulty in advancing the wire is encountered, a retrograde angiography can be easily performed after the sheath has been inserted at least a few centimeters into the radial artery.[43] Blind advancement against the resistance of the wire can lead to painful arterial spasm, dissection or perforation and should be avoided. After arterial angiogram, once the anatomy of the arm is known, the appropriate strategy can be chosen

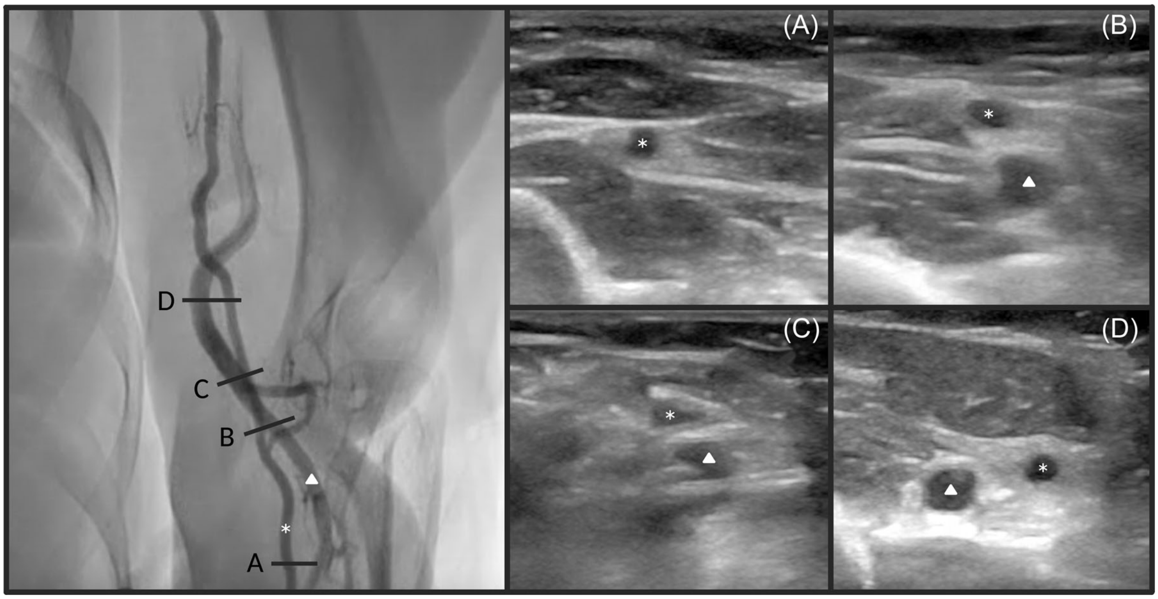

FIGURE 6 A retrograde radial angiography from partially inserted hydrophilic 6 F sheath showing a high origin radial artery (Left panel). Echo images show the relationship between the radial artery (white asterisk) and the brachial artery (white triangle) at different levels along the forearm (Panels A–D).

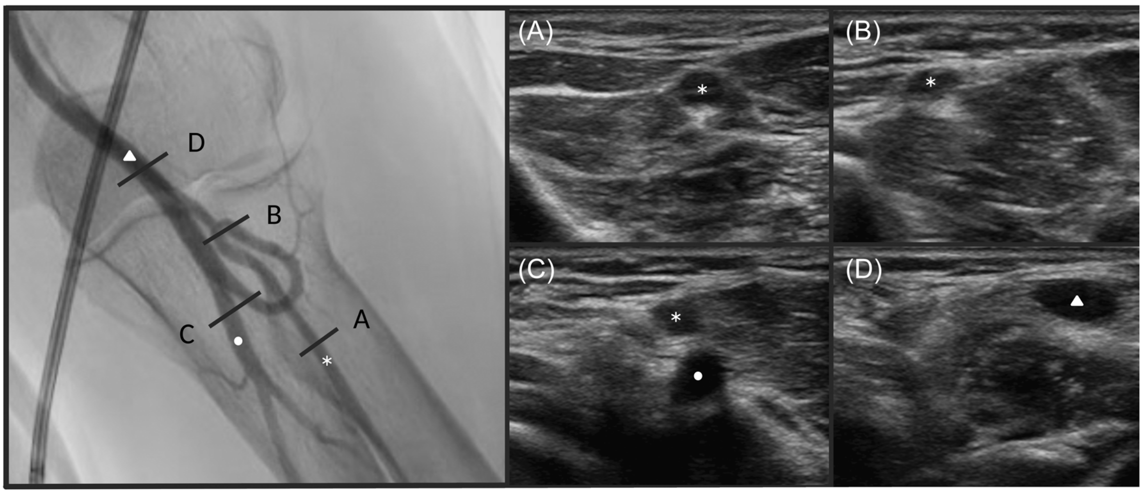

FIGURE 7 Retrograde radial angiography from a partially inserted hydrophilic 6 F sheath showing a radial loop in the distal portion of the vessel (Left panel). Echo images show the course of the radial artery (white asterisk), the ulnar artery (white circle) and the brachial artery (white triangle) at different levels along the forearm (Panels A–D).

to overcome the specific obstacle. A hydrophilic 0.035" wire can be advanced under road-mapping guidance, sometimes with the aid of a support catheter (usually 5 or 6 F Judkins Right 4 [JR4]). In rare cases (small arteries, severe angulation), a 0.014" coronary guidewire (Choice PT Extra Support, Boston Scientific, Marlborough, MA, USA) may be used, considering that its hydrophilic tip allows an easy navigation through tortuosity and its rigid shaft provides good support for advancing the sheath and/or the diagnostic catheter (preferentially a JR4 4 F). Radial and brachial loops probably represent the most difficult anatomic conditions to manage. The loop should be crossed first with a 0.035" or 0.014" wire followed by advancement of a diagnostic catheter and then straightened (using the stiffer shaft of the wire inside the support catheter). In some cases, however, catheter guidance within the loop is limited by a high acute angle which results from the sharp tip of diagnostic or guiding catheters on the arterial wall (the "razor" effect). "Balloon assisted tracking" (BAT) technique could be used when facing these complex anatomies, by inflating a small-caliber balloon to smooth the transition between the catheter and guidewire.[59] However, there are some cases where straightening of the loop is not possible or is associated with unbearable arm pain, so that a crossover is necessary. Loops of the brachial artery are uncommon and associated with a minor failure rate (due to the larger caliber of the vessel). However, because brachial artery injury can lead to upper limb ischemia, crucial attention should be paid at all stages of loop negotiation. In case of RAO, when access to the contralateral radial artery cannot be used (e.g., anatomic anomalies, artery line in use for invasive monitoring, arterio-venous fistula in dialysis patients), there are two types of approaches to avoid an unnecessary TFA: arterial puncture proximal to the occlusion (when feasible according to safe arterial compression) or recanalization with hydrophilic (and possibly tapered) workhorse or CTO guidewires (Figure 5) followed by prolonged small diameter (up to 2 mm) balloon dilation.

10 | ANATOMICAL VARIATIONS OF THE AXILLARY-SUBCLAVIAN-ANONYMOUS ARTERIAL AXIS AND OF THE AORTIC ARCH

The large number of previously described anatomical variants of the aortic arch branching pattern are usually asymptomatic and discovered incidentally during radiological exams performed for other reasons. Determination of some branching variants of the aortic arch by conventional catheter angiography, a two-dimensional imaging modality, can be difficult because of the superimposition of other major branches.[60] However, angiographic assessment, performed in multiple C-arm projections, is able to identify the most common anatomical variants and to prevent complications and failures associated with TRA.

11 | GROUP B—AXILLARY-SUBCLAVIAN-INNOMINATE AXIS VARIANTS

Variations in the axillary-subclavian-anonymous arterial axis can be characterized by varying degrees of vascular tortuosity (defined as a curvature >90° in the contour of the vessel, which may be either congenital or acquired) and loops or could be the site of atherosclerotic plaques causing significant stenosis and limiting catheter manipulation.[43]

12 | GROUP C—AORTIC ARCH VARIANTS

The aortic arch is characterized by many anatomic variations, and it can also be altered by ageing, arterial hypertension, atherosclerosis, and connective-tissue disorders.[43] Nevertheless, only some uncommon conformations of the aortic arch, such as aberrant right subclavian artery and the aortic arch elongation, are associated with a high TRA failure rate.[51] The ***aberrant right subclavian artery*** (ARSA or arteria lusoria) is defined as the right subclavian artery arising from the aorta as the fourth branch (Figure 8), distal to the left subclavian artery, instead of joining the right common carotid into the brachiocephalic artery.[43] After the origin from the aortic arch, it hooks back to reach the right side with a variable relation to the esophagus: posterior in the 80% of cases (retro-esophageal right subclavian artery, RORSA), between the esophagus and the trachea (15%) or anterior to the trachea (5%).[61] An

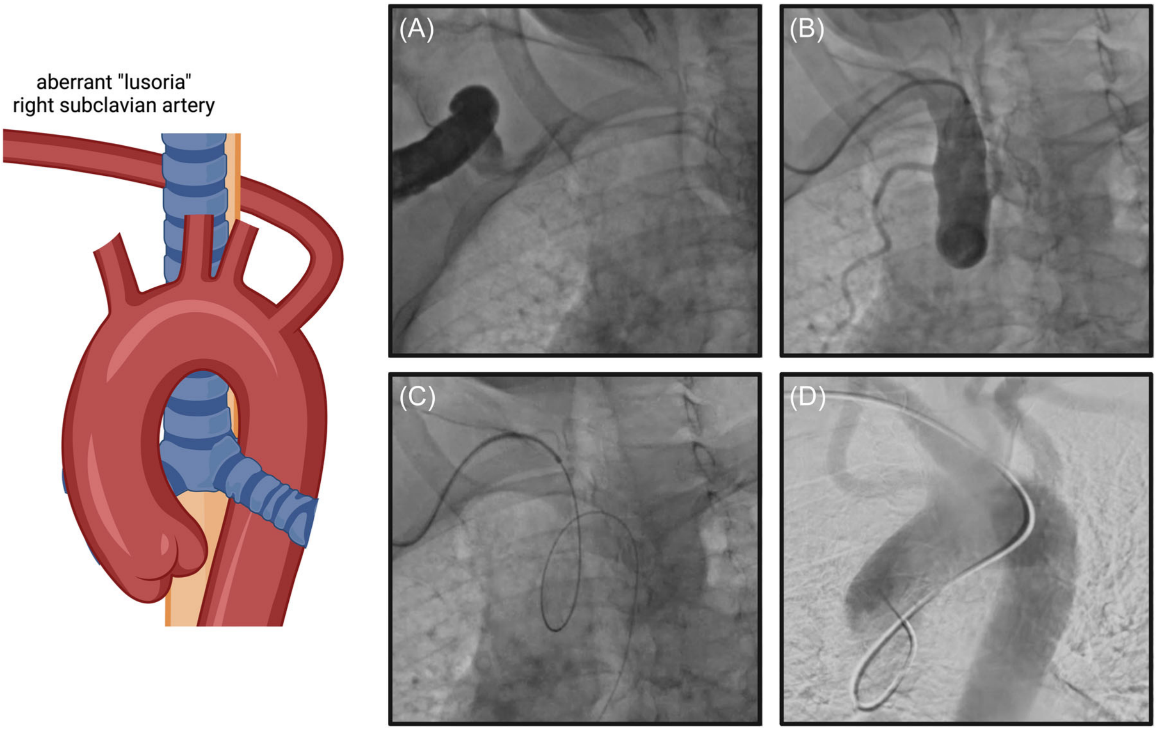

FIGURE 8 Retrograde angiography from a 6 F JR4 diagnostic catheter showing severe tortuosity of subclavian-anonymous arterial axis (Panel A and B). The diagnostic catheter is used to facilitate the advancement of a 0.035" hydrophilic wire (Panel C) which advances through the vessel. An angiography (Panel D) shows the presence of an aberrant right subclavian artery or arteria "lusoria." [Color figure can be viewed at wileyonlinelibrary.com]

elongated transverse aortic arch is characterized by the left subclavian artery originating posterior to the trachea with a greater distance between the origin of the left main carotid artery and the left subclavian artery. This implicates a convex kinking in the lesser curvature and flattening of the transverse aortic arch. It is reported to be associated with a TRA failure rate of 66%.[51]

12.1 | Tips and tricks

In most cases, tortuosities and parietal irregularities are not a major obstacle to the advancement of wires and catheters in the ascending aorta and usually a deep inspiration is sufficient to cross them. However, every time there is a difficult advancement of the standard 0.035" wire, we recommend performing an angiography with the catheter placed in the proximity of the potential obstacle. When a severe tortuosity is recognized, a diagnostic catheter may be used to support the advancement of a hydrophilic 0.035" wire (Glidewire, Terumo, Tokyo, Japan) which usually easily navigates through the bends to reach the aorta, making possible the straightening of the vessel once the diagnostic catheter is advanced (Figure 8 and Figure 9). A complementary action could be the use of the road-mapping tool to precisely visualize the wire while advancing through the tortuosity.[43] If these tricks are not sufficient, especially when a moderate-to-severe stenosis is encountered, a sheathless guiding catheter (GC) system may be helpful. As previously described,[27–30] the sheathless GC has a hydrophilic coating on its entire length and a central dilator that allows easy insertion into small and/or spastic radial arteries, but these physical properties make him suitable in dealing with upper limb anomalies too. The sheathless GC and central dilator should be advanced over a 0.035" guidewire into the ascending aorta. The central dilator and the 0.035" guidewire must be subsequently withdrawn a few centimeters from the ostium to allow safe intubation of the coronary artery (due to its stiffness, operator must be extremely careful not to bring the central dilator close to the aortic valve). It has been reported that the use of the sheathless GC to navigate vascular anomalies of the upper arm is associated with a higher procedural success rate, in comparison with the use of a conventional catheter.[29] Once the catheter has reached the ascending aorta, it is sometimes useful to leave the 0.035" guidewire inside the catheter to maximize catheter manipulations and to prevent its kinking. When the tortuosity requires the 0.035" guidewire support to increase the stability of the catheter to fulfill coronary intubation, it is advisable to advance into the target vessel a 0.014" guidewire, and additional "buddy wires" if needed, before removing the angiographic wire. All these tricks extremely increase system backup and can effectively facilitate coronary cannulation and overall procedural success in case of challenging catheter manipulation.[43]

13 | CONCLUSIONS

The progressively increasing success rate that can be achieved during the learning curve of TRA is not only related to technical improvement of radial artery puncture, but also to the avoidance of possible procedural complications, knowledge of the possible anatomical obstacles and the appropriate techniques to

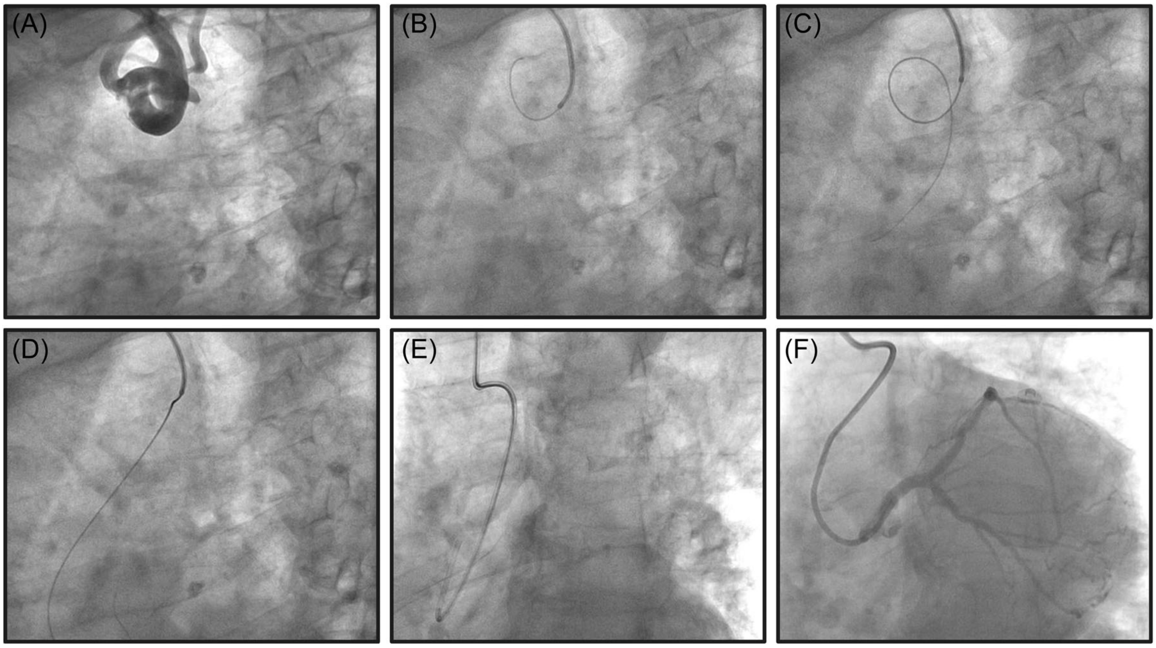

FIGURE 9 Retrograde angiography from a 6 F JR4 diagnostic catheter showing severe tortuosity of subclavian-anonymous arterial axis (Panel A). The diagnostic catheter is used to facilitate the advancement of a 0.035" hydrophilic wire (Panel B and C) which straighten the vessel with its stiffer shaft (Panel D). In such cases, wire could help rotation of the catheter in case of resistance to avoid kinking (Panel E) and to obtain coronary cannulation (Panel F).

overcome them. Herein we propose a step-by-step technical approach based on prevention of procedural issues ("echo-first" approach), prompt problem detection by retrograde arterial angiography, and application of a series of tailored maneuvers useful to overcome the anatomic obstacles hindering successful TRA coronary procedures.

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DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no data sets were generated or analyzed during the current study.

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