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Minimally Invasive Cardiology for Everyone: Challenging the Transradial Access

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Abstract

Transradial access is now well established as the safest route for percutaneous coronary intervention. Nevertheless, its use is often restricted to "easy" cases, switch to the transfemoral route being too rapidly advocated/mandated. We will discuss the different challenges associated with a "TRA for everybody" strategy. (1) The vascular access per se is challenging. TRA failure is most of the time an operator failure to cannulate this vessel. There are some ways to overcome the technical problems and to improve the operator skill and his success rate. (2) TRA is systematically denied for some patient populations: patients with previous coronary artery bypass graft surgery are particularly at risk of not being catheterized by TRA despite excellent performance of this route for diagnostic or intervention. In the same way, MI patients in unstable condition are also at risk to be catheterized by TFA although, most of the time, their condition is addressable through TRA and will largely benefit from this route. (3) Frailty and small body-sized ill patients are also at risk of TFA for PCI when proximal coronary artery disease must be treated. There are alternatives to the use of large and very large catheters for treatment of proximal coronary artery disease. (4) The radial occlusion is a manageable problem, with simple and effective solutions.

Keywords: transradial access, coronary angiography and percutaneous coronary interventions

1. Introduction

Transradial access (TRA) is now well established as the safest route for percutaneous coronary intervention (PCI) and must be attempted at first whenever possible. In real world, too many cases today are still performed though transfemoral access (TFA). In a case-to-case

confrontation, "believers" in the radial way [1] would easily refute common arguments still actually developed by TFA proponents to skip the TRA attempt (or to dash the attempt off): planned intervention better managed/proceeded through femoral access (angiography for a patient with previous coronary artery bypass graft (CABG) surgery being a frequent one), planned interventions requiring large materials/catheters, anticipated lack of support during intervention (a true but often hidden fear for several operators), poor/small/not palpable radial artery, previous attempt failure(s), lack of time ("urgency"), "fast" intervention required for a frailty patient, negative Allen test (it is the most hilarious reason for a radial believer), and finally a failed but often too short attempt.

What is the truth in the background of this resistance? The truth is TRA is not and will never be an easy way to perform cardiac catheterization, the learning curve is long (and never ends), and TRA requires from the operator a true personal investment. Hopefully—and it has to be written somewhere—the return on investments in the TRA technique is large, and succeeding in a difficult case is usually even more gratifying for the physician and his patient when the procedure involved only TRA.

"TRA for everybody" is a personal crusade, and it lets the author to succeed a "non-femoral" vascular route for 1019 of his last 1023 procedures (from mid-March 2017 to mid-November 2018). The 1023 procedures included primary PCI for 152 ST elevation myocardial infarct (STEMI) patients—femoral access for 2 of them—coronary angiography (and ad hoc PCI when requested) for 108 post-CABG patients, and a total of 568 PCI were performed (73% with 5 Fr guide catheters).

Common challenges associated with a "TRA for everybody" strategy and possible solutions must be considered. Subjects being discussed will be:

1. The vascular access.

2. Some patient populations "at risk" to be catheterized by TFA:
   • The CABG population.
   • Myocardial infarct (MI) patients in unstable condition.
   • Frailty and small body-sized ill patients.

3. The radial artery occlusion problem.

2. Access to the radial artery: the vascular access

Cannulation failure, which is the main cause of TRA failure, is disgracefully received by the majority of interventional cardiologists and stays subsequently hidden. And yet it is not a shame to fail the radial artery cannulation: it is a difficult task and so for many reasons. First, the artery is usually small-sized, its diameter being around 2–3 mm [2] depending of the individual body height as demonstrated in one recent study [3]. The arterial wall may be difficult

to go through; the vessel may flee away the tip of the needle or may simply "disappear" when a so frequently—and wrongly—invoked "spasm" occurs after a first unsuccessful stick (see discussion below). Although permeable and functional, a radial artery may be unpalpable due to a thick arterial wall or a low flow state. As any other arterial bed, the radial artery is not spared by the inverse remodeling process associated with diabetes, arteritis, and aging. Finally, the patient may be hypotensive with a more difficult vascular access.

So, the first step to optimize the TRA success rate and therefore "TRA for everybody" is investing in solving the problem of the puncture/cannulation of the radial artery.

Data clarifying the causes of TRA failure will now be presented, and secondly, some clues helping in the problem's resolution will be explored.

3. TRA failure's causes

A prospective study about the TRA, conducted by two TRA "believers" and with two major objectives in mind, started in 2015 [4]: firstly, defining the rate of conversion to transfemoral access when the operator must first attempt (and fail) both radial arteries before converting to transfemoral and secondly, the study was designed to record daily and on a case-by-case basis the causes/location of radial artery attempt failure and to define their relative occurrences. The protocol also required grading (1) the ease for cannulation (before catheterization, as assessed at the bedside), (2) the real ease for the attempt, and (3) the ease for the catheterization itself (catheter manipulation).

By protocol, every single consecutive left heart cardiac catheterization, diagnostic or interventional, elective or urgent, has to be first attempted by TRA (right or left or both). Only non-palpable radial artery (on both sides) or abnormal Allen test (Barbeau type D on both sides) and patient refusal were excluded. Let us say immediately that the two operators never encountered a patient with a Barbeau type D present on both sides and that non-palpable radial artery may be permeable and functional as easily assessed with a Doppler probe. Thus, basically, no patient was excluded from the study for such reasons: "TRA for everybody" is feasible at the level of the initial assessment for an arterial access.

As designed by the protocol, all sorts of patient populations were attempted by radial artery, including post-CABG surgery patients, even patients grafted with both left and right internal mammary artery. Some local surgeons also used the gastroepiploïc artery as graft (and not as free graft). Such patients were also included.

Even shock patients were included in the study.

From January 2005 to June 2007, both operators successively and prospectively proceeded to catheterize 1826 patients, starting from right or left TRA, at the operator discretion. PCI accounted for 40% of the procedures. The study was published as an original contribution in the Journal of Invasive Cardiology in September 2010 [4].

The first and major contribution of the study was to offer strong data for the cornerstone of an effective politic of "TRA for everybody": to have to attempt both radial arteries before converting to a femoral access. The study succeeded in offering a "TRA only" procedure for 98.8% of the study population (**Figure 1**). This high success rate was obtained after attempting the second radial artery for the 6.2% missed first radial artery, 4.4% when excluding the patients with previous CABG surgery. Attempting the second radial artery was successful in about 80% of the cases.

As illustrated in **Figure 1**, the study did not identify a special population who will not benefit from TRA. It also dismisses some apprehensions regarding TRA: rate of truly difficult cannulation was half less than anticipated, and difficult catheterizations were 50% less frequent than anticipated (and this rate stays stable at 6%), **Figure 2**.

Multivariate analysis (GEE, RMGEE program, K.Y. Liang and S.I. Zeger, Longitudinal data analysis using generalized linear models, Biometrika 73, 1986) strongly proved the learning curve existence and identified some of the major factors playing in the TRA world, namely, the artery size and a diffusely diseased arterial bed (peripheral artery disease). Four predictive variables for a first radial attempt failure emerged in the study:

- Year of the procedure, variable related to the learning curve, and operators getting better and better with time, OR 0.6, 95% C.I. 0.4–0.8, $p < 0.001$.

- Presence of peripheral artery disease, OR 1.8, 95% CI 1.1–2.8, p 0.016.

- Pre-procedure clinical evaluation for a difficult access, OR 2.5, 95% C.I. 1.3–4.9, p 0.006.

- Small radial artery size as assessed clinically before catheterization, OR 2.6, 95% C.I. 1.4–5.0, p 0.003.

The second major contribution was to reveal that the main cause of TRA failure was not at all related to difficult anatomies as commonly reported and taught (**Figure 3**). At the start of a TRA business, the radial artery cannulation is accounting for about 75% as the main cause to fail. It accounts for 90% of attempt failures when operator had gained more experience. There are several ways to fail an artery cannulation, reflecting the three steps involved: (1) the puncture itself, (2) wiring the needle or the plastic cannula when they sit in the lumen vessel, and (3) after needle/cannula removal, pushing the sheath over the wire.

When analyzing the three different steps, the far most prevalent problem arises at the wiring step: operator reaches the lumen artery, usually with a good blood's backflow, but he cannot forward the wire. Identifying this problem lets to develop better strategies and material (see below).

Thereafter 2007, enrollment in the study protocol was extended, allowing the creation of a large radial access database. With time and experience, more expertise arose [5], and looking at the same data in 2010, failures related to anatomical consideration were actually avoided: failure to cannulate the artery emerged as the cause for 92% of failed attempts (again mainly because of the wiring problem). Crossover to femoral access declined to 0.9% (2010) and is now 0.4% (2017–2018).
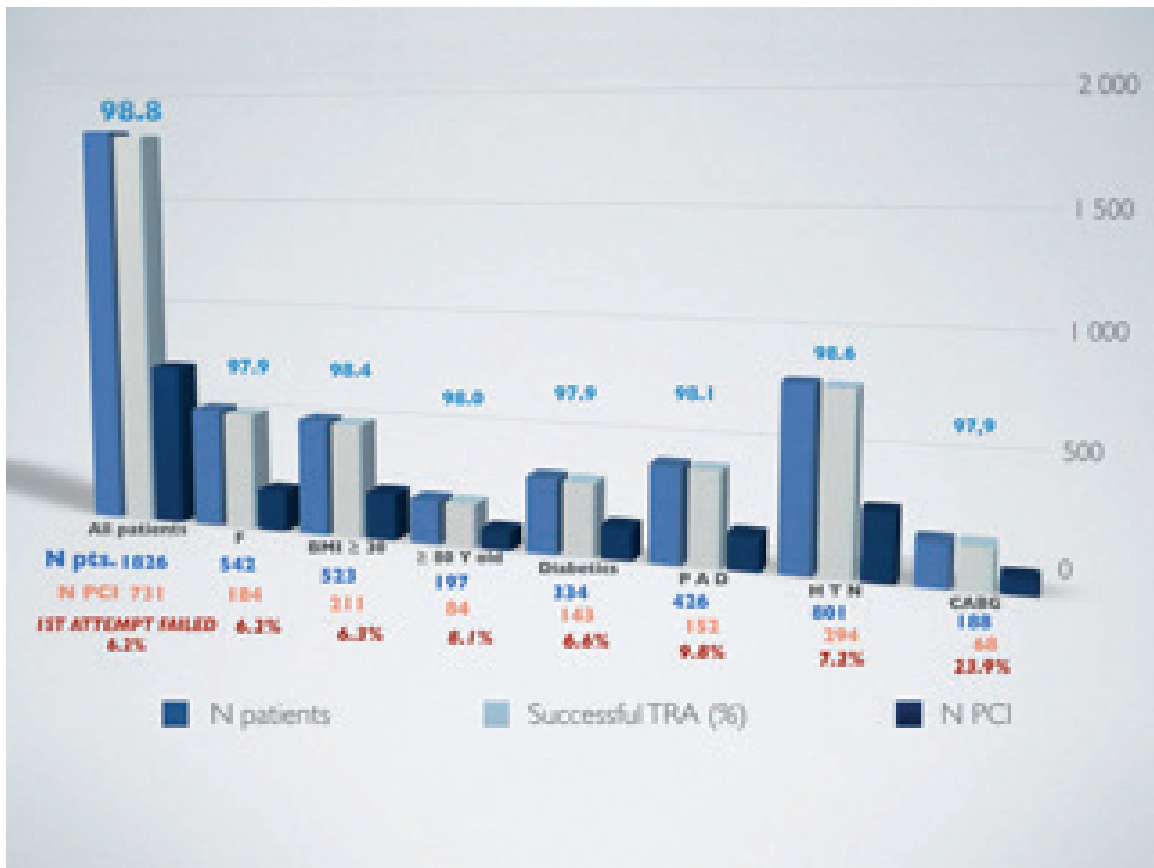
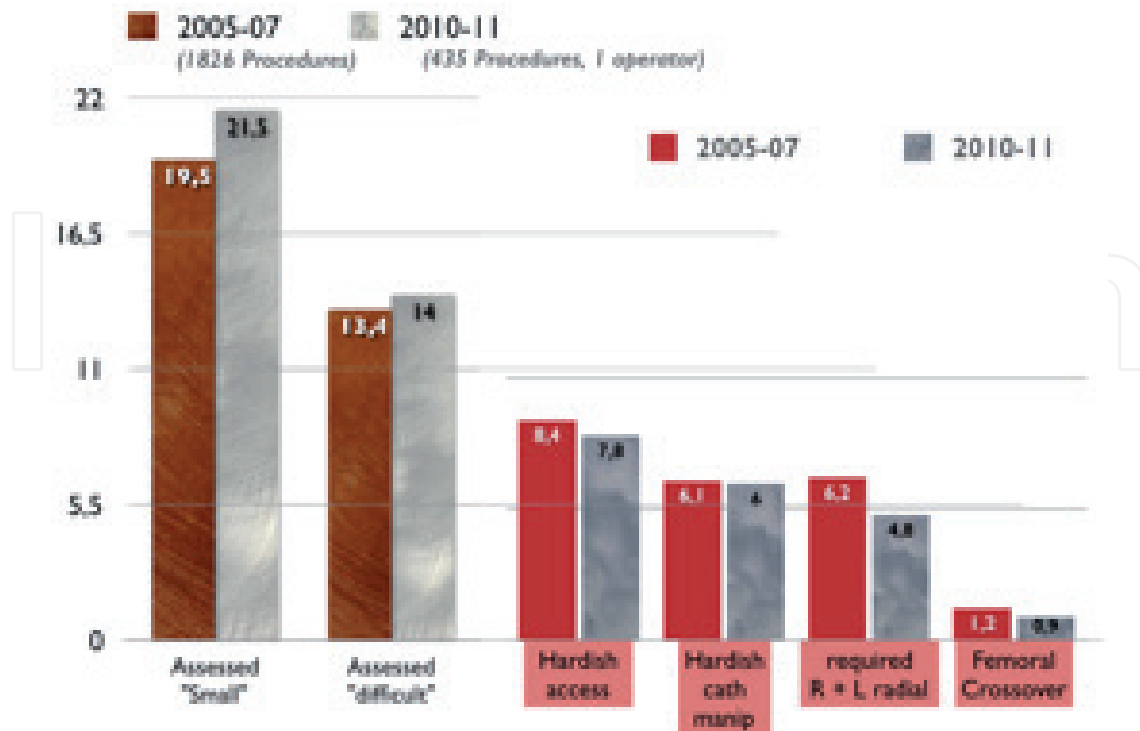**Figure 1.** TRA success rate for 1826 consecutive procedures.

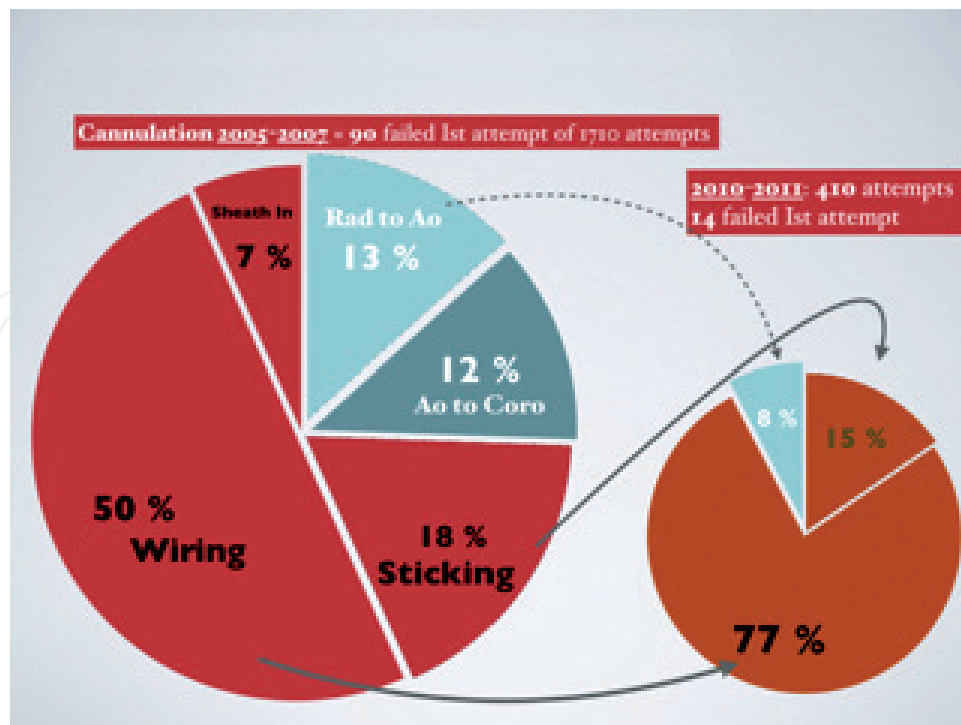**Figure 2.** TRA: Real versus anticipated difficulties.

Figure 3. Causes of TRA failure at first attempt.

4. What are the proposed solutions for improving the success rate of radial artery cannulation?

4.1. Utilizing the best techniques and materials for puncturing

Let us talk about sticking the artery, first. Two techniques for radial artery cannulation are at works in the cardiac catheterization world and both gets around 50% of the actual "market."

The first one is derived from the femoral world and is the Seldinger technique. It uses a bore metal needle (usually a 21 Gauge) wired with a short metallic 0.021" straight or J wire. Its advantage is a sharper bevel, more able to penetrate a stiff arterial wall and a better echo-genicity when puncturing with ultrasound guidance. Using the needle with a small body length is recommended: backflow at the hub, signing the puncture success, will happen quicker with a short needle like the Cook® needle 3.5 cm 21 G.

There is a major drawback with the bore metal needle technique: when the standard wire does not progress (either at the needle's entry in the vessel or further away within the artery), the choice for an alternative wire is limited, and particularly all kind of hydrophilic or angio-plasty wires may not be used (possible "peeling" of the coating). When you know that more than 75% of artery cannulation is missed because of the wiring problem, it is annoying to lose this possibility.

The second method is derived from the nursing world: it uses an over-the-needle cannula system (needles designed for puncturing veins and intravenous cannula insertion). Insertion

of the small cannula within the first mm of the radial artery greatly facilitates the radial wiring and subsequent sheath insertion. Exchange for any hydrophilic or coronary dedicated angioplasty wires is possible and may help and saves many attempts failing with standard wires. The technique is in the author's mind more successful addressing radial arteries of small diameter. Using a 22 gauge system, the vessel injury at the tip of the needle is minimal and allows a through-and-through puncture. The technique is easy to standardize and thus to teach: beginners are instructed to push more deeply the over-the-needle cannula system once the needle reaches the artery lumen (backflow at the hub): doing so, the bevel of the needle is now lying beyond the arterial's posterior wall. Keeping firmly the cannula in place, the metallic part of the system is removed. Then the plastic cannula is gently and mm per mm withdrawn until the blood flows again: the cannula is now perfectly lying in the arterial lumen, and wiring is easier (with the standard or optional wires). For wiring attempts, it is easier to secure in position a plastic cannula than a bore metallic needle. The drawback of the technique is quite minimal: the bevel of the needle is usually not well sharpened for crossing an arterial wall (stiffer and thicker than a venous one); the echogenicity is less than the bore metallic needle (smaller size); some plastics are not well supportive for the standard metallic wire when it has to enter the arterial lumen (all brands of intravenous cannula are not equivalent for that purpose).

Investing in the over-the-needle cannula system, a needle dedicated for the radial access was designed, several prototypes were successfully tested, and the needle is now patented in the USA and Japan and patent pending in the EU [6, 7]. The invention lies in a small distal aperture near the metallic needle tip combined with at least one reinforcing shoulder at the inner surface of the overlying plastic cannula: the system allows a very fast visualization of the tip needle entering the vessel lumen, faster than when you have to wait until the blood flow reaches the more distant needle hub: with the invention, the operator sees first the blood entering the needle's body and then reaching the hub. This feature helps for the first step of sticking the vessel, shortens the cannulation time, and enhances the success rate (no need to re-puncture, less chance to have "spasm" after a first unsuccessful stick). The needle is waiting investors/manufacturers to get in production.

So, the first recommendation for resolution of the cannulation problem is to invest in the over-the-needle cannula technique for puncturing, giving attention to the choice of the puncture material and to the alternative wires.

4.2. Ultrasound-guided puncture

The radial artery is a quite superficial structure easily assessed by ultrasound. The technique requires only a small-sized probe, and setup is easy and fast: puncturing while viewing the artery is obviously easier, and in the most recent author's practice, its use allowed to succeed when blinded attempt had failed. Since its introduction in January 2018 as a bailout technique, and for 439 consecutive procedures, the ultrasound-guided puncture accounted for 43 patients. The visualization of an artery just attempted blindly offered the explanation for the probably most frequent mechanism in play when reattempting unsuccessfully to re-puncture or rewire the vessel: hematoma arising around and within the wall of the vessel, reducing

further its lumen (and the pulse). So the "spasm" frequently invoked is in reality hematoma compression/expansion: it explains why the artery is no more palpable and more difficult to re-stick. Furthermore, the ultrasound guidance lets the operator decides to stick at another position or to skip to the ulnar or the contralateral radial/ulnar artery. The ultrasound-guided puncture allows the operator to stick more successfully the artery, but it does not resolve the problem of wiring.

Since many years, as soon as a Doppler signaled the presence of an arterial flow, cannulation of unpalpable radial arteries was attempted. With the ultrasound guidance, it is now far easier to perform this task (and to confirm that the operator may attempt the cannulation, the views allowing the diagnosis of an occluded artery). With the help of ultrasound, the operator may also decide to attempt a less disease or a larger vessel (ulnar or contralateral).

Clearly, the use of ultrasound-guided puncture has a major role to play in a modern strategy of "transradial (or transulnar) access for everybody," and it is the second recommendation for solving the cannulation problem.

4.3. Utilizing all individual resources of the nursing/technologist permanent cath lab staff

You may be an excellent PCI operator and be quite "ordinary" regarding the puncture task (and some hate this fundamental step). On another hand, in every catheterization laboratory, there are individuals very efficient for sticking vessels, and there are individuals well trained for surface ultrasound. A few years ago, nurses interested in the cannulation task were trained for radial artery puncture. The over-the-needle cannula technique was taught, nurses being well customized with this kind of needle and technique. The fundamental difference between their usual way of working with an over-the-needle cannula and for intravenous cannulation is that they absolutely need to go through and through the vessel for a successful radial artery cannulation. They also have to learn the use of the different wires at (good) works. Recently, the same teaching program was successfully offered to technicians in radiology working in the catheterization laboratory: it provided the advantage of adding peoples trained for ultrasound techniques. Actually, the trained nurses and technologists perform 70% of the author's artery cannulations without any undesired crossover to a femoral access.

So, the next recommendation is to train willing and well-skilled nurses and technologists to perform the cannulation task.

4.4. Using forearm artery alternatives (the ulnar artery or the left distal radial artery)

The ulnar artery has been shown to be a safe alternative route for left heart catheterization [8]. It is anyway a safer route than the femoral access and is sometimes larger than the radial artery. It seats deeper and a sensitive nerve is present along the vessel at the puncture level. Hemostasis is easily performed with the material dedicated for the radial artery compression. So, when a radial attempt fails, the ulnar artery cannulation may be a good alternative even at the same wrist. Of course, ultrasound-guided puncture is also an excellent way to optimize the success cannulation rate. Left distal radial TRA is actually in evaluation as a possible

way to further improve operator and mainly patient comfort and safety, at least when starting from the left hand. Large series looking at the ease and effectiveness of the hemostasis together with vessel patency and avoidance of ischemic/sensitive problems are mandatory.

The last recommendation will be to become familiar with ulnar artery cannulation, and ultrasound-guided puncture should be a must.

5. Some patient populations "at risk" to be catheterized by TFA

5.1. The population with previous CABG surgery

Patients with previous CABG surgery are difficult to angiography by comparison with non-CABG surgery patients. They are older and have advanced coronary artery disease for many years. Peripheral artery disease and other comorbid conditions such as some degree of chronic kidney failure and chronic obstructive pulmonary disease are frequently found. Graft assessment is an additional task after coronary angiogram and may be tricky due to nonstandard vein graft's ostial location and unavailable dedicated efficient pre-shaped catheters. Arterial grafts are also uneasy to reach: both mammary arteries are originating at a sharp angle from their subclavicular arteries that are to be engaged: the right subclavicular artery may particularly be tricky to reach, except when starting from the right upper extremity. Finally, the gastroepiploic artery, a branch of the coeliac trunk artery, used by some surgeons to graft the right posterior descending artery, may also be difficult to adequately angiography. The additional task of graft angiography and the higher-risk profile of these patients let to more catheters use, more manipulations, and therefore a greater risk of neurological complications [9].

Due to the anticipated complexity of this procedure and concerns about possible greater X-ray exposition, TRA—and its associated clinical benefits—is often denied to this population.

Louvard et al. [10] and Yabe et al. [11] reported in 1998 the feasibility of graft angiography and particularly left internal mammary artery (LIMA) angiography through a right radial artery approach. Kim [12] and Kwang [13] described bilateral selective internal mammary artery angiography via the right radial approach as early as 2001. Sanmartin et al. published in 2006 their feasibility analysis and comparison with transfemoral approach [14]. They concluded that there is no excessive delay or greater radiation exposure and that the TRA appears at least as safe as TFA. Their study was retrospective, excluded patients with bilateral mammary grafted, and the left radial access was predominant (133 of the 151 TRA compared to the 154 TFA). They reported four failures of cannulation, one puncture failure, one LIMA, and one saphenous vein graft (SVG) not reached. Only 15% of ad hoc PCI were carried out. In 2008, Burzotta [15] and experienced TRA operators described tips and tricks available for addressing post-CABG patients and already pointed out the right radial access as the best first option in case of bilateral mammary artery grafts.

In 2009, Rathore et al. [16] reported a similar technical TRA success rate for SVG-PCI compared to TFA. Periprocedural MI, access-site bleeding-related complications, and large hematomas were higher in the TFA group. They reported a 5.8% crossover to the femoral route.

The Transradial Committee of the SCAI in a 2011 publication concluded that TRA for CABG patients might safely be integrated into routine practice as experience increases [17].

The published 2010 prospective study of 1826 consecutive procedures [4] looking at the conversion rate from TRA to TFA when both radial arteries have to be attempted before the crossover to femoral included 187 patients with previous CABG surgery. The study was extended for the CABG population until 2012, and results were presented at the 2012 ACC meeting [18].

The study differs from the previously reported series: it prospectively addressed patients with previous CABG surgery; the choice of the radial artery to be attempted at first, right versus left, was free, but both radial arteries had to be attempted before converting to femoral access. Patients grafted with both mammary arteries were not excluded, and the study also included patients with gastroepiploïc arteries used as graft. Ad hoc and elective PCI were performed. Importantly, all causes of failed attempts were analyzed and classified.

This study reinforces the previous conclusions about TRA feasibility. When considering angiography for the CABG population, particularly when only one mammary artery is grafted, TRA performs as well as for the general population. A success rate above 98% was obtained with a very low requirement for a second artery access (7.2%) in case of only one internal mammary artery (IMA) grafted. Of course, the radial artery to be attempted at first must be ipsilateral to the utilized IMA, and it is better to start with in hand the description of the performed surgery. In case of bilateral IMA, the strategy of attempting the right radial artery at first enhances the chance of completing the procedure through one arterial access (actual chance of success is around 60%). To be noted, in the published series, about 35.5% of procedures included angioplasty and stenting (mainly ad hoc). **Tables 1–3** describe the CABG population (from 2007 to 2012) compared to the non-CABG population of the 2010 publication.

To summarize the published statistics, for a general population and excluding patients with previous CABG surgery, cannulation failed in 4.9% (requiring crossover to the second radial artery or to an ulnar artery). For the CABG population when the surgeon protocol is available and when only one IMA is grafted, the ipsilateral to the IMA radial cannulation fails for 5.4% of patients and requires use of the ipsilateral ulnar artery. When both IMA are grafted, starting from the right TRA succeeds for about 60% of patients; 40% will further need cannulation of the left TRA (mainly for an adequate LIMA graft patency assessment). In terms of patient safety and avoidance of vascular access-related complications and hemorrhage, a bilateral radial cannulation is far less dangerous than one femoral access, particularly in case of coronary/graft angioplasty. By the way and as reported [19], the PCI success rate stays unaltered by the vascular access.

5.2. MI patients in unstable condition

The TRA lifesaving benefit is directly linked to the illness severity: the STEMI and the unstable non-ST elevation myocardial infarct (NSTEMI) patients are the more likely to require a high level of several anticoagulants/antiplatelet therapies paving the road for serious hemorrhagic events mainly at the vascular (femoral) access site [20]. Vascular closure devices have not been demonstrated to be effective in reducing these vascular complications in the setting of ACS. On the contrary, hemostasis is easily obtained after TRA, even in situation of

Population	Any previous CABG surgery	Previous CABG surgery	p	Previous CABG surgery ≤1 IMA	p (vs. no previous CABGs)	Previous CABG surgery 2 IMA	p (vs. no previous CABGs)
N	1639	507		320		187	
Age	65 ± 11	71 ± 9	<0.001	72 ± 10	<0.001	70 ± 9	<0.001
Female (%)	31%	18%	<0.001	20%	<0.001	14%	<0.001
Diabetes (%)	17%	29%	<0.001	28%	<0.001	32%	<0.001
HTN (%)	44%	56%	<0.001	54%	0.001	58%	<0.001
Peripheral vascular disease (%)	21%	41%	<0.001	43%	<0.001	38%	<0.001
Weight (kg)	79.0 ± 16	81.6 ± 15	0.001	80.8 ± 15	0.037	83.0 ± 16	0.001
Height (cm)	168 ± 9	169 ± 8	0.26	168 ± 9	0.82	170 ± 8	0.021
BMI	27.8 ± 5	28.6 ± 9	0.001	28.6 ± 6	0.009	28.6 ± 5	0.017
BMI ≤ 22 (%)	10.5%	4.3%	<0.001	4.1%	<0.001	4.8%	0.014
Radial artery looks not easy to puncture	13.9%	12.6%	0.46	13.8%	0.94	10.7%	0.224
Volume of contrast (ml)	156 ± 78	226 ± 92	<0.001	218 ± 87	<0.0001	239 ± 97	<0.0001
Percutaneous coronary Intervention (ad hoc + elective)	40.5%	35.5%	0.04	41%	0.8	26%	<0.001

CABG, coronary artery bypass graft; **IMA**, internal mammary artery.

Table 1. TRA and CABG vs. non-CABG populations.

high anticoagulation level. Performing through a radial artery access in these circumstances removes the fear of "collateral damages" related to intense anti-clot treatments and allows retaining the benefits linked to their use. When the situation requires the use of intra-aortic counterpulsation, the TRA PCI saves at least this access from hemorrhage, the intra-aortic balloon being usually removed some days later, when the degree of anticoagulation is far less intense. Door-to-balloon time is only one of the important lifesaving parameters and must not serve as a pretext to skip a well-performed TRA attempt: speed may not lead to haste! Acute MI patients usually maintain initially a decent radial pulse, and cannulation may succeed as in stable condition. Particularly in the setting of acute coronary syndrome (ACS), a failed first attempt must lead to attempting the second radial artery (or the ulnar artery) before crossing over to the less safe femoral route. The author's most recent statistics in STEMI patients will illustrate the TRA feasibility "in real world."

Since mid-March 2017 to mid-November 2018, from a total of 1023 procedures, 152 STEMI patients were primarily addressed by PCI. A grand total of two primary PCI were performed through a femoral access: one MI patient had previously a thoracic vascular repair after a

	All	Non-CABG patients	CABG patients	p	CABG ≤1 IMA	p	CABG 2 IMA	p	TRA-IMA same side	p
N Patients	2146	1639	507		320		187		298	
TRA success	2118	1621	497		314		183		293	
(%)	98.7	98.9	98	0.13	98.1	0.247	97.9	0.216	98.3	0.395
N radial attempted	2327	1711	616		339		277		311	
N of radial attempts/patient	1.084	1.044	1.215	<0.001	1.059	0.23	1.481	<0.001	1.047	0.981
Right radial as first attempt	1560	1359	201		62		139		41	
Right radial failed at first attempt	139 (8.9%)	68 (5.0%)	71 (35.3%)	<0.001	10 (16.1%)	<0.001	61 (43.9%)	<0.001	4(9.7%)	0.175
Left radial as first attempt	586	280	306		258		48		257	
Left radial failed at first attempt	56 (9.6%)	12 (4.3%)	44 (14.4%)	<0.001	13(5.0%)	0.678	31 (64.6%)	<0.001	12 (4.7%)	0.83
All failures (first attempt)	195	80	115		23		92		16	
One (first) failure/patient	9.1%	4.9%	22.7%	<0.001	7.2%	0.091	49.2%	<0.001	5.4%	0.721

CABG, coronary artery bypass graft; **IMA**, internal mammary artery; **TRA**, transradial access; **TRA-IMA same side**, transradial access for ipsilateral IMA.

Table 2. Radial artery cannulation: failures at first attempt.

	Non-CABG patients	CABG patients	p	CABG patient ≤1 IMA	p (vs. no CABG)	CABG patient 2 IMA	p (vs. no CABG)
N	1639	507		320		187	
N R ± L radial failed (% patients)	90 (5.5%)	119 (23.5%)	<0.001	25 (7.8%)	0.106	94 (50.3%)	<0.001
N puncture/wiring failed (% total failures)	67 (74.4%)	14 (11.8%)	<0.001	12 (48%)	0.012	2 (2.1%)	<0.001
N "route to aorta" failed (% total failures)	12 (13.3%)	5 (4.2%)	0.017	2 (8%)	0.471	3 (3.2%)	0.012
N "coronary or SVG ostium" failed (% total failures)	11 (12.2%)	12 (10.0)	0.625	5 (20%)	0.32	7 (7.5%)	0.276
N "IMA contra not reached" (% total failures)	0 (0%)	88 (74.0%)	<0.001	6 (24%)	<0.001	82 (87.2%)	<0.001

CABG, coronary artery bypass graft; IMA, internal mammary artery.

Causes of radial attempt failure, puncture/wiring the radial artery; catheter, route to aorta failure; catheter, coronary/saphenous vein graft (SVG) ostia cannulation; catheter, contralateral IMA not cannulated (right TRA for left IMA or left TRA for right IMA).

Table 3. TRA CABG vs. non-CABG, causes of failed attempt.

thoracic trauma (car accident): his right arm was unavailable for left heart catheterization, and cannulation of the left radial artery led to an occluded left subclavicular artery. The second femoral case was a small-sized lady, and the attempts to wire radial (and ulnar) arteries failed at both wrists. This case happened before the availability of the ultrasound technique for rescuing the failed attempts. Seven STEMI cases required simultaneous use of the femoral artery for left ventricular assistance (intra-aortic balloon pump). The hemorrhage-saving TRA feature lets to more liberal use of potent antiplatelet drugs and high heparin doses: it may lead to less distal thrombus embolism and less no-reflow post-reperfusion states. As already stated, femoral access accounted for only 4 cases of the last 1023 author's procedures.

5.3. Frailty and small body-sized ill patients

There is another category of patients likely to get catheterized by the femoral route: the small body-sized ill patients, particularly if a frailty condition is associated. Excuses to skip the radial access stay similar: anticipated—but not objectively assessed by ultrasound—too small radial artery, need of a large guide catheter for a quicker intervention, speed required by the degree of illness, etc. Nevertheless, this kind of patient will very badly recover from any hemorrhagic event, and their condition increases greatly the vascular risk [20]. The reader is invited to look at the way a cohort of such frailty; old and severely diseased patients were successfully TRA managed through a double radial route for addressing distal left main or proximal left coronary artery disease [21]. It allowed to position and to work simultaneously with two 5 French-sized guide catheters at no cost of vascular-related complication (Table 4).

	Case 1	Case II	Case III	Case IV	Case V
Age	81	70	86	87	89
M/F	M	F	M	F	F
BMI/height (cm)/ weight (kg)	25/174/75	33/159/85	30/160/78	22/160/56	22/160/56
Frailty (0–3+)	2+	1+	3+	3+	3+
Symptoms at presentation	New chest pain and SOB CCVS Class 3	Progression of chest pain, SOB CCVS Class 3	Chest pain and SOB CCVS Class 4	Acute pulmonary edema NSTEMI VT, persistent HF	Acute pulmonary edema NSTEMI VT, persistent HF
Associated medical conditions	Severe COPD Gold IV, permanent O2 therapy	Severe COPD Gold III Past CVA and CAD	Valvular aortic stenosis, severe (< 1 cm2), COPD, transient AV block	HBP, paroxysmal atrial fibrillation Low Ef (recent)	HBP, diabetes, low Ef (recent)
CAD, syntax score (SS)	Distal LMCA Medina 1,1,1 Left dominance Syntax score 30	Distal LMCA Medina 1,1,1 Syntax score 23	distal LMCA, medina 1,1,1 occluded RCA (3VD), Syntax score 48	LMCA equivalent, 100% RCA Syntax score 28	Prox. and mid-LAD a. 75% CX a., 95% RCa. lesion 70%, syntax score 35
Addressed vessel(s)	LMCA	LMCA	LMCA	Ostial-LAD/ostial CX arteries	Prox. to distal LAD-Diag a.
Arterial access	R TUlnA/L TRA, 5F Glidesheath	R+ L TRA, 5F Glidesheath	R+ L TRA, 5F Glidesheath	R+ L TRA, 5F Glidesheath	R+ L TRA, 5F Glidesheath
Fluoroscopy time/ volume of contrast/ DAP/CPK 24 h	44′/290 ml/228 Gy/cm² CPK (−)	17′/212 ml/143 Gy/cm² CPK (−)	20′/148 ml/114 Gy/cm² CPK (−)	15′/140 ml/73 Gy/cm² CPK (−)	20′/128 ml/173 Gy/cm² CPK (−)
Follow-up	Alive > 1 year, acute pneumonia at 1 month	Alive > 1 year, no angina	Alive > 1 year, aortic valve stenosis said moderate	Alive > 1 year, class 1, normalized LV function	Alive > 1 year, class 1, normalized LV function (had 2 weeks re-hosp for HF)

SOB, shortness of breath; CCVS, Canadian Cardiovascular Society classification;

VT, ventricular tachycardia; HF, heart failure; NSTEMI, non-ST elevation myocardial infarction; COPD, chronic obstructive pulmonary disease (severity as assessed by the GOLD classification); CVA, cerebrovascular accident; CAD, coronary artery disease;

Ef, left ventricular ejection fraction; LMCA, left main coronary artery; RCA, right coronary artery; 3VD, triple vessel disease; LAD, left anterior descending (artery); CX, circumflex (artery); R TUlnA, right transulnar artery; L TRA, left transradial access;

R TRA, right transradial access; DAP, dose area product (Gy/cm²); CPK, creatine phosphokinase.

Table 4. TRA PCI and frailties, adapted from ACC, 18;3, 45-52.

6. How to avoid the radial artery occlusion problem

Coronary artery disease (CAD) is a progressive disease, and many patients "enjoying" a first successful TRA PCI will require in the future one or more interventions, evenly in emergency (subacute stent thrombosis, new STEMI or new acute coronary syndrome, etc.). So, preserving a well-patent radial artery may be lifesaving later.

In 2016, 1 year before the CRASOC studies were accepted for publication in the American Journal of Cardiology [3] as the largest randomized and prospective study analyzing the hemostasis role in radial artery occlusion (RAO). Rashid et al. published a well-documented systematic review and meta-analysis [22] about the TRA-related radial artery occlusion. It is easy to summarize the problem and to understand the different ways we must follow to reduce the RAO rate. RAO is the direct consequence of the vessel injury associated with any TRA. Injury happens at three levels, and we have to minimize the trauma at each of these levels: first, the puncture; second, the sheath insertion and catheter manipulations (within the sheath); and finally, the compression/hemostasis following the catheterization. Mention for selecting the best technique and material for artery puncture and cannulation was already made. The author makes the hope that, someday, TRA operators will get the chance to handle the specifically designed and actually patented radial artery needle: it should be the best way to reduce as far as possible the puncture-related aggression. In the same way, it is obvious that reducing the size of the sheath is another excellent way to reduce the related harm against the artery wall. Not only should the size be reduced as far as possible, but also the material must be hydrophilic: non-hydrophilic sheath should be banished from a good TRA practice. The "slippery" problem of the hydrophilic sheath is the best proof of the appropriately reduced parietal stress. This problem may be easily "fixed" at the skin level: a simple "opsite" film placed over the sheath does the job. The introduction of the Terumo® "Glidesheath" family of radial introducers represents a welcomed improvement: The company cleverly worked to offer a reduced outside diameter of the sheath (what the artery" feels") together with a normal inside diameter. It allows operators working predominantly in 5 French (including for PCI), to offer a "virtual 4F" TRA procedure for the majority of their patients.

The post-catheterization hemostasis step contributes to the global artery's damage: as proven effective thanks to the 3616 analyzed patients in the CRASOC studies, a gentle and short hemostasis with pneumatic compression (TR Band® compression device, 10 cc of air/90 minutes) represents today the best and most elegant way to minimize the RAO rate. A TRA operator has to be reminded that the hemostasis step is his last chance to save the radial artery patency.

7. Conclusion

"TRA for everybody" is highly desirable for patient safety and comfort. This strategy is achievable, and solutions for more complex populations are provided. Ways to maintain the artery patency are described. Better-suited materials for easier TRA are already offered,

and innovations will continue [23, 24]. The author still believes that in year 2018 the radial way requires a gentleman attitude (at least for the radial artery), demands a rebel inclination—to discard all the negative thinking about the TRA feasibility—and is best served by a "believer" behavior: a believer always will try to find indication rather than contraindication for TRA.

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