Transradial approach for percutaneous coronary interventions on chronic total occlusions

The transfemoral approach is the standard approach for performing chronic total occlusion procedures. However, hemorrhagic and vascular entry site complications are known to be reduced by the adoption of the transradial approach. Thus, the transradial approach is gaining interest and, facilitated by the improvement of materials and techniques, will be applied in procedures previously considered possible only by femoral access. In this article, we review the data regarding the feasibility and safety of the transradial approach for chronic total occlusion percutaneous coronary interventions and provide an overview of the technical aspects useful for performing chronic total occlusion by radial access.

KEYWORDS: chronic total occlusion ▪ percutaneous coronary intervention ▪ transradial approach ▪ vascular complication

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Chronic total occlusion (CTO) percutaneous coronary interventions (PCIs) have become one of the last frontiers of interventional cardiology. In recent years, the development of a considerable improvement in procedural techniques and dedicated devices [1–7] has occurred, resulting in increased success rates of PCI for CTO.

According to the standard practice of the majority of CTO-dedicated centers and operators, the adoption of a large guiding catheter (GC) in the femoral artery is the preferred strategy to start a PCI on a CTO lesion. However, it is well known that the use of femoral artery access is associated with a higher rate of hemorrhagic and vascular entry site complications as compared with the transradial approach (TRA) [8]. Moreover, the TRA allows earlier patient mobilization and reduction of hospital costs compared with the transfemoral approach (TFA) [9] and, as demonstrated in recent observational reports, may also result in a better clinical outcome [10–12]. For these reasons, a growing interest is arising worldwide on the replacement of the TFA with the TRA for coronary and peripheral interventions [13–17]. Furthermore, both the miniaturization of CTO-dedicated devices and the improvement of techniques for complex PCI are going to provide an improved armamentarium to successful approach CTO PCIs by radial access. Indeed, as double arterial access and long procedures are often required, a particular benefit may be anticipated by a radial-associated reduction of vascular complications in CTO PCI.

In this article we review the available literature on the TRA for PCI in CTO lesions and overviews the technical aspects that are useful for performing PCI in CTO lesions by radial access.

Feasibility of the transradial approach in CTO PCIs

In keeping with the standard practice favoring the femoral approach for CTO, data on PCI for CTOs by TRA come from a small series of observational, retrospective studies [18–23].

The main features and results of studies on TRA CTO have been searched, reviewed and extracted, and these characteristics have been summarized in Table 1.

The first reported TRA CTO procedural success rates were highly variable, ranging between 65.5 [20] and 82% [22]. This variability is similar to that encountered across studies on TFA CTO PCI [24–29] and is probably related to different definitions of procedural success, different complexity of attempted lesions and different study periods.

Regarding the issue of the definition of success adopted in the different studies, Kim *et al.* defined TRA procedural success as completion of PCI by TRA with a residual stenosis of less than 30% and no major cardiovascular complications [19], while Rathore *et al.* defined procedural success as crossing the occlusion with wire and balloon with a residual stenosis of less than 70% [22], although no clear definitions of procedural success are present in the other four studies [18,20,21,23].

Detailed data on baseline angiographic characteristics of occlusions and on predictors of CTO PCI failure [24–30] are provided only in two TRA studies (Table 1) [18,19]. The predictors of TRA PCI failure were nontapered stump and

Table 1. Main features and results of studies on PCI in CTO lesions performed by transradial access.

Study	Design	Number of CTO lesions	Main features of CTO lesions	Procedural success by transradial access (%)	Technique for CTO PCI	Guiding catheters ≤6 Fr (%)	Crossover to transfemoral access (%)	Access site complications (%)	IH MACE (%)	Ref.
Saito *et al.* (2003)	Single center, retrospective registry Years: 1997–2001	181	57% abrupt type CTO, 34% bridge collaterals, mean length 20 mm and mean duration 17 months	78	Antegrade approach with parallel wire technique	72[†]	NA	NA	0[†]	[18]
Kim *et al.* (2006)	Single center, retrospective registry Years: 2000–2003	87	28% abrupt type, 19% bridge collateral, 21% side branch at CTO, 64% length >15 mm and 63% duration >3 months	65.5	Antegrade approach with OTW balloon	81	5.7	0	1.1	[19]
Wu (2008)	Single center, retrospective registry Years: 1998–2008	909	NA	77.3	NA[‡]	NA	NA	NA	NA	[20]
Quesada (2008)	Single center, retrospective registry Years: 1998–2008	129	NA	78.9	NA	85.3	2.3	NA	NA	[21]
Rathore *et al.* (2009)	Single center, retrospective registry Years: 1998–2008	318	NA	82[§]	NA	Mainly 6 Fr	3.3	3.5[¶]	3.8	[22]
Katsuki (2009)	Single center, retrospective registry Years: 2007–2009	165	NA	76	NA	98	NA	NA	NA	[23]

[†]Data from Phase II of the study (CTO PCI performed between January and August 2001) and from all the study population (80 patients; 69% transradial acces).
[‡]Data available only for 36 patients (4%) undergoing the biradial approach with retrograde technique.
[§]Procedural success defined as the ability to cross the occluded segment with both wire and balloon and successfully open the artery with <70% stenosis.
[¶]Rate of oozing from radial artery puncture site (1%), ecchymosis (1.3%) and small (<2 cm) hematoma (1.2%); no large hematomas or other entry site complications were observed.
CTO: Chronic total occlusion; IH: Intimal hyperplasia; MACE: Major adverse cardiac event; NA: Not available; OTW: Over-the-wire; PCI: Percutaneous coronary intervention.

longer (>15 mm) and older lesions [18,19], and the causes of failure were inability to cross the occlusion with a guidewire or a balloon [18,19]. In TFA CTO studies [24–30], even if nontapered stump and longer and older lesions are reported as predictors of PCI failure, the most important predictors of failure are vessel tortuosities and calcifications, thus suggesting a possible different selection of CTO lesions between TRA and TFA studies.

Furthermore, as expected, the available literature supports the importance of the learning curve in performing TRA CTO PCI. Indeed, three different authors (Saito *et al.* [18], Kim *et al.* [19] and Wu [20]) reported a significant increment in success rate between the first and the last periods of their study.

In order to reflect the concept of encountering major procedural limitations with the radial access, the issue of crossover from TRA to TFA in PCI for CTOs should be considered. The crossover to TFA rate is reported in three studies [18,20,21] and, as shown in **Table 1**, seems to be highly variable and not negligible, ranging from 2.3 to 5.7%. Crossovers were mainly due to anatomical variants of radial and subclavian arteries (loops of radial artery and subclavian artery tortuosity). In particular, the causes of crossovers were anatomical variants of radial and subclavian arteries (three cases, 3.4%) and poor GC support (two cases, 2.3%) in the study by Kim *et al.* [19], and radial artery spasm (four cases, 1.2%), unsuccessful radial artery cannulation (four cases, 1.2%) and poor GC support due to vascular tortuosity (three cases, 0.9%) in the study by Rathore *et al.* [22].

Finally, the overall safety of adopting radial access for CTO PCI appears to be supported by the clinical outcome observed in the available studies: rates of in-hospital major adverse events are consistently low in the TRA studies [18,19,22], ranging from 0 to 3.8% (**Table 1**), and comparable with that reported in the major TFA studies [24–29] (range: 0.7–3.8%).

Comparison between transradial & transfemoral PCI for CTO

Two studies reported a direct comparison of CTO performed by TRA and TFA [18,22]. Rathore *et al.* compared 318 patients treated using TRA with 150 patients treated using TFA in a retrospective observational study conducted between 2003 and 2005 [22]. They showed a similar success rate in the two groups (82% TRA group vs 86% TFA group; p = 0.28). Saito *et al.* showed a similar rate of procedural success by TRA (126 patients) and TFA (56 patients) groups in the first phase of their observational study (between 1997 and 1999: 67% TRA group vs 68% TFA group; p = nonsignificant) and a significantly higher rate of procedural success in the TRA group (55 patients) as compared with the TFA group (25 patients) in the second phase of the study (89% TRA group vs 64% TFA group; p = 0.008), probably reflecting the best selection of CTO cases to approach using radial access [18].

Regarding the measures of resource optimization, mean values of total contrast volume and total procedure time were comparable between the TRA and TFA groups in the study by Rathore *et al.* (total contrast volume [ml] 395 ± 180 TRA group vs 406 ± 173 TFA group, p = 0.27; total procedure time [min]: 54 ± 25 TRA group vs 60 ± 28 TFA group, p = 0.23) [22].

With regard to entry site complications, Rathore *et al.* demonstrated a significantly higher rate of entry site complications in the TFA group (3.5% TRA group vs 11.3% TFA group; p < 0.001), with only ecchymosis or small hematomas (<2 cm) by transradial access [22].

Finally, early major adverse events resulted as being similar between TRA group and TFA group in the study by Rathore *et al.* (3.8% TRA vs 4.2% TFA; p = nonsignificant) [22].

Overall, data coming from observational studies suggest that the selection of radial access for CTO PCI is not associated with any penalization in terms of safety and efficacy and may reduce access site complications. Nevertheless, the question of which approach is superior can only be answered by a prospective trial comparing the results of experienced TFA and TRA operators attempting PCI on CTOs with similar complexity.

Transradial approach in CTO PCI: technical aspects

The radial approach is associated with some specific technical characteristics that make the PCI procedure quite different from the femoral approach PCI. As described previously, there is a detectable learning curve during the first phase of TRA CTO that is necessary in order to gain full familiarity with the drawbacks and also with the advantages offered by radial approach.

According to our experience, the main differences between TRA and TFA CTO PCI are the techniques required to gain sufficient active backup by the GC and the full knowledge of the material's compatibility, allowing for selective use of large (>6 Fr) GCs.

Gaining active backup by the guiding catheter using radial access

Interventional cardiologists approaching CTOs commonly use femoral access to gain the best 'passive' backup. Placing large GCs in the radial artery may be feasible, but large sheaths may not be placed in the radial arteries of all-comer patients and may increase the risk of radial artery damage and postcatheterization occlusion [31]. As a consequence, the interventional cardiologist adopting TRA for CTO usually tries to gain the maximal 'active' backup from small GCs and reserves the usage of large GCs only for the specific techniques that require bulky materials.

When looking for the best active support, the first point is to select the best radial artery entry site (the left radial artery is better for right coronary artery CTOs and the right radial artery is better for left coronary artery CTOs) (Figures 1 & 2). Moreover, when selecting the GC shape, it should be recognized that, even if 'passive backup' is always higher by TFA, some GC shapes (e.g., Ikari and Amplatz Left) have been demonstrated to have a smaller difference in provided support by radial or femoral approaches compared with other curves (e.g., Judkins family) [32].

During the GC selection for TRA CTO, an important point is to look for the possibility of having shapes suitable for the deep intubation technique [18,19]. Indeed, deep intubation may allow very strong support in specific phases of the CTO PCI (e.g., balloon crossing of the lesion) and may be facilitated by the selection of smaller GCs with smoother curves (in Figure 3 a deep intubation on the right coronary artery has successfully been performed by Judkins Right).

During recent years, the improvement of materials has provided novel strategies to enhance support during TRA CTO PCI. Interestingly, some operators have successfully introduced the five in six technique (or mother and child technique) in their practice [33]. This technique is greatly facilitated by the availability of specifically designed 5 Fr GCs that are compatible with 6 Fr GCs.

Finally, when deep intubation is not feasible (e.g., in CTOs close to the coronary ostia or CTOs located downstream of severe, diffuse disease of the proximal coronary segment), the GC may be stabilized using the anchoring balloon technique [34].

Compatibility of CTO technique with different guiding catheters

The inner diameter size of GCs has a pivotal role for the selection of techniques to be adopted during a CTO PCI. Many operators like to have a large GC size (8 Fr) to feel free to use any CTO technique during the PCI procedure [35]. Such an approach is not shared by operators using the radial access as, looking at the available data (Table 1), the 6 Fr GCs are the more common selection (>70% of cases in all studies). The border between larger and smaller GCs is being changed by the introduction of the GC not requiring the insertion of a sheath ('sheathless GCs') allowing (in the 7.5 Fr size) access to an inner lumen larger than the 7 Fr GC inner lumen with an outer diameter smaller than a 6 Fr sheath.

In order to clarify which are the techniques that can be applied in the different GCs, we have tested at the benchside (and used in our clinical practice) a series of combinations of devices that may help during a CTO PCI.

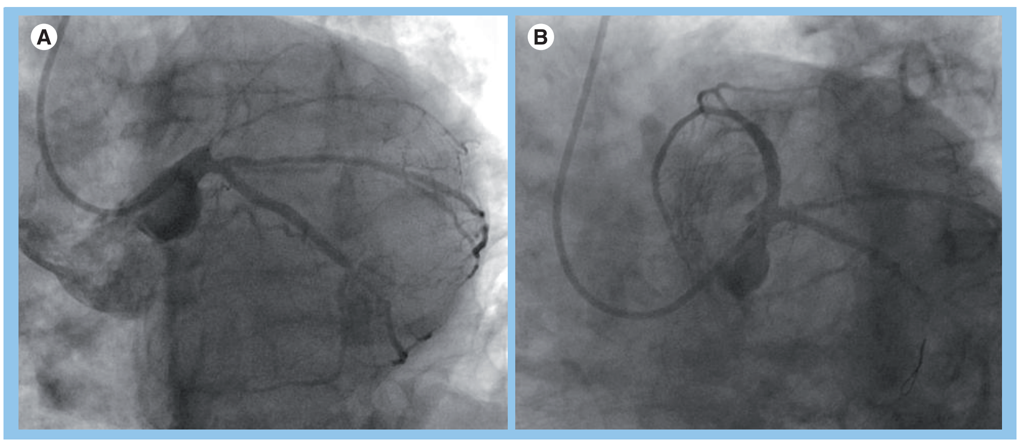

Figure 1. Example of the right radial approach with 6-Fr extra backup guiding catheter for percutaneous coronary intervention on an ostial left anterior descending chronic total occlusion. (A) Before percutaneous coronary intervention. **(B)** Result after successful percutaneous coronary intervention.

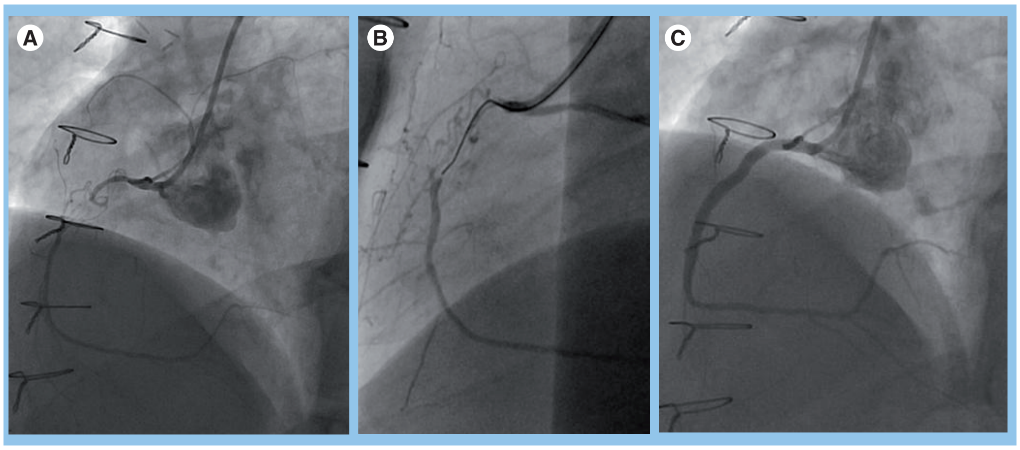

Figure 2. Example of the left radial approach with 6 Fr Judkins Right guiding catheter for percutaneous coronary intervention on a right coronary artery chronic total occlusion. **(A)** Before percutaneous coronary intervention. **(B)** During guidewire crossing of the chronic total occlusion. **(C)** Result after successful percutaneous coronary intervention.

Table 2 summarizes such devices' compatibilities as tested according to some of the materials available in our catheterization laboratory daily practice (e.g., low-profile monorail and over-the-wire [OTW] balloons, microcatheters and intravascular ultrasound probes) inserted in large lumen 6 Fr GCs, sheathless 7.5 Fr GCs and standard 8 Fr GCs. As shown in Table 2, all the techniques can be performed using a 6 Fr GC or a 7.5 Fr sheathless GC, with the exceptions of the parallel wire technique with two OTW balloons and intravascular ultrasound-guided PCI with a microcatheter or an OTW balloon, which need an 8 Fr GC. GC compatibility is an evolving field and no table may incorporate all the possible combinations using the different devices available on the market. Nevertheless, it should be emphasized that operators attempting the task of opening a CTO by the radial approach need to know the techniques that are allowed with the materials (e.g., balloons, microcatheters and GCs) they have in their catheterization laboratory very well.

Double-radial approach for retrograde techniques

The feasibility of the bilateral radial approach with a retrograde technique [35,36] has been suggested by Taketani *et al.*, who reported four successful cases of CTO PCI in which 7 Fr GCs were used for antegrade arteries and 6–7 Fr GCs for retrograde arteries without entry site complications [37]. Moreover, Wu described their experience on the retrograde strategy in 86 complex CTO lesions by biradial approach using 7 Fr GCs for retrograde arteries and 6 or 7 Fr GCs for antegrade arteries with a success rate of 80.6% without any in-hospital major adverse cardiac events [20].

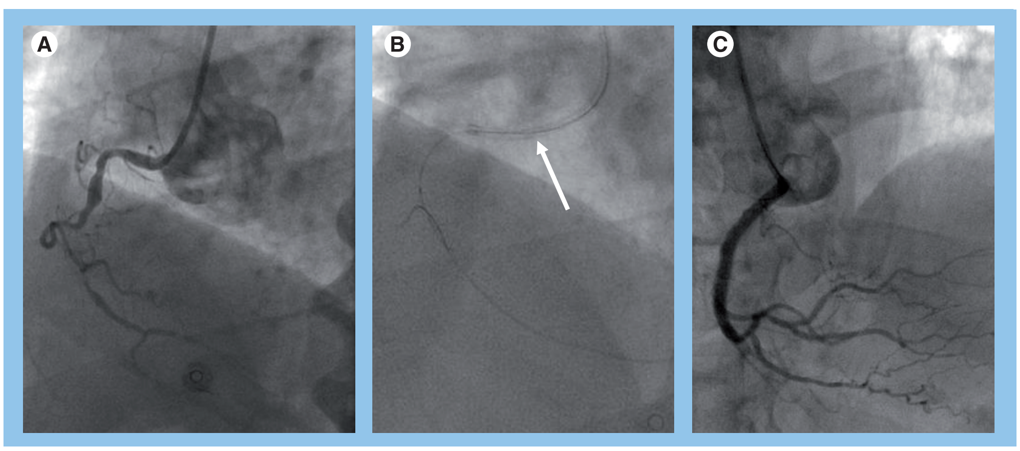

Figure 3. Deep intubation on the right coronary artery with Judkins Right guiding catheter by left radial approach. **(A)** Before percutaneous coronary intervention. **(B)** Deep intubation (white arrows) necessary to successfully cross the chronic total occlusion with an over-the-wire balloon. **(C)** Result after successful percutaneous coronary intervention.

Table 2. Compatibility of chronic total occlusion techniques with various sizes of guiding catheters tested in benchside tests.

Chronic total occlusion techinique	Large lumen 6 Fr GC	Sheathless 7.5-Fr GC	Standard 8-Fr GC
Parallel wire			
With one microcatheter	Yes	Yes	Yes
With two microcatheters	No (yes only with two FineCross, Terumo)	Yes	Yes
With one microcatheter + one OTW balloon	No	Yes	Yes
With two OTW balloons	No	No	Yes
Side-branch anchoring balloon & balloon trapping			
With 1 monorail balloon + one microcatheter	No	Yes	Yes
With one monorail balloon + 1 OTW balloon	Yes, but not advisable (too much friction)	Yes	Yes
IVUS-guide			
With wire	Yes	Yes	Yes
With wire and microcatheter (or OTW balloon)	No	No†	Yes

Data from benchside tests with GCs: 0.70" Large Lumen 6 Fr GC (Cordis), 7.5 Fr Sheathless GC (Asahi); 8 Fr GC (Cordis). Microcatheters: Quick-cross (Spectranetics). OTW and monorail balloons: Sprinter Legend (Medtronic); IVUS: Atlantis Pro (Boston Scientific).
†Katsuki T: Personal communication; Transcatheter Cardiovascular Therapeutics 2009 meeting reported the possibility for this technique in 7 Fr GCs using the FineCross microcatheter (Terumo).
GC: Guiding catheter; IVUS: Intravascular ultrasound; OTW: Over-the-wire.

According to such preliminary experiences, it appears that the biradial approach can be safely adopted to apply retrograde techniques, and we have successfully used this technique for the difficult task of reopening a chronically occluded ostial left main [38].

■ Limitations of TRA in CTO PCI

Looking at the data from the six available observational studies on TRA in CTO lesions and also at some technical aspects, a series of limitations of TRA in CTO PCI should be highlighted.

First, among the TRA studies [18–23], only two [18,19] reported the main characteristics of the CTO lesions approached transradially, not allowing us to understand if more complex CTO lesions can also be performed by radial approach. Indeed, the selection of the approach (TRA or TFA) is led by the operator's discretion in each TRA study.

Second, access site complications are under-reported in TFA studies [24–30] (being available in only one study reporting a vascular access site complication rate of 1.7% [24]), as well as in TRA studies. Indeed, they are available in only two out of six TRA studies [19,22] and the definitions used in the two studies are different. Kim *et al.* reported no local vascular hemorrhagic complications related to the TRA intervention [19], while Rathore *et al.* reported a rate of 3.5% for transradial access site complications, which included oozing from radial artery puncture site (1%), ecchymosis (1.3%) and small (<2 cm) hematoma (1.2%), managed conservatively with no impact on hospital discharge [22]. In the same article, the authors reported a significantly higher rate of transfemoral access site complications (11.3%) defined as small (<5 cm) hematoma (8.5%) and large hematoma (2%), which were managed conservatively, and retroperitoneal hematoma (0.8%) needing blood transfusion, thus suggesting that the majority of TFA complications probably had a minor impact on patients' clinical course. Moreover, the spectrum of possible access site complications reported for TRA is not complete as radial artery occlusion is not reported (and can be anticipated to occur in 2–10% of 6-Fr PCI [39–41]).

Third, the avoidance of using large GCs on a routine basis in TRA CTO is not only a major limitation to the possibility of changing CTO technique during the procedure (e.g., bailout intravascular ultrasound guidance or parallel wire technique with two OTW balloons; Table 2), but is also associated with an increased difficulty in applying the techniques that are 6-Fr GC-compatible owing to increased frictions.

Conclusion

Use of TRA to perform PCI for CTO lesions is safe and feasible, but requires a specific learning phase and careful case selection. The main limitation of TRA access is the compatibility of materials with small size GCs that can be overcome by a careful planning procedure, deep knowledge of material compatibility and selective use of large GCs.

Future perspective

The future for TRA CTO procedures is strongly linked to the development of more miniaturized angioplasty equipment that will gradually allow an extension of the number of techniques that can be performed through small sheaths. Both GCs and wire–balloon systems are undergoing a miniaturization process.

Regarding the guidewires field, 0.010" guidewires and 0.010"-compatible balloons have recently been developed in Japan and first experiences in treating CTO lesions with the device called Slender System (Japan Lifeline, Japan) come from two studies. The first, by Masutani *et al.*, reported the data on 67 CTO procedures, 64 (96%) performed by TRA, with a success rate of 68% with only the Slender System being used and a total success rate of 89%. In 70% of cases, 5 Fr GCs were used (6 Fr GCs were used for the remaining 30% of procedures) [42]. Similar results come from the 'Pikachu' trial, in which there were 141 CTO procedures, 76.6% of which were performed by TRA, giving a 58.2% success rate with only Slender System usage, an 88% total success rate, 44% 5 Fr GCs use and 47% 6 Fr GCs use [23].

Regarding the GCs and their sheathless evolution, a 5 Fr sheathless GC (Virtual 3 Fr; Medikit, Japan) with an inner diameter comparable with a standard 5 Fr GC and outer diameter comparable with a 3 Fr introducer sheath, has been developed and successfully tested in two cases of CTO PCI performed by TRA [43]. Similarly, a novel 4 Fr coronary accessor (Kiwami Heartrail II, Terumo, Tokyo, Japan) compatible with 4 Fr introducer sheaths with an inner diameter of 1.27 mm (0.050"), which can accommodate most currently available coronary stents, has been tested in 36 lesions and four CTOs, 61% of which by TRA and had a success rate of 94% [44].

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Executive summary

Background

- Femoral artery access is associated with a higher rate of hemorrhagic and vascular entry site complications as compared with the transradial approach and, for this reason, a growing interest is arising worldwide regarding the replacement of the transfemoral approach with the transradial approach for coronary and peripheral interventions.

Feasibility & safety of the transradial approach for chronic total occlusion percutaneous coronary intervention

- Several observational and retrospective studies show the feasibility of the transradial approach for chronic total occlusion (CTO) percutaneous coronary intervention (PCI), reporting a success rate comparable with that reported in transfemoral approach CTO PCI studies, with a possible reduction in access site complications. Data coming from randomized trials comparing the transradial approach with the transfemoral approach in the same complex CTO lesions will clarify the efficacy and the possible advantage of the transradial approach in reducing entry site complications.

Technical aspects of the transradial approach for chronic total occlusion percutaneous coronary intervention

- The learning curve necessary for a successful transradial approach CTO PCI program is related to the knowledge of materials and the familiarity with the technique of 'active' guiding catheter support, owing to the need to use smaller guiding catheters than for the transfemoral approach.

Future prospective

- The ongoing miniaturization of devices will further improve the chances to successfully adopt transradial access in CTO PCIs.

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