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Forearm Approach for Percutaneous Coronary Procedures

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Review
ABSTRACT
This article gives contemporary review on the forearm approach for percutaneous diagnostic and interventional coronary procedures. Advantages and disadvantages as well as practical issues and current controversies regarding both radial and ulnar artery approach are discussed throughout the paper. Having in mind advantages of forearm approach in terms of safety and comfort over the traditional femoral approach, as well as the rapid development of invasive technology in the past years, it will probably become the default vascular approach for all percutaneous coronary procedures in the near future.
Key words: Forearm approach; transradial; transulnar; percutaneous coronary procedures.

1. INTRODUCTION

Radial approach for coronary angiography was introduced in 1989 by Campeau (1). Only three years later, in 1992, Kiemeneij performed the first coronary angioplasty via this route (2). Finally, in 2001 Terashima reported the first series of nine patients in whom coronary angiography and angioplasty were performed via novel ulnar approach (3). Radial and ulnar approach nowadays serve as a forearm approach and thanks to the refinement of materials used for its performance and procedural techniques, they are increasingly used.

Only a certain time ago, radial approach was mostly ignored and neglected by a majority of interventional cardiologists and was considered only as a niche or alternative approach in comparison to traditional femoral route. However, due to constant effort, promotion, and enthusiasms of a dedicated group of transradialists, over the last twenty years radial approach has been acknowledged, and currently used as a preferred vascular entry site for primary percutaneous coronary intervention (pPCI), as stated in 2012 European Society of Cardiology guidelines for STEMI (4). Besides in the setting of STEMI, and due to substantial reduction in vascular and bleeding complications which has resulted in increased patient safety, forearm approach is gaining increased popularity and application in elective procedures as well.

According to estimations, totally 22% of all coronary procedures worldwide are currently performed via forearm approach (5). There are however, regions in the world with higher penetration of forearm approach such as Europe (mostly France, UK, Norway and Bulgaria), Canada, Australia and Japan, as well as lower penetration such as Central and South America. Extremely low penetration has been registered in USA, Middle East and Africa (5, 6). Surprisingly, USA is the only western country with low prevalence of forearm approach due to the absence of formal radial training for interventional cardiology fellows.

2. ADVANTAGES OVER FEMORAL APPROACH

There are three well established advantages of the forearm approach over the traditional femoral approach. They include increased patient safety, increased patient comfort and economic savings (6).

Increased patient safety is a result of reduction in potential life- and limb-threatening vascular complications and bleeding from the vascular access site, as well as the risk reduction of worsening of the kidney function post-catheterization. The proposed mechanism for this includes several possible factors: reduced risk for renal atheroembolization due to absence of possible contact of a catheter and aortic atheroma, reduced risk for bleeding resulting in lower incidence of ischemia and blood transfusions as well as normal intake of food and liquids and urination following catheterization (7). Regarding patient comfort and quality of life, there is no loss of privacy associated with procedural instrumentation in the intimate groin region during femoral approach. Moreover, there is an immediate ambulation after the procedure, normal social, mental and physiologic functioning including ability to use the bathroom. Economic savings are result of reduced hospital stay and reduced cost of post-procedural care. Noteworthy, post-procedural care is also easier for patients with forearm approach for attending nurses and doctors.

The same-day hospital discharge

after elective and uncomplicated coronary angiography is a contemporary practice in most facilities where forearm approach is routinely used and this is supported by a substantive data from number of clinical trials and registries (8). Several trials have recently also shown feasibility and safety of a same-day hospital discharge after elective and uncomplicated PCI via forearm approach (9). However, this is not a customized practice yet and it is not approved by the current guidelines which recommend measurement of cardiac enzymes 6-12 hours and 18-24 hours, respectively, after PCI, to exclude possible peri-procedural ischemia in order to improve patient safety and outcome. (Table 1).

3. VASCULAR COMPLICATIONS

There is a vast data confirming that incidence of vascular and bleeding complications related with cardiac catheterization is significantly lower with forearm approach in comparison to traditional femoral approach, due to favorable anatomy of the radial and ulnar artery (10). Vascular and bleeding complications are associated with unnecessary patient suffer, prolonged hospital stay and increased mortality. Bleeding from a vascular access site is the main cause of this. Bleeding contributes to increased mortality through several potential mechanisms. Anaemia may cause or deteriorate myocardial ischemia and bleeding can induce prothrombotic state which may activate the clotting system and eventually lead to stent thrombosis and myocardial infarction. The occurrence of vascular complications and bleeding requires prompt discontinuation or at least lowering dose of anticoagulants which may also deteriorate myocardial flow and induce myocardial ischemia. Blood transfusion is necessary if hemoglobin drops below 80g/L and if applied it has a potential to induce the prothrombotic state with activation of the clotting system, Obviously, myocardial ischemia is the common mechanism of all mentioned pathways contributing to increased mortality in patients with vascular and bleeding peri-procedural complications (11). Surprisingly, several trials have shown that vascular closure devices used for femoral hemostasis did not reduce the incidence of bleeding and vascular complications and their use was associated with increased risk of retroperitoneal bleeding (12).

Subgroup analysis of the large PREVAIL prospective study (1,052 subjects) showed that patients with acute coronary syndrome including STEMI who underwent PCI through radial approach have had a significantly lower incidence of bleeding (3.2%) and ischemic (1.1%) complications in comparison to patients with femoral approach PCI (6.9% and 4.9%, respectively) (13).

In another large MORTAL study (32,822 subjects), retrospective analysis showed that radial approach PCI vs. femoral approach PCI, was associated with 50% reduction in transfusion rate as well as with 29% reduction in a 30-day mortality rate, and 17% reduction in a 1-year mortality rate, respectively (14).

Forearm approach is particularly useful for patients with increased risk of vascular and bleeding complications, e.g. high-risk patients, such as elderly, women, obese, low weight, with renal failure, hypertension, anaemia and thrombocytopenia (15).

I. ***ADVANTAGES***
Increased patient safety
• Less life and limb threatening vascular complications
• Less bleeding complications from the vascular access site
• Risk reduction of worsening the kidney function after coronary procedure
Increased patient comfort and quality of life
• No procedural instrumentation in the intimate groin region
• Immediate ambulation after procedure
• Postprocedural normal social, mental and physiologic functioning
• Ability to use the bathroom
Economic savings
• Reduced hospital stay, including the same day discharge in most cases
• Reduced cost of post-procedural care
• Easier post-procedural care for attending nurses and doctors
II. ***DISADVANTAGES***
Increased learning curves
• Additional specific training
• Specific set of skills
• Experience with specific radial-dedicated interventional technologies
Increased operator radiation exposure
• Especially with the right forearm approach

Table 1. Summary of advantages and disadvantages of the forearm approach vs. femoral approach

4. CANNULATION ISSUES

Radial or ulnar approach should be used if both radial and ulnar pulses are palpable. There are currently two techniques for the radial/ulnar artery puncture, either by open needle technique with 24G micropuncture or by closed 21G needle with plastic cannula and a 0.0014-0.0018'' guide wire (16). Some operators prefer soft-tip coronary guide wires in cases of resistance. With these techniques success rate for radial artery cannulation is approximately 95% and for the ulnar artery is nearly 90% for experienced operators (17). Radial artery should be punctured approximately 2cm from the proximal pisiform bone at the site of the strongest pulse. Puncture of the ulnar artery is technically more challenging because it is situated deeply and without a bone support beneath. Its puncture site is approximately 2-3cm from the proximal pisiform bone. Patients should be given prior arriving to Cath Lab premedication with sedatives, reassured in the Cath Lab and local anesthesia applied with 1 ml of 2% lidocaine over the puncture site. Two types of hydrophilic introducers (10 cm and 21 cm) exist for forearm approach. In our opinion, like most operators prefer as well, a shorter introducer is advised because it is less traumatic and related with lower rates of arterial spasm and occlusion. A 5 Fr introducer is suitable for coronary angiography and a 6 Fr introducer for most PCIs. However, if necessary, both forearm arteries can accommodate a 7 Fr introducer as well. For patients with extremely small physical constitution or small diameter forearm arteries, a 4 Fr introducer may be the suitable option. Most recently, a sheathless technique has been introduced which allows PCI with 5 Fr catheters (18). If puncture need to be repeated it should be applied more proximally than pre-

vious attempt, but operators should keep in mind that the "first shot is always the best" because the rate of spasm and failure exponentially increases with every repeated attempt.

5. ANATOMIC CONSIDERATIONS

The mean diameter of the radial artery is approximately 2.6 cm which is large enough to accommodate a catheter up to 7 Fr (19). The ulnar artery is usually the dominant artery of the forearm and thus of larger mean diameter, approximately 2.9 cm (20). Having in mind such a small diameters of both arteries, certain degree of spasm is obviously expected with intraarterial manipulation. Usually the spasm is mild and intraarterial administration of vasodilatative drugs through introducer diminishes the spasm and allows accommodation and further manipulation with a catheter. Noteworthy, most operators apply a cocktail of heparin 5,000 IJ, verapamil 2.5 mg and nitroglycerin 200 mcg diluted in 10-20 ml saline in order to prevent burning sensation in arm because separate application of each drug could be very painful. Due to a larger mean diameter, straight course and less alpha-adrenergic receptors present within the vessel, the ulnar artery is less prone to spasm than the radial artery (21).

Anatomic anomalies of the radial artery are common and they are present in up to 25% of patients (22). Anatomic variations are the most frequent cause for radial approach failure. Most frequently seen the radial artery anomalies are tortuosities, curvatures, loops, high take-off and hypoplasia. Other possible but less commonly seen anatomic variations include brachial loops, subclavian tortuosity and retroesophageal position of the right subclavian artery. The problem of crossing the radial and brachial anomalies might be overcome by using a soft-type coronary guide wire or hydrophilic J-type guide wire. Tortuosity of the subclavian artery can be overcome with taking a deep breath by a patient that may elongate curvatures and allow passage of a catheter and intubation of the coronary ostia. Another effective solution may be to switch to the left forearm approach, but one needs to know that radial and brachial anomalies commonly tend to be bilaterally present. (Table 2).

References	Findings
Campeau L (1989)	Introduction of the radial approach for coronary angiography
Kiemeneij F. (1993)	Coronary angioplasty via radial approach
Terashima M. et al (2001)	Introduction of the ulnar approach for coronary angiography and angioplasty
Rao SV, et al. (2010)	Epidemiological study showing the current incidence of forearm approach worldwide
Pristipino C, et al. (2009)	PREVAIL study showing reduction of bleeding complications
Chase AJ, et al. (2008)	MORTAL study showing reduction of mortality
Achenbach S, et al (2008)	Usefulness in high-risk patients
De Andrade PB, et al. (2012)	Current vascular access site success rate
Li Y, et al. (2010)	Advantages of the ulnar artery vs the radial artery as vascular access site
Roberts EB, et al. (2012)	Review on the forearm vascular complications and its management

Table 2. The most important findings regarding the forearm approach

6. CATHETER SELECTION

Coronary angiography via right or left forearm approach is usually performed by "universal catheter" (Tiger, Kimny, Jacky, MAC 30/30, PAPA) in order to avoid spasm and to reduce time, radiation exposure and contrast injections during the procedure. Concept of a "universal catheter" originated from the Sones catheter used in the past for brachial cut-down approach, currently off-date technique. Left forearm approach (both radial and ulnar) can be performed without any difficulties using the catheters as for the femoral approach (Judgkins, Amplatz, etc) with the same size curves. Although the right radial or right ulnar approach can also be performed by the same catheters as for the femoral approach, a shorter Judgkins left (JL3.5) and longer Judgkins right (JR4.5) curves should be initially used for proper engagement of coronary ostia. The success rate for contemporary catheters for coronary angiography is around 99% (23).

The main disadvantage of a "universal catheter" is the learning curve. Also, aorto-coronary variations can make difficulties with either selective engagement of coronary ostia or deep seating and traumatic dissection of coronary ostia by a "universal catheter", but this is an extremely rare accident in the hand of experienced operators.

Manufacturers are constantly trying to extend the concept of universal catheter to coronary angioplasty as well, with many universal guiding catheters have been designed (Kimny, MAC 30/30, Barbeu, PAPA). The problem with them may be difficulties with proper coaxial engagement and inadequate support.. Most forearm operators therefore use guiding catheters constructed selectively for the left coronary artery (Ikari-left, LARA, MRADIAL) or the right coronary artery (Ikari-right, RRAD, MRESS) which are easier for manipulation and engagement of coronary ostia, resulting in better support necessary for optimal PCI.

7. IMA & VEIN GRAFT CANNULATION

In patients with aorto-coronary bypass grafting (CABG) special catheter shapes and access sites should be used to achieve selective engagement. The left internal mammary artery graft can be best engaged from the left forearm approach with internal mammary catheter. Vein grafts can be engaged either from the left or right forearm approach with Judgkins-right catheter, RCB catheter or Amplatz-type catheter. In case of bilateral internal mammary graft presence, bilateral forearm approach should be used (24).

Performance of graft angiography and angioplasty should be reserved only for operators with extensive experience in radial procedures, in whom procedural success rate with radial approach is comparable to femoral approach.

8. POSSIBLE DISADVANTAGES

Possible disadvantages of the forearm approach are related mainly with the learning curve, particularly with ulnar catheterization. Virtual absence of systematic training in the forearm catheterization is still reality in most countries, which adopting and promotion of this approach

makes slower. Because forearm approach requires a specific set of skills and experience with radial-dedicated interventional equipment, a significant learning curve is necessary. Widespread agreement among forearm operators is that at least 100 cases of diagnostic and additional 100 cases of interventional coronary procedures is required to adopt this approach (25). Also, during the training operators should be gradually exposed to more complex cases and challenging limb anatomy, necessary for safety and efficacy of procedures later when they become independent operators. According to the current 2011 SCAI recommendations, there are three levels of competency for forearm operators (26). Level 1 signifies an operator's ability to perform only simple diagnostic procedures. Level 2 signifies an operator's ability to perform all diagnostic and simple interventional procedures. Level 3 signifies an operator's ability to perform complex interventional procedures with challenging limb anatomy (6).

Another important drawback of the forearm approach is increased operator radiation exposure. Noteworthy, it is more prominent with the right than with the left forearm approach, and medial positioning of the arm and proper shielding can decrease it. Finally, radiation exposure decreases with the improvement of operator skills and experience.

9. SPECIFIC ISSUES OF ULNAR APPROACH

As we noted earlier, radial approach may fail in up to 10% of attempted cases. Ulnar artery cannulation was originally proposed as a viable, alternative forearm approach in patients unable to undergo femoral approach (3). Ulnar approach has certain advantageous over radial approach. In patients undergoing coronary bypass surgery, the ulnar approach spares the radial artery as a potential graft. Furthermore, the ulnar artery has a larger diameter and a straighter course so as it can accommodate easily introducers size of 7 Fr. Also, the ulnar artery has fewer alpha-adrenergic receptors than the radial artery, making it less prone to spasm (26).

10. MANAGEMENT OF POSSIBLE COMPLICATIONS

Although complications related with forearm approach are infrequent, operators should be completely familiar with management of all of them if they occur. Furthermore, predisposing factors should always be kept in mind, and preventive measures should be applied.

The most serious complication associated with the forearm approach is perforation of the cannulated forearm artery by a wire (27). It is important never to push a wire if resistance is felt and to perform a forearm angiogram to reveal the underlying reason. Hydrophilic wires may be particular dangerous when used for negotiating loops and curves, and are associated with increased risk of perforation. Vessel perforation is diagnosed by angiography with visible contrast extravasation. In case of vessel perforation, a site of perforation should be re-crossed with a floppy-type angioplasty wire, and the coronary procedure should be continued because a diagnostic or a guiding catheter will eventually seal the perforation site (28).

Forearm bleeding complications are classified in five grades (6). Grade I and II signify a local superficial hematoma (<10cm), whereas grade III (>10cm up to the elbow) and grade IV (proximal to the elbow) signify intramuscular bleeds. In rare cases grade IV hematoma may affect pectoral muscle of the neck or mediastinum. Compartment syndrome is a grade V hematoma, a limb-threatening emergency, resulting from unrecognized or inadequately treated vessel perforation or laceration. The management of hematoma include analgesia and topical ice application (grades I, II), pressure cuff inflation over the perforated vessel (grade III-V) as well as discontinuation of anticoagulants. Close monitoring of possible hand ischemia and consultation with a vascular surgeon is mandatory.

Radial or ulnar artery occlusion is usually clinically insignificant event and it may occur after the forearm catheterization with the incidence of ~ 6% (29). In the base, it is a thrombotic process and therefore heparin administration (3,000 – 5, 000 IU) is mandatory just after placing an introducer. The predisposing factors for radial or ulnar artery occlusion include catheter-vessel diameter mismatch, female gender, and prolonged hemostasis.

Other vascular complications that have rarely been reported are pseudo aneurysm and arterial-venous fistula (30). Their management includes usually a local compression, and only in rare cases surgical intervention.

11. CONTROVERSIAL ISSUES

With the development of procedural techniques and refinement of invasive technology, certain previous contraindications in the time between became controversial. These include necessity for positive modified Allen test before cannulation of forearm arteries, and possibility for homolateral forearm artery cannulation in the same setting after failure of initial attempt.

At the time of initial experience with radial approach, performance of modified standard Allen test was obligatory for the assessment of patency of homolateral ulnar artery and integrity of deep palmar arch, in order to avoid possible hand ischemia. However, in the meantime, a lot of evidence came from registries and observational studies suggesting that performance of Allen test is not necessary. Currently, most radial operators do not perform Allern test any more, and it is thought that palpable radial and ulnar pulses are quite enough to perform forearm approach (31).

In approximately 10% of cases, initial forearm approach, most frequently radial, will result in failure. The possible causes include anatomic variations of the radial artery (hypoplasia, tortuosity, curves, high take-off, radial loops) and spasm. In this setting, continuation with homolateral ulnar approach seems to be a valid alternative, because sterile preparation of another arm would be time-consuming in particular for patients with STEMI (32). The evidence for safety of homolateral forearm approach is still weak and based mainly on several case reports. Noteworthy,

Slogoff and associates reported in 1983 the series of 22 cardiothoracic patients with homolateral cannulation of both forearm arteries for the purpose of invasive monitoring, with no single hand ischemia observed (33). Also, there were reports on successful homolateral ulnar approach in cases with previously angiographically documented chronic total occlusion of the radial artery (34). More recently, homolateral forearm approach is gaining more popularity with operators experienced in ulnar approach. Although we have also performed a few homolateral cases (35), we strongly believe that homolateral approach is still experimental and it should not been used routinely if other vascular access site is available, until its safety will be proved with larger body of evidence.

12. CONCLUSION

Forearm approach has become preferable access site for percutaneous coronary procedures in last few years due to its advantages in terms of increased patient safety, comfort and quicker ambulation over the femoral approach. All these are closely associated with reduced cost of hospital stay.

Although radial cannulation is still the primary forearm access site, a growing body of evidence confirms that ulnar cannulation is an excellent alternative forearm access site. However, due to its learning curve and more challenging anatomy ulnar approach should be performed only by experienced radial operators.

Vascular and bleeding complications related with forearm approach are extremely rare, and significantly lower than with femoral approach.

Success of forearm approach is comparable to femoral approach and most frequent causes of failure are due to anomalies of the radial and/or brachial artery and spasm. Interventional cardiologists, and especially young fellows, should adopt this technique and perform coronary procedures on the basis forearm approach first, and afterwards groin in case of forearm failure.

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