

## Transradial and transulnar access for percutaneous coronary interventions

### Perkütan koroner girişim için transradial ve transulnar yaklaşımlar

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**Summary** – Periprocedural bleeding and vascular complications after percutaneous coronary intervention (PCI) are associated with worse clinical outcomes and increased short- and long-term mortality. Vascular access-related bleeding accounts for more than 80% of all major bleeding events in PCI performed by the transfemoral approach. Transradial approach (TRA), on the other hand, virtually eliminates access site bleeding and vascular complications. Although clinical trials have mostly evaluated different pharmacological strategies for reducing bleeding risk, adoption of a radial rather than a femoral access may allow greater reductions in bleeding complications than pharmacological strategies alone. High-risk patients such as those with acute coronary syndrome and ST-segment elevation myocardial infarction, women, obese patients, and elderly subjects who are at increased risk for vascular complications and bleeding might particularly benefit from the radial approach. Besides increased patient safety, the TRA is associated with improved patient satisfaction, reduced cost, and length of hospital stay, thus allowing outpatient performance of uncomplicated PCI.

**Özet** – Perkütan koroner girişimle (PKG) ilgili kanama ve vasküler komplikasyonlar, klinik sonuçların kötüleşmesine ve kısa ve uzun dönem mortalitede artışa neden olmaktadır. Vasküler girişim yeriyle ilgili kanama, transfemoral yaklaşımla yapılan PKG'lerden sonra görülen tüm önemli kanamaların %80'inden fazlasını oluşturmaktadır. Transradial yaklaşım ise, giriş yeri kanamalarını ve vasküler komplikasyonları neredeyse tümüyle ortadan kaldırmaktadır. Klinik çalışmalar kanama riskini azaltmak için çoğunlukla farklı farmakolojik stratejiler üzerinde durmasına karşın, femoral yaklaşımdan ziyade radial yaklaşımın benimsenmesiyle, kanama komplikasyonlarında tek başına farmakolojik stratejilerin sağlayacağından daha büyük düşüşler elde edilebilir. Akut koroner sendrom ve ST-segment yükselmeli miyokart enfarktüsü yüksek risk grubu hastalar ve vasküler komplikasyon ve kanama riski daha fazla olan kadınlar, obez kişiler, yaşlı hastalar radial yaklaşımdan daha fazla yarar görebilirler. Hasta için daha fazla güvenli olması yanı sıra, transradial yaklaşımda hasta memnuniyeti daha fazla, maliyet daha düşük, hastanede kalış süresi daha kısadır. Bunlar, PKG'nin nispeten sorunsuz şekilde yatışsız uygulanmasını sağlamaktadır.

Since the first human heart catheterization was performed by Werner Forssman in 1929, access site approach has undergone considerable evolution and technical refinement.

With the advent of selective coronary angiography over 50 years ago, surgical cut-down of the brachial artery became the preferred access. Although

#### Abbreviations:

AT	Allen's test
FA	Femoral approach
PCI	Percutaneous coronary intervention
RA	Radial artery
STEMI	ST-segment elevation myocardial infarction
TFA	Transfemoral approach
TRA	Transradial approach
TUA	Transulnar approach
UA	Ulnar artery

associated with excellent results, this technique required substantial surgical expertise. Later on, femoral artery puncture and sheath insertion by the modified Seldinger technique evolved into the standard method of invasive cardiovascular procedures.<sup>[1]</sup>

Currently, more than seven million invasive cardiovascular procedures are performed worldwide each year, and this number is expected to increase with aging of the population. The vast majority of these procedures are performed via the transfemoral approach. However, due to its unfavorable neurovascular anatomy, femoral artery access may result in major life-

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or limb-threatening complications (reported to be as high as 6%) and remains the leading cause of morbidity after cardiac catheterization.

Percutaneous transradial approach for diagnostic coronary angiography was first described by Lucien Campeau in 1989<sup>[2]</sup> and the first elective percutaneous coronary intervention via the TRA was performed in 1992 by Ferdinand Kiemeneij.<sup>[3]</sup>

Until recently, the TRA remained endorsed and strongly promoted by a dedicated group of transradialists and was disregarded or just ignored by a large number of operators traditionally trained in the femoral approach.<sup>[4]</sup>

More recently, transulnar approach has been proposed for interventions in patients not suitable for the TRA.

### The case for transradial access

Currently, the TRA is gaining both interest and increased application in catheterization laboratory practice worldwide. The most convincing reason for adopting the TRA is increased patient safety that results from substantial reduction in bleeding and vascular complications.

The TRA is of particular benefit in patients with increased risk for bleeding and vascular complications, more commonly associated with female gender, elder age, obesity, low weight, hypertension, renal failure, low platelet count, and anemia.

The direct impact of decreased periprocedural bleeding and access site complications on outcomes and on costs to health systems has increased the awareness about the potential benefits of the TRA as a default technique instead of the TFA.<sup>[5-8]</sup>

Furthermore, there is growing interest in improving patient satisfaction and greater administrative pressure for cost reduction, as well.

### The importance of bleeding complications

Periprocedural bleeding complications of PCI, including minor bleeding, are associated with poor clinical outcomes and increased mortality.<sup>[9-11]</sup> Access site bleeding has repeatedly been found to be the major contributor for bleeding events.<sup>[12-14]</sup>

Although the underlying mechanisms of increased mortality of patients with major bleeding remain un-

clear, increased myocardial ischemia has been proposed to be a final common pathway. Local bleeding and femoral site hematoma formation are also thought to lead to systemic activation of the prothrombotic pathways and activation of the clotting cascade. Cessation of antithrombotic therapies in blood loss and consequences of blood transfusion could further increase the risk for stent thrombosis and subsequent myocardial ischemia and reinfarction.<sup>[8]</sup>

Vascular closure devices have not been found to reduce the rates of hemorrhagic and vascular complications in several meta-analyses of randomized trials.<sup>[15-18]</sup> Furthermore, the use of these devices to close the arterial entry site was found to be associated with an increased risk for retroperitoneal hematoma.<sup>[16]</sup>

The MORTAL study retrospectively analyzed the association between access site, transfusion, and outcome in 32,822 patients who underwent PCI.<sup>[19]</sup> The radial approach was associated with 50% reduction in transfusion rate and relative risk reductions in 30-day and 1-year mortality rates of 29% and 17%, respectively.

Clinical trials have primarily evaluated different pharmacological strategies for reducing bleeding risk, but absolute reduction in bleeding risk has been modest.<sup>[11]</sup> A growing body of evidence suggests that adoption of a radial rather than a femoral access for PCI may permit greater reductions in bleeding than have been achieved with any antithrombotic strategy.

### Other advantages of the transradial approach

Radial access is of particular importance in morbidly obese patients, patients with severe peripheral vascular disease, older women with renal failure, and in fully anticoagulated patients.<sup>[20]</sup>

The TRA is generally preferred by patients because of reduced periprocedural discomfort, immediate ambulation, and improved postprocedural quality of life.<sup>[21]</sup> This preference is related to more favorable rankings for back and body pain, social functioning, mental health, and the ability to use the bathroom. There is no loss of privacy associated with instrumentation of the very intimate groin area.

Immediate in-lab sheath removal and simple and quick hemostasis make post-catheterization care much easier for the attending nurse and physician. Percutaneous coronary intervention via the TRA is associated with reduced length of hospital stay and reduced cost, thus resulting in increased turnover of patients.

Kimenej was the first to perform outpatient TRA-PCI in 1993. Lately, several trials have demonstrated the feasibility and safety as well as the positive economic impact of outpatient TRA for uncomplicated PCI.<sup>[22-25]</sup>

Recently, Vuurmans et al.<sup>[26]</sup> showed significantly reduced risk for new chronic kidney disease following catheterization with radial versus femoral access. The possible explanations could be consistently less contrast use and less contact between the catheter and the abdominal aortic atheroma, resulting in reduced likelihood of renal atheroembolization in the radial group. Another possibility is that reduction in access site bleeding via the TRA decreases the need for blood transfusion after PCI compared with that of the femoral access. Transfusion has been found to be an independent predictor of post-PCI nephropathy.<sup>[26]</sup> Furthermore, by easing urination, the TRA might prevent contrast reabsorption from the bladder, related to prolonged bed rest and more difficult urination after the TFA.

### Anatomic challenges and technical considerations

#### Access issues

Radial access should be used in the presence of patent collateral circulation to the hand, which is usually assessed with the modified or inverse Allen's test. However, the real value of the AT in assessing dual hand circulation has been questioned. Many experienced, high-volume radial operators do not use the AT in regular practice, without experiencing ischemic hand complications. A recent survey has shown that 23.4% of radial operators do not assess dual hand circulation before the procedure.<sup>[27]</sup>

Plethysmography and pulse oximetry has been found to be more sensitive than the AT. When used for TRA screening, only 1.5% of patients were not suitable candidates for the TRA compared to 6.3% determined by the AT.<sup>[28]</sup>

Radial artery puncture can be accomplished by the open needle technique (24 G micropuncture) or by closed needle (21 G plastic cannula) and a 0.018"-0.025" guidewire. With these small needle/guidewire systems, puncture failure is very rare (0.5%) and procedural success rate is high (96%) for experienced operators.<sup>[29]</sup>

The ideal site for puncture is 2 to 3 cm proximal to the flexor crease of the wrist. For local anesthesia,

a small amount (1 ml) of 2% lidocaine is injected at the site of the puncture. Most operators prefer a short ( $\leq 10$  cm) 5 or 6 F hydrophilic sheath for PCI. Repeat procedures are typically performed with a more proximal puncture to the previous one, or by ulnar artery access.

#### Spasm

Some degree of spasm is common during transradial procedures, but procedural failure is rarely seen in the hands of experienced operators.

Controlling patient anxiety and discomfort throughout the procedure is important in reducing circulating catecholamines. Pharmacologic prevention of vasospasm is important because it is associated with patient discomfort, procedural failure, and a higher rate of radial artery occlusion.<sup>[29]</sup> Before catheter insertion, most operators administer 2.5 to 5 mg of verapamil with or without 100 to 200  $\mu$ g of nitroglycerin (diluted in 10 ml saline) directly into the RA through the side arm sheath. At the same time, heparin (3,000-5,000 U) is given intravenously for prevention of RA occlusion. Focal or diffuse spasm often occurs at the site of a tortuous segment or radial loop. Frequently, it is related to a large-caliber sheath, multiple catheter exchanges, and long-catheter manipulations, particularly by inexperienced operators. Clinical evidence for radial artery spasm was observed more frequently in patients with a nonhydrophilic sheath, but it resulted in procedural failure in only 2.1% of cases.<sup>[29]</sup>

#### Anatomic variations

Anatomic variations in radial, brachial, and brachiocephalic-subclavian arterial circulations are common.<sup>[30]</sup> Sometimes, these can make it difficult to have access to the central arterial circulation and achieve adequate catheter seating. It is important that physicians learning the radial technique become familiar with common anatomic variations and learn how to navigate through them.

The most commonly encountered circulation anomalies are radial loops and curvatures (2%), tortuous radial arteries, high origin of the RA (7%), RA hypoplasia, and tortuous subclavian system (10%).<sup>[30,31]</sup> Subclavian tortuosity is associated with short stature, female gender, long-lasting hypertension, and advanced age. Taking deep breath by the patients may elongate the bends and facilitate successful cannulation of the coronary arteries. Right radial access can be challenging due to the likelihood of the retroesophageal right subclavian artery

(arteria lusoria) (<1%) that enters the aorta distal to the left subclavian artery.

Prevention of vasospasm is essential and an initial arm angiogram could be helpful in some cases. Although most of the anatomic variations, tortuous segments and loops can be overcome by hydrophilic 0.025" or 0.014" guidewires, these may increase the risk for dissection and perforation. Close attention to even the smallest resistance and low threshold for fluoroscopy and contrast injection may reveal the problem and prevent perforation.

It should be noted that there may be severe variations precluding optimal catheter backup, thus necessitating an alternative approach, particularly for complex PCI procedures.

In our institution, the right forearm (radial or ulnar artery) is preferred as the access site, followed by the left RA or UA approach when necessary (Fig. 1).

### Catheter control and backup

Most of the transradial diagnostic and PCI procedures are performed by standard catheters used for the femoral approach. The first international TRA practice survey showed that more than 65% of operators used an extra backup catheter for PCI of the left coronary artery and 70.4% used right Judkins catheters for the right coronary artery.<sup>[27]</sup>

Sometimes, it may not be possible to obtain optimal catheter backup due to an unfavorable brachiocephalic tortuosity particularly in elderly and hypertensive females and in complex PCIs. More liberal use of an extra stiff supportive 0.035" guidewire could facilitate optimal catheter control and backup. Recently, a dedicated guiding catheter (Ikari) has been introduced for TRA intervention that produces a stronger backup force by utilizing an unfavorable angle between the subclavian and brachiocephalic arteries. Most difficulties in proper selection and optimal backup support arise at the beginning of the learning curve. In the majority of cases, experienced operators can obtain guide support comparable to that from the TFA.

### The learning curve

The TRA technique requires a specific set of skills and a significant learning curve. With appropriate training, similar success rates with the radial and femoral approaches may be achieved even in complex cases. Although published data suggest that 100-200 cases are necessary to become proficient in the TRA, the learning curve is highly individual and

more experienced operators may become proficient sooner.<sup>[32]</sup>

## Ulnar artery access

The TRA is difficult and almost impossible in the presence of the following conditions: significant RA abnormalities, severe loops and curvatures, tortuous or hypoplastic RA, after failed RA puncture, and repeated use of the RA. Transulnar artery cannulation has been proposed as an alternative access for interventions in patients not suitable for the TRA. Ulnar artery access may also be preferred in patients undergoing cardiac surgery with the use of radial grafts. The UA generally has a larger diameter (UA/RA ratio=1.35) and a straighter course than that of the RA. It is more deeply seated and close to the ulnar nerve. Puncture site is around 3 cm proximal to the flexor crease along the axis with the most powerful pulsation of the UA, with a puncture angle of approximately 45°. The procedural success, advantages, and complication rates for this procedure appear similar to those of the TRA.<sup>[33]</sup>

## Technique and device compatibility in special patient subsets

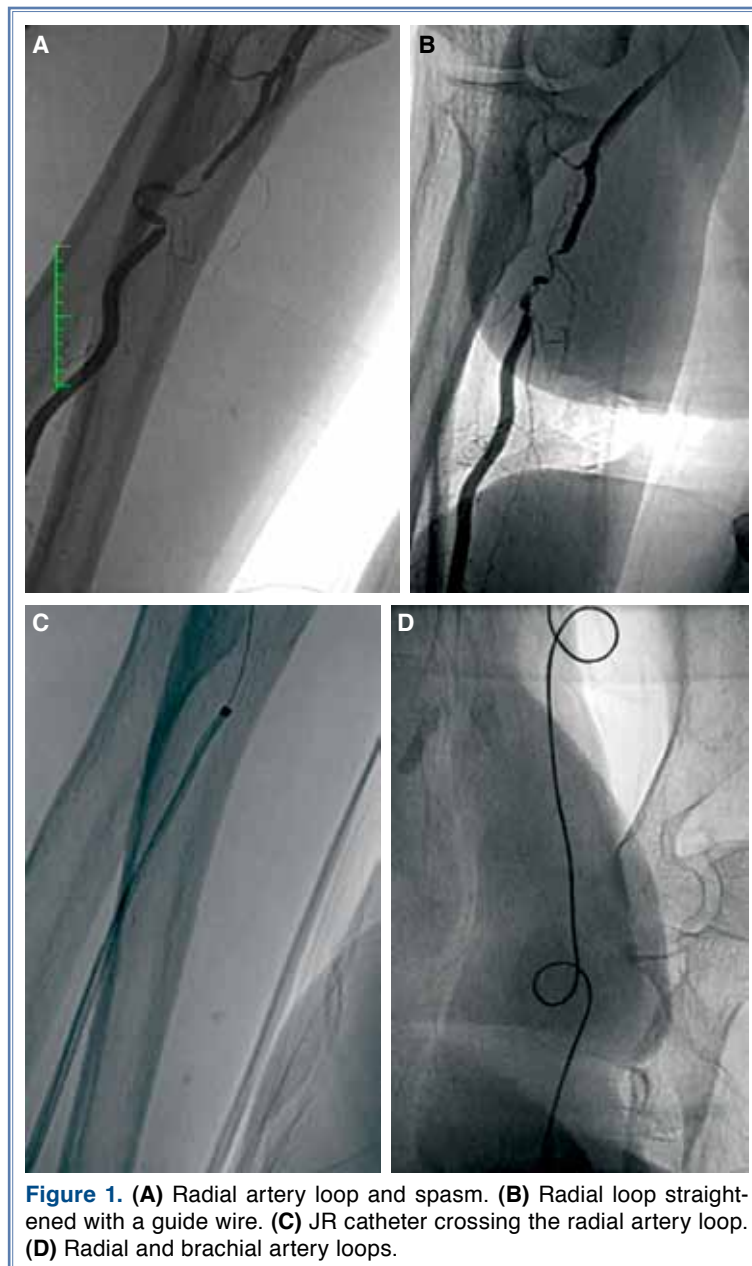
The RA is of smaller caliber compared to the femoral artery, so there are certain restrictions regarding guiding catheter size. Although a large proportion of RAs can accommodate a 7 F sheath, this is rarely needed as today nearly 95% of PCIs are performed via 5 or 6 F guiding catheters.<sup>[31,34]</sup>

A hydrophilic-coated sheathless guiding catheter, recently developed in Japan, has an outer diameter 1 French smaller than that of traditional guides, which may further expand the use of the TRA particularly in more complex chronic total occlusion PCIs.

### ST-segment elevation myocardial infarction

Primary PCI has been acknowledged by the most recent European guidelines as the preferred treatment strategy for ST-segment elevation myocardial infarction.<sup>[35]</sup> Technology has evolved in the past few years in a way that most of the materials necessary for primary PCI, i.e., catheters for thrombosuction and aspiration, distal protection devices or balloons for bifurcations, are 6 French compatible. Rapid reperfusion of the infarct-related artery in STEMI is closely associated with improved outcomes. Many consider that adopting the TRA may have an impact on needle-to-balloon





times resulting in greater access site delays. However, a recent study showed equivalent reperfusion times, with a median of 17 minutes for both approaches.<sup>[36]</sup> Patients undergoing primary PCI are expected to receive a broad spectrum of antithrombotic and antiplatelet agents, such as heparin (unfractionated or low-molecular weight), direct thrombin inhibitors, aspirin, thienopyridines, and glycoprotein IIb/IIIa inhibitors, in order to reduce ischemic events. Although effective, this strategy carries an increased risk for bleedings, most frequently involving the vascular access site. Several recent studies have reconfirmed that bleeding is as serious as ischemic complications, showing the

link between access site, bleeding complications, and mortality. These observations have strongly promoted the significance of the TRA for primary PCI.<sup>[35,37]</sup>

The PREVAIL study prospectively evaluated bleeding and vascular complications in 1,052 patients who had undergone either TRA- or TFA-PCI. In the subgroup of acute coronary syndrome and STEMI patients, both the composite of bleeding (3.2% vs. 6.9%) and ischemic complications including death (1.1% vs. 4.9%) were in favor of the TRA.<sup>[38]</sup>

A learning curve is necessary and for high success rate, TRA for primary PCI should be performed only

by skilled high-volume radial operators in elective settings.

### Bifurcations and chronic total occlusions

The TRA is compatible with most bifurcation techniques with few exceptions of trifurcational PCI and some dedicated bifurcation devices when the RA cannot accommodate larger than 7 F guides. With adjunctive imaging techniques such as intravascular ultrasound or optical coherence tomography, catheters and pressure wires can be readily used as 6 F compatible devices.

Most chronic total occlusion PCIs including the retrograde approach could be performed using bilateral TRA or TUA, since contralateral injections are frequently necessary. Guiding catheter support could be further improved with deeper seating, guide extensions, more liberal use of multiple guidewires, and anchoring balloon catheters.

### Postprocedural management

The sheath is removed in the cardiac catheterization laboratory immediately after TRA procedures. The activated clotting time is not routinely used to guide sheath removal because the RA is superficial and easily compressible. Diagnostic catheterization with the 5 F system typically requires 90 minutes for hemostasis, while PCI with the 6 F system generally needs 120-180 minutes for hemostasis, making outpatient PCI feasible and safe. Several RA compression devices have been proposed for selective compression of the target artery (radial or ulnar). Care must be taken while compressing the target artery in order to prevent venous stasis and unnecessary contralateral artery occlusion. Capillary refill, thumb pulse oximetry, and Doppler signals are used to monitor hand perfusion and for confirmation of "patent hemostasis". The TR Band hemostasis device is easy to use, allows direct visualization of the puncture site, provides effective and comfortable "patent hemostasis", and may further contribute to reduce radial occlusion rate.<sup>[39]</sup> In our experience, on more than 7,000 TRA catheterizations, we have not seen any serious ischemic hand complications, although we routinely practice ipsilateral UA approach after failed radial access.

A patient may recover from an uncomplicated TRA catheterization in an armchair rather than a bed, thus facilitating early ambulation. Before discharge, patients should be instructed to keep the puncture site clean, dry, covered with an adhesive bandage until

healed, and to limit use of the catheterized arm for 24 hours.

### Procedural complications

Although procedural complications are infrequent, they do occur. It is very important that physicians using the radial approach are aware of the incidence, predisposing factors, and available preventive and management strategies for such complications. Vagal reaction with the TRA is far more rare than with the TFA and may be related to prolonged puncture time during the early learning curve or may occur while navigating a forearm loop. Appropriate preprocedural sedation, patient relaxation, analgesia, and local infiltration anesthesia can aid in decreasing pain, anxiety, and associated vagal output.

Radial artery spasm is a frequent complication of the TRA; however, most vasospasms are temporary and resolve spontaneously. Hydrophilic sheaths facilitate sheath insertion and withdrawal and reduce patient discomfort. Intra-arterial verapamil (2.5-5 mg) administration is mandatory in preventing spasm and reducing RA occlusion rate. Using smaller-caliber catheters and restricting catheter manipulations and exchanges could further reduce vasospasm.

### Bleeding and perforation

The incidence of bleeding complications is significantly lower in comparison to the femoral and brachial approaches. Hydrophilic wires are useful in negotiating tortuous segments, loops, and curves, but are associated with increased risk for perforation. Wires should never be forced against resistance and advancement should be meticulously controlled in order to prevent perforation. When there is extravasation during the procedure, it could be traversed with a diagnostic catheter and exchanged with a guiding catheter, effectively sealing the dissection or perforation until the procedure is completed. Extravasation seen after the procedure can be treated with an adhesive pressure dressing or a blood pressure cuff at the arm or forearm level. Such conservative management with close patient monitoring for hand ischemia or bleeding with compartment syndrome is usually all that is needed. Forearm bleeding complications have been classified in five grades, ranging from a local superficial hematoma (grade I-II) related to the puncture site, grades III and IV resulting from intramuscular bleeds up to ischemic threat from compartment syndrome (grade V).

Grades I and II are best managed with analgesia, ice, and compression, while grades III and IV need more aggressive compression methods and may threaten compartment syndrome.<sup>[7,25]</sup>

### Postprocedural complications

Radial artery occlusion is the most common complication of the TRA, with a variable incidence of 3% to 9%.<sup>[40]</sup> It is a thrombotic process that can be prevented by using smaller and hydrophilic sheaths,<sup>[34]</sup> routine periprocedural heparin, and by systematic patent hemostasis practice.<sup>[39]</sup>

Although occlusion of the RA may preclude a future TRA, it is hardly ever of any clinical significance because of the anatomy of the deep and superficial palmar arches that allow the UA and probably the interosseal arteries to deliver a collateral vascular supply to the hand.

Compartment syndrome is a known, serious, but very rare complication after TRA intervention, with a reported incidence of 0.4%.<sup>[41]</sup> In our and in others' experience, this seems to be an overestimated report.<sup>[42]</sup> Possible etiologies include unrecognized distal perforation, prolonged bleeding with insufficient compression at the puncture site, or unrecognized RA laceration induced during sheath insertion. Early and proper management of hematomas is essential for prevention of compartment syndrome.

Sterile abscesses and infections infrequently occur within 2 to 3 weeks after the procedure and are associated with subcutaneous remnants of silicone from the previous model of Cook Medical hydrophilic-coated sheaths.<sup>[29]</sup>

**Chronic pain**—Prolonged and aggressive hemostatic compression at the access site may lead to vascular or neurologic complications, including persistent pain. Very rarely, chronic regional pain syndrome, so called reflex sympathetic dystrophy, may occur, presumably due to prolonged hand inactivity. Analgesic and physical therapies are potential management options.

### Conclusion

Considerable evidence now supports conversion to radial access for most PCI procedures, with an emphasis on decreasing access site bleeding and vascular complications, without sacrificing procedural success.

The forearm approach (radial or ulnar) improves patient comfort and satisfaction, allows rapid ambula-

tion, and is associated with reduced cost and hospital stay. Same-day home discharge of patients following an uncomplicated TRA-PCI, even in patients admitted for an acute coronary syndrome is feasible and safe.<sup>[25]</sup> High-risk patients such as those with acute coronary syndrome and STEMI, women and the elderly that are at increased risk for vascular complications and bleeding might particularly benefit from the radial approach. Complications arising from the radial arterial access are infrequent, negligible, and mostly avoidable compared with femoral complications. Certain limitations to the TRA such as longer radiation exposure during the learning curve and the potential influence on RA patency have limited acceptance of this technique. However, it is important to remember that the choice of access site is only one aspect of improving patient outcomes. Substantial gains are also expected with optimizing PCI procedural outcome and periprocedural pharmacologic strategies to maintain antithrombotic efficacy while limiting overall bleeding risk. Radial artery access along with optimal antithrombotic strategy may actually become the new gold standard for PCI in patients with high-risk features.

Therefore, modern interventionalists should adopt the approach of “forearm first then groin” whenever possible. Moreover, it will preserve the femoral artery integrity for access with large devices for eventual upcoming valve implantation or endovascular procedures.

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**Anahtar sözcükler:** Anjiyoplasti, balon, koroner/yöntem; koroner anjiyografi/yöntem; femoral arter; kalp kateterizasyonu/yöntem; radyal arter.