INTRODUCTION
Since the introduction of transradial access (TRA) in cardiology in 1989 (1), evidence favoring TRA over transfemoral access (TFA), in terms of patient preference, quality of life, lower complication and morbidity rates, and shorter hospital stay, has been presented (2-8).
Most studies on TRA were based on cardiology and neurointerventional procedures, and studies of the use of TRA in body and peripheral interventions performed by interventional radiologists are relatively few (4, 7-15). In this review, we aimed to compare the difference between TRA and TFA, provide the detailed technique and clinical applications of TRA in percutaneous transcatheter visceral artery embolization, and discuss the management of complications.
Keywords: TRA; TFA; Visceral artery embolization; Review

Comparison of TRA vs. TFA

Femoral Access
Percutaneous puncture of the right common femoral artery is performed during anterior wall puncture using palpation or ultrasound guidance with a micropuncture kit or an 18-gauge arterial cannulation needle using a modified Seldinger’s technique. The puncture site for the femoral artery should be below the inguinal ligament to control bleeding and prevent bleeding into the pelvis.

Radial Access
Preprocedural radial artery assessment is performed using the Barbeau test. With the patient’s left arm abducted to 75–90°, the left radial artery is accessed by performing a single-wall puncture under ultrasound guidance. Customarily, the operator stands on the patient’s right side during the procedure, with the monitors on the patient’s left. If a left radial approach is planned, the operator can maintain routine room/monitor setup by reaching over the body to the patient’s immobilized left arm, or by draping the left hand across the lower chest in a “Napoleonic” pose. The technical details are described in the following TRA technique.

Advantages of TRA over TFA
First, TRA is associated with a lower risk of access
Fifth, radial artery cocktails are necessary for TRA to prevent vasospasm and thrombus. During the administration of the cocktails, the operators should be concerned about the potential for hypotension and bradycardia associated with verapamil administration.

Technical and Clinical Success Rates of TRA vs. TFA
The technical and clinical success rates of TRA are generally comparable to those of TFA in the majority of procedures: transarterial embolization for hepatic malignancy (7, 8, 11, 13), mesenteric arterial procedures (4), prostate artery embolization (20), or uterine fibroid embolization (10). Very recently, Nakhaei et al. (10) compared the clinical and technical outcomes of TRA uterine artery embolization (UAE) with those of the TFA approach. There were 91 patients in the TFA group and 91 patients in the TRA group, with one crossover to TFA due to vasospasm (1 of 91; 1%). There were similar low rates of minor access site complications (6.6% [6 of 91] in the TFA group vs. 5.5% [5 of 91] in the TRA group).

Radiation Dose and Fluoroscopy Time
The radiation dose and fluoroscopy time remain controversial. Although some studies have claimed increased radiation dose and/or fluoroscopy time during TRA (11, 12, 21), several studies reported no significant difference in radiation dose or fluoroscopy time between TRA and TFA (8, 13-15, 22).

Operator radiation exposure could be reduced with TRA due to the positioning of the radiation shield and the longer distance between the operator and radiation source (8).

TRA Technique

Barbeau Test
Before TRA is performed, all patients undergo a modified Allen’s test with a pulse oximeter, also known as the Barbeau test (23). It is essential to evaluate the collateral circulation of the hand through Barbeau test, to avoid ischemic hand complications. A pulse oximeter is placed on the patient’s thumb, the radial pulse is identified, and the waveform is analyzed. The radial artery is then compressed, and the pulse oximeter waveform is again analyzed for up to 2 minutes and graded. Depending on the type of waveform, a registered ulnopalmar patency has the following four types: A) no damping of pulse tracing immediately after compression, B) damping of pulse tracing, C) loss of pulse

Disadvantages of TRA over TFA
First, TRA requires the use of long catheters/wires. Catheters receive less support and may be vulnerable to respiratory motion. Procedures like stenting or angioplasty can be limited by the maximum diameter of catheters and sheaths. A longer microcatheter length makes it difficult to use particles larger than 900 μm due to frequent catheter occlusions, according to Poiseuille’s rule (10).

Second, as the left radial artery is accessed, the room settings may not be familiar. A learning curve is required before the benefits and efficiencies become clear (8).

Third, TRA may be affected by the patient’s anatomy. For example, being tall, having a tortuous aorta, or having long arms may affect TRA.
tracing followed by recovery within 2 minutes, and D) loss of pulse tracing without recovery within 2 minutes (Fig. 1). According to Barbeau et al. (23), this test is more sensitive than the Allen’s test in determining suitable candidates for TRA by direct comparison in 1010 patients. A Barbeau type D waveform is the only true contraindication of TRA. It increases the risk of hand ischemia in the case of radial obstructive complication secondary to poor ulnar compensation.

**Setup**

Generally, either the right or left radial artery on the same side as the target vessel can be selected for interventional procedures above the diaphragm. However, for interventional procedures below the diaphragm, left radial artery access is preferred over right-sided access. In terms of a shorter distance to the target vessel from the left wrist and ascending aortic curvature, left radial access is more advantageous. In addition, the risk of cerebral emboli or thrombus formation is theoretically limiting because the guiding catheter or sheath is not positioned across the great vessels during the procedure.

The arm can be positioned in several ways according to the operator’s preference and angiography suite situation. One option is to position the arm at 75–90°, almost perpendicular to the table (Fig. 2A). This allows easier access to the vessel but makes catheter exchanges somewhat awkward. In our practice, the preferred method is to position the arm at the patient’s side in a position similar to that of the patient’s groin, thereby allowing for catheters/wires to be positioned over the patient’s draped body similar to that during traditional TFA (Fig. 2B). Moreover, femoral crossover is possible during the procedure, particularly in patients with aortic disease and tortuosity, anatomical variants, or smaller-caliber radial arteries.

The wrist should be supinated and slightly hyperextended, and a towel roll or a commercially available radial arm board can be used to support the wrist. Prone positioning, which allows the left radial artery to be accessed and positioned in a way similar to that of the right common femoral artery, can be used in patients with chronic back pain, who are unable to lie supine (24). Typical femoral access groin

![Fig. 1. Barbeau test and four types of Barbeau waveforms.](image1)

**Fig. 1. Barbeau test and four types of Barbeau waveforms.**

| Type | Radial artery compression | Start | After 2 minutes |
|------|---------------------------|-------|-----------------|
| A    | No damping of pulse tracing immediately after compression |
| B    | Damping of pulse tracing |
| C    | Loss of pulse tracing followed by recovery within 2 minutes |
| D    | Loss of pulse tracing without recovery within 2 minutes |

![Fig. 2. Position of left arm for TRA.](image2)

**Fig. 2. Position of left arm for TRA.**

A. Arm positioned at 75–90°, almost perpendicular to table for easier vessel access with ultrasound. Proper positioning of left wrist was achieved by using long arm board and left radial artery was punctured. B. Arm was then repositioned against patient’s side. Arm positioned at patient’s side in position similar to that of patient’s groin, which allows catheters/wires to be positioned over patient’s draped body in way similar to that in traditional transfemoral access.
dyes are used. The pulse oximeter is left in place on the left thumb during the procedure.

**Radial Artery Access**

When a local anesthetic (2% lidocaine) is administered, the radial artery is punctured with a 21-gauge needle under ultrasound guidance (Fig. 3). The recommended puncture site is 2–3 cm cephalad to the radial styloid. Then, a 0.018-inch wire is advanced into the radial artery. If there is any resistance, the wire is pulled back and readjusted. If the wire cannot be advanced, arteriography with aliquots of contrast agent is performed. A specialized radial access sheath with a hydrophilic coating is then used. The dilators on these sheaths are tapered to 0.018 inch to allow for immediate sheath placement without an incision or wire exchange. In our practice, the 7-cm-length Prelude radial sheath introducer (Merit Medical Systems) is commonly used. The commercially available hydrophilic radial sheaths are listed in Table 1. According to Rathore et al. (25), the use of hydrophilic sheaths decreases the incidences of radial artery spasm and pain during TRA. The majority of diagnostic and interventional procedures can be performed using 5- to 6-Fr sheaths.

Once the sheath is placed in the radial artery, an antispasmodic medication cocktail is administered intraradially directly through the access sheath. Nitrates, calcium channel blockers, and heparin are typically used to prevent arterial spasm and reduce vascular tone. Although there is no consensus on the ideal mixture, a combination of 2000 units of heparin, 200 μg of

---

**Fig. 3. Radial artery puncture.**

A. Diameter of radial artery (arrow) is measured at 3.2 mm on ultrasound image. Radial artery is punctured with 21-gauge needle following single-wall technique under ultrasound guidance. B, C. 0.018-inch wire is advanced into radial artery.
nitroglycerin, and 2.5 mg of verapamil is hemodiluted with aspired blood to 20 mL, and administered through the sheath. Verapamil causes a significant burning sensation upon injection; hence, continuous hemodilution and slow injection are recommended. The use of verapamil is relatively contraindicated for some patients with left ventricular dysfunction, hypotension, and bradycardia.

Snuffbox TRA Technique

Although TRA has many advantages, in case of Barbeau D waveform, small radial artery (< 2 mm), and a patient with chronic renal failure scheduled for arteriovenous fistula formation for hemodialysis, TRA is not feasible. Recently, as an alternative access, distal transradial artery access from the anatomical snuffbox on the dorsal side of the hand has been proposed (26). A patient’s left wrist is comfortably placed near the right groin in mild pronation. Before placing a sterile drape, the distal radial artery diameter and flow are evaluated by ultrasound, and Barbeau test is performed in each patient. During the vascular access procedure, the operator stands on the patient’s right side. Lidocaine is administered from the vascular puncture site to the skin at the anatomical snuffbox. The distal radial artery is accessed under ultrasound guidance using a 5-Fr transradial kit (Prelude, Merit Medical Systems; or Radifocus, Terumo) (Fig. 4). After ensuring access, a combination of 2000 IU of heparin, 200 μg of nitroglycerin, and 2.5 mg of verapamil is hemodiluted with 20 mL of aspired blood and administered through the sheath to prevent vasospasm and thrombosis. An additional 1000 IU of heparin is administered every 60 minutes after 90 minutes. The snuffbox approach has several advantages over conventional TRA. First, an occlusion at the distal radial artery potentially maintains antegrade flow through the superficial palmar arch, preventing ischemia and hand disability. Second, no need for compression around the wrist for hemostasis makes the wrist free to move, which limits venous congestion of the hand. Third, in case of vasospasm and hematoma from unsuccessful needling which make further trials difficult, an operator could easily move to the conventional radial approach. Fourth, for patients with chronic kidney disease, the distal radial artery access spares the site for future arterio-venous fistula (27).

Catheter Selection

In most cases, a 125-cm 5-Fr ultimate radial catheter (Merit Medical Systems) and a standard 0.035-inch hydrophilic guide wire (Radifocus, Terumo) are used to navigate the subclavian region and engage the descending aorta (Fig. 5). The unique shape and longer length of the ultimate catheters (Merit Medical Systems) make it easier for them to engage the target mesenteric vessels or iliac vessels. Generally, 150-cm length microcatheters are recommended when using diagnostic catheters that are longer than 100 cm.

Patent Hemostasis Technique

To minimize the risk of postprocedural radial artery thrombosis, nonocclusive patent hemostasis is a fundamental principle. Nonocclusive patent hemostasis is achieved using a radial compression device. There are several commercially available devices, which are listed in Table 2. The most commonly used radial compression device in our practice is the PreludeSYNC (Merit Medical Systems) (Fig. 6). The curved section of the clear plate is placed on the thumb side of the wrist. After aspirating the sheath, the sheath is withdrawn approximately 2.5 cm. The center of the “crosshairs” is placed over the arteriotomy site (location where the sheath entered the artery, approximately 1–2 mm proximal to the skin puncture site). The band should be fastened securely around the wrist without any slack, but it should not be extremely tightened. The bulb is slowly inflated with 20 mL of air, and the sheath is simultaneously removed. Once the sheath is completely removed, air is injected constantly into the bulb until the bleeding has

---

| Table 1. Radial Access Sheaths |
|--------------------------------|
| **Device**          | **Company**               |
| Prelude radial      | Merit Medical Systems     |
| Glidesheath, Glidesheath Slender | Terumo                  |
| Flexor Radial Introducer      | Cook Medical              |
| Rain, Avanti         | Cordis                    |

Fig. 4. Snuffbox radial artery access technique.
pulse is performed for all patients before discharge from the interventional radiology clinic.

**Clinical Applications**

**Transarterial Chemoembolization for Hepatic Malignancy**

Although TFA is the most widely used transarterial chemoembolization (TACE) approach for hepatocellular carcinoma (HCC), a growing number of TACE procedures for HCC via TRA are performed because of the emerging evidence favoring TRA over TFA in recent studies in terms of higher patient satisfaction, lower radiation exposure, and lower complication rates (8, 12, 28, 29).

Radial access is obtained using the standard technique and medications as described above, and hydrophilic 5-Fr transradial sheaths are used. Under direct fluoroscopic visualization, a 0.035-inch angled J-tip Glidewire (150–230 cm in length) and a 5-Fr, 110-to-125 cm diagnostic catheters are advanced coaxially into the descending aorta, and selective catheterization and angiography of the celiac trunk, hepatic artery, and superior mesenteric artery are performed. For super-selective catheterization and angiography, a microcatheter (135 or 150 cm in length; 1.9–2.8 Fr in diameter) is used (8, 13, 30, 31).

TACE is performed using lipiodol emulsion (Lipiodol Ultra-Fluid, Guerbet) and doxorubicin hydrochloride, followed by the administration of gelatin sponge particles (150–350 μm) mixed with contrast material until flow stasis of the tumor-feeding arteries is achieved (Fig. 7). Pua et al. (30) reported successful cone-beam CT acquisition during the...
TACE via the TRA approach with arm repositioning using the swivel arm board (100% success rate). Shiozawa et al. (29) retrospectively compared TRA with TFA in hepatic intra-arterial therapy and demonstrated comparable efficacy (98.3% technical success with TRA). Yamada et al. (8) and Hung et al. (12) suggested that TRA was the preferred access for the majority of patients and was associated with less radiation exposure to the operator. Another prospective single center study by Iezzi et al. (13) demonstrated that the technical success of hepatic chemoembolization via the TRA approach was obtained in all patients (100%). There was no switch from radial access to femoral access during any procedure (crossover rate: 0%). TRA treatments required a significantly longer preparation time for the procedure ($p < 0.008$); TRA procedures were also characterized by longer puncture, fluoroscopy, and total examination times, with higher mean radiation doses and volumes of administered contrast medium, although these differences were not statistically significant.

Lately, TRA was also applied to radioembolization for hepatic malignancy, and patients exhibited a strong preference for TRA without significant differences in radiation dose, fluoroscopy time, or procedure-related complications (7, 15).

**Renal Artery Embolization**

Percutaneous transcatheter arterial embolization (TAE) is a safe and effective method for managing renal bleeding. For example, percutaneous image-guided renal artery TAE is a widely accepted treatment for patients with renal trauma and renal angiomyolipomas (Fig. 8) (32). Recently, the role of TAE in renal cell carcinoma has been well defined. TAE of renal cell carcinoma was advocated as a means to 1) reduce tumor vascularity and intraoperative blood loss, 2) debulk the tumor in nonsurgical candidates, and 3) palliate symptoms such as flank pain and hematuria (33). More

---

**Fig. 7. Clinical applications of TRA on TACE for hepatic malignancy.**
A. Coronal contrast-enhanced CT shows 5-cm hepatocellular carcinoma (arrow) in segment 6 of liver. B. Hepatic arteriography showing multiple hypervascular tumors in both lobes of liver. C. After selection of tumor feeder using microcatheter, drug-eluting bead loaded with doxorubicin/nonionic contrast suspension is slowly injected until near stasis. D. Post-embolization hepatic arteriography showing complete devascularization of tumor in liver. E. Coronal contrast-enhanced CT image 1 month after TACE showing complete response (arrow). TRA = transradial access, TACE = transarterial chemoembolization
Prostatic Artery Embolization

Prostatic artery embolization (PAE) is an emerging therapy for the treatment of lower urinary tract symptoms secondary to benign prostatic hyperplasia (Fig. 9) (37). TRA has been investigated as a potential alternative to TFA for PAE procedures in a case report and case series in which embolization was technically successful (bilateral) in all cases (38, 39). The authors of both studies concluded that PAE via TRA was technically feasible and proposed the advantages of this approach, which ranged from immediate ambulation to relief from lower back pain by elevating the patients’ legs during prolonged procedures.

Fig. 8. Clinical applications of TRA on embolization of renal angiomyolipoma.

A. Left renal arteriography showing hypervascular tumor in right kidney upper pole (arrow). B. After selection of tumor feeder using microcatheter, permanent embolic agents (polyvinyl alcohol particle) are slowly injected until near stasis. C. Super-selective embolization of tumor feeder with microcoil (arrow). D. Post-embolization left renal arteriography showing complete devascularization of tumor and preserved perfusion in renal parenchyma.

Recent studies have shown that percutaneous renal artery angiography and embolization could employ the radial approach to create a vascular access (18, 34-36). Abrams et al. (36) reported the first case of successful adaptation of TRA in renal artery embolization for hemorrhagic angiomyolipoma in a pregnant patient, in whom femoral access or pelvic radiation was undesirable. In another study by Srinivasa et al. (18), prone TRA was found to be a safe and feasible method for performing combined arterial and posterior percutaneous interventions without the need for repositioning.
Fig. 9. Clinical applications of TRA on prostate artery embolization.
A. Left internal iliac arteriography showing enlarged prostate with prominent vascularity (arrow).
B. Selective left prostate artery angiography showing hypertrophied vasculature within prostate gland (arrow).
C. After selection of prostate artery using microcatheter, permanent embolic agents (polyvinyl alcohol particle) are slowly injected until near stasis.
D. Post-embolization left prostate artery angiogram shows complete devascularization of hypertrophied vasculature within prostate gland.
A recent retrospective single-center study that compared the outcomes of PAE procedures via TRA and TFA also demonstrated that transradial/transulnar access is a safe and feasible method for performing PAE with a safety profile comparable to that of TFA (20). Although their results may be associated with progression along the procedure learning curve, the potential for decreased PAE procedure times, fluoroscopy times, and radiation skin entry is promising.

**UAE**

UAE has been performed for more than two decades using TFA, with very low complication rates and good technical and clinical outcomes (40). Currently, many studies have demonstrated that UAE via TRA has some advantages: improved safety and feasibility in patients with obesity or coagulopathy, early ambulation, and early discharge (9, 41). In 2014, Resnick et al. (9) demonstrated the feasibility of TRA for UAE and showed that TRA is a safe alternative to TFA. However, this study did not provide a comparison between TFA and TRA in terms of its efficacy in treating uterine fibroid embolization. Mortensen et al. (42) compared 39 TFA and 27 TRA uterine fibroid embolization procedures and showed comparable fluoroscopy time. Nakhaei et al. (10) compared 91 TFA and 91 TRA uterine fibroid embolization procedures and demonstrated comparable technical and clinical outcomes between the two approaches. They also reported that TRA for UAE has a certain limitation, which is related to the length of the catheter. First, the use of a longer microcatheter makes it difficult to use particles larger than 900 μm due to the frequent occurrence of catheter occlusions. The recommended particle size for UAE is 500–700 μm (43), and a larger particle size is only used when the uterus is extremely large. The second potential limitation of TRA for pelvic procedures is that even a 125-cm parent catheter may not reach the uterine artery via a radial approach if the woman is very tall or has long arms. Hence, the radial artery should be accessed a few centimeters proximally or the parent catheter should be placed in the anterior division of the internal iliac artery and the microcatheter should be navigated to the uterine artery.

**Potential Complications and Management**

In the majority of patients who underwent TRA, access site complications are predictable and easy to treat (44). New complications associated with TRA, like forearm pain or loss of upper extremity strength, should be evaluated further in order to determine their impact on patients’ function and quality of life (45). However, the treatment of complications after TRA depends on the experience of the interventional cardiologist performing the procedure. Potential access site complications during percutaneous procedures performed with a TRA are summarized in Table 3.

### Table 3. Potential Access Site Complications during Percutaneous Procedures Performed via Transradial Access

| Complication                                      |
|---------------------------------------------------|
| Radial artery occlusion                           |
| Radial artery spasm                               |
| Persistent postprocedural pain                    |
| Upper extremity loss of strength                  |
| Hematoma                                          |
| Radial artery pseudoaneurysm                      |
| Arteriovenous fistula formation                    |
| Radial artery perforation                         |
| Radial artery eversion during sheath removal      |
| Hand ischemia                                      |
| Compartment syndrome                              |

**Radial Artery Occlusion**

The most common complication of TRA is radial artery occlusion (RAO), which occurs in about 1–10% of patients (46, 47). Endothelial injury of the radial artery and decrease in blood flow after sheath and catheter insertion appear to contribute to thrombus formation and are predisposing factors for RAO (45, 46). In addition, a repeat radial artery cannulation can promote intimal hyperplasia and increased intima-media thickness (48, 49), resulting in negative remodeling of the arterial wall and further predisposition to RAO (50). In most cases, RAO occurs immediately after the procedure, and up to 50% of patients have spontaneous recanalization of the artery within 1–3 months (51, 52).

Majority of patients with RAO are asymptomatic. This is due to the dual supply of blood to the hand and the usually rich network of collateral circulation: the radial and ulnar arteries undergo multiple anastomoses before they are connected to the hand through the superficial and deep palmar arches. Although RAO is a usually subclinical condition and can be managed conservatively, in some cases, active treatment such as long-term anticoagulation and balloon angioplasty may be needed (53-56). In Zankl et al.’s study (53), patients with early symptomatic RAO were treated with enoxaparin or fondaparinux for 4 weeks. After 1 month, 87% of patients had a recanalized radial artery.
Radial Artery Pseudoaneurysm

Radial artery pseudoaneurysm presents as a rare complication in less than 1% of these procedures (16). The known risk factors for radial pseudoaneurysm include the use of glycoprotein IIb/IIIa inhibitors and an elevated body mass index. Extremely elderly patients may also be at increased risk. Other potential factors that can be hypothesized from the more common femoral artery pseudoaneurysm include the use of larger sheaths, periprocedural use of antiplatelet agents, use of anticoagulants, and hypertension (57). There is no standard treatment for radial pseudoaneurysm. Treatment options range from percutaneous thrombin injection, surgical repair, ultrasound guided compression, external compression devices, and close monitoring for spontaneous resolution (58-60).

Radial Artery Perforation

Iatrogenic radial artery perforation has been reported in 1% of patients who underwent coronary intervention via radial access (61, 62). Uncontrolled bleeding from a perforation may lead to compartment syndrome threatening the arm and requiring emergent fasciotomy (63). Previously described risk factors for radial artery perforation include female sex, short height, hypertension, excessive anticoagulation, and aggressive wire manipulation (63, 64). Multiple protocols for management of radial artery perforation have been reported, including blocking the brachial artery flow by sphygmomanometer cuff and reversing any anticoagulation, insertion of the long-sheath or catheter, balloon tamponade, and covered stent placement (64-69).

Repeat TRA

Despite the increasingly frequent adoption of TRA in visceral artery intervention, few investigators have examined the feasibility, efficacy, and safety of repeat transradial catheterization. The technical success rates of the repeat transradial procedure were comparable with those of the initial procedure; high-volume centers reported repeat TRA with success rates of > 95% (70-72). A study by Yoo et al. (70) reported the changes in radial artery diameter after transradial procedures. The mean radial arterial diameter was 2.63 ± 0.35 mm before the initial procedure and 2.51 ± 0.29 mm 4.5 months after the first procedure ($p < 0.05$). They demonstrated that the inner diameter of the radial artery after the transradial procedure decreased significantly at the time of long-term follow-up, and the frequency of RAO was greater after repeated use than after first-time use. However, the repeated use of the same radial artery is effective when considering its high procedural success and low complication rates in the majority of patients.

CONCLUSION

In conclusion, the technical and clinical outcomes and complication rate of TRA for various types of visceral artery embolization are comparable to those of TFA. The main advantage of this approach is early ambulation after the procedure, following early discharge from the hospital, and higher patient satisfaction. Its potential limitations are the lack of adequate materials (relatively long catheters and microcatheters) that can easily reach the ostium of each visceral artery via radial access. Moreover, the diameter of the radial artery and total body height of the patient are important prognostic factors that can influence the success of the procedure.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

ORCID iDs

Hee Ho Chu
https://orcid.org/0000-0002-3903-0026

Jong Woo Kim
https://orcid.org/0000-0002-5784-922X

Ji Hoon Shin
https://orcid.org/0000-0001-6598-9049

Soo Buem Cho
https://orcid.org/0000-0001-5762-7064

REFERENCES

1. Campeau L. Percutaneous radial artery approach for coronary angiography. Cathet Cardiovasc Diagn 1989;16:3-7
2. Mitchell MD, Hong JA, Lee BY, Umscheid CA, Bartsch SM, Don CW. Systematic review and cost-benefit analysis of radial artery access for coronary angiography and intervention. Circ Cardiovasc Qual Outcomes 2012;5:454-462
3. Valgimigli M, Gagnor A, Calabró P, Frigoli E, Leonardi S, Zaro T, et al. Radial versus femoral access in patients with acute coronary syndromes undergoing invasive management: a
randomised multicentre trial. *Lancet* 2015;385:2465-2476

4. van Dijk LJD, van Noord D, van Mierlo M, Bijjedeavae DC, Bruno MJ, Moelker A. Single-center retrospective comparative analysis of transradial, transbrachial, and transfemoral approach for mesenteric arterial procedures. *J Vasc Interv Radiol* 2020;31:1130-1138

5. Feldman DN, Swaminiathan RV, Kaltenbach LA, Bakanov DV, Kim LK, Wong SC, et al. Adoption of radial access and comparison of outcomes to femoral access in percutaneous coronary intervention: an updated report from the national cardiovascular data registry (2007-2012). *Circulation* 2013;127:2295-2306

6. Andò G, Capodanno D. Radial versus femoral access in invasively managed patients with acute coronary syndrome: a systematic review and meta-analysis. *Ann Intern Med* 2015;163:932-940

7. Liu LB, Cedillo MA, Bishay V, Ranade M, Patel RS, Kim E, et al. Patient experience and preference in transradial versus transfemoral access during transarterial radioembolization: a randomized single-center trial. *J Vasc Interv Radiol* 2019;30:414-420

8. Yamada R, Bracewell S, Bassaco B, Camacho J, Anderson MB, Conrad A, et al. Transradial versus transfemoral arterial access in liver cancer embolization: randomized trial to assess patient satisfaction. *J Vasc Interv Radiol* 2018;29:38-43

9. Resnick NJ, Kim E, Patel RS, Lookstein RA, Nowakowski FS, Fischman AM. Uterine artery embolization using a transradial approach: initial experience and technique. *J Vasc Interv Radiol* 2014;25:443-447

10. Nakhaei M, Mojtahedi A, Faintuch S, Sarwar A, Brook OR. Transradial and transfemoral uterine fibroid embolization comparative study: technical and clinical outcomes. *J Vasc Interv Radiol* 2015;31:123-129

11. Ks B, Mills M, Hoffe SE. Hepatic radioembolization from transradial access: initial experience and comparison to transfemoral access. *Diagn Interv Radiol* 2016;22:444-449

12. Hung ML, Lee EW, McWilliams JP, Padia SA, Ding P, Kee ST. A reality check in transradial access: a single-centre comparison of transradial and transfemoral access for abdominal and peripheral intervention. *Eur Radiol* 2019;29:68-74

13. Iezzi R, Pompli M, Posa A, Annichiarico E, Garcovich M, Merlino B, et al. Transradial versus transfemoral access for hepatic chemoembolization: intrapatient prospective single-center study. *J Vasc Interv Radiol* 2017;28:1234-1239

14. Roy AK, Garot P, Louvard Y, Nelyon A, Spaziano M, Sawaya FJ, et al. Comparison of transradial vs transfemoral access for aortoiliac and femoropopliteal interventions: a single-center experience. *J Endovasc Ther* 2016;23:880-888

15. Loewenstern J, Welch C, Lepieric S, Bishay V, Ranade M, Patel RS, et al. Patient radiation exposure in transradial versus transfemoral yttrium-90 radioembolization: a retrospective propensity score-matched analysis. *J Vasc Interv Radiol* 2018;29:936-942

16. Jolly SS, Yusuf S, Cairns J, Niemelä K, Xavier D, Widimsky P, et al. Radial versus femoral access for coronary angiography and intervention in patients with acute coronary syndromes (RIVAL): a randomised, parallel group, multicentre trial. *Lancet* 2011;377:1409-1420

17. Chick JFB, Osher ML, Castle JC, Malaeb BS, Gemmete JJ, Srinivasa RN. Prone transradial renal arteriography and interventional nephroscopy for the visualization and retrieval of migrated renal embolization coils causing flank pain and hydronephrosis. *J Vasc Interv Radiol* 2017;28:1314-1316

18. Srinivasa RN, Chick JFB, Gemmete JJ, Majdalany BS, Hage A, Jo A, et al. Prone transradial catheterization for combined single-session endovascular and percutaneous interventions: approach, technical success, safety, and outcomes in 15 patients. *Diagn Interv Radiol* 2018;24:276-282

19. Mamas MA, Tosh J, Huime W, Hoskins N, Bungey G, Ludman P, et al. Health economic analysis of access site practice in England during changes in practice: insights from the British Cardiovascular Interventional Society. *Circ Cardiovasc Qual Outcomes* 2018;11:e004482

20. Bhata S, Harward SH, Sinha VK, Narayanan G. Prostate artery embolization via transradial or transulnar versus transfemoral arterial access: technical results. *J Vasc Interv Radiol* 2017;28:898-905

21. Brueck M, Bandorski D, Kramer W, Wieczorek M, Hötgen R, Tillmanns H. A randomized comparison of transradial versus transfemoral approach for coronary angiography and angioplasty. *JACC Cardiovasc Interv* 2009;2:1047-1054

22. Rigattieri S, Schiabasi A, Dreffah S, Mussano E, Cera M, Russo CD, et al. Transradial access and radiation exposure in diagnostic and interventional coronary procedures. *J Invasive Cardiol* 2014;26:469-474

23. Barbeau GR, Arsenault F, Dugas L, Simard S, Larivière-B51e MM. Evaluation of the ulnopalmar arterial arches with pulse oximetry and plethysmography: comparison with the Allen’s test in 1010 patients. *Am Heart J* 2004;147:489-493

24. Kwon SW, Cha JJ, Rhee JH. Prone position coronary angiography due to intractable back pain: another merit of transradial approach compared to transfemoral approach. *J Invasive Cardiol* 2012;24:605-607

25. Rathore S, Stables RH, Pauriah M, Hakeem A, Mills JD, Palmer ND, et al. Impact of length and hydrophilic coating of the introducer sheath on radial artery spasm during transradial coronary intervention: a randomized study. *JACC Cardiovasc Interv* 2010;3:475-483

26. Kiemenieij F. Left distal transradial access in the anatomical snuffbox for coronary angiography (ldTRA) and interventions (ldTRI). *EuroIntervention* 2017;13:851-857

27. Roh JH, Lee JH. Distal radial approach through the anatomical snuff box for coronary angiography and interventions. *Korean Circ J* 2018;48:1131-1134

28. Yamashita T, Imai S, Tamada T, Yamamoto A, Egashira N, Watanabe S, et al. Transradial approach for noncoronary angiography and interventions. *Catheter Cardiovasc Interv* 2007;70:303-308
29. Shiozawa S, Tsuchiya A, Endo S, Kato H, Katsube T, Kumazawa K, et al. Transradial approach for transcatheter arterial chemoembolization in patients with hepatocellular carcinoma: comparison with conventional transfemoral approach. J Clin Gastroenterol 2003;37:412-417

30. Pua U, Teo CC, U PT, Quek LHH. Cone-beam CT acquisition during transradial TACE made easy; use of the swivel arm board. Br J Radiol 2018;91:20170248

31. Meng XX, Liao HQ, Liu HC, Jiang HL, Gu YF, Li X, et al. Application of side-hole catheter technique for transradial arterial chemoembolization in patients with hepatocellular carcinoma. Abdom Radiol (NY) 2019;44:3195-3199

32. Ramaswamy RS, Darcy MD. Arterial embolization for the treatment of renal masses and traumatic renal injuries. Tech Vasc Interv Radiol 2016;19:203-210

33. Goldstein HM, Medellin H, Beydoun MT, Wallace S, Ben-Menachem Y, Bracken RB, et al. Transcatheter embolization of renal cell carcinoma. Am J Roentgenol Radium Ther Nucl Med 1975;123:557-562

34. Gunn AJ, Patel AR, Rais-Bahrami S. Role of angiographic techniques in renal cell carcinoma. Curr Urol Rep 2018;19:76

35. Scharf Z, Momah-Ukeh I, Kim AY. Trans-radial embolization of bleeding renal angiomylipoma in pregnant 30-year-old female - a case report. J Radiol Case Rep 2019;13:34-42

36. Abrams J, Yee DC, Clark TW. Transradial embolization of a bleeding renal angiomylipoma. Vasc Endovascular Surg 2011;45:470-473

37. Schreuder SM, Scholtens AE, Reekers JA, Bipat S. The role of prostatic arterial embolization in patients with benign prostatic hyperplasia: a systematic review. Cardiovasc Intervent Radiol 2014;37:1198-1219

38. Khayrutindov ER, Zharikov SB, Vorontsov IM, Vorontsov IM, Arablinskiy AV. Our first experience with prostatic artery embolization via transradial access. Int J Intervent Radiol 2015;41:32-35.

39. Isaacson AJ, Fischman AM, Burke CT. Technical feasibility of prostatic artery embolization from a transradial approach. AJR Am J Roentgenol 2016;206:442-444

40. de Bruijn AM, Ankum WM, Reekers JA, Birnie E, van der Kooij SM, Volkers NA, et al. Uterine artery embolization vs hysterectomy in the treatment of symptomatic uterine fibroids: 10-year outcomes from the randomized EMMY trial. Am J Obstet Gynecol 2016;215:745.e1-745.e12

41. Posham R, Biederman DM, Patel RS, Kim E, Tabori NE, Nowakowski FS, et al. Transradial approach for noncoronary interventions: a single-center review of safety and feasibility in the first 1,500 cases. J Vasc Interv Radiol 2016;27:159-166

42. Mortensen C, Chung J, Liu D, Ho S, Legleihen G, Machan L, et al. Prospective study on total fluoroscopic time in patients undergoing uterine artery embolization: comparing transradial and transfemoral approaches. Cardiovasc Intervent Radiol 2019;42:441-447

43. Siskin GP, Beck A, Schuster M, Mandato K, Englander M, Herr A. Leiomyoma infarction after uterine artery embolization: a prospective randomized study comparing tris-acryl gelatin microspheres versus polyvinyl alcohol microspheres. J Vasc Interv Radiol 2008;19:58-65

44. Slawin J, Kubler P, Szczepanski A, Piątek J, Stępkowski M, Rezczuk K. Radial artery occlusion after percutaneous coronary interventions - an underestimated issue. Postepy Kardiol Interwencyjnej 2013;9:353-361

45. Zwaan EM, IJsselmuiden AJ, van Rosmalen J, van Geuns RM, Amoroso G, Moerman E, et al. Rationale and design of the ARCUS: effects of tranSRadial perCutaneous coronary intervention on upper extremity function. Catheter Cardiovasc Interv 2016;88:1036-1043

46. Kotowsycz MA, Dzavik V. Radial artery patency after transradial catheterization. Circ Cardiovasc Interv 2012;5:127-133

47. Zhou YJ, Zhao YX, Cao Z, Fu XH, Nie B, Liu YY, et al. Incidence and risk factors of acute radial artery occlusion following transradial percutaneous coronary intervention. Zhonghua Yi Xue Za Zhi 2007;87:1531-1534

48. Yonetsu T, Kakuta T, Lee T, Takayama K, Kakita K, Iwamoto T, et al. Assessment of acute injuries and chronic intimal thickening of the radial artery after transradial coronary intervention by optical coherence tomography. Eur Heart J 2010;31:1608-1615

49. Wakeyama T, Ogawa H, Iida T, Takaki A, Iwami T, Mochizuki M, et al. Intima-media thickening of the radial artery after transradial intervention. An intravascular ultrasound study. J Am Coll Cardiol 2003;41:1109-1114

50. Sakai H, Ikeda S, Harada T, Yonashiro S, Ozumi K, Ohe H, et al. Limitations of successive transradial approach in the same arm: the Japanese experience. Catheter Cardiovasc Interv 2001;54:204-208

51. Nagai S, Abe S, Sato T, Hozawa K, Yuki K, Hanashima K, et al. Ultrasonic assessment of vascular complications in coronary angiography and angioplasty after transradial approach. Am J Cardiol 1999;83:180-186

52. Saito S, Ikei H, Hosokawa G, Tanaka S. Influence of the ratio between radial artery inner diameter and sheath outer diameter on radial artery flow after transradial coronary intervention. Catheter Cardiovasc Interv 1999;46:173-178

53. Zankl AR, Andrassy M, Volz C, Ivandić B, Krumdsorf U, Katus HA, et al. Radial artery thrombosis following transradial coronary angiography: incidence and rationale for treatment of symptomatic patients with low-molecular-weight heparins. Clin Res Cardiol 2010;99:841-847

54. Bernat I, Bertrand OF, Rokya R, Kacer M, Pesek J, Koza J, et al. Efficacy and safety of transient ulnar artery compression to recanalize acute radial artery occlusion after transradial catheterization. Am J Cardiol 2011;107:1698-1701

55. Babunashvili A, Dundua D. Recanalization and reuse of early occluded radial artery within 6 days after previous transradial diagnostic procedure. Catheter Cardiovasc Interv 2011;77:530-536

56. Pancholy SB. Transradial access in an occluded radial artery:
Transradial Access

57. Hamid T, Harper L, McDonald J. Radial artery pseudoaneurysm following coronary angiography in two octogenarians. *Exp Clin Cardiol* 2012;17:260-262

58. Komorowska-Timek E, Teruya TH, Abou-Zamzam AM Jr, Papa D, Ballard JL. Treatment of radial and ulnar artery pseudoaneurysms using percutaneous thrombin injection. *J Hand Surg Am* 2004;29:936-942

59. Bhat T, Teli S, Bhat H, Akhtar M, Meghani M, Lafferty J, et al. Access-site complications and their management during transradial cardiac catheterization. *Expert Rev Cardiovasc Ther* 2012;10:627-634

60. Iftikhar S, Jamil A, Savoj J, Hu P. Noninvasive treatment approach of radial pseudoaneurysm. *Cardiol Res* 2019;10:131-134

61. Patel T, Shah S, Sanghavi K, Pancholy S. Management of radial and brachial artery perforations during transradial procedures-a practical approach. *J Invasive Cardiol* 2009;21:544-547

62. Bertrand OF, Larose E, Rodés-Cabau J, Gleeton O, Taillon I, Roy L, et al. Incidence, predictors, and clinical impact of bleeding after transradial coronary stenting and maximal antiplatelet therapy. *Am Heart J* 2009;157:164-169

63. Kanei Y, Kwan T, Nakra NC, Liou M, Huang Y, Vales LL, et al. Transradial cardiac catheterization: a review of access site complications. *Catheter Cardiovasc Interv* 2011;78:840-846

64. Calviño-Santos RA, Vázquez-Rodríguez JM, Salgado-Fernández J, Vázquez-González N, Pérez-Fernández R, Vázquez-Rey E, et al. Management of iatrogenic radial artery perforation. *Catheter Cardiovasc Interv* 2004;61:74-78

65. Gunasekaran S, Cherukupalli R. Radial artery perforation and its management during PCI. *J Invasive Cardiol* 2009;21:E24-E26

66. Mamarelis I, Kantounakis I, Kotileas P, Takos P, Stefanopoulos T. Radial artery angioplasty after perforation during diagnostic cardiac catheterisation. *Hellenic J Cardiol* 2010;51:467-471

67. Rigatelli G, Dell'Avvocata F, Ronco F, Doganov A. Successful coronary angioplasty via the radial approach after sealing a radial perforation. *JACC Cardiovasc Interv* 2009;2:1158-1159

68. Al-Sekaiti R, Ali M, Sallam M. Radial artery perforation after coronary intervention: is there a role for covered coronary stent? *Catheter Cardiovasc Interv* 2011;78:632-635

69. Narayan RL, Vaishnava P, Kim M. Radial artery perforation during transradial catheterization managed with a coronary polytetrafluoroethylene-covered stent graft. *J Invasive Cardiol* 2012;24:185-187

70. Yoo BS, Lee SH, Ko JY, Lee BK, Kim SN, Lee MO, et al. Procedural outcomes of repeated transradial coronary procedure. *Catheter Cardiovasc Interv* 2003;58:301-304

71. Valsecchi O, Vassileva A. Radial artery: how many times? *Indian Heart J* 2010;62:226-229

72. Chralambous MA, Constantinides SS, Talias MA, Soteriades ES, Christou CP. Repeated transradial catheterization: feasibility, efficacy, and safety. *Tex Heart Inst J* 2014;41:575-578