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Transradial Approach for Neuroendovascular Procedures: A Single-Center Review of Safety and Feasibility

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ABSTRACT

BACKGROUND AND PURPOSE: In recent years, the transradial approach has become more widely adopted for neuroendovascular procedures. The purpose of this study was to evaluate the safety and feasibility of a transradial approach and distal transradial access for neuroendovascular procedures in a single center.

MATERIALS AND METHODS: Retrospective analysis was performed for all patients who underwent transradial approach or distal transradial access neuroendovascular procedures from January 2016 to August 2019 at a single center. Exclusion criteria included a Barbeau D waveform, a radial artery of <2 mm on sonographic evaluation, and known radial artery occlusion. Procedures were evaluated for technical success (defined as successful radial artery access and completion of the intended procedure without crossover to an auxiliary access site), complications, and adverse events during follow-up at 30 days.

RESULTS: The transradial approach or distal transradial access was attempted in 279 consecutive patients (58.1% women; median age, 57.7 years) who underwent 328 standard or distal transradial approach procedures. Two-hundred seventy-nine transradial approach and 49 distal transradial approach procedures were performed (cerebral angiography [$n = 213$], intracranial intervention [$n = 64$], head and neck intervention [$n = 30$], and stroke intervention [$n = 21$]). Technical success was 92.1%. Immediate adverse events (2.1%) included radial access site hematoma ($n = 5$), radial artery occlusion ($n = 1$), and acute severe radial artery spasm ($n = 1$). Thirty-day adverse events (0.3%) included a radial artery pseudoaneurysm ($n = 1$). Twenty-six cases (7.9%) required crossover to transfemoral access.

CONCLUSIONS: The transradial approach for neuroendovascular procedures is safe and feasible across a wide range of neuroendovascular interventions.

ABBREVIATIONS: dTRA = distal transradial approach; TFA = transfemoral approach; TRA = transradial approach

The transradial approach (TRA) is well-established within interventional cardiology and is recommended as first-choice access by the American Heart Association.¹⁻⁶ Large, randomized, multicenter trials from the cardiology literature show that TRA is associated with lower rates of access site morbidity and mortality compared with the transfemoral approach (TFA).⁷⁻¹¹ Additional

evidence supports the use of TRA in peripheral vascular interventions.¹²


Given the associated benefits to patient safety, satisfaction, and decreased recovery time, a first-line transradial approach for endovascular surgery has gained traction in both peripheral and neurointerventional radiology.¹³⁻¹⁵ Matsumoto et al^{16,17} published the earliest study of TRA for cerebral angiography in 2000, demonstrating the technical feasibility and safety of this approach. Since then, further studies have added to the neuroendovascular literature on TRA.¹⁸⁻²¹ Nevertheless, the common femoral artery remains the primary access site for cerebral angiography and neurointerventional procedures.

The distal transradial approach (dTRA) is a further modification by which the radial artery is accessed distal to the flexor retinaculum as the radial branch courses superficial to the scaphoid bone within the anatomic snuffbox. This access site allows

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Table 1: Procedure characteristic (n = 328)

Characteristic	Value
Age (yr)	57.7 [SD, 15.9] (48–68)
Sex	
Male	41.9 (137/327)
Female	58.1 (190/327)
Height (cm)	165.2 [SD, 10.1] (157.5–172.7)
Weight (kg)	77.3 [SD, 21.7] (63.0–88.5)
BMI (kg/m ²)	28.3 [SD, 7.4] (23.4–31.7)
Procedure	
Cerebral angiography	64.9 (213/328)
Head and neck	9.1 (30/328)
Intracranial intervention	19.5 (64/328)
Acute stroke intervention/mechanical thrombectomy	6.4 (21/328)
dTRA access	14.9 (49/328)
Prior TRA	15.5 (51/328)
Technique failure	7.9 (26/328)
Sheath size (Fr)	
4	50.6 (166/328)
5	35.7 (117/328)
6	12.5 (41/328)
Arm accessed	
Left	4.3 (14/328)
Right	94.5 (310/328)
Coagulopathy	10.7 (35/328)
Crossover	7.9 (26/328)
Vessel accessed	
Right common carotid artery	64.9 (213/328)
Right internal carotid artery	50.3 (165/328)
Right external carotid artery	19.8 (65/328)
Left common carotid artery	62.8 (206/328)
Left internal carotid artery	47.6 (156/328)
Left external carotid artery	19.2 (63/328)
Right vertebral artery	55.8 (183/328)
Left vertebral artery	35.7 (117/328)

Note:—BMI indicates body mass index.

preservation of the more proximal radial artery for future interventions or access requirements.

Here we present our initial institutional experience performing TRA and dTRA for diagnostic neuroangiography and neurointerventions.

MATERIALS AND METHODS

Study Design and Exclusion Criteria

This single-center retrospective study was approved by the local institutional review board, and all study activities followed Health Insurance Portability and Accountability Act regulations. A retrospective analysis was performed of 279 patients evaluated for 328 consecutive TRA or dTRA neuroendovascular procedures from January 2016 to December 2019.

All neurointerventional procedures, both diagnostic and interventional, were included and separated into 4 groups: cerebral angiography, head and neck interventions, intracranial interventions, and acute stroke intervention/mechanical thrombectomy.

All patients were given the option of TRA and consented appropriately. Testing for ulnar-palmar arch patency was performed using a technique previously described by Barbeau et al.²² This practice was abandoned in 2019 following updated

guidelines from the Society of Neuro-Interventional Surgery Standards and Guidelines Committee highlighting the limitations of the test in predicting ischemic complications.²³ Before these updated guidelines exclusion criteria for TRA included a Barbeau D waveform (when Barbeau test was performed), a radial artery diameter <2 mm on initial sonographic evaluation, and known radial artery occlusion. Radial artery diameter <2 mm is treated as a relative contraindication to radial access at our institution due to the reported association between a smaller radial artery diameter and an increased risk of radial artery occlusion following TRA procedures.²⁴ Distal TRA was specifically considered in patients with limited supination of the arm, though the decision to proceed with dTRA was ultimately made by the operator.

Additional patient demographic data were collected retrospectively using the electronic medical record system, Epic Systems (Verona, Wisconsin) and the Mount Sinai Data Warehouse (Table 1).

TRA Access

Standard radial artery access technique, previously described by Posham et al¹² and Snelling et al,²¹ was used for all procedures. Under sonographic guidance, the radial artery was localized with compression on B-mode and color Doppler flowmetry, confirming patency.

Local anesthesia (1% lidocaine) was infiltrated in the subdermal layer. A single-wall puncture of the radial artery was performed at the level of the radial epiphysis on the volar radial surface under real-time sonographic guidance. Using the modified Seldinger technique, the proceduralist inserted an access sheath into the radial artery.

dTRA Access

The patient was positioned with the access arm partially pronated at his or her side in a thumbs-up position. Under sonographic guidance, the metacarpals of the thumb and index finger were identified first, followed by the trapezium and the scaphoid bones below the distal radial artery. A single-wall puncture of the artery was performed through the anatomic snuffbox under real-time sonographic visualization. Using the modified Seldinger technique, the proceduralist inserted an access sheath into the radial artery.

Procedural Technique

A 4F or 5F Glidesheath Slender (Terumo) sheath was used for diagnostic studies, and a 5F or 6F Glidesheath Slender sheath was used for most head and neck and intracranial interventions. For stroke interventions and select aneurysm treatments using flow diversion, a 0.088-inch-long guide sheath was used without a

short sheath. Maintenance of the radial access sheath on continuous heparinized flush was left to the proceduralist's discretion. Following sheath insertion, a radial artery access cocktail consisting of 3000 U of heparin, 200 µg of nitroglycerin, and 2.5 mg of verapamil was mixed with 10 mL of the patient's blood and slowly infused through the sheath for 5–10 minutes to induce vasodilation. Administration of the access cocktail was omitted during the stroke intervention to expedite the procedure and avoid inducing hypotension.

Equipment selection was dependent on the procedure type. For diagnostic angiography, a 5F Simmons 2 Glidecath catheter (Terumo) was advanced over a Bentson guidewire and formed within the aortic arch before selectively catheterizing the vessels of interest. For most nonstroke interventions, a 0.071-inch guide catheter was advanced over a 125-cm Select catheter (Penumbra) and guidewire into the vessel of interest. For stroke interventions and selected flow-diverter cases, a 0.088-inch guide catheter was used without a sheath and advanced over a selecting catheter and stiff guidewire for added support. Once the guide catheter was positioned, the procedure followed a similar vessel-selection technique used during femoral access.

Following the procedure, a radial artery compression device was placed over the arteriotomy site for a minimum of 60 minutes. The band was removed after arterial hemostasis and pulse were reconfirmed. Similar closure techniques were followed for both TRA and dTRA procedures. Repeat evaluation of the access site and radial pulse was performed for all patients before discharge and during the 30 day follow-up outpatient visit.

Technical Success and Complications

Technical success was defined as successful radial artery access and completion of the intended procedure without crossover to an auxiliary access site.

Major complications included the need for prolonged hospitalization, an unplanned increase in the level of care, permanent adverse sequelae, and death. Minor complications included the need for additional nominal therapy, overnight admission for observation, loss of a radial pulse without evidence of distal ischemia, and hematoma or blood loss not requiring transfusion or open surgical repair. In addition to the periprocedural data, the access site was evaluated for bleeding and neurologic events before and after the procedure with additional evaluations up to 30 days postprocedure.

Statistical Analysis

Data are presented as mean and range for continuous variables and frequency for categorical variables. Univariate and multivariate analyses of complications and crossover were performed using logistic regression. A *P* value of ≤ .05 was considered statistically significant. SPSS Statistics for Windows, Version 23.0 (IBM) was used for statistical analyses.

RESULTS

Procedure

A total of 328 radial procedures were performed during the study period, including cerebral angiography (*n* = 213), intracranial interventions (*n* = 64), head and neck interventions (*n* = 30), and

Table 2: Adverse events

Adverse Event	No. (%)
Early complications	
Hematoma	1.5 (5/328)
Radial artery spasm	0.3 (1/328)
Radial artery occlusion	0.3 (1/328)
30-Day complications	
Radial artery pseudoaneurysm	0.3 (1/328)

stroke interventions (*n* = 21) (Table 1). Of the 328 procedures, 279 procedures used the TRA and 49 procedures used the dTRA. A total of 51 procedures were performed in patients who had undergone prior TRA, and 8 cases were transitioned to TRA after failed TFA. Crossover to the TRA was most often necessary due to tortuous vascular anatomy preventing supra-aortic vessel selection from the femoral artery. Radial artery micropuncture and vessel access were successful in all cases. Completion of the intended procedure via TRA was achieved in 255 of 279 cases (91.3%), while it was via the dTRA in 47 of 49 cases (95.9%). Composite success in completing the intended procedure via TRA or dTRA was achieved in 302 of 328 cases (92.1%).

Crossover to TFA

Crossover to TFA was required to successfully complete 26 of 328 (7.9%) cases. Of all TRA crossovers, 19 (73.1%) were attributed to vascular anomalies or severe tortuosity of the subclavian artery (*n* = 7), aortic arch (*n* = 7), or carotid artery (*n* = 5), which undermined stability and/or prevented navigation of the catheter system. An additional 6 failures (23.1%) were related to radial artery vasospasm (*n* = 3), severe radial and brachial artery tortuosity secondary to hypertensive vasculopathy (*n* = 1), and an aberrant right subclavian artery morphology that prevented target artery access (*n* = 2). In 1 patient, crossover to TFA was performed due to patient discomfort.

Analysis of TFA crossover is presented in the Online Table. There were no significant predictors of crossover from TRA to TFA.

The Barbeau test was performed for assessment of collateral circulation to the hand in 306 cases (93.3%) and was stopped in 2019 following guidelines that highlight the inability of the test to predict ischemic complications.²⁵ All tested patients had favorable Barbeau test outcomes (grade A and B), and no correlation was demonstrated between the test result and access site complication or crossover to TFA.

Complications

A total of 8 adverse events (2.4%) were recorded among all radial artery cases: 7 in the TRA group (2.5%, 7/279) and 1 in the dTRA group (2.0%, 1/49). Seven of these events were immediate, and 1 was delayed (noted at 30-day follow-up). Immediate adverse events included hematoma (*n* = 5), radial artery occlusion (*n* = 1), and severe radial artery spasm (*n* = 1). The delayed adverse event was a radial artery pseudoaneurysm measuring < 2 mm that was managed conservatively with observation. An analysis of the TRA adverse events is presented in Table 2. Larger sheath size (≥ 6 F) was a significant predictor of adverse events (*P* < .001).

Table 3: Analysis of total adverse events

Predictor/Category	OR (95% CI)	P
Age (yr)		
60 or older	1.00	
Younger than 60	0.53 (0.12–2.25)	.39
Sex		
Male	1.00	
Female	2.20 (0.44–11.1)	.34
Height (cm)		
≥165.1	1.00	
<165.1	0.36 (0.07–1.80)	.21
Weight (kg)		
≥74.3	1.00	
<74.3	1.70 (0.40–7.23)	.47
BMI (kg/m ²)		
≥27.4	1.00	
<27.4	7.37 (0.90–60.6)	.06
Procedure		
Cerebral angiogram	1.00	
Head and neck intervention	11.7 (1.87–73.3)	.05
Intracranial intervention	3.40 (0.47–24.7)	.86
Acute stroke intervention/ mechanical thrombectomy	5.28 (0.46–60.8)	.69
Prior TRA		
No	1.00	
Yes	1.84 (0.36–9.4)	.46
Sheath size (Fr)		
4	1.00	
5	0.71 (0.06–7.89)	.19
6	8.87 (1.57–50.2)	.004
Coagulopathy		
No	1.00	
Yes	0.76 (0.09–6.52)	.80

DISCUSSION

The success and widespread adoption of the TRA in cardiology has highlighted the benefits of radial access. Unlike traditional femoral access, TRA is associated with a decreased risk of bleeding and arterial damage, both of which are critical for patients on anticoagulant or antiplatelet therapy.¹² TRA has been associated with lower access site infection rates, expedited postprocedural ambulation, reduced postprocedure nursing care, and shorter hospital stay.²¹ Patient preference for TRA over TFA has been demonstrated previously.²⁶

The present study describes data from 328 TRA neuroendovascular procedures performed in 279 patients. Both diagnostic and interventional procedures were included from a practice of 8 neurointerventionalists, each having varying levels of TRA case experience. Two interventionalists performed most procedures (40% and 30%, respectively). Six interventionalists performed between 11 and 28 procedures each (median, 13.5).

Our overall success rate, defined as successful completion of the intended procedure from the initial radial access, was 92.2% (302/328 cases). The success rate of TRA neuroendovascular procedures in the literature is reportedly 92.7%–99%.¹⁸ A dedicated analysis of TRA to TFA crossover in the current study showed that the primary factors contributing to crossover included the following: vascular anomalies and tortuosity of the subclavian artery ($n = 7$), aortic arch ($n = 7$), and carotid artery ($n = 5$); radial artery spasm ($n = 3$); severe radial artery tortuosity ($n = 1$); variant arch anatomy ($n = 2$); and excessive arm pain ($n = 1$). A combination

of factors led to the high crossover rate (7.9%) in the current study, including operator experience, position on the TRA learning curve, availability of access catheters, and case selection.

Various studies have examined the relationship between operator volume and procedural outcomes, suggesting 30–50 cases as the general learning curve.^{27,28} We separately analyzed the 100 most recent cases and demonstrated a technical success rate of 95% with 5 crossover cases (5%). While the operator's learning curve was not directly studied, this is a likely contributor to the overall crossover rate of 7.9% for the entire cohort. To that end, this study was performed at an academic teaching hospital with neurointerventional trainees of varying experience in performing transradial neurointerventional procedures.

Although our study did not elucidate significant predictors for conversion from TRA to TFA, other, non-neurointervention-focused studies have identified such predictors. Posham et al¹² noted procedural type, female sex, and height of <1.7 m as significant predictors of radial-to-femoral crossover using univariate analysis. However, these were not significant by multivariate analysis. Additionally, Carvalho et al²⁹ reported short sheaths, female sex, multivessel disease, body surface area, and age older than 66 years as independent predictors of conversion from radial to femoral access. To our knowledge, no prior studies on TRA neuroendovascular procedures have examined the predictors of conversion from radial to femoral access.

The radial artery is easily compressible against the volar radial surface, permitting easy hemostasis. Titano et al³⁰ showed that TRA was associated with a low incidence of bleeding complications in patients with an elevated international normalized ratio (>1.5) undergoing below-neck interventions. Our study reaffirms this finding in a neurointerventional population with no significant difference in adverse events between patients with and without coagulopathy.

The overall adverse event rate in our study was 2.4%, including 7 immediate adverse events (access site hematoma [$n = 5$], radial artery occlusion [$n = 1$], severe radial artery spasm [$n = 1$], and one 30-day adverse event (radial artery pseudoaneurysm of <2 mm). No major access site complications occurred. This complication rate of 2.4% is similar to those published for TRA in visceral interventions and TRA in neurointerventions.^{12,31} All immediate adverse events were managed conservatively. An analysis of the total adverse events is presented in Table 3. Significantly higher adverse events rates were observed for procedures that used 6F sheaths ($P < .001$). All access site hematomas were small and resolved following conservative management. One of the 5 patients who developed an access site hematoma had been placed on dual-antiplatelet therapy following intracranial stent placement.

Four of the 8 total adverse events occurred when a 6F sheath was used (access site hematoma [$n = 3$] and severe radial artery spasm [$n = 1$]). The significant association observed between larger sheath size and access site complications is in keeping with

previous studies examining both transfemoral and transradial procedures.³²⁻³⁴ This association is thought to arise from larger radial arteriotomy size, increased potential for intimal damage, and longer procedure times associated with interventional cases in which 6F sheaths are common. dTRA was used in 49 cases with a procedural completion rate without crossover to TFA of 95.6% (47/49). This outcome measure and the reported adverse events are comparable with those in the TRA cohort and previously reported dTRA data. dTRA allows preservation of the more proximal radial artery, which may be required for other interventions/therapies, enhanced operator and patient comfort, and easy hemostasis.

Direct comparison of complication rates of TRA and TFA cannot be made from the current study. However, comparison of complication rates for TRA versus TFA have been described previously.^{35,36} Stone et al³⁵ performed a prospective comparison of TFA to TRA for diagnostic cerebral angiography and demonstrated no significant difference in complication rates between the 2 groups.

Our study did not demonstrate a relationship between repeat catheterization and adverse events. Repeat TRA was performed in 51 cases (15.5%) and accounted for 2 of the 8 total minor adverse events (25%): 1 hematoma and 1 radial artery occlusion. These findings are consistent with the previously published literature, describing same-site repeat TRA success rates of >94% with up to 6 prior TRA procedures.²⁵

The primary limitation of the present study is the retrospective design and lack of a comparator control arm, making it difficult to appreciate subtle differences in procedural success and complication rates. Additionally, patient selection for TRA was based on both operator and patient preference in addition to the specific procedure performed.

CONCLUSIONS

Our institution's initial experience using TRA for diagnostic angiography and neurointerventional procedures was comparable with that of previously reported TRA studies. No major complications were noted, and the rate of femoral crossovers will likely continue to improve with technical familiarity and case selection. Furthermore, favorable outcomes were observed in patients on anticoagulation, mirroring findings from the coronary/cardiac literature. The transition of practice to a radial first approach is a safe and worthwhile endeavor that may substantially improve the morbidity and mortality of select patients.

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REFERENCES

1. Archbold RA, Robinson NM, Schilling RJ. Radial artery access for coronary angiography and percutaneous coronary intervention. *BMJ* 2004;329:443–46 [CrossRef Medline](#)
2. Caputo RP, Tremmel JA, Rao S, et al. Transradial arterial access for coronary and peripheral procedures: executive summary by the Transradial Committee of the SCAI. *Cathet Cardiovasc Interv* 2011;78:823–39 [CrossRef Medline](#)

3. Hamon M, Pristipino C, Di Mario C, et al; Working Group on Thrombosis on the European Society of Cardiology. Consensus document on the radial approach in percutaneous cardiovascular interventions: position paper by the European Association of Percutaneous Cardiovascular Interventions and Working Groups on Acute Cardiac Care** and Thrombosis of the European Society of Cardiology. *EuroIntervention* 2013;8:1242–51 [CrossRef Medline](#)
4. Mann JT 3rd, Cubeddu MG, Schneider JE, et al. Right radial access for PTCA: a prospective study demonstrates reduced complications and hospital charges. *J Invasive Cardiol* 1996;8 (Suppl D):40d–44 [Medline](#)
5. Mason PJ, Shah B, Tamis-Holland JE, et al; American Heart Association Interventional Cardiovascular Care Committee of the Council on Clinical Cardiology; Council on Cardiovascular and Stroke Nursing; Council on Peripheral Vascular Disease; and Council on Genomic and Precision Medicine. An update on radial artery access and best practices for transradial coronary angiography and intervention in acute coronary syndrome: a Scientific Statement From the American Heart Association. *Circ Cardiovasc Interv* 2018;11:e000035 [CrossRef Medline](#)
6. Mitchell MD, Hong JA, Lee BY, et al. Systematic review and cost-benefit analysis of radial artery access for coronary angiography and intervention. *Circ Cardiovasc Qual Outcomes* 2012;5:454–62 [CrossRef Medline](#)
7. Bernat I, Horak D, Stasek J, et al. ST-segment elevation myocardial infarction treated by radial or femoral approach in a multicenter randomized clinical trial: the STEMI-RADIAL trial. *J Am Coll Cardiol* 2014;63:964–72 [CrossRef Medline](#)
8. Jolly SS, Yusuf S, Cairns J, 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;377:1409–20 [CrossRef Medline](#)
9. Mehta SR, Jolly SS, Cairns J, et al; RIVAL Investigators. Effects of radial versus femoral artery access in patients with acute coronary syndromes with or without ST-segment elevation. *J Am Coll Cardiol* 2012;60:2490–99 [CrossRef Medline](#)
10. Romagnoli E, Biondi-Zoccai G, Sciahbasi A, et al. Radial versus femoral randomized investigation in ST-segment elevation acute coronary syndrome: the RIFLE-STEACS (Radial Versus Femoral Randomized Investigation in ST-Elevation Acute Coronary Syndrome) study. *J Am Coll Cardiol* 2012;60:2481–89 [CrossRef Medline](#)
11. Valgimigli M, Gagnor A, Calabró P, et al; MATRIX Investigators. Radial versus femoral access in patients with acute coronary syndromes undergoing invasive management: a randomised multicentre trial. *Lancet* 2015;385:2465–76 [CrossRef Medline](#)
12. Posham R, Biederman DM, Patel RS, 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;27:159–66 [CrossRef Medline](#)
13. Kumar AJ, Jones LE, Kollmeyer KR, et al. Radial artery access for peripheral endovascular procedures. *J Vasc Surg* 2017;66:820–25 [CrossRef Medline](#)
14. Ruzsa Z, Nemes B, Pinter L, et al. A randomised comparison of transradial and transfemoral approach for carotid artery stenting: RADCAR (RADial access for CARotid artery stenting) study. *EuroIntervention* 2014;10:381–91 [CrossRef Medline](#)
15. Zussman BM, Tonetti DA, Stone J, et al. A prospective study of the transradial approach for diagnostic cerebral arteriography. *J Neurointerv Surg* 2019;11:1045–49 [CrossRef Medline](#)
16. Matsumoto Y, Hokama M, Nagashima H, et al. Transradial approach for selective cerebral angiography: technical note. *Neurol Res* 2000;22:605–08 [CrossRef Medline](#)
17. Matsumoto Y, Hongo K, Toriyama T, et al. Transradial approach for diagnostic selective cerebral angiography: results of a consecutive series of 166 cases. *AJNR Am J Neuroradiol* 2001;22:704–08 [Medline](#)

18. Jo KW, Park SM, Kim SD, et al. **Is transradial cerebral angiography feasible and safe? A single center's experience.** *J Korean Neurosurg Soc* 2010;47:332–37 [CrossRef Medline](#)
19. Levy EL, Boulos AS, Fessler RD, et al. **Transradial cerebral angiography: an alternative route.** *Neurosurgery* 2002;51:335–42 [Medline](#)
20. Park JH, Kim DY, Kim JW, et al. **Efficacy of transradial cerebral angiography in the elderly.** *J Korean Neurosurg Soc* 2013;53:213–17 [CrossRef Medline](#)
21. Snelling BM, Sur S, Shah SS, et al. **Transradial cerebral angiography: techniques and outcomes.** *J Neurointerv Surg* 2018;10:874–81 [CrossRef Medline](#)
22. Barbeau GR, Arsenauf F, Dugas L, et al. **Evaluation of the ulnopalmar arterial arches with pulse oximetry and plethysmography: comparison with the Allen's test in 1010 patients.** *Am Heart J* 2004;147:489–93 [CrossRef Medline](#)
23. Starke RM, Snelling B, Al-Mufti F, et al. **Transarterial and transvenous access for neurointerventional surgery: report of the SNIS Standards and Guidelines Committee.** *J Neurointerv Surg* 2020;12:733–41 [CrossRef Medline](#)
24. Rashid M, Kwok CS, Pancholy S, et al. **Radial artery occlusion after transradial interventions: a systematic review and meta-analysis.** *J Am Heart Assoc* 2016;5:e002686 [CrossRef Medline](#)
25. Chen SH, Brunet MC, Sur S, et al. **Feasibility of repeat transradial access for neuroendovascular procedures.** *J Neurointerv Surg* 2020;12:431–34 [CrossRef Medline](#)
26. Khanna O, Sweid A, Mouchtouris N, et al. **Radial artery catheterization for neuroendovascular procedures.** *Stroke* 2019;50:2587–90 [CrossRef Medline](#)
27. Hess CN, Peterson ED, Neely ML, et al. **The learning curve for transradial percutaneous coronary intervention among operators in the United States: a study from the National Cardiovascular Data Registry.** *Circulation* 2014;129:2277–86 [CrossRef Medline](#)
28. Sur S, Snelling B, Khandelwal P, et al. **P-005 adoption of the transradial approach for cerebral angiography: learning curve and early experience.** *J Neurointerv Surg* 2017;9:A24 [CrossRef](#)
29. Carvalho MS, Calé R, de Araújo Gonçalves P, et al. **Predictors of conversion from radial into femoral access in cardiac catheterization [in Portuguese].** *Arq Bras Cardiol* 2015;104:401–08 [CrossRef Medline](#)
30. Titano JJ, Biederman DM, Zech J, et al. **Safety and outcomes of transradial access in patients with international normalized ratio 1.5 or above.** *J Vasc Interv Radiol* 2018;29:383–88 [CrossRef Medline](#)
31. Brunet M-C, Chen SH, Peterson EC. **Transradial access for neurointerventions: management of access challenges and complications.** *J Neurointerv Surg* 2020;12:82–86 [CrossRef Medline](#)
32. Levin SR, Farber A, Bertges DJ, et al. **Larger sheath size for infrainguinal endovascular intervention is associated with minor but not major morbidity or mortality.** *Ann Vasc Surg* 2019;60:327–34 [CrossRef Medline](#)
33. Chung R, Weller A, Morgan R, et al. **Are complication rates lower with 4-Fr versus 6-Fr transfemoral arterial access: prospective audit at a single interventional radiology centre.** *CVIR Endovasc* 2018;1:15 [CrossRef Medline](#)
34. Uhlemann M, Möbius-Winkler S, Mende M, et al. **The Leipzig prospective vascular ultrasound registry in radial artery catheterization: impact of sheath size on vascular complications.** *JACC Cardiovasc Interv* 2012;5:36–43 [CrossRef Medline](#)
35. Stone JG, Zussman BM, Tonetti DA, et al. **Transradial versus transfemoral approaches for diagnostic cerebral angiography: a prospective, single-center, non-inferiority comparative effectiveness study.** *J Neurointerv Surg* 2020;12:993–98 [CrossRef Medline](#)
36. Chen SH, Snelling BM, Sur S, et al. **Transradial versus transfemoral access for anterior circulation mechanical thrombectomy: comparison of technical and clinical outcomes.** *J Neurointerv Surg* 2019;11:874–78 [CrossRef Medline](#)