5-13-2021

Lessons Learned After 760 Neurointerventions via the Upper Extremity Vasculature: Pearls and Pitfalls.

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Recommended Citation
Sweid, Ahmad; Weinberg, Joshua H.; Khanna, Omaditya; Das, Somnath; Kim, Julie; Curtis, Darcy; Hammoud, Batoul; El Naamani, Kareem; Abbas, Rawad; Majmundar, Shyam; Sajja, Kalyan C.; Chalouhi, Nohra; Al Saiegh, Fadi; Mouchtouris, Nikolaos; Atallah, Elias; Gooch, M. Reid; Herial, Nabeel A.; Tjoumakaris, Stavropoula; Romo, Victor; Rosenwasswer, Robert H.; and Jabbour, Pascal, "Lessons Learned After 760 Neurointerventions via the Upper Extremity Vasculature: Pearls and Pitfalls." (2021). *Department of Neurosurgery Faculty Papers.* Paper 154.
https://jdc.jefferson.edu/neurosurgeryfp/154

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Abstract

*Backgroud***:** The radial approach has been gaining more widespread use by neurointerventionalists fueled by data from the cardiology literature showing better safety and overall reduced morbidity. *Objective:* Herein, we present our institution's experience with the radial approach for neuroendovascular interventions in 614 consecutive patients who underwent a cumulative of 760 procedures.

*Methods***:** A retrospective analysis was performed and identified neuroendovascular procedures performed via the upper extremity vasculature access site.

*Results***:** Amongst 760 procedures, 34·2% (260) were therapeutic, and 65·7% (500) were non-therapeutic angiograms. Access sites were 71·5% (544) via a conventional radial artery, 27·8% (211) via a distal radial artery, 0·5% (4) via an ulnar artery, and 0·1% (1) via the brachial artery. Most of the procedures were performed via the right side, 96·9% (737), 2·9% (22) via the left-sided, and 0·1% (1) via a bilateral approach. Major access site complications occurred at a rate of 0·9% (7). The rate of transfemoral conversion was 4·7% (36). There was a statistically higher incidence of transfemoral conversion when repeat procedures were performed using the same access site. Also, there was no significant difference between non-therapeutic procedures performed using the right and left radial access, and conventional versus distal radial access. Procedural metrics improved after completion of 14 procedures, indicating a learning curve that should be surpassed by operators to reach optimal outcomes.

Conclusions: Radial artery catheterization is a safe and effective means of carrying out a wide-range of neuroendovascular procedures associated with excellent clinical outcomes and an overall low rate of periprocedural complications.

Introduction

The radial approach has been gaining more widespread use by the neurointerventionalist community fueled by data from cardiology literature showing safety and overall reduced morbidity & mortality.[1-14] The RIVAL trial presented compelling evidence that transradial access (TRA) is associated with reduced morbidity, mortality, length of hospital stay, and costs.[1-13] This compelling evidence, in addition to other studies, lead to the American Heart Association recommendation of TRA as a first-line approach for patients undergoing cardiac interventions.[1,4,5,11,12,15-19] However, radial artery access has inherent limitations: the artery is smaller in size, has several anatomical variations, and provides a challenge to catheterize left-sided supra-aortic vessels. Additionally, there is a paucity of radial-specific devices and catheters for neurointerventions. However, given the decreased risk of access-site and peri-procedural complications seen in the cardiac literature, many neurointerventionalists have begun to pursue a 'radial first' strategy in their practice. Our institution has reported improved patient satisfaction metrics for radial artery neurointerventions.[20] In this study, we present our institution's experience with a radial approach for neuroendovascular interventions. We aim to demonstrate the pearls and pitfalls of TRA in both diagnostic and a wide range of interventional neuroendovascular procedures.

Methods

Study Design

Institutional review board approved the study protocol, and the need for informed consent was waived due to the study's design. The authors declare that all supporting data is present within the article. We conducted a retrospective analysis of a prospectively maintained database. We identified 614 patients who underwent 760 consecutive neuroendovascular procedures via upper extremity vasculature access site at our academic institution between April 2018 and January 2020. The adoption of the radial approach was performed progressively by one of the four neurointerventionalists in the division beginning with diagnostic cerebral angiograms, and as he gained more experience and expertise, progressing to perform all his procedures via a ‘radial first’ approach.

Medical charts were reviewed for baseline characteristics such as age and gender, the indication of the interventional procedure whether for diagnostic purpose, follow-up, or as a therapeutic intervention, procedure characterstics such as laterality, vessel(s) accessed, sheath size, number of selected vessel(s), fluoroscopy duration, procedure duration defined as time interval between starting patient preparation to the completion of the procedure, and lastly radiation exposure. Transfemoral approach (TFA) conversion, access site complications, and technical accomplishment of therapeutic procedures were gathered. Access site complications excluded mild hematoma and subjective post-operative pain. Follow-up diagnostic imaging was not routinely aquired to assess the patency of the radial artery, which limits our ability to accurately assess radial artery stenosis or occlusion. Access site conversion was defined as a failure to complete the procedure after the successful cannulation of the radial artery (RA). We defined technical success as effective accomplishment of the interventional procedures after effective cannulation of the target artery. An alternate access site was described as any access site in the upper limbs, including the contralateral limb different from the initial approach used. As a general rule, the distal radial access is primarily used for diagnostic cerebral angiograms, and the conventional radial access is used for therapeutic procedures. Left radial access is used when the left vertebral artery is the target vessel.

Data Availability

Data will be shared to other investigators upon reasonable request.

Technical Procedure

The arm is positioned on the Rad Board (Merit Medical, South Jordan, UT) that is stretched from the head of the bed to the control board. When performing a diagnostic angiogram, we position the arm at the patient's side in a neutral position with the thumb pointing upwards. The hand, including the thumb, is taped so that it is flexed to the board. The hand is padded with the Rad Rest (Merit Medical, South Jordan, UT) or a piece of foam to decrease pressure and pain on the hand.

We either use the Glidesheath slender (Terumo Interventional Systems, Somerset, NJ) or the Prelude (Merit Medical, South Jordan, UT) radial sheath. We typically use a 5 Fr for diagnostic purposes and a 6 Fr for interventional procedures, and in cases of more proximal support is anticipated a long 6 Fr long sheath is used (Ballast [Balt, Irvine, CA], Shuttle [Cook Medical, Bloomington, IN], Infinity [Stryker, Kalamazoo, MI]). An ultrasound is used to eye the vessel to determine what size system it can accommodate and puncture the artery. Local anesthesia is administered subcutaneously, and the micropuncture needle is advanced into the radial artery under ultrasound guidance. Once the artery is catheterized, and there is spontaneous blood flow return, a 0.021 inch microwire is placed through the needle. Once the wire is confirmed to be intraluminal, the needle is removed, and the hydrophilic sheath is advanced over the wire into the vessel. A radial cocktail consisting of 2000 units of heparin, 5mg of Cardene, and 200 μg of Nitroglycerin is injected through the sheath. The sheath is then flushed clear with heparinized saline and hooked to continuous heparinized saline flush.

A radial angiogram is obtained to look for any evidence of vasospasm, vascular anomalies, and flow into the ulnar circulation. A roadmap is performed to navigate the wire and the catheter in the arm. We routinely use a 5 Fr Simmons select catheter (Penumbra Incorporation, Alameda, CA). The other catheters we use are Glidecath (Terumo Interventional Systems, Somerset, NJ) that are available in forms (Sim 1, 2, and 3). If the aim is to catheterize the posterior circulation vessels only, any Berenstein catheter (Merit Medical, South Jordan, UT) or an angled catheter allows easy access without the need to reform the Simmons catheter. We use a 0.038 Glidewire (Terumo Interventional Systems, Somerset, NJ) as our standard wire that can be used for the entire case.

Statistical Analysis

All data analyses are performed using the Stata software (StataCorp, College Station, TX). Continuous variables are presented as mean, standard deviation, and ninty five percent confidence interval. Categorical variables are presented as absolute numbers and percentages. Unpaired t-test, $\chi 2$, Fisher's exact tests, and ANOVA were used as appropriate. A p-value < 0.05 was considered statistically significant.

Results

Patient Demographics

A total of 614 patients underwent 760 neuroendovascular procedures using the upper extremity vasculature access site. The average age of the patients was 59·9 years, with females constituting 57·4% of the cohort. There were 34·3% therapeutic procedures and 65·7% non-therapeutic angiograms. Therapeutic procedures included 44·2% aneurysm treatment, 20·0%

mechanical thrombectomy, 10·7% carotid artery stenting, 12·7% arteriovenous malformations treatment, and 9·6% as others. Of 115 aneurysms, 20·9% were ruptured aneurysms.

Access sites were 71·5% via conventional RA (cTRA), 27·6% via distal RA (dTRA), 0·5% via a proximal ulnar artery, and 0·1% via the brachial artery. Most of the procedures were performed via the right side, 96·9%, 2·9% via the left-sided, and 0·1% via a bilateral approach. (Table 1A)

Procedure Details

A sheath size of 5-Fr was used in 72·6%, a 6-Fr in 24.1%, a 7-Fr in 3·1%, and 4-Fr and 8-Fr were each used in 0·1% case. The right internal carotid artery (ICA) was the most common vessel catheterized (47·1%), followed by the left ICA (45·3%) and right vertebral artery (VA) (32·4%). Overall, the mean procedure duration was 72·2 minutes, the mean fluoroscopy time was 14·7 minutes, the mean contrast dose was 82·9 ml, and the mean radiation exposure was 45·6 $Gycm^2$. (Table 1B)

Outcomes and Complications

Technical success was achieved in 244 (93·8%) therapeutic procedures. Of 115 neuroendovascular aneurysm treatments, a modified Raymond Roy Occlusion (mRRO) grade I/II was observed in 91·8% patients at follow-up. Of 52 mechanical thrombectomy, a TICI score $\geq$ 2b was achieved in 76·9% patients.

The rate of transfemoral (TF) conversion was 4·7% and was significantly higher in therapeutic procedures compared to diagnostic angiograms (9·2% vs. 2·7, p=0·01). The most common reasons for conversion were anatomic variants (0·8%), vascular tortuosity (0·7%), and failure to catheterize left-sided supra-aortic vessels (0·7%).

Major access site complications occurred at a rate of 0·9%, including radial artery spasm (RAS) and radial artery occlusion (RAO) at an incidence of 0·4% and 0·1% (one patient identified), respectively. Radial artery extravasation was managed with pressure applied to the forearm while monitoring the oxygen saturation via a pulse oximeter. The single case of psudoaneurysm required surgical resection due to the delayed diagnosis. There was no significant difference in access site complications between therapeutic and non-therapeutic procedures (1 [0·4%] vs. 6 [1·2%]; p=0·43). Major procedure-related complications occurred at a rate of 0·8%, including 0.5% of cases of stroke/TIA and 0·3% cases of intracerebral hemorrhage. Minor procedure-related complications occurred in 0·3% of patients. (Table 1C, Figure 1A & 1B)

Number of Procedures Per Patient

Of the 614 patients, 81·1% underwent one procedure, 14·0% underwent two procedures, 4·2% underwent three procedures, and 0·5% underwent four procedures. Amongst patients who underwent multiple procedures, the same access site and an alternative access site were used in 40·0% and 60·0% of patients, respectively.

A comparative analysis was performed between four groups of patients based on the total number of procedures per patient. There was no significant difference in contrast dose per vessel (p=0·71), radiation exposure per vessel (p=0·18), fluoroscopy time per vessel (p=0·15), rate of access site complications (p=0·10), or TF conversion rate (p=0·45). (Table 2A)

Multiple Procedures & Access Site

A comparative analysis was performed for patients that underwent repeat procedures using the same access site (60·0%) vs. an alternative access site (40·0%). There was no significant difference in the contrast dose per vessel (*p*=0·39), radiation exposure per vessel (*p*=0·98), fluoroscopy time per vessel (*p*=0·19), or rates of access site complications (*p*=0·32). There was a statistical significance for a higher rate of transfemoral conversions (14·5% vs. 0·0%; *p*=0·01) in repeat procedures performed using the same access site. (Figure 2)

Laterality in Non-Therapeutic Procedures

A comparative analysis was performed between non-therapeutic procedures between right and left-sided access. There was no significant difference in contrast dose per vessel (*p*=0·34), radiation exposure per vessel (*p*=0·22), fluoroscopy time per vessel (*p*=0·15), access site complication rate (*p*=0·80), or TF conversion rate (*p*=0·58). (Table 2B)

Conventional Transradial vs. Distal Transradial in Therapeutic Procedures

A comparative analysis was performed between therapeutic procedures using cTRA and dTRA. There was no significant difference in radiation exposure per vessel (*p*=0·14), access site complication rate (*p*=1·00), or TF conversion rate (*p*=0·09). The cTRA group had a significantly higher mean contrast dose per vessel (*p*=0·01), and a significantly higher mean fluoroscopy time per vessel (*p*=0·01). (Table 2C)

Conventional Transradial vs. Distal Transradial in Non-Therapeutic Procedures

A comparative analysis was performed between non-therapeutic procedures performed using cTRA and dTRA. There was no significant difference in contrast dose per vessel (*p*=0·07), access site complication rate (*p*=0·40), or TF conversion (*p*=0·37). The cTRA group had a significantly higher mean radiation exposure per vessel (*p*=0·02), and significantly higher mean fluoroscopy time per vessel (*p*=0·02). (Table 2D)

Discussion

Findings Summary

In the present study, we aimed to assess the safety and efficacy of neuroendovascular procedures performed via radial artery catheterization. This is an extensive single-center case series involving neuroendovascular procedures via RA access, including both diagnostic angiograms and wide-ranging interventions.

There was no significant difference in access site complications between patients undergoing diagnostic and interventional procedures, which signify that complex treatments, which require larger-bore catheters, can be effectively carried out via radial artery access. There was also no significant difference in access site complications or conversion rates in patients undergoing multiple procedures, suggesting that radial artery access can be safely used for multiple procedures. However, the rate of transfemoral conversion was significantly higher in repeat procedures completed using the same access site as compared to an alternative access site (14·5% vs. 0·0%, *p*=0·01). Additionally, there was no significant difference in performance measures compared to right-sided access. Operators can achieve optimal performance by suprassing the learning curve, after completing 14 procedures. (Figure 3)

Diagnostic Cerebral Angiography

Several retrospective studies have demonstrated the feasibility and safety of TRA for cerebral angiography.[7,20,21] Snelling et al. reported a technical success rate of 99·3%, with no major complications, and a transfemoral conversion rate of 4.7%.[7] In a prospective non-inferiority study, Stone et al. found no significant difference in the primary outcome (97·0% vs. 99·0%, p=0·27) or complication rates (2·5% vs. 5·8%, p=0·14) between right TRA and TFA.[21] There was a difference in fluoroscopy time between the two cohorts (14·8 vs. 11·8 min, p=0·001), but this had no clinical consequence as there was no difference in radiation exposure (1631 vs. 1510 mGy, p=0·11). Transfemoral conversion was required in 2·9% of procedures. In the present study, there was a similar rate of technical success (97·6%) and TF conversion (2·7%) as well as a lower mean fluoroscopy time (11·1 min) than both studies. (Video 1)

Therapeutic Neuroendovascular Procedures

Ultimately, the benchmark of transitioning to TRA is to achieve the same treatment outcomes as with TFA with similar procedural times and rates of periprocedural complications. Previous studies have demonstrated the feasibility and safety of TRA for cerebral aneurysm embolization, mechanical thrombectomy, carotid-artery stenting, and etc. [9,22-31] Recently, Chivot et al. reported outcomes of aneurysm embolization via TRA, including a technical success rate of 96·9%, with no patients experiencing permanent neurological complications.[25] In the present study, 91·8% of patients with follow-up showed an mRRO I/II on the latest imaging, further supporting the efficacy of TRA for cerebral aneurysm embolization. Chen et al. compared outcomes of mechanical thrombectomy in TRA and TFA groups and found no significant difference in technical or clinical outcomes.[28] Khanna et al. also reported time to reperfusion and revascularization rates with TRA similar to that of TFA.[32,33] In the present study, TICI $\geq$ 2b was achieved in 78·9%, and with a total mean procedure duration of 60 mins, including converted cases. Finally, the RADCAR trial for CAS showed no significant differences in procedural metrics or major adverse events between TRA and TFA.[34] In the present study, there was a 100% technical success rate and no major neurologic complications.

The rate of TF conversion in therapeutic procedures was 9·2%, which is almost four folds higher than the diagnostic procedure. There are inherent limitations of the TRA approach, which becomes more evident in therapeutic procedures, especially with the current lack of radial specific catheters. The laterality of the pathology, the arch anatomy, the type of devices required, and the amount of proximal support are essential factors that should be considered in planning for therapeutic procedures. Pathologies located in the left supra-aortic vessels may be very challenging to access using the right radial approach. An angled catheter with a more extended distal tip allows a more manageable selection of the left supra-aortic vessels. Also, left radial access provides a shorter direct trajectory to select the left vertebral artery. When larger devices are required, a sheathless system may be employed where the guiding sheath may also serve as additional proximal support. (Video 2)

Left Transradial Access

Left transradial access has also recently gained attention in cerebral angiography. In a multicenter study, Barros et al. demonstrated the feasibility and safety of left TRA for both non-therapeutic and therapeutic neuroendovascular procedures.[35] The mean fluoroscopy time per vessel was four minutes and 45·9 minutes, and TF conversion occurred at a rate of 8·3% and 7·7% for diagnostic and therapeutic procedures, respectively. However, the overall conversion rate was 4·0% (1/25). In the present study, the mean fluoroscopy time per vessel was 6·1 minutes, and there were no cases of access complications or conversion when using left TRA for non-therapeutic procedures. There was no significant difference in all procedural metrics between left and right TRA for non-therapeutic procedures. These results further support the technical feasibility and safety of the left TRA. However, with limitations, for the treatment of challenging left-sided pathologies or in the setting when right-sided TRA is not feasible.

It is exceptionally paramount to acknowledge the limitations of the left radial approach, especially in emergency conditions. Catheterizing the left ICA and external carotid artery (ECA) may be extremely challenging due to the acute angle between the left subclavian artery and the left common carotid artery (CCA). The development of catheters designed explicitly for radial access may alleviate such limitations. Another limitation is the distance between the access site and the operator, which is more evident in obese patients.

Distal Transradial Access

dTRA is an alternative access site that allows keeping the cTRA intact for subsequent procedures. Moreover, it decreases the risk, although very low, of radial artery occlusion and, ultimately, hand or thumb ischemia. The prime usage of the dTRA is for diagnostic procedures; however, when the vessel caliber allows, therapeutic procedures may be performed. We usually use either a 5-Fr or a 6-Fr sheath for dTRA. Several neurointerventional studies published have demonstrated the feasibility, safety, and efficacy of dTRA in both non-therapeutic and therapeutic neuroendovascular procedures.[36-40] Brunet et al. demonstrated the feasibility of dTRA for diagnostic cerebral angiography reporting conversion to cTRA or TFA in 8·2% and a mean fluoroscopy time per vessel of 2·6 minutes.[36] In the present study, the mean fluoroscopy time per vessel was 4·4 minutes, access complications occurred in 0·5%, and the conversion rate was 1·5% for dTRA in non-therapeutic procedures. There was no significant difference in access complications (p=0·70) or conversion rate (p=0·37) when compared to cTRA.

As for therapeutic procedures performed using the dTRA, Kuhn et al. demonstrated the safety and efficacy of a variety of therapeutic neuroendovascular procedures.[39] Technical success was achieved in 89·6%, and 10·4% of cases required conversion mainly due to tortuous anatomy and limited support in the aortic arch. In the present study, TF conversion occurred at a rate of 25·0% due to pathologies requiring endovenous access.

Multiple Procedures: Same vs. Alternative Access

The small size of the radial artery (2·3 ± 0·4 mm, 6·6 mm femoral artery) is a significant limitation when larger devices are required or in case of repetitive procedures.[41-43] Repetitive procedures, especially if the ratio of sheath size to radial size is not respected, may result in a progressive luminal narrowing of the RA.[44] Several studies have described the changes inflicted by radial access to the endothelium including intimal damage, inflammation, and dissection.[45-49] Yoo et al. found that repeat TRA resulted in a significant reduction in RA diameter and increased risk of RAO.[50] Interventional cardiology literature has demonstrated the feasibility and safety in up to ten repeat TRA procedures. However, linear regression analysis estimated a 5·0% failure rate for each repeated attempt.[51] Although these concepts may be applied to neuroendovascular procedures, neurointerventions may require larger device systems. Chen et al. demonstrated the feasibility and safety of repeat TRA in up to six successive neuroendovascular procedures.[52] In the present study, the maximal number of repeat procedures per patient were four procedures, and because of that, our outcomes should be interpreted with caution. We did not observe any significant difference in procedural metrics, access site complications, and TF conversion across the four groups. However, there was a statistically significant difference in TF conversion (15·9%

vs. 0·0%, p=0·01) when repeat procedures were performed using alternative access compared to the same access site.

Advantages of TRA

TRA may be particularly advantageous in the setting of specific vascular anatomies. In neurointerventions requiring navigation of the left carotid artery in a bovine arch, the common origin of the innominate artery and left CCA enables direct catheterization of the left CCA without forming the Simmons catheter in the aortic arch. In the setting of elongated or tortuous aortic arches (type II or III), catheterization of arch vessels from a transfemoral approach may be particularly challenging.[53] A transradial approach may enable more direct vessel catheterization, especially for right-sided vessels as the catheter does not need to be reformed.[23] Posterior circulation interventions are even more straightforward using a transradial approach,[23] which may reduce time to revascularization in the setting of vertebrobasilar occlusions.[27] Additional populations that may benefit from TRA are the elderly, patients on anticoagulation or tissue plasminogen, pregnant patients (less fetal radiation exposure), severely obese patients (pannus), and patients with severe iliofemoral atherosclerotic disease.[54-56]

Typical transradial neuroendovascular procedures are performed with right-sided access, yet left-sided TRA also has unique advantages, mostly based on pathology location and anatomic limitations.[35] The left vertebral artery, dominant in most patients,[57] can be accessed with relative ease, and without reforming the catheter from a left transradial approach. Left TRA may also be advantageous in patients with right subclavian tortuosity, which has been shown to have a higher incidence than the left in clinical trials.[58,59]

dTRA can be viewed as a slight modification or refinement of cTRA.[60] Recent interventional cardiology literature regarding dTRA suggest a decreased risk of RAO and ischemic hand events as well as improved patient-operator ergonomics compared to cTRA.[60-66] As RAO classically occurs at the puncture site, puncture of the distal RA within the anatomic snuffbox would preserve perfusion of the superficial palmar branch if distal RAO were to occur. Therefore, the risk of hand ischemia is limited, and the RA is preserved for future TRA or surgical grafting even in the setting of distal RAO.[36,37] Improvement in patient-operator ergonomics results from the patient's neutral hand position as procedures via dTRA does not require the supination of the hand. This is particularly true for cases using left-sided access as the hand can be comfortably draped across the body.[36,67]

Complications and Management

Although low risk, several complications are associated with TRA, such as RAS, RAO, pseudoaneurysm, perforation and hematoma formation or compartment syndrome, and distal embolization.[68,69] RAS has been reported to occur in 4%-20% of TRA procedures.[70] RAS typically manifests at the start of the procedure preventing RA access, which may result in a transfemoral conversion or procedural failure. Factors that may increase the risk of RAS include small radial artery diameters, repetitive friction with catheter manipulation/exchanges, patient discomfort (pain and anxiety), guidewire entrance into side branches, and unsuccessful access attempts.[71-75] In randomized controlled trials, the use of a hydrophilic coated sheath significantly decreased the rate of RAS potentially due to reduced patient discomfort and repetitive friction against the RA intima.[73,76]

If intraprocedural (post-cannulation) RAS were to occur, nitroglycerin and verapamil may be promptly administered through the sheath or guide. Additional sedation and analgesia may also facilitate resolution.[71,77] Additional RA vasodilation may be achieved via warm compress, ulnar artery compression, or by inflating a cuff around the arm that would cause ischemia and subsequently vasodilation, flow-mediated dilatation/reactive hyperemia, and/or spasmolytic subcutaneous injection.[71,77,78] If the catheter encounters significant resistance and is unable to be removed, general anesthesia or regional nerve block may be required.[41,71]

RAO is a significant post-operative complication of TRA, which has been reported to occur in one to six percent of procedures.[41,63,79-81] RAO is usually asymptomatic due to ulnar-palmar collaterals. However, the persistence of RAO renders the RA unviable for future TRA or surgical grafting.[36] Previously reported risk factors include a high sheath to RA diameter ratio, compression time and pressure (occlusive hemostasis), heparin dose, procedural duration, diabetes, low body mass index, and female sex.[82-84] Saito et al. reported a significant reduction in the incidence of RAO when the RA inner diameter to sheath outer diameter ratio was > 1.[85] Previous studies, including randomized trials, have demonstrated that modern patent hemostasis techniques, including ulnar compression, significantly reduce the prevalence of RAO to approximately 1·0%.[86-89] In patients requiring more than one procedure, we also suggest considering an alternative access site when possible.

Challenges and Limitations of TRA

Anatomic nuances specific to TRA may affect the operator's ability to catheterize the supra-aortic vessel such as RA anomalies and tortuosity, severe subclavian tortuosity, arteria lusoria, and aortic arch type.[7,41,71] RA anomalies have been reported in approximately 13·8% of patients and are associated with an increased risk of TRA procedural failure (14·2% versus 0·9%).[90] High-bifurcation radial origins require navigation of an elongated smaller RA diameter, which may contribute to RAS. In this setting, a more extended sheath may be advantageous.[71] Radial artery loops also pose a challenge, especially when accompanied by a recurrent RA branch at the loop apex as wire advancement into the recurrent RA may cause perforation.[41,90] Proper identification and artery selection on angiographic roadmap before wire advancement is essential to prevent vasospasm, perforation, or avulsion of the recurrent branch.[41,71]

Severe subclavian artery tortuosity is associated with difficult catheterization of supra-aortic vessels as the additional turns/loops decrease the translational force. This may lead to higher radiation exposure and prolonged catheter manipulation with an increased risk of RAS, thromboembolism, vessel dissection, and catheter kinking.[71] Severe subclavian artery tortuosity has an incidence of approximately 6-10%,[91] which can often be managed with deep inspiration, leftward cephalic rotation, and upward chin tilt.[92] A longer vascular sheath may also be advantageous in these cases. Additionally, left TRA may be considered in patients with right subclavian tortuosity, which has been shown to have a higher incidence than the left in clinical trials.[58,59] Arteria lusoria, an aberrant right subclavian artery, has a prevalence of approximately 0·6-1·4%, often causing repeated entry of the guidewire/catheter into the descending aorta.[71,93]

Although type III aortic arches may enable more direct catheterization via TRA, the more inferior location of the brachiocephalic artery may make selecting the descending aorta challenging. Reforming the catheter in the CCA or ascending aorta may be required.[7,23] (Video 3) Additionally, left-sided interventions can be challenging due to lack of support and catheters engineered explicitly for the forward loads experienced during transradial neurointervention, especially in the setting of tortuosity or type III aortic arch.[23] The left vertebral artery may be particularly challenging via right TRA with a Simmons 2 catheter but is relatively more straightforward with the longer distal limb of a Simmons 3 catheter.[7] If left vertebral artery access is required, it may be accessed with relative ease via left TRA.[35]

There are several limitations to the interpretation of our data. Primarily, this is a retrospective, non-randomized study. Therefore, there may be other forms of bias regarding patient selection that are not captured by the data. Additionally, data was not collected in a prospective, standardized fashion. As such, there are some patients with missing information, which may bias the results based on the data that is available. Lastly, patients did not receive routenly a follow-up imaging to assess the patency of the radial artery. Despite this, the results from our analysis are consistent with previous studies.

Conclusion

Radial artery catheterization is a safe and effective means of carrying out a wide-range of neuroendovascular procedures associated with excellent clinical outcomes and an overall low rate of periprocedural complications. Some limitations and challenges should be acknowledged, and a learning curve to accomplish optimal safe outcomes.

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Legends:

Tables:

Table 1A: Baseline Characteristics, Access Site, and Therapeutic Procedures.

Table 1B: Procedure Details.

Table 1C: Procedural Outcomes, Conversion Rate, and Complications.

Table 2A: Procedural Metrics, Conversion Rate, and Complications for Patients with One, Two, Three, or Four Procedures (n=614).

Table 2B: Procedural Metrics, Conversion Rate, and Complications for Right vs. Left Diagnostic Angiograms for Non-Therapeutic Procedures (n=500).

Table 2C: Procedural Metrics, Conversion Rate, and Complications for Therapeutic Procedures performed via Conventional TRA vs. Distal TRA (n=259).

Table 2D: Procedural Metrics, Conversion Rate, and Complications for Non-Therapeutic Procedures performed via Conventional TRA vs. Distal TRA (n=496).

Figures:

Figure 1A: Procedural Metrics, Conversion Rate, and Complications

Figure 1B: Mechanical Thrombectomy Procedural Metrics, Conversion Rate, and Functional Outcome

Figure 2: Procedural Metrics, Conversion Rate, and Complications for Patients Undergoing Repeat procedures using Same Access vs. Alternative Access.

Figure 3: Learning Curve; Fluoroscopy time per vessel as a function of number of procedures. The curve deflected at 14 procedures from 5.8 mins/vessel to plateau at 4.2 mins/vessel. The blue curve is the average fluoroscopy time/vessel of seven fellows performing diagnostic cerebral angiograms.

Videos:

Video 1: Four Vessels Diagnostic Cerebral Angiogram.

Video 2: Therapeutic Neuroendovascular Procedures; Intra-arterial Chemotherapy, Carotid Artery Stenting and Mechanical Thrombectomy for ICA Stenosis and Tandem M2 Occlusion, Flow Diversion for Superior Hypophyseal Artery Aneurysm that grew is size.

Video 3: Pathologies and TF Conversion; 1- Radial Artery Spasm; 2- Small Caliber Radial Artery; 3- Radial Artery Extravasation; 4- Brachial Loop; 5- Brachial Artery Occlusion; 6- Arteria Lusoria.