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ABSTRACT

BACKGROUND AND PURPOSE: The feasibility and safety of transradial angiography is not established outside the adult literature. The objective of this study was to assess the feasibility and safety of transradial access for neuroangiography in adolescents.

MATERIALS AND METHODS: A retrospective case-control study was performed, comparing transradial neuroendovascular procedures in adolescents (age range, 10–18 years) with an age- and procedure-matched cohort of transfemoral neuroendovascular procedures. Clinical and procedural details, including type of procedure, conversion rate, fluoroscopy time, radiation dose, complications, and readmissions, were reported by descriptive statistics or measures of central tendency and compared using a *t* test or nonparametric equivalent. A *P* value $<$ .05 was considered statistically significant.

RESULTS: Twenty adolescents (mean age, 14.6 [SD, 1.7] years, M/F ratio = 9:11) who underwent transradial neuroangiography were compared against 20 adolescents (mean age, 14.4 [SD, 2.1] years, M/F ratio = 12:8) who underwent transfemoral neuroangiography. We found no significant difference in procedural success (0% conversion rate), fluoroscopy times (33.7 [SD, 40.2] minutes versus 23.3 [SD, 26.2] minutes, $P = .34$) and radiation dose (150.9 [SD, 133.7] $Gy \times cm^2$ and 122.9 [SD, 79.7] $Gy \times cm$,[2] $P = .43$) There were 2 self-limiting postprocedural complications in the transradial group. There were no major hemorrhages, need for further interventions, or readmissions in either group.

CONCLUSIONS: The benefits of transradial angiography described for adults can likely be safely extended to adolescents. These are important data before transitioning to smaller children and should be prospectively evaluated in a larger cohort.

Several randomized controlled trials in cardiovascular intervention have shown the superiority of transradial angiography over transfemoral access for procedural safety, outcomes, and health care costs in adults, with the American Heart Association supporting a "radial-first" strategy for patients with acute coronary syndrome.[1-3] A lower rate of access-site complications, including life-threatening hemorrhage, pseudoaneurysms, and ischemic limbs and a lower rate of procedural adverse events, including death, myocardial infarction, and stroke, have resulted in this paradigm clinical shift.[2] In the past few years, there has also been increased adoption of the transradial approach for neurointerventional procedures, with substantially increased patient preference and reduced hospital costs in the adult neurointerventional literature.[4-9] In the Patient Preference for Radial versus Femoral Vascular Access for Elective Coronary Procedures (PREVAS) trial, >70% of patients preferred transradial access over transfemoral access.[10] Similarly, in a recent study in 25 patients having undergone neurointerventional procedures who received transradial access after previous transfemoral access, 96% reported preference for the former.[4]

In contrast to its increasing acceptance in adults, radial arterial access for neuroangiography in children and adolescents has traditionally been performed via the femoral route. Some recent reports describe specific cases in which transradial cerebral and coronary angiographic procedures were performed successfully and safely in children.[5,6,11] However, concerns regarding arterial size and an increased incidence of spasm, dissection, and occlusion have led to modest adoption of this technique for angiography outside adult populations. It was recently shown that radial arteries approach adult dimensions by adolescence.[12] In addition, the recently described distal radial access technique in adults (ie, the "snuffbox" technique) for coronary and neuroangiography procedures uses the distal radial artery branch, which is comparable in size with a pediatric radial artery at the wrist.[13-15] However, there is no study reporting the feasibility and safety of transradial

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FIG 1. Arm position for radial angiography. *A*, Right arm positioned at the same height as the groin during transradial neuroangiography, with the wrist slightly hyperextended and a saturation probe on the thumb. *B*, Postdraping appearance, showing the wrist and right groin exposed. For the operator's working position, this is akin to bilateral groin access.

access for angiography in larger cohorts of patients younger than 18 years of age. In our practice, we started offering transradial access for neuroendovascular procedures in adolescents (10–18 years of age) in November 2019. We, therefore, began to evaluate and report this experience, as well as compare this technique with transfemoral access.

MATERIALS AND METHODS

An institutional review board–approved retrospective analysis of cerebral angiography in adolescents, during a 1-year period from November 2019 to October 2020, was performed. Procedures were categorized as "cases" (consecutive procedures of neuroangiography performed via radial access) and "controls" (consecutive age and procedure-matched patients who underwent neuroangiography via femoral access in the same period), all of whom were age- and procedure-matched. Procedures performed via brachial or axillary artery access were excluded. All neuroangiographic procedures were performed by the same neuroradiologist (P.M.) in a biplane angiography suite (Artis Q BA Twin; Siemens) with the patient under general anesthesia or local anesthesia with or without mild sedation or anxiolysis. Sonography-guided access was performed in all cases, using an out-of-plane method with a single-wall puncture followed by a standard Seldinger technique for sheath insertion.

Transfemoral Neuroangiography and Embolization

Transfemoral neuroangiography was performed under systemic heparinization (50 IU/kg up to a maximum of 3000 IU), using a 4F Glidesheath (Terumo) and a 4F diagnostic catheter with standard projections. The catheter system was maintained on a continuous flush of heparinized saline. Digital subtraction angiography was performed using an iodinated contrast agent (Iohexol, Omnipaque, 300 mg I/mL; GE Healthcare) injected through a power injector at 3–5 mL/s, depending on the age and arterial size. Rotational angiography was performed in the vessels of interest at the discretion of the operator. Embolization procedures, if any, were performed following diagnostic angiography, after upsizing the sheath if required. Postprocedural hemostasis was achieved with manual compression or a vascular closure device, followed by local instillation of 2–6 mL of 0.25% bupivacaine. Patients were asked to remain supine for 5 hours following the procedure, after which they were slowly ambulated, and, if uneventful, discharged home at 6–7 hours. Some patients required additional postprocedural sedation to prevent movement. In the event of hematoma or new bleeding at the arteriotomy site, additional manual compression was applied until hemostasis was achieved. Following discharge, patients could resume daily activities but avoid strenuous physical activity or sports for 1 week.

Transradial Neuroangiography and Embolization

Procedures were performed with the arm supported as close to the body as possible, with the wrist supinated and slightly hyperextended, and a saturation probe on the ipsilateral thumb (Fig 1). Access was obtained using a 5F Glidesheath Slender (Terumo), which is 25-cm in length. A radial cocktail consisting of heparin (1000 IU), verapamil (1 mg), and nitroglycerin (1.5 mcg/kg up to a maximum of 150 mcg) was given as a slow intra-arterial injection. Initial access into the subclavian artery was performed over a Glidewire Baby-J (Terumo). Diagnostic angiography was performed using a 5F Sim-1 Glide catheter (Terumo), using hand injections and rotational angiography if considered relevant. Postprocedural hemostasis was performed using an inflatable wrist TR Band (Terumo). Patients were ambulated after 30 minutes of observation, were discharged following wrist band removal 2–3 hours following the procedure, and could resume all activities the following day except lifting heavy objects.

Patient demographics and clinical details including complications, follow-up, further admissions, consults, or procedures needed were retrieved from electronic patient charts (Table 1). Procedural details were obtained from the radiology PACS report and image review. These included procedural and technical details, parameters for procedural safety (complications, type, and severity), fluoroscopy time, procedural time, procedural completion, and conversion rate to another site. Complications were graded according to the Clavien-Dindo classification.[13] Clinical and procedural details were reported as descriptive or as means (SDs). Fluoroscopy times and radiation doses were compared using 2-tailed t tests or their nonparametric equivalents. $P < .05$ was considered statistically significant.

RESULTS

A total of 40 adolescents were included, of whom 20 (mean age, 14.6 [SD, 1.7] years, M/F ratio = 9:11) underwent transradial angiography, and 20 age- and procedure-matched adolescents (mean age, 14.4 [SD, 2.1] years, M/F ratio = 12:8) underwent transfemoral angiography. Clinical and demographic details are shown in Table 1.

Table 1: Demographics of our cohorts ($n = 40$) and clinical features

	Transradial Neuroangiography (n = 20)	Transfemoral Neuroangiography (n = 20)	P Value
Age (mean) (yr)	14.6 (SD, 1.7)	14.4 (SD, 2.1)	.69
M/F	9:11	12:8	.35
Indication (No.)			
Ischemic stroke work-up	6	10	
Arteriovenous malformation/ fistula	14	9	
Other	0	1 (Ruptured aneurysm)	
Procedures (No.)			
Diagnostic cerebral angiography	18	18	
Endovascular embolization	2	2	
General anesthesia (%)	95	95	1.0
Preprocedural hemoglobin (mean) (g/dL)	132.8 (SD, 18.5)	123.8 (SD 9.5)	.21
Preprocedural INR (mean)	1.1 (SD, 0.1)	1.1 (SD, 0.1)	1.0
Preprocedural routine use of anticoagulants/antiplatelets (No.) (%)	4, 20	6, 30	.47

Note:—INR indicates international normalized ratio.

Table 2: Comparison of transradial ($n = 20$) and transfemoral ($n = 20$) cohorts

	Transradial Neuroangiography (n = 20)	Transfemoral Neuroangiography (n = 20)	P Value
Conversion rate to another site (%)	0	0	1.0
Fluoroscopy time (mean) (min)	33.7 (SD, 40.2)	23.3 (SD, 26.2)	.34
Total radiation dose (mean) (Gy × cm^2)	150.9 (SD, 133.7)	122.9 (SD, 79.7)	.43
Complications, grade I (No.)	2	0	.15
Complications, grades I–V (No.)	0	0	
Readmissions (No.)	0	0	1.0

Procedural and Technical Success

Under sonographic guidance, successful catheterization was achieved in all cases. The mean radial artery diameter was 2.6 [SD, 0.4] mm (range, 2.0–3.3 mm), and all showed a type A Barbeau response to radial artery test occlusion. The right radial artery was used in 19/20 (95%) cases, and left radial arterial access, in 1 case. Radial-to-femoral conversion was not required in any case for procedure completion. Mean fluoroscopy duration in the transradial and transfemoral groups was 33.7 [SD 40.2] minutes versus 23.3 [SD, 26.2] minutes in the transfemoral group ($P = .34$), whereas the mean fluoroscopy doses for the transradial and transfemoral groups were 150.9 [SD, 133.7] Gy × cm^2 and 122.9 [SD, 79.7] Gy × cm^2, respectively ($P = .43$) (Table 2).

Closure and Complications

Hemostasis in all transradial procedures was achieved using the TR Band; in transfemoral cases, using manual compression in 19/20 cases, and a closure device (Angio-Seal Vascular Closure Device; Terumo) in 1 case. One patient in the transradial group developed forearm swelling and pain requiring conservative management. Sonography and Doppler sonography showed no radial arterial thrombosis or occlusion. There was 1 instance of hemorrhage after TR Band removal, which required manual compression. There were no instances of major hemorrhage or pseudoaneurysm formation in either group and no readmissions for delayed complications. There were no significant vascular access-site complications that required surgical or image-guided interventions in either group.

DISCUSSION

There are robust data favoring transradial angiography in adults. These include data on procedural outcomes, hospital costs, and patient preference in the cardiac and neurologic literature.[15-17] Although the transradial approach for angiography has been described in a few reports in children, there is still controversy about safety, feasibility, cost, and patient preference.[12,18] Our early experience with transradial neuroangiography confirms the safety and feasibility in adolescents and shows that the benefits of this technique over transfemoral neuroangiography can be extended to this population. These data form the basis for designing a randomized controlled trial for assessing patient preference and procedure-associated costs and also serve as the first step toward a discussion of the merits and demerits of transradial neuroangiography in smaller children.

Similar to the proved benefit in adults, radial artery access for angiography could also have several potential advantages over femoral artery access for angiography in children. Because the radial artery is a superficial artery, access and monitoring hemostasis are more straightforward. The median nerve is relatively distant, there are no major veins in the vicinity, and these are well-visualized under sonography, thereby minimizing the risk of neurovascular complications or arteriovenous fistula formation. The transradial approach allows early ambulation and discharge, reducing hospital costs.[1-4,10] If proved feasible and safe in future studies, small children can particularly benefit from a transradial approach due to sedation or immobilization not being required, the small risk of hemorrhage, and early return to sports and school activities.[6] In addition, transradial angiography is likely well-suited for systemic angiography in children, which often requires a cephalad approach due to the smaller diameter of the aorta. In our radial cohort, there were 2 adolescents who required systemic angiography in addition to cerebral angiography for the work-up of vasculopathy. Traditionally, this procedure has been performed via a brachial or axillary artery approach, with concomitant high morbidity and access-site complications.[18]

Radiation exposure during transradial angiography has not yet been investigated in children. Studies in adults have shown that transradial procedures may result in more radiation to both the patient and operator than transfemoral procedures.[19,20] However, it has also been shown that as operator experience increases, radiation exposure decreases to levels comparable with those seen in transfemoral procedures.[21-23] In the present study in adolescents, though the fluoroscopic times and doses were higher in the transradial cohort, the differences, we believe, were not statistically nor clinically significant.

It has been shown that failure to access the radial artery is typically due to puncture error or radial artery spasm.[24] In our experience, the routine use of sonography for radial artery access eliminated access failure and spasm in all patients. Radial artery spasm has been reported in the adult literature in 10%–30% of cases.[21] Spasm has been shown to be related to arterial size, initial wire or catheter manipulation, and patient anxiety.[18,23] A radial cocktail of verapamil, nitroglycerin, and heparin given intra-arterially immediately after sheath insertion has been shown to reduce the rates of spasm.[22,23,25] Longer sheaths may also reduce the development of radial artery spasm,[18] by covering a greater length of the artery and offering more protection from catheter manipulations during vessel selection.[6] We did not observe any cases of intraprocedural radial artery spasm because all patients received either a general anesthetic or anxiolysis, and we routinely used a long radial sheath advanced above the elbow joint.

The risk of radial artery occlusion following cannulation in adults has been reported as 0.8%–38%.[21,26] This has been shown to be related to patient characteristics such as high body mass index and diabetes, as well as intraprocedural precautions like sheath size, use of anticoagulants, and postprocedural patent hemostasis. Whereas testing in adults for ulnar patency before radial puncture with the Allen or Barbeau test is no longer recommended, we still perform this check in adolescents, in whom it is possible that the 2 major arteries have not yet achieved their full adult dimensions. Although we did not see any instances of radial artery occlusion in our cohort, this would require a forward-looking study with delayed sonographic follow-up to definitively exclude it, being usually a clinically quiescent condition. Because the radial artery is 1 of 2 arteries to the hand, there is no major ischemic risk from occlusion of the radial artery, as opposed to femoral occlusion,[27-29] albeit the likelihood and frequency of the latter is arguably less.

The only complications in our series were minor and self-limiting, occurring during diagnostic angiography. The first was swelling of the forearm and hand, which subsided with arm elevation and encouraging finger movement. This occurred early in our transradial experience, presumably related to the use of a flush at the side arm of the sheath, similar to our transfemoral practice. We have since abandoned using this flush for transradial procedures and have not seen this complication since. The second was a postprocedural small hematoma immediately after removing the TR Band. This subsided with manual compression with no significant clinical sequelae. We have since moved from a single-step deflation of the TR Band to a 2-step process. Of note, this transradial cohort represents our learning curve with the radial approach to angiography in adolescents, and we expect reduced postprocedural complications going forward.[30] We had no instances of having to switch to femoral access due to the inability to catheterize the neck arteries in adolescents, despite the narrower arch and acute angles of arterial origin compared with adults.

Our study had certain limitations. Being retrospective in design, it has associated biases. However, all procedures were performed by the same operator using standardized protocols. The cohorts were small-but-adequate to assess feasibility and procedural safety. We did not have data regarding procedure-related costs, patient preference, or long-term data regarding radial artery occlusion rates, but this information was not within the scope of this study and requires a prospectively designed trial to satisfactorily evaluate it. Although the cohorts did not include children younger than 10 years of age, this study represents the next logical step in assessing the benefits of transradial neuroangiography documented in the adult literature when balanced against a potential risk to pediatric radial arteries. Finally, this study represents our early experience with transradial angiography, naturally skewing results in favor of the more established transfemoral technique. Nevertheless, the lack of major differences in procedural efficacy, radiation doses, and major complications is a testament to the safety of the transradial technique in adolescents.

CONCLUSIONS

Transradial neuroangiography is feasible and safe in adolescents. As shown in adult practice, success rates are likely to be high, with increasing operator experience. Evidence from prospective studies is required to compare patient preference and long-term occlusion rates, as well as for extending the benefit of this technique to smaller children.

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