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Original Article

Predicting difficult transradial approach guiding into left internal carotid artery on unruptured intracranial aneurysms

Michiyasu Fuga[1], Toshihide Tanaka[1], Rintaro Tachi[1], Kyoichi Tomoto[1], Ryoto Wachi[1], Akihiko Teshigawara[1], Toshihiro Ishibashi[2], Yuzuru Hasegawa[1], Yuichi Murayama[2]

[1]Department of Neurosurgery, Jikei University School of Medicine, Kashiwa Hospital, Kashiwa, Chiba, [2]Department of Neurosurgery, Jikei University School of Medicine, Minato-Ku, Tokyo, Japan.

E-mail: *Michiyasu Fuga - fugamichiyasu@icloud.com; Toshihide Tanaka - ttanaka@jikei.ac.jp; Rintaro Tachi - rintaro.t0609@gmail.com; Kyoichi Tomoto - annindof72@gmail.com; Ryoto Wachi - rw.orecchi@gmail.com; Akihiko Teshigawara - de.apipiko817tepigawara@gmail.com; Toshihiro Ishibashi - t-ishibashi@jikei.ac.jp; Yuzuru Hasegawa - yuz-yuz@next.odn.ne.jp; Yuichi Murayama - ymurayama@jikei.ac.jp

***Corresponding author:**
Michiyasu Fuga,
Department of Neurosurgery,
Jikei University School of Medicine, Kashiwa Hospital,
Kashiwa, Chiba, Japan.

fugamichiyasu@icloud.com

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ABSTRACT

Background: The transradial approach (TRA) is less invasive than the transfemoral approach (TFA), but the higher conversion rate represents a drawback. Among target vessels, the left internal carotid artery (ICA) is particularly difficult to deliver the guiding catheter to through TRA. The purpose of this study was thus to explore anatomical and clinical features objectively predictive of the difficulty of delivering a guiding catheter into the left ICA via TRA.

Methods: Among 78 consecutive patients who underwent coil embolization for unruptured intracranial aneurysms through TRA in a single institution between March 1, 2021, and August 31, 2022, all 29 patients (37%) who underwent delivery of the guiding catheter into the left ICA were retrospectively analyzed. Clinical and anatomical features were analyzed to assess correlations with difficulty in guiding the catheter into the left ICA.

Results: Of the 29 aneurysms requiring guidance of a catheter into the left ICA, 9 aneurysms (31%) required conversion from TRA to TFA. More acute innominate-left common carotid artery (CCA) angle ($P < 0.001$) and older age ($P = 0.015$) were associated with a higher conversion rate to TFA. Receiver operating characteristic analysis revealed that optimal cutoff values for the innominate-left CCA angle and age to distinguish between nonconversion and conversion to TFA were 16° (area under the curve [AUC], 0.93; 95% confidence interval [CI], 0.83–1.00) and 74 years (AUC, 0.79; 95% CI, 0.61–0.96), respectively.

Conclusion: A more acute innominate-left CCA angle and older age appear associated with difficulty delivering the guiding catheter into the left ICA for neurointervention through TRA.

Keywords: Anatomical feature, Conversion, Crossover, Innominate artery, Transradial access

INTRODUCTION

Both neurointervention and interventional cardiology have recently been transitioning from the transfemoral approach (TFA) to the transradial approach (TRA). This is because TRA is considered superior to TFA in terms of complications related to access site,[3,7] lengths of stay in the intensive care unit and hospital,[3,7] health-care system costs,[14,26,36,37,40] comfort associated with quicker postintervention ambulation and less postprocedural pain,[5,23,31,50] and patient satisfaction.[33,51] Further, this method is considered preferable for elderly patients,[1,2,42] obese patients,[6,9,22,35,38] and those receiving pharmacotherapies such as anticoagulants.[24] On the other hand, a high conversion rate from TRA to TFA has been noted as a drawback,[10,27,52] and this represents a major psychological barrier for inexperienced neurointerventional surgeons considering switching from TFA to TRA.

In the field of interventional cardiology, causes of high procedural failure and conversion rates have been extensively analyzed.[10,27,52] For neurointerventional procedures, however, these factors have not yet been fully investigated. With respect to neurointerventional TRA, delivery of the correct TRA into the left internal carotid artery (ICA) or left vertebral artery (VA) is difficult.[8,12,28,32,48,53,55] For the left VA, this can be overcome by the left TRA.[25] In contrast, directing a guiding catheter into the left ICA is particularly difficult for anatomical reasons such as the acute angle of the common carotid artery (CCA) orifice at the aortic arch or tortuosity of the CCA, which represents the main reason for conversion to TFA.[12,28,32,48,53] However, most of the aforementioned reports have been based primarily on subjective judgments, and more objective indicators are needed. Therefore, the purpose of this research was to quantitatively investigate factors associated with conversion to TFA in patients who underwent coil embolization through TRA for unruptured intracranial aneurysms, focusing exclusively on treatments requiring placement of a guiding catheter into the left ICA.

MATERIALS AND METHODS

Study design

From March 1, 2021, neurointerventional treatment through TRA became the first option in our institution. Before the initiation of neurointerventional treatment through TRA at our institution, these two neurointerventional operators had already experienced at least 50 cases of diagnostic angiography through TRA. Among the 78 consecutive patients who underwent coil embolization for unruptured intracranial aneurysms through TRA in a single institution between March 1, 2021, and August 31, 2022, all 29 patients (37%) who required delivery of a guiding catheter into the left ICA were retrospectively analyzed from the maintained database. The present cohort research was implemented in adherence with Strengthening the Reporting of Observational Studies in Epidemiology guidelines for cohort studies. This research was conducted with the approval of the institutional review board (IRB). In addition, the need to obtain consent was waived with IRB approval because of the retrospective nature of the investigation.

Endovascular procedure

Coil embolization through TRA was conducted only in patients who met the following inclusion criteria: (1) presence of collateral vessels from the ulnar artery on preoperative digital subtraction angiography (DSA) and (2) radial artery diameter ≥2.0 mm. All procedures were completed through the "right" radial artery. The procedure through TRA was conducted exclusively by two neurointerventional surgeons (M.F. and R.T.) in a uniform fashion. The following procedure was employed to navigate the guiding catheter into the target vessel through TRA.

With ultrasound assistance, the right radial artery was punctured using an anterior or counter-puncture technique, and a 4-Fr short sheath (Terumo, Somerset, NJ, USA) was inserted. When vasospasm occurred in the radial artery, 1 mg of isosorbide dinitrate was infused over 1 min. The 4-Fr short sheath was then exchanged with a straight-shaped 8-Fr guiding catheter (FUBUKI Dilator Kit [OD, 2.7 mm; ID, 0.090 inch; length, 90 cm]; Asahi Intecc, Aichi, Japan). The guiding catheter was subsequently navigated to the target vessel in telescopic fashion using a 130-cm 5-Fr Simmons-shaped catheter (Medikit, Tokyo, Japan) and a 180-cm soft-tipped 035-inch hydrophilic wire (Terumo). We directed the guiding catheter into the cervical segment of the ICA and performed coil embolization due to the more selective angiographic imaging and improved microcatheter manipulation. Every attempt was made to assess the correct origin of the artery using different angles, such as oblique views, to the aortic arch to facilitate arterial selection and overcoming the tortuosity of the arteries during the advancement of the guidewire, inner catheter, and guiding catheter under fluoroscopic guidance. In addition, when the guiding catheter was difficult to direct to the target vessel, changing the stiffness of the guidewire and the carotid-compression technique were attempted.[54] Once the guiding catheter was placed in the target vessel, coil embolization was accomplished, including primary coiling, balloon-assisted, and stent-assisted techniques.

Definition of conversion for access site

To evaluate the difficulty of directing the guiding catheter into the left ICA through TRA, we divided patients into a nonconversion group and a conversion group. The nonconversion group was defined as patients in whom the guiding catheter was successfully directed into the left ICA through TRA and stabilized to complete coil embolization. On the other hand, the conversion group was defined as patients in whom TRA was attempted but failed to direct and stabilize the guiding catheter into the left ICA, and the access was therefore converted to TFA to complete coil embolization.

Definition of anatomical features

CCA angle was defined as the angle between the proximal and distal CCA at the most curved part within the proximal CCA [Figure 1a]. Based on the definition provided by Snelling *et al.*,[49] the presence of proximal tortuosity of the left CCA was counted when the CCA angle was <90°. Innominate-left CCA height was defined as the distance between the horizontal line through the midpoint of the diameter at the orifice of the innominate artery and the left CCA [Figure 1b]. Innominate-left CCA angle was defined as the angle between the flow axis of the innominate artery and left CCA at the orifice from the aortic arch [Figure 1c]. A radial artery loop was defined as the radial artery turning 360° in the opposite direction before unifying with the ulnar artery into the forearm.[11] The brachioradial artery was defined as a high origin of the radial artery branching from the brachial artery proximal to the intercondylar line of the humerus, a fixed line marking the proximal border of the antecubital fossa.[19]

Diameter of the aortic arch, subclavian-innominate angle, and innominate-aortic angle were adopted from the definitions advocated by Khan *et al.* and for Simmons angle by Sattur *et al.*, respectively.[30,46] The diameter of the aortic arch was measured at the apex of its curve. On the portion of the vessels running continuously from innominate artery to subclavian artery, the primary curve of the subclavian-innominate angle is determined by the angle formed by the proximal innominate artery and the distal innominate artery, with the convex part at the top [Figure 1d]. On the other hand, the secondary curve of

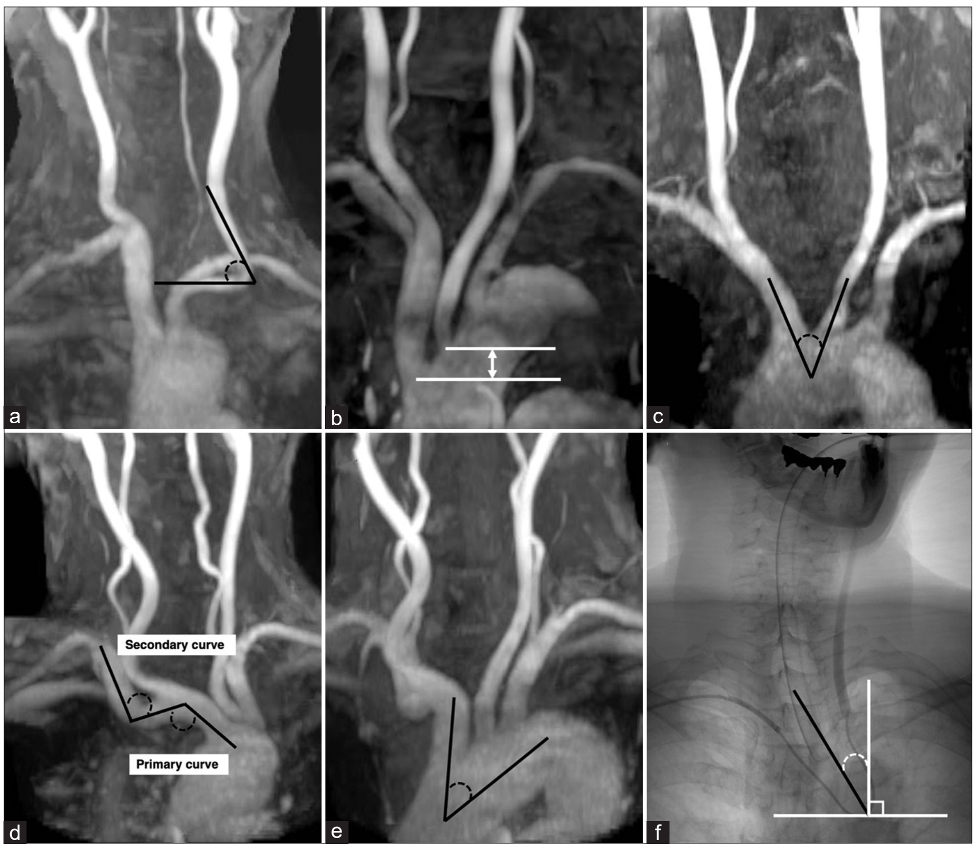

Figure 1: Definitions of anatomical features. (a) Common carotid artery (CCA) angle was defined as the angle between the proximal and distal CCA at the most curved part within the proximal CCA. (b) Innominate-left CCA height was defined as the distance between the horizontal line through the midpoint of the diameter at the orifice of the innominate artery and left CCA. (c) Innominate-left CCA angle was defined as the angle between the flow axis of the innominate artery and left CCA at the orifice from the aortic arch. (d) The primary curve of the subclavian-innominate angle is determined by the angle formed by the proximal innominate artery and the distal innominate artery, with the convex part at the top. The secondary curve of the subclavian-innominate angle is defined as the angle formed by the distal innominate artery and the proximal subclavian artery, with the convex part at the bottom. (e) Innominate-aortic angle was defined as the angle between the aortic arch and the orifice of the innominate artery. (f) Simmons angle was defined as the angle formed by a line bisecting the apex of the Simmons curve and the horizontal line diverging from 90° in either direction.

the subclavian-innominate angle is defined as the angle formed by the distal innominate artery and proximal subclavian artery, with the convex part at the bottom [Figure 1d]. Single subclavian-innominate tortuosity was defined as either the primary or secondary curve of the subclavian-innominate angle <90°. Double subclavian-innominate tortuosity was defined as both angles of subclavian-innominate curve <90°. Innominate-aortic angle was defined as the angle between the aortic arch and the orifice of the innominate artery [Figure 1e].

In the setting of after complete contact with the left CCA, Simmons angle was defined as the angle formed by a line bisecting the apex of the Simmons curve and the horizontal line diverging from 90° in either direction [Figure 1f].

Assessment of anatomical features

All parameters for angle except the Simmons angle were measured by 3-T magnetic resonance angiography (MRA). With reference to Narsinh *et al.*,[41] MRA data were reconstructed in a 3D volume-rendering reformat with a slice thickness of 1.0 mm. The arbitrary view with the maximum angle for each parameter in the reconstructed 3D-MRA was determined, and the angle from lumen to lumen corresponding to the flow axis was calculated by the maximum intensity projection data of the MRA.

Only the Simmons angle was measured by DSA, at any view where the angle was the largest imaged. In arteria lusoria, angles involving the innominate artery were excluded because of calculation difficulties. Each parameter of the anatomical angle was measured separately by three certified neurointerventional surgeons (M.F., R.T., A.T.) and determined by the median of the three values.

Statistical analysis

To compare the nonconversion and conversion groups, categorical variables expressed as frequencies and percentages were evaluated employing χ^2 analyses or Fisher's exact test, as appropriate. All continuous variables are presented as median and range (interquartile range). The nonparametric Mann–Whitney U-test was used to evaluate the statistical significance of differences between the two populations. Receiver operating characteristic (ROC) curves were used to examine the impact of varying the discriminant variables. The optimal cutoff value was determined as the threshold on the ROC curve closest to the upper left corner. All statistical calculations were carried out using R and R Commander-based Easy R (EZR) software (Saitama Medical Center, Jichi Medical University, Saitama, Japan).[29] $P < 0.05$ was considered statistically significant.

RESULTS

In all 29 left ICAs, guidewire and inner catheter guidance into the left ICA was successful. However, 9 (31%) of the 29 left ICAs failed to direct the guiding catheter to the left ICA and were consequently converted from TRA to TFA. In the first 10 consecutive neurointerventional procedures through TRA initiated at our institution on March 1, 2021, no conversions from TRA to TFA occurred.

Characteristics of clinical and procedural features

Sex, body mass index, smoking and drinking history, medical history including hypertension, diabetes mellitus, hyperlipidemia, and dialysis, and aneurysm location did not differ significantly between the nonconversion and conversion groups [Table 1]. Median age was significantly higher in the conversion group (79 years) than in the nonconversion group (67 years; $P = 0.015$) [Table 1]. There were also no significant differences in initial coiling rate, retreatment rate, and embolization technique (including primary coiling, balloon-assisted, and stent-assisted methods), fluoroscopy time, and total contrast medium volume between the nonconversion and conversion groups [Table 1].

Characteristics of anatomical features

Frequencies of radial artery loop, brachioradial artery, type of aortic arch, bovine arch, and arteria lusoria did not differ significantly between the nonconversion and conversion groups [Table 2]. Median radial artery size, diameter of the aortic arch, length of the innominate artery, innominate-left CCA height, innominate-aortic angle, and Simmons angle did not differ significantly between the nonconversion and conversion groups [Table 2]. Median angle of proximal tortuosity of the left CCA was 139° in the nonconversion group and 135° in the conversion group. Percentage of proximal tortuosity of the left CCA was 15% in the nonconversion group and 11% in the conversion group. No significant differences were seen in either parameter between groups [Table 2]. Subclavian-innominate angles in the nonconversion and conversion groups were 140° and 135° for the primary curve and 131° and 133° for the secondary curve, respectively. In addition, distributions of subclavian-innominate tortuosity in the nonconversion and conversion groups were 5.0% and 0% for double angle, 15% and 13% for single angle, and 80% and 88% for no angle, respectively. No significant differences in these factors were evident between groups [Table 2]. Median innominate-left CCA angle was significantly greater in the nonconversion group (23°) than in the conversion group (3°; $P < 0.001$) [Table 2].

ROC analysis for optimal cut-off values

ROC analysis revealed that the optimal cutoff innominate-left CCA angle for distinguishing between the nonconversion and conversion groups was 16° (sensitivity, 100%; specificity,

Table 1: Comparison of clinical and procedual features between Non-conversion and Conversion groups.

Characteristic	Non-conversion (*n*=20)	Conversion (*n*=9)	*P* value
Age, years	67 [59, 74]	79 [73, 81]	0.015*
Sex, female	12 (60)	8 (89)	0.2
Body mass index, kg/m^2	22 [21, 25]	23 [20, 25]	0.71
Smoking			
Current smoker	3 (15)	0 (0)	0.66
Past smoker	3 (15)	2 (22)	
None	14 (70)	7 (78)	
Drinking	7 (35)	4 (44)	0.69
Medical history			
Hypertension	10 (50)	6 (67)	0.45
Diabetes mellitus	4 (20)	3 (33)	0.64
Hyperlipidemia	8 (40)	5 (56)	0.69
Dialysis	1 (5.0)	0 (0)	1
Aneurysm location			
ICA	14 (70)	4 (44)	0.1
MCA	6 (30)	3 (33)	
ACA/ACoA	0 (0)	2 (22)	
Initial coiling	17 (85)	8 (89)	1
Retreatment	3 (15)	1 (11)	
Embolization technique			
Primary coiling	4 (20)	1 (11)	0.62
Balloon-assisted	5 (25)	1 (11)	
Stent-assisted	11 (55)	7 (78)	
Fluoroscopy time, min	94 [84, 124]	113 [89, 132]	0.51
Total contrast medium volume, mL	150 [125, 163]	170 [125, 193]	0.2
Catheter size			N/A
8-Fr	20 (100)	9 (100)	

ACA: Anterior cerebral artery, ACoA: Anterior communicating artery, ICA: Internal carotid artery, MCA: Middle cerebral artery, *n*: Number, N/A: Not available. *$P<0.05$. Unless otherwise indicated, values represent the number of aneurysms (%) or the median [Interquartile range]. Not all percentage totals reach 100% because of rounding.

85%; area under the curve (AUC), 0.93; 95% confidence interval (CI), 0.83–1.00) [Figure 2a]. On the other hand, the optimal cutoff age for distinguishing between the nonconversion and conversion groups was 74 years (sensitivity, 67%; specificity, 80%; AUC, 0.79; 95%CI, 0.61–0.96) [Figure 2b].

Illustrative cases

Easy case for TRA

As illustrative angiographic findings for neurointervention through the TRA, a 50-year-old woman with the left ICA aneurysm underwent easy navigation of the guiding catheter into the left ICA cervical segment with an innominate-left CCA angle of 44°, more than the cutoff of 16° [Figures 3a-c].

Difficult case for TRA

On the other hand, in an 81-year-old woman with the left posterior communicating artery aneurysm, difficulty was experienced directing the guiding catheter into the left ICA cervical segment. The innominate-left CCA angle was 3°, less than the cutoff of 16° [Figures 3d and e]. The patient was eventually converted from TRA to TFA and coil embolization was completed.

DISCUSSION

To explore predictive factors for technical difficulty delivering the guiding catheter into the left ICA through TRA, we focused on correlations between anatomical structures seen on preoperative neuroradiological imaging and conversion rate to TFA. Based on statistical analyses in the present cohort, acute innominate-left CCA angle and older age were identified as predictive factors for a higher conversion rate from TRA to TFA. Furthermore, ROC curves showed that an innominate-left CCA angle <16° or patient age over 74 years might be inherent factors to determine difficulty in direct delivery of the guiding catheter into the left ICA, elevating the conversion rate from TRA to TFA.

Difficult factors for TRA in light of anatomy

Direct guidance of a catheter to a nonbovine left CCA through TRA is challenging due to the anatomy. To date, the left CCA or ICA tortuosity, acute angle of the left CCA takeoff, larger Simmons angle, and subclavian-innominate tortuosity are considered to impact the technical difficulty of guiding a catheter toward the left ICA.[12,13,15,17,28,39,43-45,48] Chen *et al.* reported that among 49 transradial flow diversion procedures attempted, eight failed to achieve entry of the guiding catheter into the left CCA and ICA because of left CCA or ICA tortuosity or acute angle of the left CCA takeoff.[12] On the other hand, Sattur *et al.* proposed the angle formed by the apex of the Simmons angle after complete contact with the left CCA as an indicator of the difficulty of distal navigation into the left ICA. They pointed out that the closer the Simmons angle is to 90°, the easier the guiding catheter can be navigated into the left ICA.[46] Furthermore, Khan *et al.* demonstrated that the presence of a double subclavian-innominate tortuosity can cause a loop in the catheter, decreasing torquability and resulting in loss of control of the distal catheter and difficulty selecting the target vessel.[30] Tortuosity affects the capability to form the Simmons shape in an aortic arch with a large diameter or aortic arch Type 2 or 3.

However, most of the aforementioned reports were based primarily on subjective judgments, and more objective

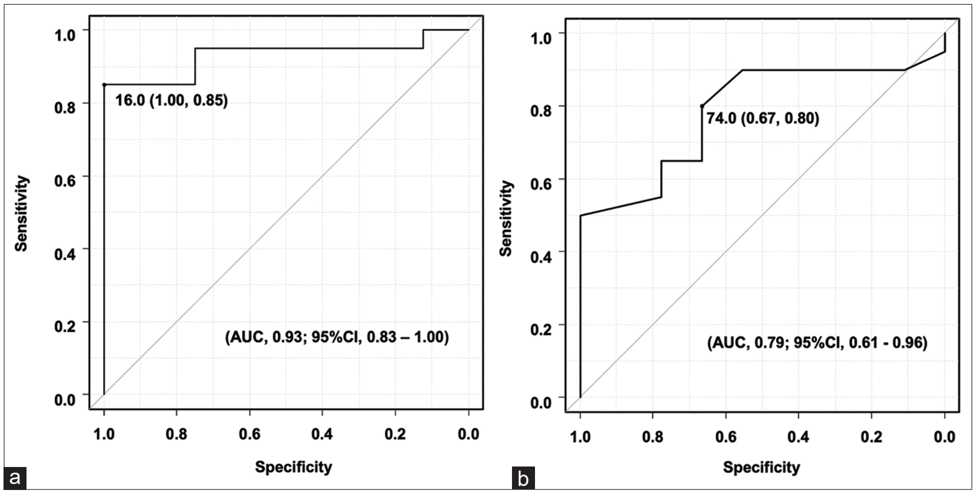

Figure 2: ROC curve of the optimal cutoff value of the innominate-left CCA angle (a) and age (b) for distinguishing between the nonconversion and conversion groups. AUC: Area under the curve, CCA: Common carotid artery, CI: Confidence interval, ROC: Receiver operating characteristic.

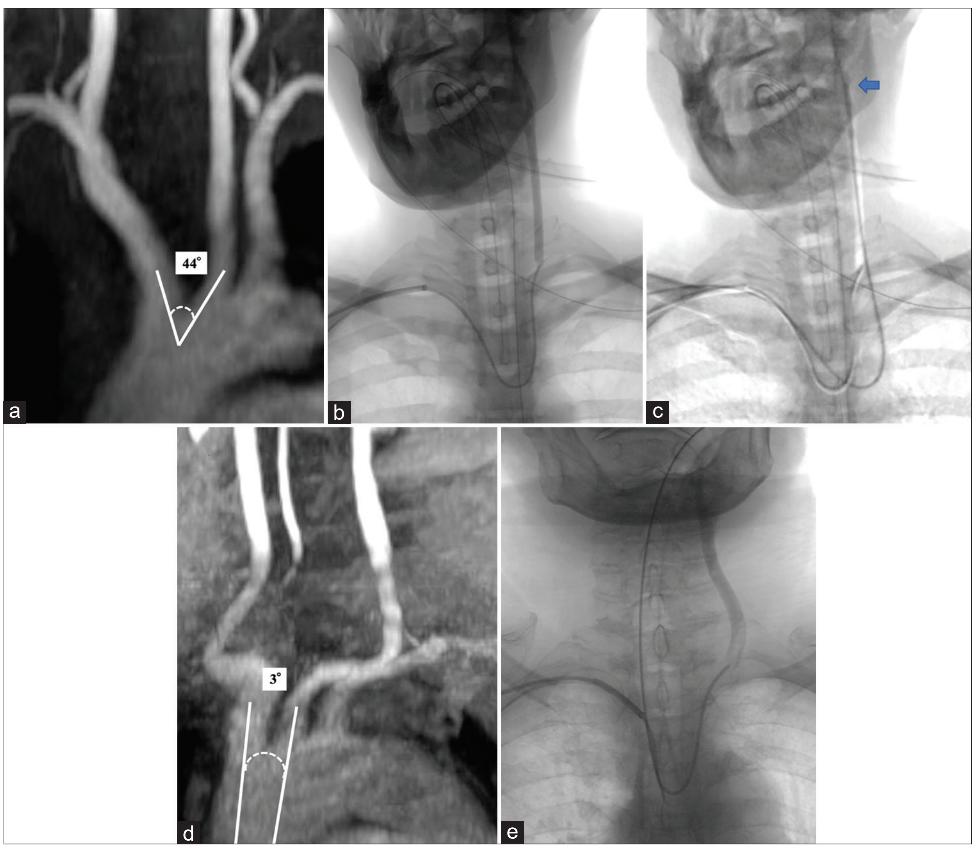

Figure 3: Representative angiographic findings showing neurointervention through transradial approach. In a 50-year-old woman with the left internal carotid artery (ICA) aneurysm, the guiding catheter was easily navigated into the left ICA cervical segment because the innominate-left common carotid artery (CCA) angle was 44°, more than the cut-off of 16° (a-c). Blue arrow: tip of guiding catheter. Conversely, in an 81-year-old woman with the left posterior communicating artery aneurysm, difficulty was encountered directing the guiding catheter into the left ICA cervical segment because the innominate-left CCA angle was 3°, less than the cutoff of 16° (d and e).

Table 2: Comparison of anatomical features between Non-conversion and Conversion groups.

Characteristic	Non-conversion (*n*=20)	Conversion (*n*=9)	*P* value
Radial puncture side, right	20 (100)	9 (100)	N/A
Radial size, mm	2.5 [2.3, 2.7]	2.7 [2.5, 2.7]	0.46
Radial artery loop	1 (5.0)	0 (0)	1
Brachioradial artery	0 (0)	1 (11)	0.31
Type of aortic arch			
Type I	5 (25)	1 (11)	0.77
Type II	6 (30)	3 (33)	
Type III	9 (45)	5 (56)	
Bovine arch	4 (20)	0 (0)	0.28
Arteria lusoria	0 (0)	1 (11)	0.31
Anatomical parameter			
Subclavian-innominate angle†			
Primary curve, degree	140 [122, 152]	135 [129, 149]	0.96
Secondary curve, degree	131 [112, 144]	133 [123, 139]	0.92
Subclavian-innominate tortuosity†			
Double	1 (5.0)	0 (0)	1
Single	3 (15)	1 (13)	
None	16 (80)	7 (88)	
Diameter of aortic arch, mm	24 [22, 25]	25 [23, 26]	0.42
Length of innominate artery, mm†	41 [39, 44]	43 [38, 45]	0.92
Innominate-left CCA height, mm†	5.4 [4.7, 6.3]	8.4 [7.1, 9.0]	0.098
Innominate-aortic angle, degree†	63 [54, 75]	59 [44, 59]	0.18
CCA angle, degree	139 [107, 151]	135 [115, 144]	0.52
CCA tortuosity	3 (15)	1 (11)	1
Innominate-left CCA angle, degree†	23 [18, 32]	3.0 [1.5, 6.3]	<0.001*
Simmons angle, degree	7.5 [2.8, 15]	10 [6.0, 11]	0.72

CCA: Common carotid artery, *n*: Number, N/A: Not available. †Arteria lusoria was excluded due to computational difficulties. *$P<0.05$. Unless otherwise indicated, values represent the number of aneurysms (%) or the median [Interquartile range]. Not all percentage totals reach 100% because of rounding.

indicators are needed. In the present study, we added variables such as innominate-left CCA height and innominate-left CCA angle to previously reported factors and analyzed factors potentially associated with conversion to TFA. The evaluation was then quantified for a more objective assessment. The results showed that only innominate-left CCA angle was associated with significant difficulty necessitating conversion to TFA. Conversely, in the present study, no cases required conversion to TFA in patients with bovine arch, which has been noted to be easier to directly guide a catheter into.[30] The reason may be that the innominate-left CCA angle is more obtuse in the bovine arch than in the non-bovine arch. In addition, the results of the ROC curve showed that an innominate-left CCA angle of 16° or less was at a higher probability of conversion when navigating the guiding catheter into the left ICA through TRA. These findings might provide useful information for avoiding the conversion to TFA.

Clinically difficulty factor for TRA

A higher conversion rate to TFA was represented in older patients for neurointerventional treatment through TRA, for delivery of a catheter into the left ICA. Elderly patients, especially those with hepatic dysfunction or undergoing antithrombotic therapy, may be at higher risk for hemorrhagic complications and may therefore benefit from TRA.[16,18] Randomized and controlled trials of cardiovascular interventions among elderly patients have already shown that TRA was associated with significantly lower complications, including requiring surgery, transfusion, discharge delay or related to limb ischemia, and stroke, as compared with TFA.[1,34]

However, TRA may be technically more challenging, especially in elderly patients due to morphological changes to the vascular wall, including vascular tortuosity, atherosclerosis, calcification, and vessel elongation compared with younger patients.[1,16,18] In a randomized and controlled trial of coronary angiography and intervention in patients 75 years or older, 152 patients were assigned to a TRA group. Of those, 13 (9%) required conversion to TFA. In contrast, of 155 patients assigned to TFA, only 1 (0.6%) required conversion to TRA.[1] Similarly, the present study suggested that TRA into the left ICA for patients older than

74 years would be less likely to be accomplished. Therefore, when neurointervention is necessary for elderly patients, consideration might be given beforehand to selecting TFA.

How to overcome difficulties

This difficulty in delivering the guiding catheter into the left ICA may be overcome by changing to a left TRA, developing a dedicated device, or increasing the experience of the surgeon.

Left TRA

All patients in this study were treated with a right radial artery puncture. However, the left radial artery puncture could have allowed navigation of the guiding catheter into the left ICA. A meta-analysis of interventional cardiology demonstrated that the left TRA is superior to the right TRA in terms of contrast use and fluoroscopy time, probably due to a higher degree of tortuosity in the right subclavian artery than in the left subclavian artery.[47] However, tortuosity in the right subclavian artery, fluoroscopy time, and total volume of contrast medium used did not significantly impact the conversion rate from TRA to TFA in the present study. On the other hand, Ito *et al*. accomplished neurointervention through left TRA in 21 patients, including five procedures into the left ICA.[25] They used Simmons-shaped catheters through TRA on the left side, whereas we used straight-type guiding catheter through TRA on the right side. To the best of our knowledge, no studies have yet compared left and right TRA in the field of neurointervention.

Lack of dedicated TRA devices

Due to the lack of handy devices specific to TRA, the conversion rate from TRA to TFA remains relatively high.[12,13,28,48] Technical constraints on conventional femoral systems are related to catheter flexibility and trackability.[13] Compared with TFA, neurointerventional TRA requires navigation of the catheter to the target vessel in the reverse curve. The straight-type guiding catheter specific to TFA is particularly more difficult to deliver to the left ICA.[13] Moreover, kinking of the guiding catheter could be problematic for navigation to target vessels with steep angles.[13] To overcome such problems, Hanaoka *et al*. successfully avoided conversion from TRA to TFA using a TRA-specific Simmons-shaped sheathless guiding catheter (Axcelguide STIFF-J; Medikit), including in the coil embolization of the left ICA aneurysms through TRA.[20] The Simmons-shaped catheter developed by Hanaoka *et al*. may raise the success rate for TRA in neurointervention, even in the presence of difficult clinical and anatomical features such as old age patients or an acute innominate-left CCA angle. At present, equipment applicable to TRA appears restricted, and development of TRA-specific devices is expected to improve options in the future.

Experience level of neurointerventional surgeons

In the field of interventional cardiology, the rate of successful radial artery cannulation increases with experience.[4] Research involving 942 new TRA operators showed that the threshold at which improvement in procedural metrics begins to flatten is 30–50 cases.[21] In the present study, however, all neurointerventional procedures were performed by two experienced neurointerventional surgeons each with more than 50 cases of DSA through TRA. In the field of neurointervention, the empirical value of more than 50 TRAs on improvement of the success rate with avoidance of conversion to TFA has not yet been fully scrutinized. At least in the present study, no conversion from TRA to TFA occurred in the first 10 consecutive procedures after neurointervention through TRA was initiated at our institution.

Limitations

Several limitations need to be kept in mind with the present study. First, only two experienced neurointerventional surgeons conducted the procedures. Second, the left CCA or ICA tortuosity, larger Simmons angle, and subclavian-innominate tortuosity are thought to be associated with difficulty of TRA according to the literature.[12,13,15,17,28,39,43-45,48] However, no significant differences in those findings were evident in the present study. As Snelling *et al*. indicated, the most difficult configuration was the combination of acute proximal left CCA tortuosity, a Type III arch, and left-sided TRA.[48] Although these factors could have represented confounding factors, we could not perform verifications by multivariate analysis in the present study due to the relatively small number of cases. A prospective, multi-center study including less-experienced surgeons and a larger number of patients is needed in the future. In addition, a guiding catheter with smaller caliber than 8-Fr might contribute to raising the success rate for TRA. Regardless of the limitations described above, the present results provide some insights into the prediction and validation of the likely difficulty of TRA before neurointervention.

CONCLUSION

The present study suggested that predictors of likely technical difficulty in TRA include innominate-left CCA angle and patient age. A more acute innominate-left CCA angle and older age were associated with difficulty delivering the guiding catheter into the left ICA for neurointervention through TRA.

Ethical approval statement

The present cohort research was implemented in adherence with Strengthening the Reporting of Observational Studies in Epidemiology guidelines for cohort studies. This research was conducted with the approval of the Institutional Review Board.

Authors' contributions

All authors fulfill the four criteria for authorship as outlined by the journal.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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