Feasibility of Using Neck Extension to Overcome a Difficult Aortic Arch and Gain Access to the Carotid Artery

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■ OBJECTIVE: **The purpose of this study was to investigate neck movement and various conditions of the aortic arch that may hinder access to the carotid artery during neurointerventional procedures.**

■ METHODS: **We reviewed 230 patients who underwent internal carotid artery angiography between February 2016 and October 2016. Use of a Davis catheter (DC) was first attempted and if not possible, movement (right, left, flexion, and extension) of the patient's head was tried before catheter exchange. We analyzed the success rate after neck motion in relation to various aortic arch factors.**

■ RESULTS: **Only extension of the patient's neck was effective. Of the 209 patients with right side angiography, 23 had failed access with a DC, but neck extension was effective in 3 patients (13%). Failure to insert a DC was significantly correlated with age, male sex, acute angle, arch elongation, aortic calcification, and carotid artery angulation on the right side, whereas access was not gained in 24 out of 208 patients who underwent left side angiography, and neck extension was successful in 7 patients (29.2%). Also, significant factors determining the catheter exchange were age, male sex, acute angle, arch elongation, and aortic calcification.In the DC access failure group, neck extension was significantly more effective for younger aged patients ($P = 0.011$).**

■ CONCLUSIONS: **Factors such as older age, acute arch angle, higher elongation type, arch calcification, and carotid artery angulation were verified as factors affecting access by a simple catheter; however, neck extension was shown to facilitate access in about 10%-30% of patents.**

INTRODUCTION

Most neurointerventional procedures are performed through the transfemoral arterial approach to access the common carotid artery (CCA).[1,2] This conventional method occasionally encounters anatomic limitations, including tortuous or occluded iliofemoral or abdominal aorta, various conditions of the aortic arch such as calcification, elongation, anomaly or bovine arch, and angulated CCA,[3-5] starting at the femoral artery and reaching the CCA via the subclavian artery.

To overcome these difficulties, other alternatives may be considered, such as exchanging the catheter, turning the patient's neck, and finding another access route.[2,6,7] However, these processes add time to the procedure, increase expenses through use of different instruments, and require additional invasive procedures.

Some authors have suggested that turning the patient's head could facilitate catheterization,[8] but no further studies on the specific method or its effectiveness have been conducted. Thus, in this study, we investigated the relationship between difficulty in accessing the carotid artery and factors concerning the aortic arch, such as angle of the aortic arch, elongation, calcification, bovine type and CCA angulation, and the feasibility of overcoming these factors by changing the neck motion, which could improve access without added time, cost, or invasive procedures.

MATERIALS AND METHODS

This study was approved by the institutional review board of St. Vincent's Hospital at the Catholic University College of Medicine, Suwon, Republic of Korea. We reviewed 230 patients (right side, 209 cases; left side, 208 cases) who underwent internal carotid angiography for various reasons at our institution between February 2016 and December 2016. Internal cerebral artery (ICA) angiographic recordings were retrospectively checked for use of neck movement or other additional catheters. Procedures using

Key words
- Angiography
- Aortic arch
- Catheter
- Neck motion

Abbreviations and Acronyms
CCA: Common carotid artery
CTA: Computed tomography angiogram
DC: Davis catheter
ICA: Internal cerebral artery

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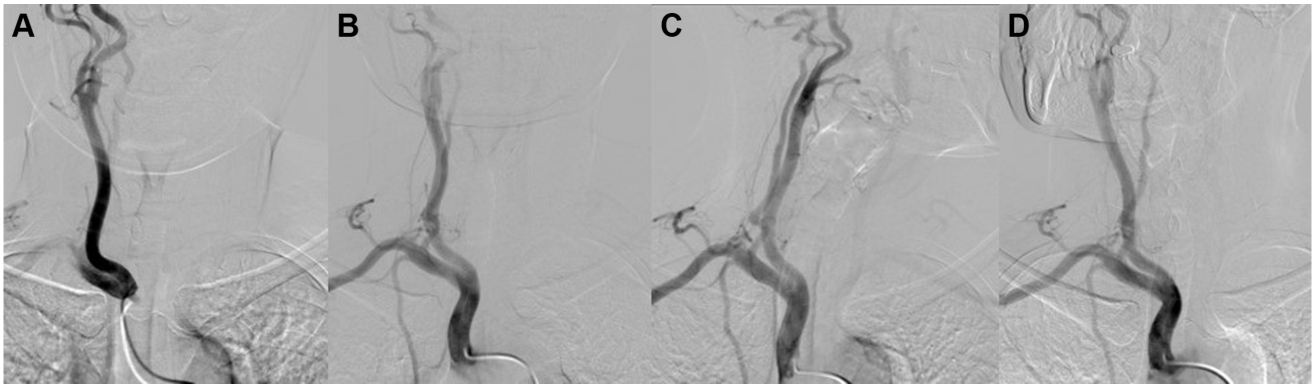

Figure 1. After failure of 2 attempts to access the common carotid artery, a 52-year-old woman underwent subclavian artery angiography, changing the neck position by flexion, extension, left, and right neck rotation (**A**, **B**, **C** and **D**).

inspiratory breath-hold maneuver or a long femoral sheath were excluded.

ICA Angiography Procedures

After local anesthesia using 1% lidocaine, the femoral artery was punctured and a 10 cm 5F introducer sheath (Terumo, Tokyo, Japan) was placed. A 5F Davis catheter (DC) (Jungsung Medical, Seoul, Korea) and a 0.035" guide wire (Terumo) were advanced through the aortic arch to the brachiocephalic artery or left CCA under fluoroscopy monitoring.

If the carotid artery approach failed after a couple of attempts, access was attempted again after changing the patient's neck position using methods such as flexion, extension, right, or left neck rotation (Figure 1 and Figure 2). However, if the access still failed, the DC was replaced with another catheter, such as a 5F Headhunter or a Sims II catheter (Cook, Bloomington, Indiana, USA).

Factors of Aortic Arch

Aortic arch elongation was divided into 3 types of locations of the brachiocephalic artery. Above the horizontal tangent of the outer curvature of the aortic arch was defined as type I, between the outer and inner curvature was defined as type II, and below the inner curvature was defined as type III (Figure 3). Also, the bovine type was defined as the common origin of the innominate artery and left CCA. Arch calcification was confirmed through a brain computed tomography angiogram (CTA) with a width of 2.0 mm^2 or more on the aortic arch wall, and the aortic arch angle was measured through the coronal view of a CTA. The CTA was taken at the

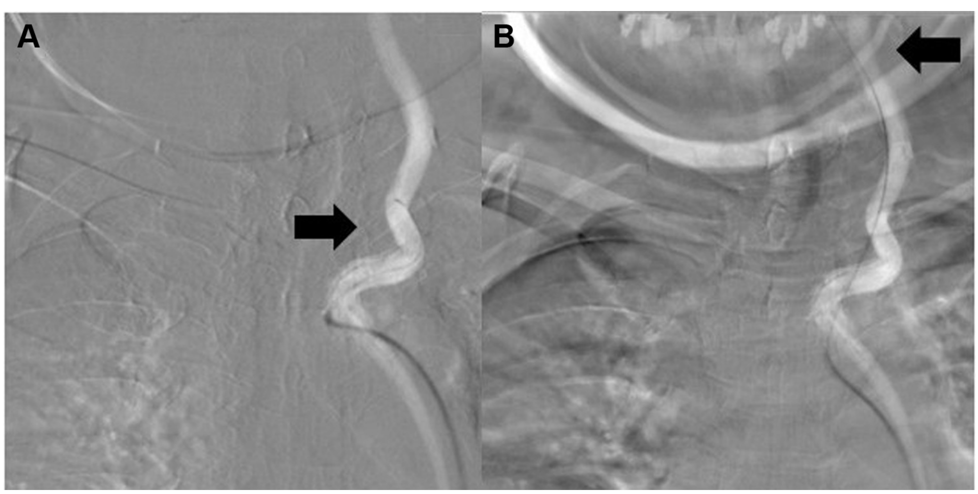

Figure 2. On the internal cerebral artery (ICA) angiogram of a 72-year-old woman, a diagnostic wire (*arrow*) was blocked on the angled vessel wall of tortuous common carotid artery (CCA) and could not be raised sufficiently to move the catheter along the vessel at the neutral position (**A**). After neck extension, the CCA stretched out, allowing the wire to be navigated to the ICA, and the catheter to be delivered (**B**).

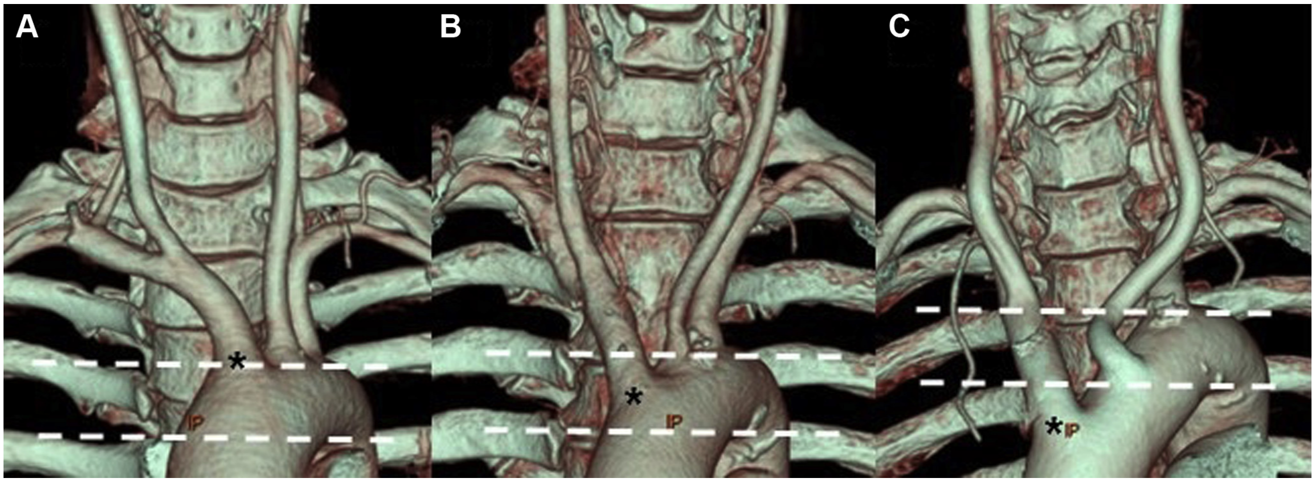

Figure 3. Elongation of the aortic arch was assessed through the relationship between the origin of the target vessel (*asterisk*) and horizontal lines (*dotted lines*) to the greater (outer) and lesser (inner) curvature of the arch. Type I (**A**) represents the vessel origin as the same or above the upper horizontal plane of the aortic arch. Type II (**B**) is between the upper and lower lines. Type III (**C**) is defined below the lower line.

angle of the outer curvature of the aortic arch, at the center of the subclavian artery origin, and at the middle of 1–2 cm above this point. CCA angulation was defined as the difference in angle between the extension line of the proximal CCA and CCA >90° (Figure 4).

Statistical analyses were performed using SPSS version 18.0 (IBM Corporation, Armonk, New York, USA). Variables were compared between the 2 subgroups using the Fisher exact test or the χ^2 test and the Mann-Whitney U test, as appropriate. Continuous variables are presented as means and standard deviations. The confidence intervals (CI) of success rates, according to neck movement were calculated using the exact Clopper Pearson method. A probability value <0.05 was considered statistically significant. Odd ratios (OR) and their 95% CIs were also reported.

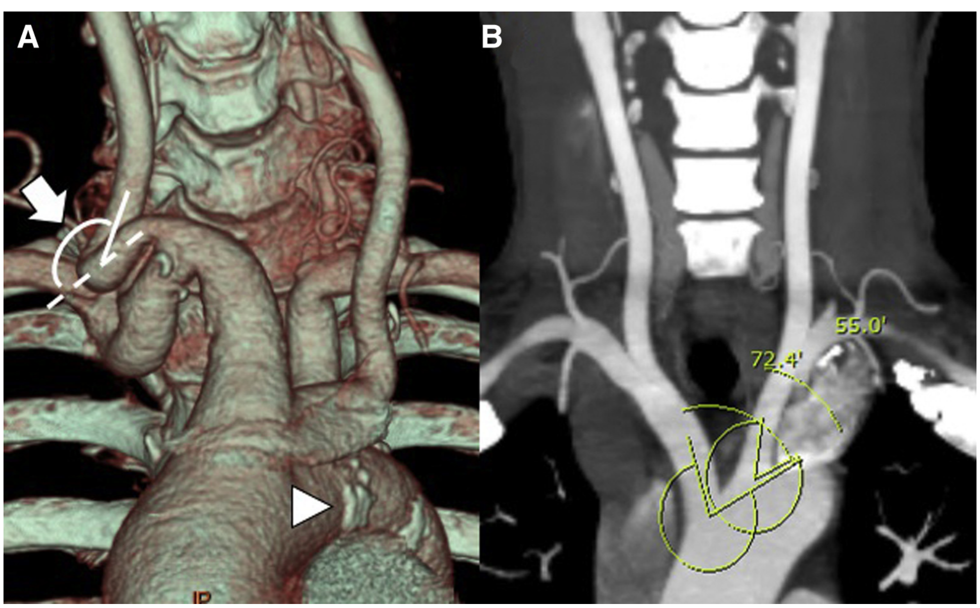

Figure 4. (**A**) The common carotid artery (CCA) angulation and calcification of the aortic arch. The angle (*arrow*) between the proximal CCA extension line (*dotted line*) and the CCA (*full line*) is >90° and was classified as angulation. A calcification was defined as a white patch (*arrow head*) >2 mm^2 on the aortic arch wall. (**B**) Illustration of the method for measuring the angle of the right brachiocephalic artery and left CCA at the origin and 1–2 cm above, as well as at the outer curvature of the aortic arch.

Table 1. Baseline Characteristics of Patients Who Underwent Right Side and Left Side Carotid Angiogram

	Total (n = 230)	Right Side (n = 209)	Left Side (n = 208)
Mean age ± SD (years)	59.5 ± 12.8	59.5 ± 12.7	60.0 ± 12.6
Male sex	95 (41.3%)	86 (41.1%)	86 (41.3%)
Arch angle		78.0 ± 24.0°	69.0 ± 20.8°
Aortic elongation			
Type I		81 (38.8%)	151 (72.6%)
Type II		119 (56.9%)	56 (26.9%)
Type III		9 (4.3%)	1 (0.5%)
Bovine type	35 (15.2%)	32 (15.3%)	30 (14.2%)
Arch calcification	84 (36.5%)	77 (36.8%)	75 (36.0%)
CCA angulation	14 (6.1%)	12 (5.7%)	2 (0.9%)

SD, standard deviation; CCA, common carotid artery.

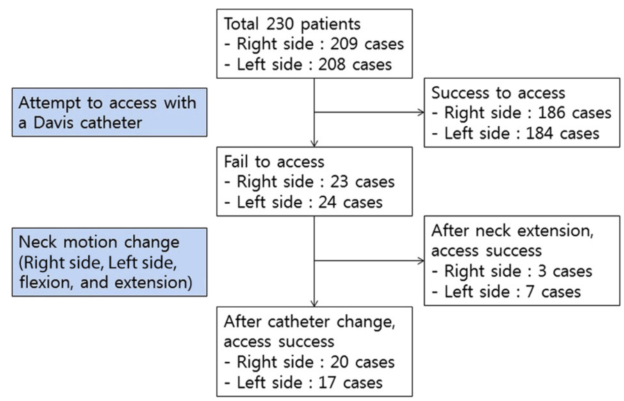

Figure 5. Flow diagram of an attempt to access the common carotid artery by inserting a Davis catheter (DC) and changing neck motions. There were 230 (right side: 209; left side: 208) patients who underwent an internal cerebral artery angiogram. First, common carotid artery access was attempted using a DC. In failure cases (right side: 23; left side: 24), access was retried with the neck motion (right side, left side, flexion, and extension). If it was still not accessible, the remainder (right side: 20; left side: 17) were successfully accomplished by replacement with another catheter.

RESULTS

Baseline characteristics for the 2 groups who underwent right and left carotid angiogram are presented in Table 1. The mean age was 59.5 ± 12.8 (right side: 59.5 ± 12.7; left side: 60.0 ± 12.6) years. Of the 230 patients, 41.3% were men, and the right and left side angiography were similar in 41.4% and 41.3%, respectively. The bovine type and arch calcification also showed similar rates in both angiograms. However, the mean of the right-side (78.0 ± 24°) arch angle was greater than the left side (69.0 ± 20.8°) arch angle.

Figure 5 shows 230 (right side: 209; left side: 208) patients who underwent ICA angiograms for 10 months. Except for the success of 1 or 2 attempts without neck manipulation using the DC, the remaining cases (right side: 23 [11%]; left side: 24 [11.5%]) were retried after moving the patient's head (right, left, flexion, and extension). Of these, problems accessing the aortic arch in 3 patients on the right side and 7 patients on the left side were overcome through neck extension, and replacement of the catheter was successful in the remainder of patients.

Comparing patients with 1 or 2 successful attempts on both sides with a DC and to those with DC failure (Table 2), the group successfully accessed with a DC were significantly younger than the failed group by about 10 years (right side: 58.3 ± 12.7 years vs. 69.7 ± 8.4 years, P = 0.000; left side: 58.7 ± 12.5 years vs. 70.0 ± 7.9 years, P = 0.000), and were predominantly men (right side: 43.5% vs. 21.7%, P = 0.045; left side: 44.6% vs. 16.7%, P = 0.009). In addition, arch angle was increased approximately 30° in the DC group (right side: 81.4 ± 22.6° vs. 50.7 ± 15.6°, P = 0.000; left side: 72.4 ± 19.2° vs. 43.6 ± 14.3°, P = 0.000). However, in the failed group, the aortic elongation was more severe (right side: P = 0.001; left side: P = 0.000) and frequency of arch calcification was significantly increased (right side: 32.8% vs. 60.9%, P = 0.008; left side: 32.6% vs. 62.5%, P = 0.004). Although no CCA angulation was observed in the failed group on the left side, on the right side it was seen in 8 of 23 (34.8%) patients in the failed group, and only 4 of 186 (2.2%) patients in the DC success group (P = 0.000).

As shown in Table 3, multivariate logistic regression of risk factors for simple catheter failures showed that the elongation of types 2 and 3 was 5 times and 70 times more than type 1, respectively (OR, 5.79; 95% CI, 1.26–26.6; P = 0.024; and OR 70.4; 95% CI, 8.59–577.3; P = 0.000). The CCA angulation was also 30 times more (OR 31.9; 95% CI, 7.02–145.0; P = 0.000) on the right side. On the left side, multivariate logistic regression analysis identified male sex (OR 0.135; 95% CI, 0.034–0.533; P = 0.004), type 2 (OR 18.8; 95% CI, 0.098–1.24; P = 0.000), and arch calcification (OR 4.01; 95% CI, 1.37–11.8; P = 0.011) as predictors of simple catheter failure.

When reattempting access after failure of a DC placement by changing the neck position, using maneuvers such as flexion, extension, right, and left neck rotation, extension was only effective in 3 (13.04%, CI, 2.78–33.59) cases and 7 (29.1%, CI, 12.62–51.09) cases on the right and left sides, respectively (Table 4).

Among the 47 patients who failed using the DC (Table 5), the effective neck extension group was significantly younger than the catheter exchange group (64.2 ± 8.7 years vs. 71.4 ± 7.2 years, P = 0.011).

DISCUSSION

To the best of our knowledge, this is the first study done to investigate patient factors impacting difficult access to the carotid artery, and to describe how neck movements could effectively be used as a technique to overcome this. Although previous studies have reported that simple neck extension techniques were useful in successfully coil embolizing patients with tortuous cervical ICA, we believe our study was the first clinical study performed to show

Table 2. Comparison of Trial Results of Davis Catheter in Right Side and Left Side Carotid Angiograms

	Right Side			Left Side		
	Success (n = 186)	Failure (n = 23)	*P* Value	Success (n = 184)	Failure (n = 24)	*P* Value
Mean age ± SD (years)	58.3 ± 12.7	69.7 ± 8.4	***0.000***	58.7 ± 12.5	70.0 ± 7.9	***0.000***
Male sex	81 (43.5%)	5 (21.7%)	***0.045***	82 (44.6%)	4 (16.7%)	***0.009***
Arch angle	81.4 ± 22.6°	50.7 ± 15.6°	***0.000***	72.4 ± 19.2°	43.6 ± 14.3°	***0.000***
Aortic elongation			***0.001***			***0.000***
Type I	78 (41.9%)	3 (13.0%)		146 (79.3%)	5 (20.8%)	
Type II	103 (55.4%)	16 (69.6%)		38 (20.7%)	18 (75.0%)	
Type III	5 (2.7%)	4 (17.4%)		0 (0%)	1 (4.2%)	
Bovine type	29 (15.6%)	3 (13%)	1.000	27 (14.7%)	3 (12.5%)	1.000
Arch calcification	61 (32.8%)	14 (60.9%)	***0.008***	60 (32.6%)	15 (62.5%)	***0.004***
CCA angulation	4 (2.2%)	8 (34.8%)	***0.000***	2 (1.1%)	0 (0%)	1.000

Success: Group with 1 or 2 successful attempts with a Davis catheter. Failure: Group with failure to access with a Davis catheter.
Italics/bolding represent statistcally significant ($P < 0.05$).
SD, standard deviation; CCA, common carotid artery.

how neck motion (especially neck extension) could be helpful in the same procedure.

Failure of the DC approach was significantly associated with older age, acute angle of aortic arch, severe aortic elongation, and arch calcification. Aortic elongation type was an especially strong risk factor for DC failure on both sides in the multivariate logistic regression analysis.

Some authors have classified arch elongation according to the relationship between the brachiocephalic artery and the aortic arch. Burzotta et al.[9] showed that age and arch elongation were related, and more severe arch elongation is associated with longer catheter manipulation times.[9-11] Similarly, in our study, the greater the arch elongation the more difficult successful catheterization was to achieve.

The angle from the aortic arch to the right brachiocephalic artery or left CCA is the first curve that must be accessed to perform a neurointervention; overcoming this positively increases the success of the procedure.

To access the right brachiocephalic artery or left CCA, the catheter guided up the descending aortic artery is deflected down

Table 3. Univariate and Multivariate Logistic Regression of Risk Factors for Simple Catheter Failure

	Right Side				Left Side			
	Univariate Analysis		Multivariate Analysis		Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Male sex	0.349 (0.098—1.24)	0.104	0.331 (0.098—1.18)	0.088	0.131 (0.033—0.525)	***0.004***	0.135 (0.034—0.533)	***0.004***
Aortic elongation								
Type I	Ref							
Type II	7.96 (1.49—42.3)	***0.015***	5.79 (1.26—26.6)	***0.024***	19.74 (6.06—64.2)	***0.000***	18.8 (0.098—1.24)	***0.000***
Type III	84.89 (8.76—822.9)	***0.000***	70.4 (8.59—577.3)	***0.000***	-	-	-	-
Bovine type	2.50 (0.44—14.3)	0.303			1.65 (0.314—8.68)	0.553		
Arch calcification	1.63 (0.56—4.68)	0.368			3.91 (1.33—11.5)	***0.013***	4.01 (1.37—11.8)	***0.011***
CCA angulation	29.48 (6.18—140.6)	***0.000***	31.9 (7.02—145.0)	***0.000***	0.0	1.000		

OR, odds ratio; CI, confidence interval; Ref, reference; CCA, common carotid artery.
Italics/bolding represent statistcally significant ($P < 0.05$).

Table 4. Success Rate of Access According to Neck Motion in Right Side and Left Side Angiographies

	Right Side Angiogram (n = 23)	Left Side Angiogram (n = 24)
Right side rotation	0	0
Left side rotation	0	0
Flexion	0	0
Extension (success rate [95%CI])	3 (13.04% [2.78—33.59])	7 (29.17% [12.62—51.09])

CI, confidence interval.

Table 5. Comparison of Neck Extension and Catheter Exchange

	Neck Extension (n = 10)	Catheter Exchange (n = 37)	*P* Value
Mean age ± SD (years)	64.2 ± 8.7	71.4 ± 7.2	***0.011***
Male sex	1 (10%)	8 (21.6%)	0.660
Right side	3 (30%)	20 (54.1%)	0.286
Arch angle	40.6 ± 10.4°	48.9 ± 0.4°	0.127
Aortic elongation			0.452
Type I	3 (30%)	5 (13.5%)	
Type II	6 (60%)	28 (75.7%)	
Type III	1 (10%)	4 (10.8%)	
Bovine type	1 (10%)	5 (13.5%)	1.000
Arch calcification	6 (60%)	23 (62.2%)	1.000
CCA angulation	1 (10%)	7 (18.9%)	0.667

SD, standard deviation; CCA, common carotid artery.
Italics/bolding represent statistcally significant ($P < 0.05$).

to the ascending aortic artery at the top of aortic arch, which is a point of support or a turning-point. There, it is supported at the inside wall of the vessel and raised up through the brachiocephalic artery. The greater the arch elongation, the lower the location of the support points and the acute angle that surmounts climb up. It seems reasonable that catheterization of elongation type 1, which has higher support points and a wider angle, can be accomplished more easily than that of elongation type 3. This observation may explain our results showing an increased frequency of acute angles in the failed group.

Furthermore, in a study on the aortic aging process, Adriaans et al.[12] reported that the length of the ascending aorta was significantly prolonged through aging. Setacci et al.[13] showed that elongation type 3 was more common in octogenarians. This means that the ascending aorta becomes longer and that the elongation progresses as age advances, making simple catheterization more difficult. In agreement, our study showed significant failure in older age.

In addition, CCA angulation and arch calcification are also caused by changes in blood vessels owing to aging and seem to be associated with failure in this study. As a result of aging symptoms, the carotid artery turns sinuous and calcification accumulates, affecting the elasticity and stiffness of the blood vessels and interfering with the passage of the catheter along this route.[14,15]

Several methods have been proposed to overcome the tortuosity of the carotid artery for neurointerventional procedures. First, the access route may be changed by puncturing other sites. The radial artery approach can overcome angles difficult to approach from the femoral artery by moving the access direction, and direct carotid artery puncture can also allow passage through difficult angles.[16,17] Second, some methods exchange the catheter or wire and use additional devices. These procedures are accomplished by switching the DC with a catheter of various shapes or a stiff wire, adding another sized catheter for the coaxial double guiding catheter technique, another wire for the double wire technique, or a special purposed instrument, such as balloon catheter.[18-21] Finally, waiting for 20—30 minutes before attempting catheterization again is another approach.[22] Although all of the previously mentioned methods incur extra expense and take additional time by preparing and replacing with new devices, the neck extension technique can be a cost-effective method used with existing catheters. This method also saves time as it is accomplished in only the few seconds it takes to move the patient's neck.

Takata et al.[23] pointed out that the neck extension technique elongates the cervical ICA by extending the distance from the anterior portion of the foramen magnum to upper cervical vertebrae, and enhanced lordotic alignment of the cervical spine.[23,24] These factors seem to support our results, which showed effectiveness only with extension and no other neck movements. In addition, the success rate was higher on the left side than on the right side (Table 4), because the left side is structurally closer to the aortic arch and the cervical ICA to be passed through is relatively shortened. Additionally, the proportion of elongation type I, in which anatomic features made it less difficult to achieve stable catheter guiding,[13] was higher in the left side (Table 1; right side: 38.8% vs. left side: 72.6%).

One limitation of this study was the retrospective collection and analysis of patients' data from a single institution. Operational biases, such as different skill level of the operator, the possible degree of each patient's neck movement, and the measurement errors of the researcher may also have been limitations. The small number of patients in the simple DC failure groups was another limitation of this study.

CONCLUSIONS

Almost all factors, such as older age, acute arch angle, high elongation type, arch calcification, and CCA angulation, were verified as factors that make a simple catheter placement on left or right single sides, or both sides, difficult. In the multivariate logistic regression analysis, the risk factors for a simple catheter failure showed that elongation types 2 and 3 were 5 times and 70 times, respectively, and that CCA angulation was >30 times in the right side. The type 2 elongation was 2 times and the arch calcification was 4 times on the left side. The neck extension helped overcome these obstacles by about 13% and 29% on the right and left sides, respectively. Since simply moving the patient's neck could help overcome obstacles in just a few seconds, we advise neck extension before exchanging or adding a device.

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