学位論文

「Angiographic Characterization of the External Carotid Artery
：Special Attention to Variations in Branching Patterns」

（分岐様式に注目した脳血管撮影による外頸動脈の特徴解析）

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著者の宣言

本学位論文は、著者の責任において実験を遂行し、得られた真実の結果に基づいて正確に作成したものに相違ないことをここに宣言する。

論文要旨

Angiographic Characterization of the External Carotid Artery : Special Attention to Variations in Branching Patterns

（分岐様式に注目した脳血管撮影による外頸動脈の特徴解析）

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【背景】外頸動脈の解剖学的特徴、特に分岐様式を理解することは頭頸部外科手術および血管内治療における安全な手術計画を立てるために必須である。外頸動脈は、その本幹から頸動脈三角の位置で分岐する superior thyroid artery、lingual artery (LA)、facial artery (FA)、occipital artery (OA)、and ascending pharyngeal artery (APA)、その遠位から分岐する posterior auricular artery (PAA)、maxillary artery (MA)、superficial temporal artery の計８本の分岐血管を有する。これらの血管は共通幹を呈することがあり、thyrolingual trunk、linguofacial trunk、thyrolinguofacial trunk、occipitoascending pharyngeal trunk、occipitoauricular trunk が報告されている。外頸動脈の分岐様式に関しては、Ogeng’o らの 224 例のケニア人の剖検を用いた 2015 年の報告を除くと、いずれも少数例の検討に基づいたものであり統一された分類はなされていない。

【目的】本研究は多数例の脳血管撮影画像を用いて外頸動脈の分岐様式を日常臨床に用いやすいようにシンプルな３つのタイプに分類し、それぞれの特徴を明らかにすることを目的とした。

【対象と方法】2014 年１月から 2016 年３月までに当院で脳血管撮影が行われた連続 302 人・532 本の外頸動脈を後方視的に研究した。評価した分岐血管は、頸動脈三角から分岐する LA、FA、OA、APA、thyrolingual trunk、linguofacial trunk、thyrolinguofacial trunk、occipitoascending pharyngeal trunk とし、同一部位での外頸動脈本幹からの分岐血管の本数に基づいて３つに分類した。Type A は外頸動脈本幹から同一部位で２本が分岐、Type B は３本が分岐、Type C は４本以上が分岐しているものと規定した。それぞれの Type の頻度をまとめ、Type 別の総頸動脈分岐部から外頸動脈の初めの分岐血管までの長さ、Type 別の頸椎レベルにおける総頸動脈分岐高位を測定し、統計解析を行って分析した。

【結果】 Type A は 344 本（64.6%）・237 人（78.5%）、Type B は 134 本（25.2%）・110 人(36.4%)、Type C は 54 本（10.2%）・49 人（16.2%)に認めた。左右で同じ Type を示すものは両側性血管撮影を行うことができた 230 人の内 136 人（59.1%)であり、両側ともに Type C であったのは両側性血管撮影を行うことができた 41 人の内 5 人（12.2%)であった。総頸動脈分岐部から外頸動脈の初めの分岐血管までの長さは、Type A では 21.8 ± 15.6 mm、Type B では 20.6 ± 8.9 mm であった一方、Type C では 14.7 ± 6.6 mm と有意に短かった（$p< 0.05$)。Type C の総頸動脈分岐部は 54 例中 52 例（96.3%）で第 3 /4 頸椎より高位に存在し、Type A, B と比較して第 4 頸椎以下である可能性は有意に低かった（$p < 0.001$)。

【考察】本研究では、外頸動脈の分岐様式を本幹からの同一部位における分岐本数によってシンプルな 3 つに分類した。Ogeng’o らも同一部位での分枝本数に着目し分類していたが、関連するはずの OA に関する記述が認められない。そのため、我々の Type C は Ogeng’o らの quadrifurcation と pentafurcation に相当するとの推測となるが、彼らの 14.2%と近似した 10.2%であった。なお Type C を構成する分岐血管は多岐にわたり、それぞれに注意を払って分類を細かくするのは煩雑で実用的ではなかった。我々の検討により、総頸動脈分岐部から外頸動脈の初めの分岐血管までの長さは Type C で有意に短いことが初めて解明された。さらに Type C の総頸動脈分岐高位が有意に高いことが明らかとなった。Type C のこれらの特徴は発生に基づく複雑な血管形成機序が関与していると推測された。Type C を理解することは、外頸動脈でバルーンを使う頸動脈ステント治療を含め、血管内治療において重要である。

【結論】本研究で、外頸動脈の分岐様式を 3 つに分類し特徴を明らかにした。Type C は分岐血管が同高位に集簇し、その位置までの分岐血管までの総頸動脈からの長さは短く、総頸動脈分岐部も高位であった。このような分岐様式は約 10%に認めた。今回のシンプルな 3 分類を用いて外頸動脈の分岐様式を理解することは、手術合併症を防ぐためには有用であると考えられた。

Contents

1. Introduction

Knowledge of the branching pattern of ECA is important for head and neck surgeries or performing selective intra-arterial chemotherapy for head and neck cancer.[19] Interventional radiologists, neurosurgeons, vascular, craniofacial, and neck surgeons should be aware of branch variants of ECA to obtain the correct interpretation of radiological images, for planning safe surgical approaches, and to execute surgeries including carotid endarterectomy (CEA) and carotid artery stenting (CAS) as a representative example of neuroendovascular surgeries.

The external carotid artery (ECA) has eight named branches distributed to the head and necks. It gives off the superior thyroid artery, lingual artery (LA), facial artery (FA), occipital artery (OA), and ascending pharyngeal artery (APA) in the carotid triangle.[14] After these branches, the ECA branches off into the posterior auricular artery (PAA), maxillary artery (MA), and superficial temporal artery. Some common trunks, such as thyrolingual, linguofacial, thyrolinguofacial, occipitoascending pharyngeal, and occipitoauricular trunks, were also identified.[5,16,20]

Variants of the branching pattern of ECA have been discussed in the literature.[3,4,6,7,8,12,13,14,15,16,17,19]

However, the classification for branch variants of ECA is not unified because the previous analyses were performed using small number of cases,[6,8,13,15,17] or focused only on data of interest.[12,14,16,19]

The widespread four-type classification of ECA is as follows: type I, separate origin of the superior thyroid artery, LA, and FA; type II, the LA and FA originate together from a common trunk (linguofacial trunk); type III, the superior thyroid artery and LA originate together from a common trunk (thyrolingual trunk); and type IV, the superior thyroid artery, LA, and FA originate together from a common thyrolinguofacial trunk.[14] This classification focused only on the front branch of ECA.

Ogeng'o et al. (2015)[12] took particular note of the branch patterns of ECA based on the number of branches arising close together from a common point of the ECA, as the trifurcation, quadrifurcation, and pentafurcation of ECA. In the trifurcation, the ECA after the origin of superior thyroid artery trifurcated into the linguofacial trunk, APA, and distal ECA. In the quadrifurcation, the ECA branched into the LA, FA, APA, and distal ECA. In the pentafurcation, ECA branched into the superior thyroid artery, LA, FA, and APA arose within close proximity from a common short stem. In addition to these branch variants, they defined the typical branch pattern as the artery having a long stem from which the superior thyroid artery, LA, FA, and APA arose while the ECA ended by bifurcating into the MA and superior temporal artery.

The bifurcation was defined as the ECA after giving the superior thyroid artery branched into a linguofacial trunk and distal ECA. Ogeng'o et al. (2015)[12] analyzed 224 ECAs from 112 cadavers, the largest number of ECA samples used for examining the branch patterns. However, they did not describe the data whether the OA was involved in the formation of quadrifurcation and pentafurcation or not. In contrast, several case reports mentioned that the OA was involved in the quadrifurcation branch variant of ECA.[6,8,15,17]

The present study, using angiographic images, classified the branch variants of

ECA into three types simply based on the number of branches arising close together from a common stem of proximal ECA. In this classification, the distal ECA was counted as one branch. Type A, B, and C variant was defined as two, three, and four or more branches of ECAs arising at a common point from the proximal ECA, respectively. We also analyzed several characteristics of each variant, including its frequency, the distance from the common carotid artery (CCA) bifurcation to the first branch of ECA, and the correlation between the position of CCA bifurcation and the cervical vertebral level.

In this report, we would like to advocate the simple classification of ECA for the daily usage.

2. Materials and Methods

2-1. Patients

This study evaluated digital subtraction angiography (DSA) images of 532 ECAs from 302 consecutive patients aged from 15 to 94 years treated at Kitasato University Hospital from January 2014 to March 2016. Their clinical characteristics are summarized in Table 1.

This is a retrospective study; thus, the bilateral external carotid artery angiography was performed for 230 patients, not for all the patients.

All DSA procedures were performed in the angiographic suite (*syngo* X Workplace VB21c; Siemens Healthcare GmbH, Erlangen, Germany). Arterial catheterization was performed through the radial artery or femoral artery to the CCA. After placement of the angiographic catheter, flush angiography from the CCA was performed to evaluate the CCA bifurcation, neck internal carotid artery

(ICA) stenosis, and the branching variation of the ECA. Selective angiograms were obtained using a 4-Fr modified Simmons catheter® (Medikit, Tokyo, Japan). Iodine contrast medium was used for all procedures. Other procedures were performed according to the indications for angiographic intervention or treatment.

2-2. Outcome Measures

Images were obtained from at least two different angles (frontal and lateral views). Three-dimensional (3D) reconstruction images using rotational DSA (3D DSA) was performed for some cases.

Their branching variations were evaluated by a qualified neuroendovascular surgeon and two other qualified neurosurgeons. All branches from the ECA of our interest were superior to the level of CCA bifurcation in the carotid triangle, specifically the LA, FA, OA, APA, thyrolingual, linguofacial, thyrolinguofacial, and occipitoascending pharyngeal trunks. In this study, the superior thyroid artery branching only from the ECA was included. We evaluated the number of branches arising close together from a common point of the ECA. The distal ECA was counted as one branch.

All the common trunks were regarded as one branch. The APA could sometimes not be recognized on DSA; in such cases, APA was not counted as one branch.

Branch variants of the ECA were divided into three types: Type A, all individual branches arising separately from the proximal ECA (the number of branches arising from the proximal ECA is two); Type B, three branches of ECAs arising close together at a common point from the proximal ECA; and Type C, four or more branches of ECAs arising close together at a common point from the proximal ECA.

The distances from the CCA bifurcation to the first branch of ECA and the correlation between the position of CCA bifurcation and the cervical vertebral level were analyzed from DSA images.

This study was approved by the institutional ethics committee of Kitasato University Hospital (B19-097, September, 12, 2019). Patient consent was neither required nor sought because this was retrospective observational study. Instead, we provided a means to opt out from this study on the internet to the patients.

2-3. Statistical analysis

We compared distance from the CCA bifurcation to the first branch of ECA, among three type classification. Analysis of covariance following Dunnett's post-hoc analysis was applied. Next, we investigated the association between prevalence of the three type variants and CCA bifurcation level using univariate logistic regression model. CCA bifurcation level were divided into three groups, higher third cervical vertebral level (C3); C3 or third–4^{th} junction cervical vertebra (C3/4); and 4^{th} cervical vertebra (C4) or lower. Two-sided $P < 0.05$ was regarded as statistical significance. Statistical software Stata13.1 (StataCorp) and R-3.6.1 (R Foundation for Statistical Computing) were used for analysis.

3. Results

3-1. Branch variants of the ECA

Branching variations of the ECA are classified into the following three types (Fig. 1), based on the DSA findings of 532 ECAs from 302 patients, including 230 patients with both-side carotid angiograms. The same branch variant was observed on the right and left sides in 136 patients (59.1%).

Type A: The number of branches arising from the proximal ECA is two. Type A was found in 344 vessels (64.6%; right, 175; left, 169) of 237 patients (78.5%). Among 230 patients with both-side carotid angiograms, bilateral Type A was found in 107 patients (46.5%); Type A and Type B, 58 patients (25.2%); and Type A and Type C, 24 patients (10.4%).

Type B: The number of branches arising from the proximal ECA is three. Type B was found in 134 vessels (25.2%; right, 61; left, 73) of 110 patients (36.4%). Bilateral Type B was found in 24 patients (10.4%); and Type B and Type C, 12 patients (5.2%).

Type C: The number of branches arising from the proximal ECA is four or more. Type C was found in 54 vessels (10.2%; right, 24; left, 30) of 49 patients (16.2%). The representative images of Type C are shown in Fig. 2. Bilateral symmetrical Type C branch variants were present in 5 patients (2.2%) out of 230 patients with both-side carotid angiograms.

Both-side carotid angiograms were available for 41 patients with Type C. Among these 41 patients, bilateral symmetrical Type C was found in 5 patients (12.2%); Type C and Type A, 24 patients (58.5%); and Type C and Type B, 12 patients (29.3%).

The compositions of branches involved in Type C were divided into the twelve patterns (Table 2). The top three branching patterns were as follows: LA, FA, OA, and distal ECA, 13 cases (24.0%); linguofacial trunk, OA, APA, and distal ECA, 13 cases (24.0%); and LA, FA, OA, APA, and distal ECA, 6 cases (11.1%; Fig. 3).

3-2. The distances from the CCA bifurcation to the first branch of ECA

The distance from the CCA bifurcation to the first branch of ECA was 21.8 ± 15.6 mm in Type A and 20.6 ± 8.9 mm in Type B. By contrast, the distance in Type C was 14.7 ± 6.6 mm, and significantly shorter than those of the other types (Dunnett's post-hoc test between Type A and Type C; $p = 0.002$ and between Type B and Type C; $p = 0.032$).

3-3. The correlation between the position of CCA bifurcation and the cervical vertebral level

When the most common C3 or C3/4 level bifurcation group was regarded as reference group, Type C was significantly uncommon in the group with C4 level or lower CCA bifurcation (Odds Ratio [95% confidence interval]: 0.06 [0.015 to 0.24], $P < 0.001$) (Fig. 4). The position of CCA bifurcation with Type C was detected at the C3/4 level or higher in 52 of 54 ECAs (96.3%) (Table 3).

4. Discussion

The present study proposes the three-type classification for branch variants of ECA, simply based on the number of branches arising close together at a common point from the proximal ECA. Type A is that all individual branches arise separately from the proximal ECA. The number of branches arising from the proximal ECA is two, including the distal ECA. Type B is that three branches arise close together including the distal ECA. Type C is defined as four or more branches arising close together including the distal ECA.

In the first place, we determined the incidence of the branch variants of ECA using DSA results from a large consecutive series. In the results, the frequency of Type A, B, and C was 64.6%, 25.2% and 10.2%, respectively. A cadaveric study using a black Kenyan population showed that the typical pattern of branching, bifurcation, trifurcation, quadrifurcation, and pentafurcation, was observed in 41.1%, 17.9%, 26.8%, 8.9%, and 5.3% of cases, respectively.[12]

In comparison with their study, our type A includes the typical branch pattern and the bifurcation of them. Our type B is the same as the trifurcation. Our type C includes the quadrifurcation and pentafurcation; thus, the frequency of each type of our classification was similar to the results of Ogeng'o et al. (2015)[12].

Next, we focused on Type C. Previous reports concerning this characteristic branch variant of the ECA are summarized in Table 4.[6,8,12,13,15,17] We can recognize that various branches and trunks were involved in the composition of this branch variant of the ECA. Five of these six papers were case reports analyzing a human cadaver.[6,8,13,15,17] Gluncic et al. (2001)[6] reported a case with a quadrifurcation into the superior thyroid artery, LA, OA, and distal ECA. Each of T et al. (2010)[15] and Thwin et al. (2010)[17] reported the ECA after the origin of superior thyroid artery quadrifurcated into the LA, FA, OA, and distal ECA. Rao and Shetty (2011)[13] reported a case in which all eight branches arose close together from a common point just above the origin of the ECA. Like these previous case reports, various branches and trunks were involved in our Type C (Table 4). To classify the branch patterns of ECA based on these diverse variations is so complicated and impractical. For the daily usage, our three-type classification for branch variants of ECA, simply based on the number of branches arising close together at a common point from the proximal ECA, must be convenient.

Interestingly, Kishve et al. (2011)[8] reported a case with simultaneous Type C branching on both sides. This was the only case of bilateral Type C branching of ECA, so far. In our study, the 5 cases of bilateral Type C variant of the ECA had 2.2% probability in 230 patients with the data of both side carotid angiograms. The fact that 12.2% of cases with Type C had the contralateral Type C ECA branching pattern is worthy for remark.

In the second place, our study demonstrated that the distance from the CCA bifurcation to the first branch of ECA was mean 14.7 ± 6.6 mm in our cases of Type C. This length is statistically shorter than those of the other variations ($P < 0.05$). Previously, Ogeng'o et al. (2015)[12] pointed out that the pentafurcation showed the early division within the carotid triangle in 12 out of 224 cadavers (5.3%). However, the precise distance from the CCA bifurcation to the first branch of ECA has not been reported yet. This short distance of proximal ECA in Type C should be recognized during head and neck surgery or neuroendovascular therapy.

In the third place, we analyzed the correlation between the ECA branch variations and the position of the CCA bifurcation. The CCA usually bifurcates at the level of the upper border of the thyroid cartilage into the ECA and ICA.[14] Zümre et al. (2005)[20] did a study of the bifurcation levels of the CCA and origin variations of the branches of the ECA in 20 human fetuses. In their analyses, the bifurcation level of the CCA was determined to be 55% at the C3 level, 35% at the C4 level, 10% at the C5 level on the right side and 60% at the C3 level, 40% at the C4 level on the left side. Thus, the CCA usually bifurcates at the level of the C3 level.

Recently, a higher level of origin was noted in 20 of 80 cadavers (25%).[5] They concluded that the higher level of the carotid bifurcation exhibited a great degree of anatomical variability. Our study showed that 96.3% of CCA bifurcation level with Type C was C3/4 or higher. The rate in CCA bifurcation level with Type C C4 level or lower was significantly lower than those of the other variations ($P < 0.05$). These results well accorded with the previous reports of the quadrifurcation.[6,8,15,17] The CCA was bifurcated at the level between C2 and C3 in the case of Gluncic et al. (2001)[6], and Thwin et al. (2010)[17] reported that the CCA bifurcation level was as high as C2, corresponding to the hyoid bone. Kishve et al. (2011)[8] also reported the association of high carotid bifurcation at 1 cm above the greater cornu of hyoid bone and bilateral three branches, including linguofacial trunk, OA, APA, and the distal ECA, arising close together from a common point just above the origin of the ECA. Thus, the higher position of CCA bifurcation is associated with the variant, equivalent to Type C. The development of ECA is a complicated process of angiogenesis and remodeling which includes annexation and regression of vessels.[11] The variation in this developmental process results in long CCA with aggregated ECA branches; thus, high CCA bifurcation must be one unique feature of type C.

The clinical implementation of recognizing type C is important for various endovascular treatments in particular carotid artery stenting (CAS).

CAS is a common and effective treatment for carotid artery stenosis.[18] However, several complications, such as ischemic stroke and intracranial hemorrhage, sometimes occur despite improvements in techniques and equipment.[2,9] Several cerebral protection techniques have been developed,[10] including distal protection devices and proximal occlusion balloons, to prevent the passage of embolic material into the cerebral vasculature during CAS. Previous studies have reported that the 30-day mortality and stroke rates are significantly lower in CAS procedures performed with embolic protection devices than without protection.[1]

The combination of proximal balloon protection techniques for both the external carotid artery (ECA) and common carotid artery (CCA) is effective in the majority of CAS procedures, especially for large, soft atherosclerotic internal carotid artery (ICA) plaques with high embolic potential, whereas only proximal balloon protection for the CCA may not be effective in preventing the passage of embolic particles to the brain. In addition, combining both distal and proximal balloon protection techniques could overcome the disadvantages of single techniques. Our proximal protection method has been based on a modification of Parodi's method, which has been used in 18.2% of cases from 2009 to 2010 in Japan.[10] In this method, a PercuSurge Guardwire balloon® temporary occlusion and aspiration system (Medtronic, Santa Rosa, CA, USA) or Mo-Ma® Ultra proximal protection device (Invatec, Roncadelle, Italy) is placed in the most proximal side of the ECA for protection from retrograde flow from the ECA to the ICA.

Recently, we experienced a case of massive subcutaneous hemorrhage between branches from the ECA during CAS when balloon inflation was performed just at the ECA of Type C (Fig. 5). We concluded that the bleeding had occurred from dissection between the branches of Type C because of balloon inflation (Fig. 5). This case indicated that unprotected balloon inflation for the Type C branching pattern carries the risk of massive subcutaneous hemorrhage.

There are several limitations. First, this is the most extensive study for evaluation of branch patterns of ECA, but it is retrospective. We could not perform complete bilateral external carotid artery angiograms for all 302 consecutive patients. In addition, we analyzed not the healthy volunteers, but the patients suffering from a disease. Thus, our data might have some bias. Second, we could not discuss the ethnic differences of variations in branching of ECA, because our materials were only Japanese. Third, most of the branch variation of ECA was evaluated by images obtained from two different angles (frontal and lateral views), resulting the APA could not be visualized in some cases. At this point, our angiographical evaluation is inferior to the data obtained by cadaver dissection. However, even in the angiographical evaluation, 3D DSA can demonstrate the precise stereoscopic anatomy of ECA with the APA (Fig. 3).

5. Conclusion

In conclusion, our three-type classification for branch variants of ECA is simply based on the number of branches arising close together at a common point from the proximal ECA and is practical in clinical usage. We thus found that about 16.2% of analyzed subjects carry the Type C branching pattern (10.2% of the ECA). Importantly, the Type C branching pattern is characterized by the short distance from the CCA bifurcation to the first branch of ECA and by the higher cervical vertebral position of its CCA bifurcation. This unique Type C with aggregated ECA branches needs to be paid attention to avoid complication during surgeries.

6. Acknowledgements

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7. References

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the bifurcation level of the common carotid artery and variations of the branches of the external carotid artery in human fetuses. Ann Anat 2005;187:361-369.

8. Accomplishments

(I) Original articles

◎ 1 . **Yamamoto D**, Koizumi H, Ishima D, Kuroda H, Shibahara I, Niki J, Miyasaka K, Watanabe T, Kondo R, Kumabe T: Angiographic Characterization of the External Carotid Artery: Special Attention to Variations in Branching Patterns. Tohoku J Exp Med, 249(3): 185-192, 2019.

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（Ⅱ）**Literary works**

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（Ⅲ）**Public lectures・Educational lectures**

none

（Ⅳ）**Case reports**

○１．Yamamoto D, Ishima D, Inukai M, Niki J, Usui R, Koizumi H, Saegusa M, Nishiyama K, Kumabe T: Cerebral amyloid angiopathy-related inflammation demonstrating early venous filling on digital subtraction angiography: A case report. No shinkei geka, (in press)

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9. Figures and tables

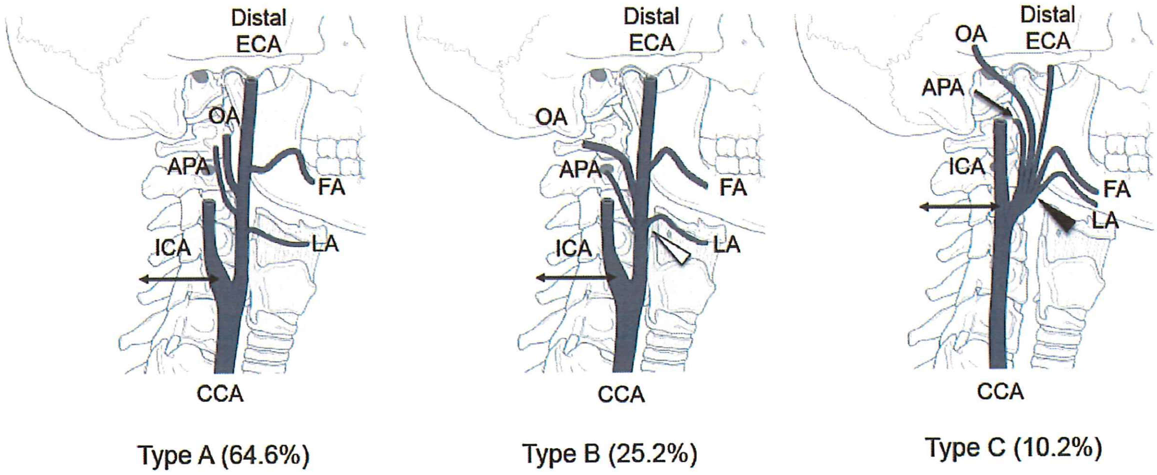

Fig. 1. Illustrations of our three types classification for branch variant of the external carotid artery (ECA) with incidences.

Figure 1. Illustrations of our three type classification for branch variant of the external carotid artery (ECA) with incidences.

Branch variants of the ECA were divided into three types: Type A, all individual branches arising separately from the proximal ECA (the number of branches arising from the proximal ECA is two, including distal ECA); Type B, three branches of ECAs arising close together at a common point from the proximal ECA (white arrow head); and Type C, four or more branches of ECAs arising close together at a common point from the proximal ECA (black arrow head). The gray double-headed arrows indicate the common carotid artery bifurcation level of cervical vertebra. APA = ascending pharyngeal artery; CCA = common carotid artery; ECA = external carotid artery; FA = facial artery; ICA = internal carotid artery; LA = lingual artery; OA = occipital artery.

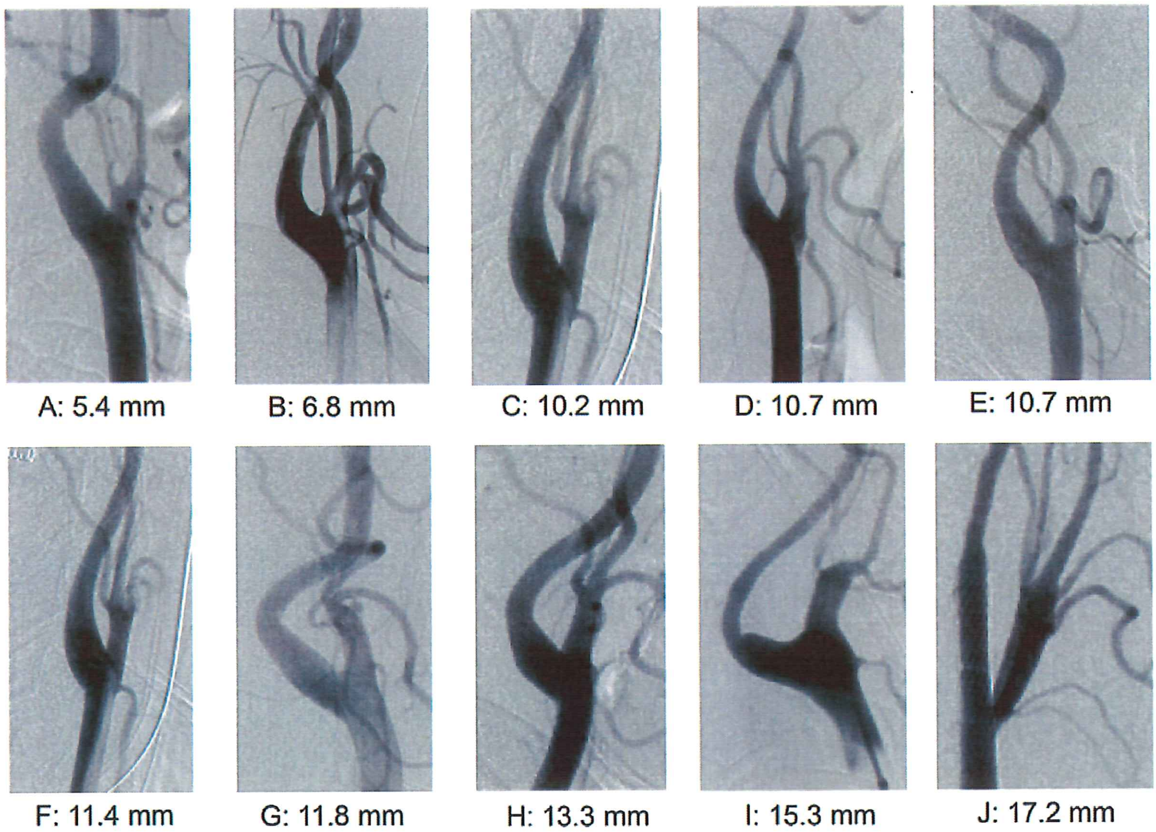

Fig. 2. Lateral views of digital subtraction angiograms (DSAs) showing representative 10 cases of Type C.

Figure 2. Lateral views of digital subtraction angiograms (DSAs) showing representative cases of Type C.

The distances from the common carotid artery (CCA) bifurcation to the first branch of ECA were indicated below the each DSA. The average length from CCA bifurcation to the first branch of the ECA was 14.7 ± 6.6 mm.

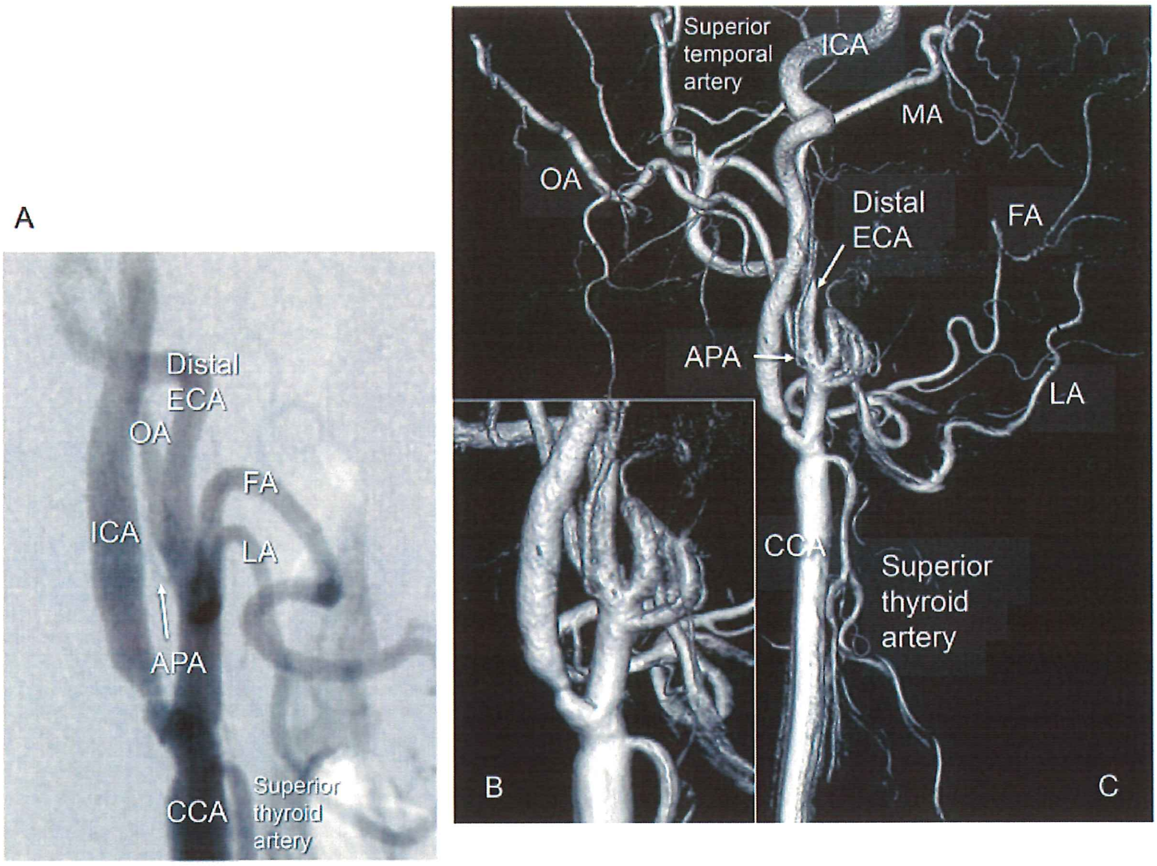

Fig. 3. Representative angiographic finding of external carotid artery (ECA) with Type C.

Figure 3. Representative angiographic finding of external carotid artery (ECA) with Type C.

Shown are digital subtraction angiogram (DSA) and 3-dimensional (3D) reconstruction images, obtained with rotational DSA (3D DSA). Lateral views of left common carotid artery DSA (A) and 3D DSA (B, magnified view; C, overall view), depicting left internal carotid artery stenosis and Type C branching pattern of ECA. Branches from the proximal external carotid artery (ECA) are five as follows, the lingual artery, facial artery, ascending pharyngeal artery, occipital artery, and distal ECA. APA = ascending pharyngeal artery; CCA = common carotid artery; ECA = external carotid artery; FA = facial artery; ICA = internal carotid artery; LA = lingual artery; MA = maxillary artery; OA = occipital artery.

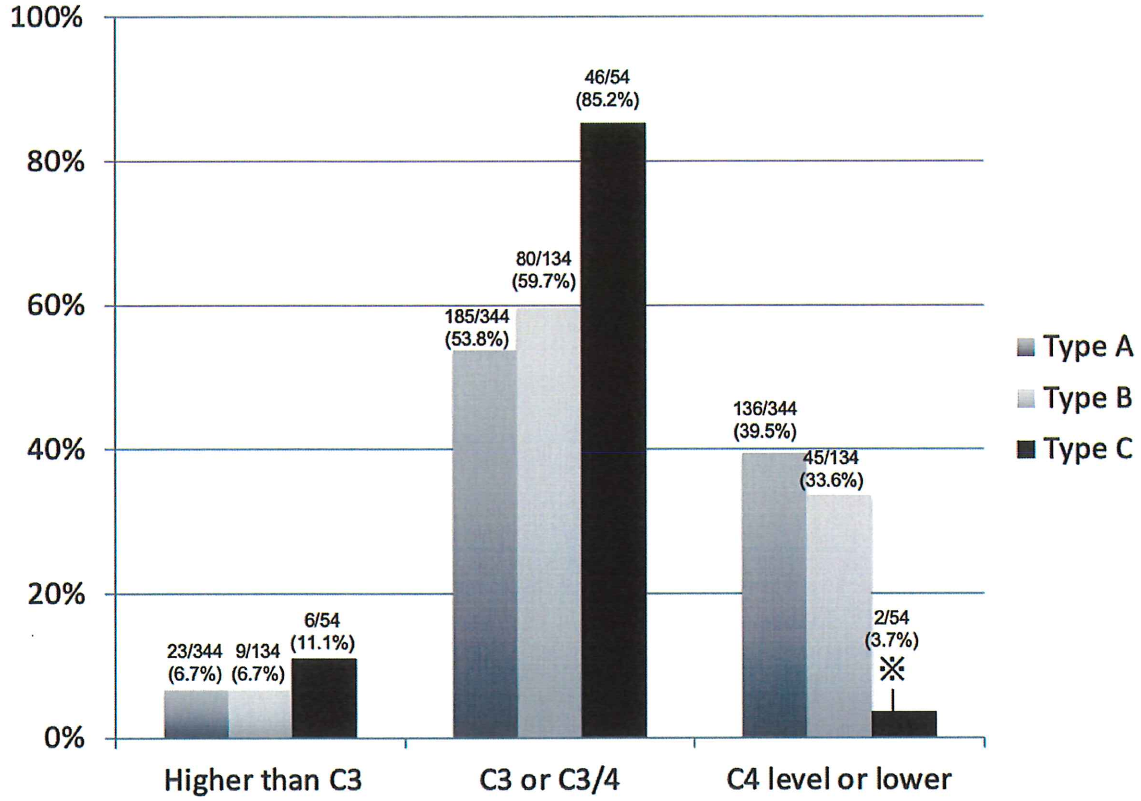

Fig. 4. The common carotid artery (CCA) bifurcation level of cervical vertebra in each external carotid artery (ECA) branch variant of the three-type classification.

Figure 4. The common carotid artery (CCA) bifurcation level of cervical vertebra in each external carotid artery (ECA) branch variant of our three type classification.

The group name of "Higher than C3" includes the CCA bifurcation level of second cervical vertebra and second–third junction cervical vertebra. "C3 or C3/4" includes the bifurcation level of third cervical vertebra and third–fourth junction cervical vertebra. "C4 level or lower" includes the bifurcation level of fourth cervical vertebra, fourth-fifth junction cervical vertebra, and fifth cervical vertebra. There were no cases with the CCA bifurcation level of higher than first-second junction cervical vertebra and lower than fifth-sixth junction cervical vertebra. CCA bifurcation level with Type C C4 level or lower was statistically lower than those of the other variants (*$P < 0.05$). The ordinate (%value) indicate the frequency of CCA bifurcation level group in each type.

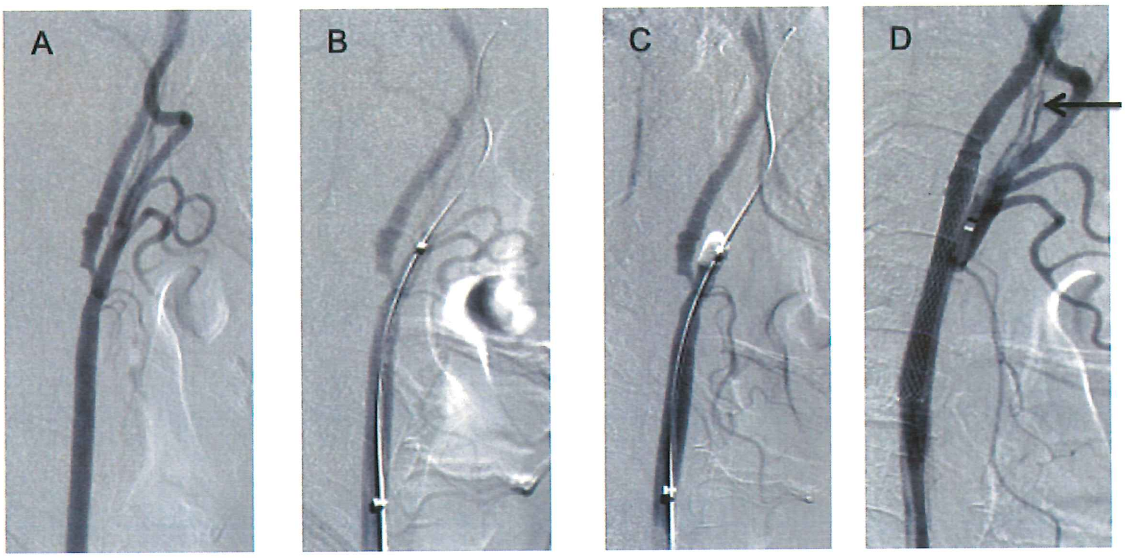

Fig. 5. Complication occurred in a patient with the Type C of the external carotid artery (ECA).

Fig. 5. Complication occurred in a patient with the Type C of the external carotid artery (ECA). Shown are lateral views of digital subtraction angiogram (DSA). **A:** Lateral view of the left ECA with Type C. **B:** Distal balloon of the Mo.Ma® (Invatec, Roncadelle, Italy) was placed in the left ECA with Type C to perform carotid artery stenting (CAS). **C:** Distal balloon of the Mo.Ma® was inflated in the ECA just proximal to branches of Type C. **D:** Extravasation of contrast medium could be identified (arrow) between the branches of Type C.

Table 1. Clinical characteristics of the cases.

Number of patients	302
Age, range (median), yrs	15-94 (61.8)
Male:female ratio (% of males)	130:172 (43)
Primary disease, number (%)	
Aneurysm	149 (49.3)
Artery occlusion	34 (11.3)
Artery stenosis	34 (11.3)
Tumor	28 (9.3)
Arterial dissection	17 (5.6)
Arteriovenous malformation	12 (4.0)
Arteriovenous fistula	9 (3.0)
Trauma	4 (1.3)
Moyamoya disease	3 (1.0)
Others	12 (3.9)

Table 2. Frequency of Type C branching pattern of the external carotid artery in the present study.

Branches	Number
LA, FA, OA	13 (24.0%)
Linguofacial trunk, OA, APA	13 (24.0%)
LA, FA, OA, APA	6 (11.1%)
LA, FA, Occipitoascending pharyngeal trunk	5 (9.2%)
LA, OA, APA	4 (7.4%)
FA, OA, APA	4 (7.4%)
LA, FA, APA	4 (7.4%)
Superior thyroid artery, LA, FA, OA	1 (1.9%)
Superior thyroid artery, Linguofacial trunk, OA, APA	1 (1.9%)
Superior thyroid artery, LA, FA, OA, APA	1 (1.9%)
Superior thyroid artery, LA, FA, Occipitoascending pharyngeal trunk	1 (1.9%)
Superior thyroid artery, LA, FA, OA	1 (1.9%)

LA, lingual artery; FA, facial artery; OA, occipital artery; APA, ascending pharyngeal artery.

Table 3. CCA bifurcation level of the cervical vertebra in each ECA branch variant.

	C2	C2/3	C3	C3/4	C4	C4/5	C5
Type A	9	14	118	67	107	17	12
Type B	2	7	60	20	40	1	4
Type C	2	4	35	11	2	0	0

Variation	No. (%)	Higher C3/4
Type A	344 (64.6)	208 (60.5)
Type B	134 (25.2)	89 (66.4)
Type C	54 (10.2)	52 (96.3)

C2, second cervical vertebra; C2/3, second-third junction cervical vertebra; C3, third cervical vertebra; C3/4, third cervical vertebra and third-fourth junction cervical vertebra; C4, fourth cervical vertebra; C4/5, fourth-fifth junction cervical vertebra; C5, fifth cervical vertebra.

Table 4. Frequency of the branching pattern of the ECA corresponding to Type C in our classification in previous reports.

Authors	Materials	Sample size	Frequency	Branches	CCA bifurcation level
Gluncic et al. 2001	Cadaver	1	NA	Superior thyroid artery, LA, OA, and distal ECA	C2/3
Thwin et al. 2010	Cadaver	1	NA	LA, FA, OA, and distal ECA	C2 (hyoid bone)
T et al. 2010	Cadaver	1	NA	LA, FA, OA, and distal ECA	2.2 cm above the superior border of the lamina of the thyroid
Kishve et al. 2011	Cadaver	1 (bilateral)	NA	Linguofacial trunk, OA, APA, and distal ECA	1cm above the greater cornu of hyoid bone
Rao 2011	Cadaver	1	NA	Superior thyroid artery, LA, FA, OA, APA, MA, superior temporal artery, and PAA	NA
Ogeng'o et al. 2015	Cadaver	224	14.2%	Quadrifurcation (n = 20, 8.9%): LA, FA, APA, and distal ECA Pentafurcation (n = 12, 5.3%): superior thyroid artery, LA, FA, APA, and distal ECA	NA

NA, not applicable, LA, lingual artery; OA, occipital artery; ECA, external carotid artery; FA, facial artery; APA, ascending pharyngeal artery; MA, maxillary artery; PAA , posterior auricular artery.