VIA MEDICA

ORIGINAL ARTICLE

Vol. 74, No. 2, pp. 206–211
DOI: 10.5603/FM.2015.0032

ISSN 0015–5659
www.fm.viamedica.pl

Morphological variation of carotid artery bifurcation level in digital angiography

A. Kurkcuoglu[1], C. Aytekin[2], H. Oktem[1], C. Pelin[1]

[1]*Department of Anatomy, Faculty of Medicine, Baskent University, Ankara, Turkey*
[2]*Department of Radiology, Faculty of Medicine, Baskent University, Ankara, Turkey*

[Received 2 September 2014; Accepted 10 October 2014]

Knowing of the level of carotid artery bifurcation (CB) is important for vascular surgery in the neck, radical neck dissections, carotid sinus baroreceptor stimulation, catheterisations, and aneurysms. The aim of this study was to determine the CB level in relation with the cervical vertebral levels, compare them on the right and the left sides, and investigate the relation of CB level with the length of neck. In this study, 100 conventional carotid angiographies were performed. The CB level was determined in relation with 10 different levels which were the levels of the cervical vertebrae and intervertebral disks, and the relation of CB level with the length of neck was investigated. The right and left CB levels of the patients were also determined, and compared. The highest level of CB was at the level of C2 vertebra, and the lowest level of CB was at the level of C6–C7 intervertebral disk in both male and female. When all patients were taken into consideration, CB level was most frequently seen at the level of C4–C5 (29%) on the right side, and at the level of C4 (26%) on the left side. The CB levels were not symmetrical in 10 female and 23 male. Knowing of the anatomical variations of CB level is important in surgical procedures. The anatomical differences must be taken into consideration since the neighbouring structures of CB change in case of variations. We believe that the results of this study will shed light to planning of all interventional methods concerning common carotid artery and its branches as well as surgery in the neck, and will help to minimise the complications. (Folia Morphol 2015; 74, 2: 206–211)

Key words: carotid artery bifurcation, common carotid artery, variation

INTRODUCTION

Carotid bifurcation (CB) is the natural end of common carotid artery (CCA) which is the largest artery of the neck, and it originates from the brachiocephalic trunk on the right side, and directly from the aortic arch on the left side CCA, internal carotid artery (ICA) and external carotid artery (ECA) are the main arteries supplying head and neck [5, 14]. ICA begins at the end of the CCA, at the level of superior margin of the thyroid cartilage, and terminates in the middle cranial fossa by dividing into the anterior and middle cerebral arteries. ECA arises from the CCA at level of the upper border of the thyroid cartilage, somewhat medial to, and in front of, ICA [5]. ECA and its rami are known to supply the neck, face, head, as well as dura mater. Therefore, the rami of ECA may be involved in a number of diseases of interest to laryngologists, ophthalmologists, radiologists, neurosurgeons, plastic surgeons, and oral surgeons [25]. CB usually lies at the level of the C4 vertebra or the upper border of

Address for correspondence: A. Kurkcuoglu, MD, PhD, Department of Anatomy, Faculty of Medicine, Baskent University, 06530 Bağlıca Ankara, Turkey, tel: +90 312 2341010 1524, fax: +90 312 2341180, e-mail: kayla@baskent.edu.tr; kurkcuoglua@hotmail.com

The data of this study were used in the poster presentations on International Journal of Experimental and Clinical Anatomy 9th–11th July, 2010, Czech Republic.

the thyroid cartilage, however it may be seen as low as the level of the T3 vertebra or as high as the hyoid bone [24]. CCA was found to be absent; instead, the external and ICAs aroused directly from the innominate artery or the aortic arch. It is extremely rare that the CCA ascends in the neck without undergoing bifurcation. Morimoto et al. [17] presented such a case in whom the non-bifurcating left carotid artery gave origin to all branches normally given off by the ECA, and subsequently constituted the ICA [17]. In head and neck surgery, CCA and its bifurcation level are important landmarks, defining the plane of the dissection during radical neck surgery [1]. Differential diagnosis requires the awareness of possible changed topography of the structures like carotid sinus (CS), and the dilation of CCA CB is the most common site of atherosclerotic plaque formation [1, 22]. Determining the CB level accurately with non-invasive techniques is still an important goal, and external anatomical landmarks can be clinically useful for predicting the localisation of it. There is still no consensus among various anatomy texts regarding the relationship of CCA and the neighbouring structures [19]. A clear understanding of the anatomy is essential to minimise surgical morbidity and mortality in patients undergoing operations involving the CCA [13].

The aim of this study was to determine the CB level in relation with the cervical vertebrae, compare them symmetrically, and investigate relation of CB level with the length of neck.

MATERIALS AND METHODS

This study was performed retrospectively on conventional angiography images of 100 (68 males, 32 females) patients between the ages of 22 and 91 years, in Radiology Department of Başkent University Faculty of Medicine. Our study was approved by Baskent University's Institutional Review Board (KA 14/19), and supported by Baskent University Research Fund. Digital subtraction angiography (DSA) device (Siemens Artis Zee monoplan) was used. The patients were prepared under standard sterile conditions on the angiography table, in the Interventional Radiology Department. Following local anaesthesia, a 4 F or 5 F introducer was placed into the right or left common femoral artery, 4 F pig-tail catheter glide was advanced into the aortic arch through the guidewire, and aortic arch aortography was performed. Later, the branches were selectively catheterised using Simon 1 and Simon 2 catheters. The images obtained were installed into CT Leonardo, MR Satellite work stations, and the measurements were made. The patient's head was held still using a strap in neutral position during the procedure. Radiograms obtained in all other positions (hyperextension, lateral rotation etc.) except neutral position were excluded from the study. In each patient, a lateral (left or right) and an oblique (left or right) radiogram were obtained during selective CCA injections. In some cases, an anteroposterior radiogram was also added.

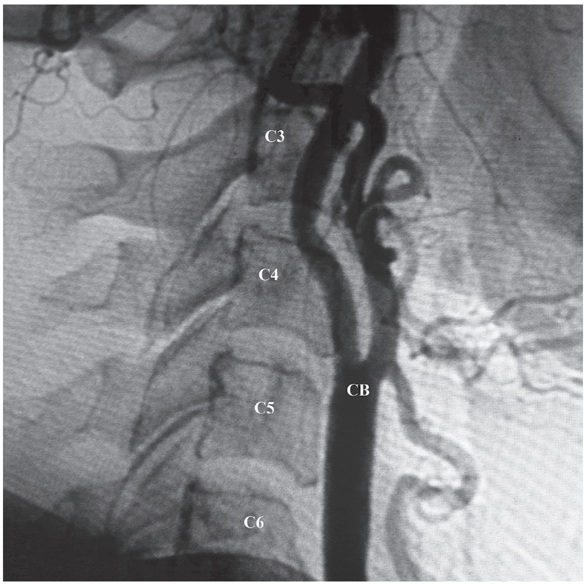

Figure 1. Carotid bifurcation level, determined in relation to cervical vertebra levels.

The level of CB was determined in two or more projections in each patient. The level of CB was identified with relation to the levels of the cervical vertebrae, and the patients' neck lengths were determined. The vertebral levels were determined as C2, C2–3, C3, C3–4, C4, C4–5, C5, C5–6, C6, and C6–7, and CB levels were determined with relation to those levels (Fig. 1). The distance between the angle of the mandible and midpoint of the clavicle was used to measure the length of neck (Fig. 2). All measurements were performed bilaterally, by the same investigator. The patients who had surgery in their neck or interventions directed to CCA or its branches were excluded. In addition, presence of hyperextension or excessive lateral rotation of the neck during the procedure was also regarded as exclusion criteria.

Statistical analysis

The analysis of data was performed using SPSS 17.0 (SPSS Ver. 17.0, Chicago IL, USA) statistical pack-

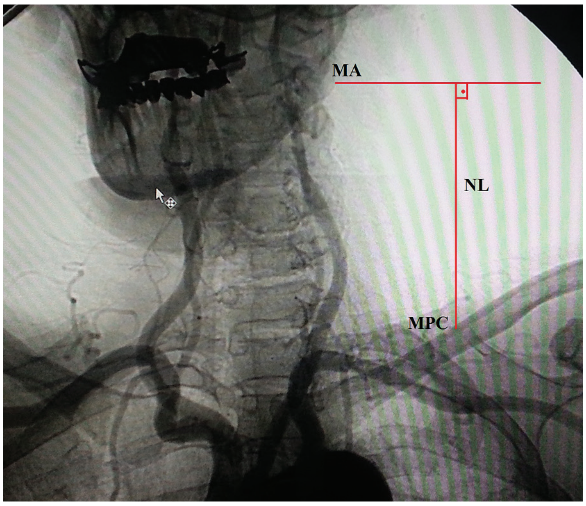

Figure 2. The distance between the angle of the mandible and midpoint of the clavicle was used to measure the length of neck; MA — mandibular angle; MPC — midpoint of clavicle; NL — neck lenght.

age program. The normality of the distribution of the variables was analysed with Shapiro-Wilk test. The homogeneity of the group variances was analysed with Levene test. Student's t-test was used for comparison of the means of parametric variables between two independent groups. The means of two dependent groups were compared using paired t-test. The medians of two independent groups' parameters that did not fulfil the prerequisites for the parametric tests were compared with Mann-Whitney U test. The medians of dependent groups were compared with Wilcoxon test. The correlations among the variables were analysed with Spearman rho correlation coefficient. The categorical variables were presented as frequency (n) and per cent (%). $P < 0.05$ was regarded as statistically significant.

RESULTS

The levels of CB were analysed on angiographic images of in 68 males and 32 females. The ages of the females were between 32 and 97 (mean 70.47 ± 13.84) years, and the ages of the males were between 34 and 92 (mean 73.12 ± 12.86) years, without any significant difference in between ($p = 0.416$). The length of the neck was 57–114 mm (77.59 ± 13.63 mm) in females, and 45–108 mm (76.19 ± 12.17 mm) in males, without any significant difference in between ($p = 0.982$).

The level of CB was determined in relation to the levels of the cervical vertebrae in all patients. In female, the highest level of CB was at C2–3 intervertebral disk level on the right side (3.1%), and the lowest level of CB was at the level of C6–C7 intervertebral disk level on the left side (3.1%). In male, the highest level of CB was at the level of C2 on the right side (2.9%), and the lowest level of CB was at the level of C6–C7 intervertebral disk level on the right side (1.5%). When all patients were taken into consideration, CB level was most frequently seen at the level of C4–C5 (29%) on the right side, and at the level of C4 (26%) on the left side (Table 1).

The left and right CB levels were compared between two genders. For this, we grouped our data into three groups as CB level at C2–4, C4–6 or C6 and lower. We compared the symmetricity of the CB levels both in male and female. The level of CB was symmetrical at the level of C2–4 vertebrae in 9.4%,

Table 1. Computed tomography (CT) angiography images of variation in carotid bifurcation location. The location of CT the corresponding level of cervical vertebrae

Level of cervical vertebrae	Female (n = 32)		Male (n = 68		Total (n = 100)	
	Right side	Left side	Right side	Left side	Right side	Left side
C2	–	–	2 (2.9%)	–	2 (2%)	–
C2–C3	1 (3.1%)	–	1 (1.5%)	–	2 (2%)	–
C3	2 (6.3%)	4 (12.5%)	2 (2.9%)	4 (5.9%)	4 (4%)	8 (8%)
C3–C4	3 (9.4%)	5 (15.6%)	6 (8.8%)	10 (14.7%)	9 (9%)	15 (15%)
C4	6 (18.8%)	9 (28.1%)	14 (20.6%)	17 (25%)	20 (20%)	26 (26%)
C4–C5	10 (31.3%)	4 (12.5%)	19 (27.9%)	15 (22.1%)	29 (29%)	19 (19%)
C5	7 (21.9%)	6 (18.8%)	19 (27.9%)	18 (26.5%)	26 (26%)	24 (24%)
C5–C6	1 (3.1%)	2 (6.3%)	1 (1.5%)	4 (5.9%)	2 (2%)	6 (6%)
C6	2 (6.3%)	1 (3.1%)	3 (4.4%)	–	5 (5%)	1 (1%)
C6–C7	–	1 (3.1%)	1 (1.5%)	–	1 (1%)	1 (1%)

Table 2. The symmetricity of the carotid bifurcation levels in female

Right	Left			
	C2–4	C4–6	C6 and below	Total
C2–4	3 (9.4%)	3 (9.4%)	0 (0%)	6 (18.8%)
C4–6	4 (12.5%)	11 (34.4%)	1 (3.1%)	16 (50.0%)
C6 and below	1 (3.1%)	2 (6.3%)	7 (21.9%)	10 (31.3%)
Total	8 (25%)	16 (50%)	8 (25%)	32 (100%)

Table 3. The symmetricity of the carotid bifurcation levels in male

Right	Left			
	C2–4	C4–6	C6 and below	Total
C2–4	4 (5.9%)	6 (8.8%)	1 (1.5%)	11 (16.2%)
C4–6	6 (8.8%)	33 (48.5%)	2 (2.9%)	41 (60.3%)
C6 and below	3 (4.4%)	5 (7.4%)	8 (11.8%)	16 (23.5%)
Total	13 (19.1%)	44 (64.7%)	11 (16.2%)	68 (100%)

at the level of C4–6 vertebrae in 34.4%, and at the level of C6 or lower in 21.9% of the female (Table 2). In male, it was situated bilaterally at the level C2–4 in 5.9%, at the level of C4–6 in 48.5%, and at the level of C6 or lower in 11.8% of the patients (Table 3). The relation between the length of the neck and the level of CB was analysed, however any statistically significant correlations could not be found ($p = 0.342$ for right side, and $p = 0.101$ for left side).

DISCUSSION

The variations of the carotid artery have been usually studied in cadaver studies, and carotid angiographic studies, and there are also some case reports of variations determined during neck surgery [10, 11, 16, 21, 24]. Our research is an angiographic variation study performed on 100 patients. Different from the other studies, we investigated the CB level in more detail, in relation with 10 different levels of cervical vertebrae. In addition, we compared sides (left–right), and investigated the relation between CB level and the length of neck.

Carotid artery injury is a rare but potentially devastating event that can occur during anterior cervical approaches. When a neurosurgeon encounters a low-lying bifurcation of the CCA during anterior neck dissection, use of an operating microscope might be helpful for preventing injury. A lower location of the CB may obviate some manipulations during anterior cervical approach such as placement of an artificial disc or cage to the intervertebral space on account of its wider transverse diameter. The information on CB is also important for the interventions performed in the CS [12, 14]. In individuals that display superior or inferior CB position, the internal pressure transmission at CS region changes and an external neck pressure stimulus causes an attenuated response in those people when compared to the individuals with a CS located in the middle part of the neck [18]. Therefore, it is important to know the location of CS during cervical lymph node palpation due to likelihood of syncope during this examination [12].

The CB is most commonly located between the C3–4 and C4–5 levels, but it may be at any cervical level [5]. In our 100 patients, CB level was most frequently located at the level of C4 (in 26% of the patients) on the left side, and at the level of C4–C5 intervertebral disk level (in 29% of the patients) on the right side. On the other hand, CB was above the level of C4 on the right side of 17, and on the left side of 23 patients. The bifurcation level was above C4 level in 9.4% of the female and 5.9% of the male, when both sides were taken into account. A bifurcation level above C4 level was reported in 2.4% of the patients in Klosek and Rungruang's [12], in 1% of the patients in Gluncic et al.'s [6], and in 10% of the patients in Anu et al.'s [2] studies.

A high CB level is important since a close neighbourhood to hypoglossal nerve and superior cervical ganglion occurs in this case. Hayashi et al. [8] reported that bifurcation of the CCA was located near the inferior part of the C3 vertebral body in Japanese individuals. Ito and associates reported a high common CB in 25 (31.2%), a standard bifurcation (C4) in 46 (57.5%), and low bifurcation in 9 (11.3%) patients in their series of 80 cases [9].

Klosek and Rungruang [12] performed a study on 43 cadavers, and found the absence of ECA unilaterally in 4, and bilaterally in 4 cases. Bregman et al. [3] also reported the absence of ECA. We did not encounter absence of CB in any of our patients.

Anu et al. [2] determined the level of CB according to the levels of cervical vertebrae in a total of 95 cadavers. In their study, they found CB at the level of C3 in 50%, C4 in 40%, and C2 in 10% of the cases on the right side; and at the level of C3 in 55%, C4 in 35%, C5 in 1%, and C2 in 9% of their cases on the left side. In our study, we did not find this high C3 level in either male or female, or either on the left or the right sides (females 6.3–12.5%, males 2.9–5.9%). The reason for this may be a more detailed cervical vertebral level determination in our study.

Gulsen et al. [7] found that CB bifurcation was at the level of C6–C7 on the right side, and at the level of C5–C6 on the left side during neck dissection of a 42-year-olde woman. In their clinical experience, high bifurcation of the CCA did not cause any problems regarding anterior cervical discectomy, but a low bifurcation may cause some problems if surgeon is not careful. In our study, we found that CB level was at C6 level or below in 15% of the patients. Toyota et al. [23] performed an angiographic study on 147 patients, and found that CB was at the level of C3 in 81.6% (n = 240) of the cases. This rate is quite high when compared to our results. In our study, we found CB at C3 level in 4% of the cases on the right side, and in 8% of the cases on the left side.

The embryology of carotid arteries may explain variations of CB location as well as existence of only one arterial trunk. CCA and the proximal part of ICA develop at the level of the third aortic arch, and the rest of ICA develops from cranial portion of dorsal aorta. However, ECA branches from the third aortic arch. Thus, the position of the CB depends on how low or high ECA originates from the third aortic arch [3, 5].

If ECA originates close to the aortic sac, the level of CB appears low; on the contrary, if ECA originates either at the top of the third aortic arch or directly originates from dorsal aorta, CB appears high. Moreover, the development of ICA from the second aortic arch and parts of dorsal aorta with simultaneous formation of ECA from small canals obtained by obliteration of the first aortic arch may shift the CB higher [20]. Very high position of CB (in the cranium) or disproportional growth of some segments of carotid tree could explain the observations of no CB found in some cases. Zümre et al. [25] investigated the CB level bilaterally in 40 foetuses. The CB was found at the level of C3 in 55%, at the level of C4 in 35%, and at the level of C5 in 10% of the cases on the right side. They found CB at the level of C3 in 60%, at the level of C4 in 40% of the cases on the left side. The difference between our and aforementioned study's results may be due to the unparallel embryological development of the vascular structures and the bones.

Morimoto et al. [17] found that CB was at C4 level or at the upper border of the thyroid cartilage most of the time; however it might be as low as T3 level and as high as hyoid bone level. When our 100 patients were taken into consideration, CB level was most frequently found at the level of C4–C5 (n = 29, 29%) on the right side, and at the level of C4 (n = 26, 26%) on the left side in our study (Table 1). Klosek and Rungruang [12] determined the CB level by taking cervical vertebrae (particularly C4), thyroid cartilage, angle of the mandible, superior thyroid artery level and lingual artery level into consideration in their cadaver study. The authors found CB level at the level of C4–5 on the right side in 28%, and at the level of C4 on the left side in 50% of the males. In the same study, CB was most frequently found at C4 level in females (right 39%, left 33%). The authors stated that CB level was approximately 6 mm superior to thyroid cartilage. They concluded that CB level was not symmetrical on the right and the left sides, there may be no bifurcation on the right side, and the level of the angle of the mandible was an important reference point [12]. In our study, we compared right and the left sides. We found that CB levels were not symmetrical in 10 female and 23 male (Tables 2, 3). We think that this is important for planning interventions. Our literature review showed that only Klosek and Rungruang [12] analysed the symmetry of CB levels, and reported that CB levels were asymmetrical in 4 cadavers (2 females and 2 males).

Mcafee et al. [15] dissected 140 cadavers, and did not find CB below the levels of C3–C5 vertebrae in any of their cases. However, the CB was located below C5 vertebra level on both sides in 18 patients in our study. Our literature search revealed that CB level was usually reported more superiorly in cadaver studies. We have two possible explanations for this difference: first, in most of the cadaver studies it is hard to determine a standard neck position. Death in different positions may naturally affect the determination of CB level. Second, the changes occurring after death may affect the findings of those studies [4, 15, 20].

CONCLUSIONS

In conclusion, knowing of the variations of CB level is important for carotid endarterectomy, radical neck dissections, catheterisations, vascular aneurysms, and vascular surgical interventions in the neck. Knowing of abnormal branching is also necessary for the diagnosis and treatment of intracranial aneurysms. We believe that the results of this study will shed light to planning of all interventional methods concerning CCA and its branches as well as all surgical procedures performed in the neck, taking the right and left sides into consideration, and will help to minimise the complications.

ACKNOWLEDGEMENTS

We thank A. Canan Yazıcı, Department of Biostatistics, Faculty of Medicine at Baskent University for help with statistical analysis and Algan Turgut, Zühre Melike Özdamar, Özge Irem Morkoç, Sıla Çelik, Çağla Nakkaş Term II, Faculty of Medicine at Baskent University for help with the measurements.

REFERENCES

1. Anangwe D, Saidi H, Ogeng'o J, Awori KO (2008) Anatomical variations of the carotid arteries in adult Kenyans. East Afr Med J, 85: 244–247.
2. Anu VR, Pai MM, Rajalakshmi R, Latha VP, Rajanigandha V, D'Costa S (2007) Clinically-relevant variations of the carotid arterial system. Singapore Med J, 48: 566–569.
3. Bergman RA, Thompson SA, Afifi AK, Saadeh FA (1998) Compendium of human anatomic variation. Urban and Schwarzenberg, Baltimore-Munich, pp. 28–31.
4. Bernard K (2004) The pathology of death. In: Pekka Sauko ed. Knight's forensic pathology. 3rd Ed. CRC Press Taylor and Francis Group, London, pp. 52–97.
5. Drake R, Vogl A, Mitchell A (2010) Gray's anatomy for students. 2nd Ed. Churchill Livingstone, Philadelphia, pp. 958–959.
6. Gluncic V1, Petanjek Z, Marusic A, Gluncic I (2001) High bifurcation of common carotid artery, anomalous origin of ascending pharyngeal artery and anomalous branching pattern of external carotid artery. Surg Radiol Anat, 23: 123–125.
7. Gulsen S, Caner H, Altinors N (2009) An anatomical variant: low-lying bifurcation of the common carotid arteryand its surgical implications in anterior cervical discectomy. J Korean Neurosurg Soc, 45: 32–34.
8. Hayashi N, Hori E, Ohtani Y, Ohtani O, Kuwayama N, Endo S (2005) Surgical anatomy of the cervical carotid artery for carotid endarterectomy, Neurol Med Chir, 45: 25–29.
9. Ito H, Mataga I, Kageyama I, Kobayashi K(2006) Clinical anatomy in the neck region-the position of external and internal carotid arteries may be reversed. Okajimas Folia Anat Jpn, 82: 157–167.
10. Jadhav SD, Ambali MP, Patil RJ, Roy PP (2011) Thyrolingual trunk arising from the common carotid bifurcation. Singapore Med J, 52: 265–266.
11. Kishve PS, Kishve SP, Joshi M, Aarif SM, Kalakoti P (2011) An unusual branching pattern of common and external carotid artery in a human cadaver: a case report. Australas Med J, 4: 180–182.
12. Klosek SK, Rungruang T (2008) Topography of carotid bifurcation:considerations for neck examination. Surg Radiol Anat, 30: 383–387.
13. Lo A, Oehley M, Bartlett A, Adams D, Blyth P, Al-Alı S (2006) Anatomical variations of the common carotid artery bifurcation. ANZ J Surg, 76: 970–972.
14. Lucev N, Bobinac D, Maric I, Drescik I (2000) Variations of the great arteries in the carotid triangle. Otolaryngol Head Neck Surg, 22: 590–591.
15. Mcafee DK, Anson BJ, McDonald JJ (1953) Variation in the point of bifurcation of the common carotid artery. Northwestern University Medical School, Chicago Ill, 27: 129–137.
16. Manyama M, Rambau P, Gilyoma J, Mahalu W (2011) A variant branching pattern of the aortic arch: a case report. J Cardiothorac Surg, 6: 29.
17. Morimoto T, Nitta K, Kazekawa K, Hashizume K (1990) The anomally of a non-bifurcating cervical carotid artery, case report. J Neurosurg, 72: 130–132.
18. Querry RG, Smith SA, Stromstad M, Ide K, Secher NH, Raven PB (2001) Anatomical and functional characteristics of carotid sinus stimulation in humans. Am J Physiol Heart Circ Physiol, 280: 2390–2398.
19. Rosse C, Gaddum-Rosse P (1997) Hollinshead's textbook of anatomy. 5th Ed. Lippincott-Ravwen, Philadelphia, pp. 138–145.
20. Sadler TW (1990) Langman's medical embryology. 6th Ed. Williams and Wilkins, Baltimore, pp. 89–95.
21. Sasaki T, Nagashima H., Oya F, Satoh D, Kobayashi S (2013) Carotid artery stenting for atherosclerotic stenosis associated with non-bifurcating cervical carotid artery, Neurol Med Chir, 53: 228–232.
22. Schulz UG, Rothwell PM (2001) Sex differences in carotid bifurcation anatomy and the distribution of atherosclerotic plaque. Stroke, 32: 1525–1531.
23. Toyota A, Shima T, Nishida M, Yamane K, Okada Y, Csiba L, Kollár J, Sikula J (1997) Angiographical evaluation of extracranial carotid artery: comparison between Japanese and Hungarian. Brain Nerve, 49: 633–674.
24. Vitek JJ, Reaves P (1973) Thoracic bifurcation of the common carotid artery Neurodialogy, 5: 133–139.
25. Zümre O, Salbacak A, Çiçekcibaşi AE, Tuncer I, Seker M (2005) Investigation of the bifurcation level of the common carotid artery and variations of the branches of the external carotid artery in human fetuses. Ann Anat, 187: 361–369.