INTRODUCTION

The vertebral artery is generally the largest branch of the subclavian artery and usually branches off from the upper surface of the subclavian artery near its origin. The vertebral artery ascends posterior to the scalenus anterior muscle and enters the transverse foramen of the sixth cervical vertebra. After entering the transverse foramen, the vertebral artery ascends the transverse foramina of each cervical vertebra until it reaches the first cervical vertebra where it turns medially on the upper surface of the Atlas and further ascends to the cranial cavity through the foramen magnum. In the cranial cavity, the vertebral artery proceeds between the medulla obligata and clivus of the occipital bone superior-medially, and the bilateral vertebral arteries join at the posterior border of the pons and become the basilar artery [1].

Anatomically, the vertebral artery sometimes varies with regard to origin and the entrance level to the transverse foramen [2, 3]. We encountered a rare case of duplication of the right vertebral artery in an anatomical dissection course in Kurume University School of Medicine in 2015.

CASE PRESENTATION

Right duplicated vertebral arteries were found in a 91-year-old female cadaver. The cause of death was lung cancer and there was no evident disease or other anatomical abnormalities in the head and neck region. Two right vertebral arteries were observed in the right neck. The proximal leg of the arteries arose from the area between the right subclavian artery and the right common carotid artery that diverged from the brachiocephalic artery. The distal leg arose from the right subclavian artery as expected. The proximal leg entered the transverse foramen of the fourth cervical vertebra and the distal leg entered the transverse foramen of the sixth cervical vertebra. The two right vertebral arteries joined to form one artery just after the origin of the right vertebral artery of the brachiocephalic artery entered the transverse foramen of the fourth cervical vertebra. This artery then traveled up in the transverse foramina and became the basilar artery, joining with the left vertebral artery. We discuss the embryological origin of this case and review previously reported cases.

Summary: We encountered a case of duplicated right vertebral artery during an anatomical dissection course for medical students in 2015. Two vertebral arteries were found in the right neck of a 91-year-old female cadaver. The proximal leg of the arteries arose from the area between the right subclavian artery and the right common carotid artery that diverged from the brachiocephalic artery. The distal leg arose from the right subclavian artery as expected. The proximal leg entered the transverse foramen of the fourth cervical vertebra and the distal leg entered the transverse foramen of the sixth cervical vertebra. The two right vertebral arteries joined to form one artery just after the origin of the right vertebral artery of the brachiocephalic artery entered the transverse foramen of the fourth cervical vertebra. This artery then traveled up in the transverse foramina and became the basilar artery, joining with the left vertebral artery. We discuss the embryological origin of this case and review previously reported cases.

Key words vertebral artery, duplicated vertebral artery, cerebellar ataxia, transverse foramen, brachiocephalic artery, right subclavian artery, intersegmental artery, dorsal aorta
artery at the origin was 2.6 mm and that at the entrance to the transverse foramen was 2.1 mm. The other vertebral artery arose from the right subclavian artery and entered the transverse foramen of the sixth cervical vertebra. The diameter of the artery at the origin was 4.0 mm and the diameter at the entrance to the transverse foramen was 3.8 mm. The right vertebral artery

Fig. 1. Duplication of the right vertebral artery. The bilateral vertebral arteries were removed from the body with brain and the cervical spinal cord. The two right vertebral arteries existed and they joined together in the transverse foramina just after the right vertebral artery of proximal origin entered the transverse foramen of the 4th cervical vertebra.

AIC, anterior inferior cerebellar artery; B, basilar artery; LV, left vertebral artery; PIC, posterior inferior cerebellar artery;

Yellow arrow head, right vertebral artery arising from the brachiocephalic artery
Red arrow head, right vertebral artery arising from the right subclavian artery

Fig. 2. a. The finding of the origin of the duplicated right vertebral arteries.
Two right vertebral arteries existed in this case. One arose from the usual position on the right subclavian artery, the other arose from the brachiocephalic artery on the bifurcation of the right common carotid artery and the right subclavian artery.

b. The finding from the reverse view of the origin of the duplicated right vertebral arteries
The brachiocephalic artery was held and turned over to show the origin of the right vertebral arteries.

BC, brachiocephalic artery; RCC, right common carotid artery; RSC, right subclavian artery; Yellow arrow head, right vertebral artery arising from the brachiocephalic artery
Red arrow head, right vertebral artery arising from the right subclavian artery
DUPLICATED VERTEBRAL ARTERY

at the origin of the right subclavian artery ascended the transverse foramina of each cervical vertebra after entering the transverse foramen of the sixth cervical vertebra. This artery then joined with the right vertebral artery from the brachiocephalic artery, and became one right vertebral artery. The right vertebral artery continued to ascend in the transverse foramina and proceeded to the cranial cavity.

The left vertebral artery arose from the left subclavian artery as the first branch as usual and entered the transverse foramen of the sixth cervical vertebra. This artery then traveled upward in the transverse foramina of each cervical vertebra. The bilateral vertebral arterties met in the cranial cavity to form a single basilar artery (Fig. 3).

In the cranial cavity, the right posterior inferior cerebellar artery arose from the common trunk. The anterior inferior cerebellar artery arose from the basilar artery, which is different from normal cases in which the anterior inferior cerebellar artery arises from the vertebral artery. No other cranial vascular abnormalities were observed in this case.

DISCUSSION

A duplicated vertebral artery is a rare anatomical variation. A total of 52 cases of this type of artery have been reported in the English literature, including this case [5-18], but not including cases that were described vaguely in the 19th century [4]. A summary of the cases is as follows. Twenty-three cases were male and 26 were female, and sex was not described in three cases. The duplicated vertebral artery was found on the right side in 20, in the left side in 28, and bilaterally in four cases. In our school, five cases (two on the left side and three on the right side) of duplicated vertebral artery were found in a survey of 856 cases in our facility over 26 years from 1990 to 2015. Previously reported duplicated right vertebral arteries can be classified into three categories: (1) in 21 (87%) cases, both arteries arose from the right subclavian artery; (2) in two (8%) cases, one artery arose from the brachiocephalic artery and the other from the right subclavian artery; and (3) in one (4%) case, one artery arose from the brachiocephalic artery and the other from the right subclavian artery. Duplication of vertebral arteries on the left side has been reported in 32 cases. The vertebral arteries arose from the aortic arch and the left subclavian artery in 27 (84%) cases, both arose from the left subclavian artery in three (9%), and both arose from the aortic arch in two (6%). The diameter of the vertebral artery was described in 32 cases. When we compared the two vertebral arteries that arose from the proximal and distal sides, the proximal artery was larger in 16 (50%) cases, the distal artery was thicker in nine (28%), and they were approximately the same size in seven (22%). In our case, the distal artery was larger in diameter than the proximal artery, and this is considered to be relatively rare.

A duplicated vertebral artery usually does not cause any clinical symptoms [5]. However, in some cases, this variation is found accidentally during a clinical examination of headache or vertigo. Thirty-eight of 52 previously reported cases were found in X-ray examinations with the development of new radiological techniques. Because radiological reports of duplicated vertebral arteries have been increasing, detailed

Fig. 3. Schematic diagram of the vertebro-basilar arterties of this case
AIC, anterior inferior cerebellar artery; AS, anterior spinal artery; B, basilar artery; LV, left vertebral artery; PIC, posterior inferior cerebellar artery; RVB, right vertebral artery arising from brachiocephalic artery; RVS, right vertebral artery arising from subclavian artery; SC, superior cerebellar artery
Embryologically, six pairs of aortic arches, which connect to the aortic sac and bilateral dorsal aortas, appear at the 4th week. Most of the first and second aortic arches disappear soon. The bilateral third aortic arches become the common carotid artery and internal carotid artery at a later stage. The left aortic arch becomes the aortic arch (Figure 4) [20]. The dorsal aorta sends out three types of branches: ventral, lateral, and dorsal. The dorsal branch consists of 30 pairs, emerges from the dorsal aortas, and travels between each body segment. This is then called the dorsal intersegmental artery. These three branches create three types of longitudinal linkage, pre-costal, post-costal, and post-transverse anastomosis, and the residual parts disappear. In the neck region, these longitudinal linkages connect to the seventh intersegmental artery, which becomes the subclavian artery. On the left side, only the seventh intercostal artery is considered to become the subclavian artery. However, on the right side, the subclavian artery consists of three elements, the right fourth aortic arch, the dorsal aorta, and the seventh intersegmental artery from proximal to distal of the right subclavian artery. The pre-costal linkage creates the thyrocervical trunk in the neck and cost-cervical artery in the upper chest. The post-costal linkage becomes the vertebral artery and the post-transverse linkage becomes the deep cervical artery [21].

In our case, one right vertebral artery arose from the right subclavian artery and entered the transverse foramen of the sixth cervical vertebra. This artery is considered to be formed by the usual longitudinal linkage of the first to the sixth intersegmental arteries, and it connects them to the subclavian artery. The other vertebral artery arose from the brachiocephalic artery and entered the transverse foramen of the fourth cervical vertebra. This vertebral artery is considered to derive from the remnant of the fifth intersegmental artery, most of which usually disappear [14]. The dorsal aorta forms a part of the brachiocephalic artery between the origins of the right subclavian artery and the right common carotid artery.

**CONCLUSION**

We report a rare case of right duplicated vertebral arteries. One of the duplicate right vertebral arteries in the present case arose from the brachiocephalic artery and was thought to be a remnant of the intersegmental artery, which usually disappears. This case was unusual because in most previous reports of right duplicated vertebral arteries, the two right vertebral arteries arose from the right subclavian artery. Moreover, in previous cases the diameter at the proximal origin tended to be larger than that at the distal origin, but the distal diameter was larger in this case.

**ACKNOWLEDGMENTS:** The authors wish to thank the individuals who consented to donate their bodies and tissues for the advancement of education and research.

**REFERENCES**

1. Hirasawa K, Okamoto M. Kaibougaku (Anatomy) Vol.2. Kanehara Shuppan, Tokyo, pp43-44, 1982. (in Japanese)
2. Satou T, Akita K. Nihonjinn no Karada: Kaibougakuteki
3. Yamaki K, Saga T, Hirata T, Sakaino M, Nohno M, et al. Anatomical study of the vertebral artery in Japanese adults. Anat Sci Int 2006; 81:100-106.
4. Komiyama M, Morikawa T, Nakajima H, Nishikawa M, and Yasui T. High incidence of arterial dissection associated with left vertebral artery of aortic origin. Neurol Med Chir 2001; 41:8-12.
5. Komiyama M, Nakajima H, Yamanaka K, and Iwai Y. Dual origin of the Vertebral Artery-Case Report-. Neurol Med Chir 1999; 39:932-937.
6. Watanabe K, Saga T, Tabira Y and Yamaki K. A rare case of dual origin of the left vertebral artery without convergence. Folia Morphol 2016; 75:136-142.
7. Mahmutyazicioğlu K, Sarac K, Bölük A and Kutlu R. Duplicate origin of left vertebral artery with thrombosis at the origin: color Doppler sonography and CT angiography findings. J Clin Ultrasound 1998; 26:323-325.
8. Goddard AJP, Annesley-Williams D, Guthrie JA and Weston M. Duplication of the vertebral artery: report of two cases and review of the literature. Neuroradiology 2001; 43:477-480.
9. Koenigsberg RA, Pereira L, Nair B, McCormick D, and Schwartzman R. Unusual Vertebral Artery Origins: Examples and Related Pathology. Catheter Cardiovasc Interv 2003; 59:244-250.
10. Satti SR, Cerniglia CA and Koenigsberg RA. Cervical Vertebral Artery Variations: An Anatomic Study. AJNR Am J Neuroradiol 2007; 28:976-980.
11. Harnier S, Harzheim A, Limroth V, Horz R and Kuhn J. Duplication of the common carotid artery and the ipsilateral vertebral artery with a fenestration of the contralateral common carotid artery. Neurology India 2008; 56:491-493.
12. Kendi ATK and Brace JR. Vertebral artery duplication and aneurysms: 64-slice multidetector CT findings. Br J Radiol 2009; 82:e216-e218.
13. Melki E, Nasser G, Vandendries C, Adams D, Ducreux D, et al. Congenital vertebral duplication: A predisposing risk factor for dissection. J Neurol Sci 2012; 314:161-162.
14. Meila D, Tysiac M, Petersen M, Theisen O, Wetter A, et al. Origin and course of the extracranial vertebral artery: CTA findings and embryologic considerations. Clin Neuroradiol 2012; 22:327-333.
15. Uchino A, Saito N, Takahashi M, Okada Y, Kozawa E, et al. Variations in the origin of the vertebral artery and its level of entry into the transverse foramen diagnosed by CT angiography. Neuroradiology 2013; 55:585-594.
16. Shin SW, Park DW, Park CK, Lee YJ, and Lee SR. Duplication of the Left Vertebral Artery Origin: A Case Report. J Korean Soc Radiol 2013; 68(1):1-4.
17. Jung S, Jung C, Bae YJ, Choi BS and Kim JH. Duplicated Origin of the Left Vertebral Artery: A Case Report and Embryological Review. Neurointervention 2016; 11:50-54.
18. Baik J, Baek HJ, Shin HS and Choi KH. Duplication of the right vertebral artery: MRA findings and review of the literature. Springerplus 2016; 5:1123.
19. Rameshbabu CS, Gupta OMP, Gupta KK, and Qasim M. Bilateral asymmetrical duplicated origin of vertebral arteries: Multidetector row CT angiographic study. Indian J Radiol Imaging 2014; 24:61-65.
20. Moore KL and Persaud TVN. The Developing Human: Clinically Oriented Embryology (ed4). Saunders, Philadelphia, pp179-184, 1988.
21. Arey LB and Gray CE. Developmental anatomy. WB Saunders co, Philadelphia and London, pp350-360, 1935.