Anatomical Variations of the V_2 Vertebral Artery Study by Measuring the Width of Transverse Foramen

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Objective: *To evaluate the incidence of anatomical variations of the V_2 segment of the vertebral artery (VA) using dry bones.*
Material and Method: *The sample group was 181 cervical spines (equal 362 courses of VA), male 111 and female 70, average age 68 years old (range 26 to 95 years). The width of transverse foramens (TF) was visually inspected, starting at C7, looking upward to find the greatest width of TF meaning the beginning of V_2. Then, measurements were taken of the TF width (AP, ML) followed by measurements of those of one level below and above.*
Results: *The VA entered the C6 TF in 89.0% (322 out of 362 courses). The variations level of entrance was observed in 11.0% of specimens (40 courses), with the level of C4, C5, and C7 TF in 1.1% (4 courses), 4.4% (16 courses), and 5.5% (20 courses), respectively. Nineteen out of 40 VA (47.5%) of variations were on the left side and twenty-one (52.5%) were on the right side. Twenty-three out of 40 VA (57.5%) of variations were men and seventeen (42.5%) were women. The areas of TF filled with VA were significantly larger than before and after the entrance level ($p < 0.0001$).*
Conclusion: *Anatomical variations of the V_2 segment of the VA do exist at C4, C5, and C7. The awareness of this abnormality may reduce the risk of catastrophic intraoperative VA injury.*

Keywords: *Vertebral artery, V_2 segment of the VA, Anterior decompression of spinal cord*

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The vertebral artery (VA) is classically divided into four segments. The first segment (V_1) passes from the subclavian artery to the C6 transverse foramen (TF), the second (V_2) from C6 to C2 TF, the third (V_3) from C2 to foramen magnum and the fourth (V_4) from the foramen magnum and penetrates the dura mater. The left and right vertebral join together to become the basilar artery supplying the hindbrain[1-4]. The mean size of normal TF filled with VA was 24.2 mm^2, the mean size of unfilled C7 foramen was 10.3 mm^2, and unfilled TF above C7 was 9.0 mm^2. TF filled with VA were significantly larger than unfilled foramen $p < 0.01$, but there was no significant difference between the area of C7 unfilled foramen and the area of unfilled foramen above C7 $p = 0.260$[5]. The same as others studied the area of TF unfilled C7 was 15.79 mm^2, and the filled foramen level above was 28.92 mm^2[6], and the area of unfilled was significantly smaller than the contralateral filled foramen $p < 0.0001$[1]. Usually, the VA enters the TF at the C6 level but in about 10% of cases there is abnormality where the VA enters at other levels such as C4, C5, and C7[1,5,7]. Anterior decompression of the cervical spine is becoming increasingly popular for the treatment of cervical nerve root or spinal cord compression. Vertebral artery (VA) injury can be a catastrophic iatrogenic complication of cervical spine surgery. It can be prevented by careful review of preoperative imaging studies, having a sound anatomical knowledge and paying attention to surgical landmarks intraoperatively. When VA injury occurs, prompt recognition and management are important[8]. There is a case report of a 47-year-old man who had surgery for ossification of posterior longitudinal ligament (OPLL). During removal of the OPLL, the patient's right VA was injured. Although the bleeding was controlled intraoperatively, the patient developed an expanding cervical hematoma until the third postoperative day[9]. Another case study of a 59-year-old woman also had an intraoperative injury of the left VA during elective anterior cervical discectomy and fusion from C3 to 7[10]. The incidence

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of vertebral artery injury during cervical spine surgery was 0.3% to 0.5%[11,12]. The authors suggest to be careful about the variations of VA in the open space causing uncontrollable bleeding. Unfortunately, there are no reports of V_2 variations in Thailand and so the purpose of the present study was to describe the variation of V_2 segments of the vertebral artery and how they differ from others reported.

Material and Method

One hundred eighty one cervical spines of dry bone (362 courses of VA) were obtained from the Department of Anatomy, Chiang Mai University. In all known cases, the mean age of the individuals at the time of death was 68 years (range 26 to 95 years); there were 111 males and 70 females. The criterion used was the area of transverse foramen filled with VA was significantly larger than unfilled foramen[1,5,6]. The authors visually inspected both sides of TF, starting at C7, looking upward to find the greatest width of transverse foramen. Then measurements were taken of the TF width (anteroposterior, mediolateral) followed by measurements of those of one level below and one above. Statistical descriptive analysis and comparison means of the width of transverse foramen by Paired-Sample t-test were performed, $p < 0.01$ was considered significant. The present study has passed the ethic committee of the faculty of medicine.

Results

The VA entered the C6 TF in 89.0% (322 out of 362 courses), Fig. 1. The variations level of entrance was observed in 11.0% of specimens (40 courses), with the level of the entrance into the C4, C5 (Fig. 2, 3), and C7 (Fig. 4) TF respectively, in 1.1% (4 courses), 4.4% (16 courses), and 5.5% (20 courses). Nineteen (47.5%) variations were on the left side and twenty-one (52.5%) were on the right side. One hundred fifty seven out of one hundred eight one cervical spines (87%) had entered a bilateral and twenty-four cervical spines (13%) had a unilateral entry. Twenty-three VA (57.5%) variations level of entry were men and seventeen (42.5%) were women.

The mean width of C6 TF that VA entered bilaterally was selected to be compared with those of C7 (unfilled) and C5 (after the VA entered). The mean AP and ML width of TF of C6 were significantly larger than C5 and C7 $p < 0.0001$) (Table 1, Fig. 1).

Discussion

The variations of V_2 segments of VA have been reported in the literature[1,5,7] the study designs used different types of specimens and methods (Table 2). The report by Bruneau[1] studied the incidence of anatomic variations of the V_2 segment in 250 patients (500 course of VA) on 200 magnetic resonance imaging and fifty contrast-enchanced computed tomographic scans. The results showed the VA entered the C6 TF in 93.0% of specimens (465 out of 500 courses). An abnormal level of entrance was

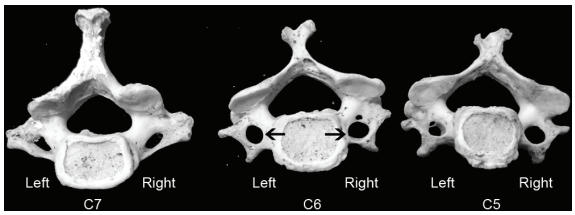

Fig. 1 The TF of V_2 entered normally at C6 on the right and left (black arrow)

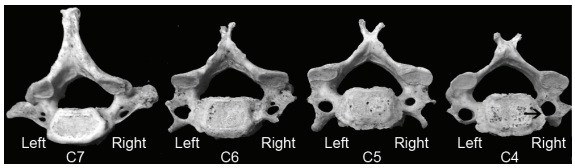

Fig. 2 The TF of V_2 entered abnormally at C4 on the right (black arrow)

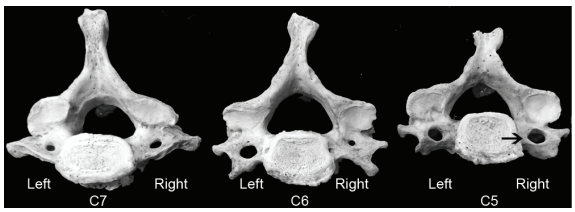

Fig. 3 The TF of V_2 entered abnormally at C5 on the right (black arrow)

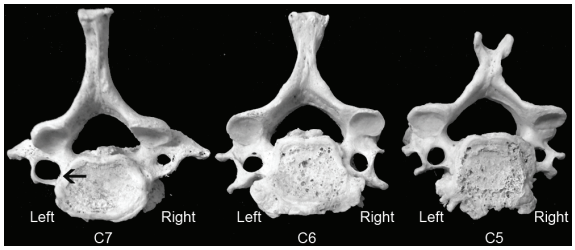

Fig. 4 The TF of V_2 entered abnormally at C7 on the left (black arrow)

7.0% of specimens (35 courses) in C3, C4, C5, and C7 were 0.2% (one course), 1.0% (five courses), 5% (twenty-five courses), and 0.8% (four courses), respectively. Thirty-one patients out of 250 (12.4%) had a unilateral entrance. Twenty-two patients (66.7%) of variations entrance were women and eleven (33.3%) were men. The area of the unfilled TF was significantly smaller than filled foramen ($p < 0.0001$).

The report by Civelek[7] studied the anatomical variations and landmarks to the surgical procedure during the anterolateral approach to the cervical spine from thirty fresh cadavers. The VA entered the TF of C6 in twenty-seven cadavers (90%). An abnormal level of entrance was found in 10.0% of specimens (three cadavers) in C4 and C7 were 3% (one cadaver) and 7.0% (two cadavers), respectively.

The report by Hong[5] studied the anatomical variations of the VA in the lower cervical spine of 350 patients by CT angiography analysis. The VA entered the TF of C6 in 94.9% of the specimens (664 out of 700 courses). An abnormal VA entrance was seen in 5.1% of the specimens (36 courses), with entrance in to the TF of C4, C5, and C7 (1.6%, 3.3%, and 0.3%), respectively.

The previous studies[1,5,7] reported the VA entered normally at C6 range 90 to 94.9%, an abnormally entered at C3, C4, C5, and C7 with range 5.1 to 10%. The present study normal entrance was 89% at C6, which closely matches the study of Civelek[7]. The abnormally entered was 11% at C7, C5, and C4 (5.5%, 4.4%, and 1.1%), respectively, which was similar to his study but had few specimens (Table 2). The unilateral entry of VA in the present study was 13% similar to the study of Bruneau[1], which was 12.4%. From Table 2, the authors concluded that the variations are 5 to 10%. The mean AP and ML width of TF of filled in the present study were significantly larger than unfilled ($p < 0.0001$), which concurs with previous studies[1,5,6].

The vertebral artery was formed in the third to the fourth week[13-15] whereas the transverse foramina were formed in infancy and very young children[16]. The cause of the variation might be too early filling in of bone (or cartilage) in the lower transverse processes. These impede the entrance of the artery. The artery then has to penetrate in a higher level. The other possibility is that the vertebral artery is taking a course too far ventrally so it could not be included in the transverse foramina. With these findings of vertebral artery abnormal courses, the authors think they are clinically relevant because many surgical interventions are being carried out in this anatomical area.

Table 1. The results of mean $\pm$ SD (mm) of the width of transverse foramen of C6 (the first entered) compared with C5 and C7 (significant at 0.01 level)

Width	Level	Mean $\pm$ SD	t	Sig. (2 tailed)
AP	C5	5.51 $\pm$ 0.531	11.458	0.000
	C6	6.17 $\pm$ 0.723		
	C7	3.64 $\pm$ 0.892	31.694	0.000
ML	C5	5.95 $\pm$ 0.548	9.062	0.000
	C6	6.42 $\pm$ 0.637		
	C7	4.35 $\pm$ 1.089	22.420	0.000
Average	C5	5.73 $\pm$ 0.458	13.761	0.000
	C6	6.30 $\pm$ 0.587		
	C7	3.99 $\pm$ 0.931	30.313	0.000

Conclusion

The studies of the anatomical variations of the V_2 segment of VA are important to avoid VA injury

Table 2. The prevalence of the variations of V_2 in the previous studies and the present study

Authors	Material	Method	Prevalence (%)					Variations (%)
			C3	C4	C5	C6	C7	
Bruneau[1] (2006) France	Patients 250 cases (500VA)	MRI 200 cases, CT scan 50 cases	0.2	1.0	5.0	93.0	0.8	7.0
Civelek[7] (2007) Turky	Fresh cadavers 27 cadavers (60VA)	Dissections	-	3.0	-	90.0	7.0	10.0
Hong[5] (2008) Korea	Patients 350 cases (700VA)	CT scan	-	1.6	3.3	94.9	0.3	5.1
Present study (2011) Thailand	Dry bones 181 cervical columns (362VA)	Observation, measurements TF	-	1.1	4.4	89.0	5.5	11.0

during surgery of cervical approach. If the VA is entering above C6, the pre-entry course may be at risk of injury. The understanding of the anatomical variations of the V_2 segment will help to protect against complications after cervical spine surgery.

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Potential conflicts of interest

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กายวิภาคศาสตร์ความแปรปรวนของหลอดเลือด vertebral artery ส่วนที่ 2ศึกษาจากการวัดขนาดความกว้างของ transverse foramen

พัชรินทร์ ชนะพาห์, ผาสุก มหรรฆานุเคราะห์

วัตถุประสงค์: *เพื่อศึกษาความแปรปรวน ของหลอดเลือด vertebral artery ส่วน V_2*

วัสดุและวิธีการ: *ศึกษาโครงกระดูกต้นคอชนิดแห้งจำนวน 181 โครงร่าง (หมายถึงหลอดเลือด VA จำนวน 362 เส้น) เป็นเพศชายจำนวน 111 โครงร่าง และเพศหญิงจำนวน 70 โครงร่าง อายุเฉลี่ย 68 ปี (26-95 ปี) สังเกตขนาดความกว้างของ TF โดยเริ่มที่ C7 เพื่อหาขนาดของ TF ระดับที่มีขนาดกว้างที่สุดนั่นหมายถึงจุดเริ่มต้นของ V_2 แล้ววัดขนาดด้าน anteroposterior (AP) และด้าน mediolateral (ML) ที่ระดับนั้นและทำการวัดขนาดของ TF ในระดับที่อยู่บนและล่างต่อระดับนั้นอีก จำนวน 1 ระดับ*

ผลการศึกษา: *ระดับของ TF ที่หลอดเลือด VA ส่วน V_2 เริ่มเข้าไป คือระดับ C6 ร้อยละ 89.0 (322 ของ VA จาก 362) และที่ระดับอื่น ๆ ที่มีความแปรปรวน ร้อยละ11(40 VA) โดยเข้าที่ระดับ C4 ระดับ C5 และระดับ C7 ร้อยละ 1.1 (4 VA), 4.4 (16 VA) และ 5.5 (20 VA) ตามลำดับในจำนวนหลอดเลือด VA 19 เส้นจาก 40 (ร้อยละ 47.5) ของความแปรปรวนพบเข้า TF ที่ด้านซ้าย และจำนวน 21 เส้น (ร้อยละ 52.5) เข้าที่ด้านขวา จำนวนหลอดเลือด VA 23 เส้นจาก 40 (ร้อยละ 57.5) ของความผิดปกติ พบในเพศชาย และจำนวน 17 เส้น (ร้อยละ 42.5) ในเพศหญิง ขนาดความกว้างของ TF ที่หลอดเลือดส่วน V_2 เริ่มเข้าไปมีขนาดกว้างกว่าระดับที่หลอดเลือดยังไม่ผ่านเข้าไป และระดับหลังจากที่หลอดเลือดผ่านเข้าไปแล้วอย่างมีนัยสำคัญทางสถิติ ($p < 0.0001$)*

สรุป: *ความรู้ที่ได้จากการศึกษาความแปรปรวนของหลอดเลือด VA ส่วน V_2 นี้ จะช่วยลดความเสี่ยงต่อการเกิดอันตรายกับหลอดเลือดขณะผ่าตัดกระดูกต้นคอได้*