Longus Colli and Vertebral Artery Guide Safety of Cervical Spine Surgery

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ABSTRACT

Objective: To improve the safety of the anterior cervical vertebral surgical approach, MRI and CT have been used and the distances between the medial borders of the longus colli (LC) to expose the uncinated process (UP) have been reported. The anatomic parameters of the LC and vertebral artery (VA) were considered here in relation to the UP to minimize complications.

Materials and Methods: Data were obtained from 60 Thai adult skeletons and 20 embalmed cadavers. Direct measurements of the dry cervical vertebrae were performed using digital Vernier calipers, while computer imaging analysis was used for the cadaveric measurements after capturing the images.

Results: No significant difference was noted in the inter-UP distance between the dry and cadaveric cervical measurements. The average UP width was 6.7 ± 0.2 mm. The average distance from the tip of the UP to the VA was 2.6 ± 0.1 mm. The calculated distance from the LC to the UP which derived from the inter-UP distance and the distance between the LC increased from C2 to C7 with an average distance of 11.9 ± 0.3 mm.

Conclusion: Within a distance of 11.9 ± 0.3 mm from the medial border of the LC, UP can be identified. Dissecting at a distance less than 10 mm posterior, 5–6 mm lateral and superior to the base of the UP can avoid VA injury and optimize the safety of the anterior cervical vertebral surgical approach.

Keywords: Cervical vertebra; uncinate process; anterior cervical surgery; vertebral artery (Siriraj Med J 2022; 74: 502-508)

INTRODUCTION

The anterior surgical approach of the cervical vertebrae is commonly used as the surgical procedure for cervical vertebral pathologies, including disc herniation, cervical spondylotic myelopathy, tumor, and infection. Several potential risks of injury after these surgeries have been reported. One of them is Horner's syndrome, which is related to cervical sympathetic trunk (CST) injury and has been reported to have an incidence of between 0.2%–4%.[1,2] The vertebral artery (VA) injury associated with cervical spine surgery has also been reported, and although it has shown a rare incidence (0.3% to 0.5%), it carries a threat of fistulas, pseudo-aneurysm, cerebral ischemia, and even death.[3-5] Neural foramen decompression during anterior cervical discectomy has been used to relieve pressure upon the affected nerve root. In this procedure, the medial border of the longus colli muscle (LC) has been suggested as a landmark for lateral dissection to

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the medial portion of the uncinate process (UP) at the uncovertebral joint and as a guided safe area of the bone, which in most patients should have been removed.[6,7] In addition, it should be done carefully to avoid injury to the CST as well as to the VA. Therefore, this study aimed to clearly delineate the surgical anatomy of the LC and its related structures (VA and UP) to aid developing safer surgery for minimizing the potential risks.

MATERIALS AND METHODS

The morphometric evaluation with known genders and ages according to the personal records of body donors was approved by the Siriraj institutional Review Board (SIRB), protocol no. 629/2556 (Exempt). In total, 300 dry cervical spines (C3–C7) of 60 Thai adult skeletons (age range 19–83 years old; mean age 43.9 years old in 38 males and 42.4 years old in 22 females), and 20 formalin-fixed cadavers (age range 50–93 years old; mean age 68.4 years old in 10 males and 68.2 years old in 10 females) were obtained from Department of Anatomy.

Fig 1 shows the dry bone measurements performed on the UP of the cervical vertebrae, including the inter-UP distance (a), between the tip of the right and left UP, the anteroposterior (AP) distance of the UP (b), along the medial side of the UP and the width of the UP (c), at the base of the UP. For the cadaveric measurements, cadavers with a history of neck trauma and cervical vertebral operation were excluded. Along the anterior border of the sternocleidomastoid muscle (SCM), the superficial layer of cervical fascia was opened to expose the anterior view of the cervical vertebrae. The SCM was moved laterally. The coverage fat and fascia were cleaned to expose the LC and the VA as shown in Fig 2A. The cervical vertebrae and intervertebral spaces from C2 to C7 were exposed. The levels of the vertebrae were checked from the superior part by counting the disc space levels. The distance between the medial borders of the LC (m) measured at each disc space level and also its height at midline (n) were also measured. In Fig 2B, dissection of the transverse process to clearly expose the UP of each cervical vertebra and the VA at the C2–C3, C3–C4, C4–C5, C5–C6, and C6–C7 levels was performed after removing the LC. The drawing in Fig 2C shows the positions of the three measurements: the inter-UP distance (a), distance between the LC (m), and the distance between the tip of the UP and the medial wall of the VA (p). The calculation for the distance between the medial border of the LC and the tip of the UP (o) was calculated from this equation (o = a/2–m/2).

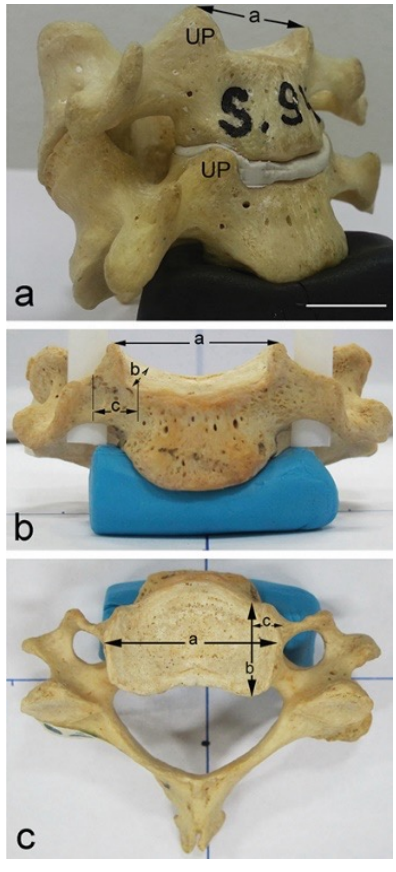

Fig 1. Cervical vertebra showing the anterolateral view (1a), anterior view (1b), and superior view (1c) , indicating the measurements, a, b, and c of the uncinate process (UP).
Scale bar is 1 cm. a, inter-UP distance; b, AP distance of the UP; c, width of the UP.

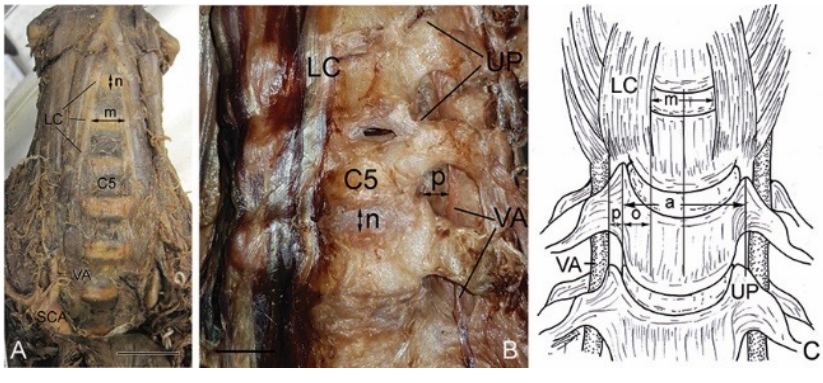

Fig 2. The anterior views of the longus colli (LC) muscles showing the measurements,: 2A) the representative cadaveric specimens along the side of the cervical spines (C5) and the vertebral artery (VA) originating from the subclavian artery (SCA); 2B) the representative cadaveric specimens after removing the LC with a clearer uncinate process of the cervical spines and VA; 2C) drawing indicating more of the measurements.
Scale bar is 2 cm (in 2A and 2B), Abbreviation: m, distance between the LCs; n, height of the intervertebral space; a, inter-UP distance; p, distance between the tip of the UP and the VA; o, distance between the medial border of the LC and the tip of the UP.

To minimizing the errors inherent in this morphometric study, all the measurements were performed using a digital Vernier caliper accurate to 0.1 mm and taken three times by a single person. In addition, they were repeated by computer image analysis with ImageJ 1.52v (National Institutes of Health, USA, http://imagej.nih.gov/ij) after capturing images of the anterior view of the cadaveric cervical vertebrae. As shown in Fig 3, each measurement of the captured image with its scale was analyzed as the "Length" by drawing with the straight line tool, such as the distance between the medial borders of the LC muscles (m). In the ImageJ program, "Analyze and Set Scale" was used for calibration (white arrow in the inset picture), and then "Analyze and Measure" was performed and the result is shown in the result table as the "Length". The repeated length measurements in the table were transferred to Excel for statistical analysis.

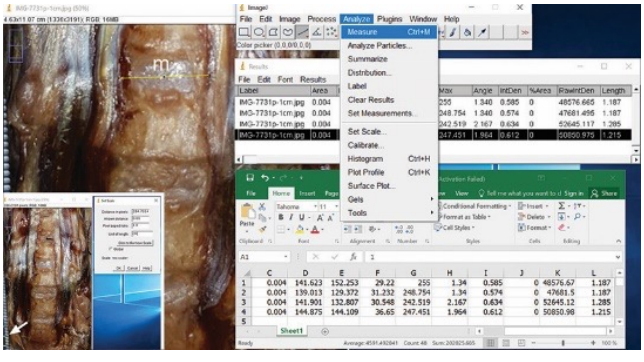

Fig 3. ImageJ 1.52 v was utilized to analyze the distance between the LCs (m). Each measurement of the captured image with scale was analyzed as the "Length" by drawing with the straight line tool, also using "Analyze and Set Scale" for setting the calibration (white arrow in the inlet picture), and then "Analyze and Measure" to show the length in the results table, which were then transferred to the Excel program for the statistical analysis.

Statistical analysis

The average of three observations was used for statistical evaluation with the SPSS software, version 18.0 for Windows (SPSS Inc., Chicago, IL, USA). Differences in the various parameters between age groups and vertebral levels were analyzed statistically using a single factor analysis of variance (ANOVA), while differences between the two sides and the genders were analyzed with the Student's t-test, and considered statistically significant at $p < 0.05$.

RESULTS

Morphometric measurements of dry cervical vertebrae

Dry cervical vertebrae (C3–C7) were studied in a total of 60 Thai adult skeletons, comprising 38 male (63.3%) and 22 female (36.7%) specimens with a mean age of 43.56 ± 16.8 years old (range, 19 to 83 years old). All the symmetrical structures were measured bilaterally and the results are shown in Table 1. Average measurements relative to the UP were compared between genders, sides, and among age ranges. All the parameters of UP in the males were greater than in the females, with significance at $p < 0.05$. In addition, all the parameters of UP in both younger groups were less than in the older group significantly at $p < 0.05$. In Table 2, comparison of the measurements among the levels of the cervical vertebra showed significant increases when compared to C3, at $p < 0.05$. The average AP distance of the UP was 12.1 ± 0.2 mm and became widened from C3 (11.5 ± 0.2 mm) to C6 (12.5 ± 0.3 mm) but shorter at C7. Moreover, the average inter-UP distance of 27.9 ± 0.3 mm was also widened from C3 (24.39 ± 0.3 mm) to C7 (31.9 ± 0.5 mm), whereas the average width of UP of 6.5 ± 0.1 mm was shorter from C3 (6.7 mm) to C7 (6.3 mm), both in males (6.7 ± 0.2 mm) and in females (6.2 ± 0.1 mm).

TABLE 1. Average measurements of dry cervical vertebrae expressed as the mean ± SEM compared between genders, sides, and among age ranges.

Parameters (mm)	Gender		Side		Age range (years)		
	male	female	right	left	18–40	41–60	61–85
Inter-UP distance	28.7±0.5	26.7±0.4*	27.9±0.4	27.1±0.3[a]	27.4±0.3[a]	31.1±0.7	
AP distance of UP	12.7±0.2	11.0±0.2*	11.9±0.2	12.1±0.2	11.4±0.1[a]	11.6±0.2[a]	14.6±0.3
Width of UP	6.7±0.2	6.2±0.1*	6.5±0.2	6.5±0.1	6.3±0.1[a]	6.2±0.1[a]	7.8±0.2

*significant difference ($p < 0.05$) comparing gender.

[a] significant difference ($p < 0.05$) compared with the age range 61–85 years old.

TABLE 2. Comparison of measurements among levels (C3–C7) in dry cervical vertebrae and in the anterior view of cadaveric cervical vertebrae, expressed as the mean ± SEM. Abbreviations (a, b, c, m, n, o, and p) are shown in Figs 1–2.

Parameter (mm)	Level of the cervical vertebra					Average distance
Dry bone measurements	**C3**	**C4**	**C5**	**C6**	**C7**	
Inter-UP distance (a)	24.39±0.3	26.6±0.4	27.3±0.4	29.4±0.6*	31.9±0.5*	27.9±0.3
AP distance of UP (b)	11.5±0.2	12.1±0.2	12.2±0.2	12.5±0.3*	11.9±0.2	12.1±0.1
Width of UP (c)	6.7±0.1	6.6±0.1	6.5±0.1	6.4±0.2	6.3±0.1	6.5±0.1
Cadaveric measurements	**C2–C3 (C3)**	**C3–C4 (C4)**	**C4–C5 (C5)**	**C5–C6 (C6)**	**C6–C7 (C7)**	
Inter-UP distance (a)	21.4±1.0	23.2±1.0	24.3±1.1*	26.8±1.1*	30.9±1.3*	25.5±0.5
Distance between LCs (m)	9.4±0.3	13.4±0.3[a]	15.7±0.3[a]	15.9±0.3[a]	15.3±0.2[a]	13.9±0.4
Height of intervertebral space (n)	5.5±0.3	6.3±0.3	6.4±0.3[a]	6.3±0.3	6.0±0.3	6.1±0.1
UP to VA (p)	3.4±0.2	2.6±0.3*	2.4±0.2*	2.3±0.2*	2.2±0.2*	2.6±0.1
LC to UP (calculated by a/2 – m/2 = o)	10.3±0.5	10.9±0.5	11.3±0.5	12.6±0.6*	14.3±0.7*	11.9±0.3

*significant difference ($p < 0.05$) compared with the level at C3.
[a] significant difference ($p < 0.05$) compared with the distance at the space between C2–C3

Morphometric measurements of the anterior view of the cadaveric cervical vertebrae

Anterior views of the cervical vertebrae of 20 cadavers with an average age of 68.3 years old (ranging from 50 to 93 years old) were studied. Two vertical arrangements of LC lying along the anterolateral aspect of the cervical vertebrae and anterior cervical discs are shown in Fig 2A.

Table 2 presents a comparison of the measurements among the cervical vertebral levels (C2–C3 to C6–C7). The distances between the medial border of the right and left LC increased from C2 (9.4 ± 0.3 mm) to C6 (15.9 ± 0.3 mm) and decreased at C7 (15.3 ± 0.2 mm) significantly when compared to C2, at $p < 0.05$. In addition, comparisons between the genders and age range groups were also performed. The average distance between LCs was 12.5 ± 0.5 mm (13.1 ± 0.5 mm in males and 11.9 ± 0.5 mm in females; 13.4 ± 0.5 mm in the 50–60 year olds and 12.1 ± 0.5 mm in the 61–93 year olds). The height of the intervertebral space was significantly greater at C4–C5 when compared to C2–C3. The average height was 6.1 ± 0.1 mm (6.4 ± 0.1 mm in males, 5.8 ± 0.1 mm in females; 6.0 ± 0.1 mm in 50–60 year olds and 6.1± 0.1 mm in 61–93 year olds). The average distance between the LCs and the height of the intervertebral space showed no significant differences between genders and among the age ranges at $p < 0.05$.

After the LCs were removed, the inter-UP distance and the distance from the tip of the UP to the VA were measured and the results are presented in Table 2. The average inter-UP distance in the cadaveric study of 25.5 ± 0.5 mm was also widened from C3 (21.4 ± 1.0 mm) to C7 (30.9 ± 1.3 mm). The distance from the tip of the UP to the VA was measured bilaterally and showed no significant difference between genders (average 2.6 ± 0.1 mm; 2.4 ± 0.1 mm in males, 2.5 ± 0.1 mm in females), but a significant difference was found between the sides (2.6 ± 0.1 mm in the right side, 2.3 ± 0.1 mm in the left side), and age ranges (2.8 ± 0.1 mm in 50–60 year olds, 2.3± 0.1 mm in 61–93 year olds) at $p < 0.05$. Therefore, the tip of the UP was closer to the VA in the left side, and in the older specimens with an age over 60 years old. In the comparisons among the vertebral levels in Table 2, the tip of the UP was closer to the VA at C4 (2.6 ± 0.3 mm) to C7 (2.2 ± 0.2 mm) with significance at $p < 0.05$ when compared to C3 (3.4 ± 0.2 mm). The calculated

distance from the LC to the UP (indicated by "o" in Fig 2C) increased from C2 (10.25 ± 0.5 mm) to C7 (14.3 ± 0.6 mm) with an average distance of 11.9 ± 0.3 mm.

Table 3 presents a comparison of the inter-UP distance among each cervical vertebra (C3–C7) in the dry bones (average 27.9 ± 0.3) and cadaveric materials (average, 25.5 ± 0.5). There was no significant difference in each cervical vertebra between the dry bones and cadaveric materials at $p < 0.05$ as indicated with the *P* values. In addition, in Table 3, the inter-UP distance was also considered and compared to the reported results in previous studies.[5-9]

TABLE 3. Inter-UP distance of each cervical vertebra (C3–C7) expressed as the mean ± SEM, showing no significant difference between dry bones and cadaveric specimens at $p < 0.05$. Comparison of the inter-UP distance to other studies with different races and different studied materials.

Parameter (mm)	Level of the cervical vertebra					Average distance	Materials
	C3	C4	C5	C6	C7		
In this study							
Bone inter-UP distance	24.39±0.3	26.6±0.4	27.3±0.4	29.4±0.6*	31.9±0.5*	27.9±0.3	Dry bones (60 adults, M=38, F=22)
Cadaveric inter-UP distance	21.4±1.0	23.7±1.0	24.3±1.1*	26.8±1.1*	30.9±1.3*	25.5±0.5	Cadaveric study (20 adults, M=10, F=10)
P value**	0.108	0.062	0.078	0.996	0.777		
Inter-UP distance from other studies	**C3**	**C4**	**C5**	**C6**	**C7**		**Materials**
Lu et al. (1998)	19.4±1.3	20.5±1.8	21.4±1.7	23.4±1.9	25.2±2.0		Dry bones (54 adults)
Ebraheim et al. (1998)	19.4±1.3	20.5±1.8	21.4±1.7	23.4±1.9	25.2±2.0		Dry bones: (M=31)
	18.9±1.7	20.5±1.0	20.9±1.5	22.6±1.8	23.7±1.9		Dry bones: (F=23)
Park et al. (2016)	-	16.4±0.8	17.4±2.0	18.1±2.3	17.8±2.7		MRI and CT (n=120)
Guvencer et al. (2006)	23.7±3.2	24.0±3.1	25.5±3.0	28.3±4.5	-		Cadaveric radiographic study (n=12)
Guvencer et al. (2016)	23.7±3.4	24.0±3.3	25.4±3.7	27.0±3.4	29.0±3.0		CT study (M=13)
Guvencer et al. (2016)	20.8±1.0	21.9±1.7	23.7±2.0	25.5±2.3	28.1±2.4		Cardaveric study (M=13)

Abbreviations: M; male, F; female, n; number.

*significant difference ($p < 0.05$) compared with the level at C3.

** *P* value when comparing the inter-UP distance between bones and cadaveric determination.

DISCUSSION

The anterior cervical vertebral approach for decompression is widely used for many pathologies. The anatomical relationships between the LC and VA have been widely studied and marked as a safety guide to reduce the risk of complications during surgery, particularly VA injury. The anterior approach for the distracted disc space and for bone removal at the cervical vertebrae has been considered, using the UP as an important landmark.[10] The UP is located in the superior surface of the cervical vertebral body, except for C1 and C2, and also on the first thoracic vertebra.[11] In addition, the anatomical relationship between the LC and the UP is also beneficial for performing a thorough decompression of the intervertebral foramen in cases of arthroplasty. Recently, preoperative magnetic resonance imaging (MRI) and computed tomography (CT) scans have been recommended to help guide a safe dissection for Koreans by mobilizing the LC laterally 5 mm at C3–5, 6 mm at C5–6, 7 mm at C6–7, and 8 mm at C7–T1 to fully expose the UP.[5] However, these lengths may be different in other races, and there are no reports yet on the recommended lengths for Thai patients. A previous study by Raykateeraroj et al.[12] reported a greater anteroposterior (AP) distance of UP in males than in females with significance in dry cervical vertebrae. That study also reported the inter-UP distance and the width of UP. The average inter-UP distance was performed in both dry (27.9 ± 0.3 mm) and cadaveric cervical vertebrae (25.5 ± 0.5 mm) and showed no significant difference; therefore suggesting other related measurements from dry bones and cadaveric materials could be used for the calculation and might be approximately reported as a safe guideline for anterior cervical surgery in Thai patients. For each side of measurements, the distance from the medial border of the LC to the tip of the UP was calculated and the mean value was 11.9 mm and ranged from C3 (10.3 ± 0.5 mm) to C7 (14.3 ± 0.7 mm). This study includes data for both Thai dry bones and cadaveric materials with the higher numbers and race-dependent measurements presented as a guiding distance for surgery, as shown in Table 3.

In the calculation, the inter-UP distance (a) and the distance between the LC (m) was multiplied by 1/2 at each vertebral level. To locate the medial border of the left and right LC of the atlas to the bodies of the C3 to T3 vertebrae, it was assumed it was also attached to the transverse processes of the C3 to C6 vertebrae. Dissection of the LC beyond the transverse process to expose the UP was performed from the midline equally and in the same manner with the bilateral UPs. This distance was calculated because the LC had already been mobilized to fully approach and easily identify the UP during surgery. For the LC, it was necessary to identify the longest and most medial part of the prevertebral muscle during uncinectomy. Even though, using MRI and CT scans, Park et al.[5] reported that in right-handed patients, the distance from the medial border of the right LC that should be dissected laterally to expose the UP was larger than in the left side, no difference was reported in the distance to locate the bilateral UP.

In addition, the inter-UP distance showed a gradual increase from the C3 to C7 levels. Therefore, the use of fixed values for anterior decompression from the C3 to C7 levels may not be appropriate and may lead to inadequate decompression at the lower levels. In this study, to fully expose the tip of the UP, the LC had to be dissected laterally 10.3 ± 0.5 mm at C3, 10.9 ± 0.5 mm at C4, 11.3 ± 0.5 mm at C5, 12.6 ± 0.6 mm at C6, and 14.3 ± 0.7 mm at C7.

According to the reviews results in other studies and as shown in Table 3, the inter-UP distance (an important value for calculating the distance from the LC to the UP) was also compared among C3 to C7, and in different studied materials and different races. Our study showed no significant difference in the inter-UP distance between dry bones and cadaveric materials. Reports of the inter-UP distance of the cervical vertebrae of Thai, Turkish, and American people also showed quite similar values in the cadavers, radiographs[7], CT scans[8], and dry bones[6,9], which were all longer distances than in the MRI/CT findings of Park et al.[5] Therefore, the safety guidance for the anterior cervical vertebral surgical approach should be based on race. In addition, reports from cadavers and dry bones should be considered along with the MRI/CT findings before surgery and vice versa. MRI/CT of individual case would be more reliable and accurate to that specific person, while dry bone measurement my help clarify certain questions from CT/MRI.

Kim et al.[13] also used the UP as the reference point to determine its distance from the related anatomical structures because the LC was removed during the surgery. Therefore, the location of the VA should be estimated from the UP. In this study, the average distance from the tip of the UP to the VA was 2.6 mm. As mentioned above, the medial border of the LC can guide the tip of the UP within 10.25 to 14.3 mm (average distance, 11.9 mm) laterally. To avoid VA injury, considering the average UP width (6.5 ± 0.1 mm), AP distance of the UP (12.1 ± 0.1 mm), and our previous findings[12] of the UP height (6.6 ± 0.19 mm for males and 5.8 ± 0.2 mm for females), the safety point for lateral dissection at the

base of the UP could be performed less than 5–6 mm medial to the lateral margin of the UP, not deeper than 10 mm or higher than 5–6 mm.

Similar to Lu et al.[6], who reported that resection of the UP is usually performed 5–6 mm medial to the lateral margin of UP, our study also provides additional suggestion and consideration for avoiding VA injury within about 2.6 mm from the tip of the UP. Also, more caution must be taken in the midcervical region (C4–C6), which is very close to the VA, similar to previous reports.[14,15] The anatomical relationship between the LC and VA was also reported by Lu and Ebraheim[16], who suggested the need to consider an anomalous VA, which could increase the risk of injury. Therefore, the preoperative MRI and/or CT scans should be carefully reviewed about anomalous VA for safer operation. In addition, many studies have reported that an anterior cervical approach is associated with more post-operative airway embarrassment than posterior procedures and this therefore should be considered[17,18], because during this procedure, the trachea and esophagus are retracted to the contralateral side of the neck to expose the anterior aspect of the cervical spine, which can result in post-operative airway edema.

CONCLUSION

Using the UP as a reference point in relation to the LC and VA taken at the level of the C3–C7 vertebrae, the UP can be located within 11.9 ± 0.3 mm from the medial border of the LC. To avoid VA injury, the safety point for lateral dissection at the base of the UP is a distance less than 10 mm posteriorly, 5–6 mm laterally, and superiorly to the base of the UP. The LC and VA can help surgeons performing anterior cervical surgery by decreasing the rate of complications and increasing the rate of success.

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Conflict of interest: none

REFERENCES

1. Hankinson HL, Wilson CB. Use of the operating microscope in anterior cervical discectomy without fusion. J Neurosurg. 1975;43(4):452-6.
2. Tew JM, Jr., Mayfield FH. Complications of surgery of the anterior cervical spine. Clin Neurosurg. 1976;23:424-34.
3. Abumi K, Shono Y, Ito M, Taneichi H, Kotani Y, Kaneda K. Complications of pedicle screw fixation in reconstructive surgery of the cervical spine. Spine (Phila Pa 1976). 2000;25(8):962-9.
4. Daentzer D, Deinsberger W, Boker DK. Vertebral artery complications in anterior approaches to the cervical spine: report of two cases and review of literature. Surg Neurol. 2003;59(4):300-9; discussion 9.
5. Park MS, Moon SH, Kim TH, Oh JK, Kim HJ, Park KT, et al. Surgical anatomy of the longus colli muscle and uncinate process in the cervical spine. Yonsei Med J. 2016;57(4):968-72.
6. Lu J, Ebraheim NA, Yang H, Skie M, Yeasting RA. Cervical uncinate process: an anatomic study for anterior decompression of the cervical spine. Surg Radiol Anat. 1998;20(4):249-52.
7. Guvencer M, Men S, Naderi S, Kiray A, Tetik S. The V2 segment of the vertebral artery in anterior and anterolateral cervical spinal surgery: a cadaver angiographic study. Clin Neurol Neurosurg. 2006;108(5):440-5.
8. Guvencer M, Naderi S, Men S, Sayhan S, Tetik S. Morphometric evaluation of the uncinate process and its importance in surgical approaches to the cervical spine: a cadaveric study. Singapore Med J. 2016;57(10):570-7.
9. Ebraheim NA, Lu J, Haman SP, Yeasting RA. Anatomic basis of the anterior surgery on the cervical spine: relationships between uncus-artery-root complex and vertebral artery injury. Surg Radiol Anat. 1998;20(6):389-92.
10. Pait TG, Killefer JA, Arnautovic KI. Surgical anatomy of the anterior cervical spine: the disc space, vertebral artery, and associated bony structures. Neurosurgery. 1996;39(4):769-76.
11. Payne EE, Spillane JD. The cervical spine; an anatomico-pathological study of 70 specimens (using a special technique) with particular reference to the problem of cervical spondylosis. Brain. 1957;80(4):571-96.
12. Raykateeraroj N, Kitisin N, Kasemassawachanont A, Porkaew J, Rungruang T, Wunnasinthop S, et al. Morphometric evaluation of the uncinate process of cervical spine for surgical approaches in Thai patients. Siriraj Med J. 2019;71(Suppl 1):S39-44.
13. Kim SH, Lee JH, Kim JH, Chun KS, Doh JW, Chang JC. Anatomical morphometric study of the cervical uncinate process and surrounding structures. J Korean Neurosurg Soc. 2012;52(4):300-5.
14. Devin CJ, Kang JD. Vertebral artery injury in cervical spine surgery. Instr Course Lect. 2009;58:717-28.
15. Peng CW, Chou BT, Bendo JA, Spivak JM. Vertebral artery injury in cervical spine surgery: anatomical considerations, management, and preventive measures. Spine J. 2009;9(1):70-6.
16. Lu J, Ebraheim NA. The vertebral artery: surgical anatomy. Orthopedics. 1999;22(11):1081-5.
17. Pangthipampai P, Chinachoti T, Halilamien P, Jirativanont T, Nivatpumin P, Jalayanavin S, et al. Factors Contributing to Delayed Extubation After Cervical Spine Surgery in Siriraj Hospital. Siriraj Med J. 2011;63(4):123-7.
18. Anastasian ZH, Gaudet JG, Levitt LC, Mergeche JL, Heyer EJ, Berman MF. Factors that correlate with the decision to delay extubation after multilevel prone spine surgery. J Neurosurg Anesthesiol. 2014;26(2):167-71.