Morphometry of the Cervical Uncinate Process and its Relation to the Vertebral Artery in a Select Kenyan Population: A Computed Tomography Study

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Abstract

Background: The cervical uncinate process (UP) is of clinical importance due to its proximity to vital neurovascular structures that are at risk of compression as well as iatrogenic injury during anterior cervical spine surgery. This study therefore aimed to describe the morphometric features of the UP and its relation to the vertebral artery. **Materials and Methods:** This descriptive cross-sectional study was carried out at the Department of Radiology, Kenyatta National Hospital. One hundred contrast-enhanced neck CT scan images were obtained in coronal reformat, and the following parameters were analyzed using NeusoftTM software: the UP extents, height, width, angle of inclination, and uncovertebral artery distance. **Results:** The UP was observed caudally at C7 (100%), T1 (49%), and T2 (1%). Sex, age, vertebral level, as well as side differences were observed in the aforementioned parameters. **Conclusion**: The variations in the UP morphometry emphasize the utility of CT imaging of the UP in order to reduce the incidence of surgical complications as well as in the diagnosis of related pathologies. The knowledge of the vertebral artery's proximity to the UP is useful during procedures of the cervical spine in order to reduce the incidence of iatrogenic injury to the artery.

Key words: uncinate process; vertebral artery; radiological.

Introduction

The uncinate process (UP) is a bony protuberance that is present on the superolateral margins of the vertebral bodies of C3 to C7 vertebrae (1). It may occasionally extend to as low as T2 (2). Uncinate processes have an anterior slope, a posterior slope, an apex, and an articular medial slope. The UP forms the anterior boundary of the intervertebral foramen in the cervical region, and it is closely related to the vertebral artery, cervical spinal nerves, radicular arteries, and cervical sympathetic chain (1). The UPs allow movement in the cervical region through uncovertebral joints, offer spine stability, and protect the intervertebral foramen from compression by preventing posterolateral disc herniation (3).

Variations in the extents and morphometry of the UPs are clinically significant due to the risk of compression of important neurovascular structures as well as their important role in cervical spine mobility and stability (1)(3). Furthermore, the spatial relationship between the uncinate process and vertebral artery is important for spine neurosurgeons in order to reduce the risk of iatrogenic injury to the vertebral artery, which has been reported to have a prevalence of 0.3 to 0.5% (4). Cervical total disc replacement (CTDR) has been reported to have better outcomes than the traditional anterior cervical discectomy and fusion (ACDF) for the treatment of degenerated intervertebral discs (IVDs) (5). Owing to the important role of the UP in the stability of implanted IVDs in CTDR, data on the UP morphometry may help in guiding the acquisition of prosthetic IVDs when CTDR is adopted locally.

There is a scarcity of data on the variable anatomy of the cervical UP. CT imaging has been reported to be accurate and reliable for taking osteometric measurements (6). Accurate descriptions of UP morphometry and uncovertebral artery distance would aid clinicians and surgeons in making better cervical spine pathology diagnoses and improving success rates of anterior cervical spine surgery. There is also a paucity of adequate radiographic data on the morphometry of the cervical UP globally. This study therefore aimed to describe the morphometry of the UP and its relation to the vertebral artery using CT scan imaging.

Materials and methods

This was a descriptive cross-sectional study. The study setting was at Kenyatta National Hospital, Radiology Department. One hundred computed tomography (CT) scan images (50 males and 50 females) of the cervical region were obtained and assessed in the Radiology Department reporting stations, Kenyatta National Hospital. The digital repository of cervical spine CT scans performed at the Kenyatta National Hospital Radiology Department was used as the source of materials for this study.

People of all ages and genders were included in this study. With the help of a qualified radiologist, CT scans of subjects with evidence of cervical spine fractures, previous cervical spine surgery, scoliosis, or other apparent cervical spine anomalies were excluded from the study. Consecutive sampling was employed, whereby the first 100 CT scan images that fit the selection criteria were used for the study. Ethical approval was sought from the Kenyatta National Hospital-University of Nairobi Ethics and Research Committee (Ref: KNH-ERC/UA/137) before the commencement of the study. Permission to conduct the study on the premises was then obtained from the Kenyatta National Hospital administration and the Department of Radiology.

Contrast-enhanced CT scans of the cervical spine in bone window coronal reformat were used for this study. A slice thickness of 2mm was used and measurements were taken using the ruler and protractor features inbuilt into the Neusoft™ CT imaging software. The CT scan images were analyzed for: the extents of the uncinate process down the spine, the height, the width, the angle of inclination of the cervical uncinate process

and the uncovertebral artery distance. The height of the UP (*Figure 1*) was defined as the distance from the superior vertebral end plate of the cervical vertebra to the tip of the UP. The angle of inclination of the UP was measured as the angle between one line following the medial slope of the UP through its tip and a horizontal line along the superior vertebral end plate (*Figure 2)*. The width was measured between the medial aspect of the base of the UP and the lateral aspect of the UP base (*Figure 3*). The uncovertebral distance (*Figure 4*) was measured as the distance between the medial aspect of the base of the uncinate process and the medial aspect of the vertebral artery.

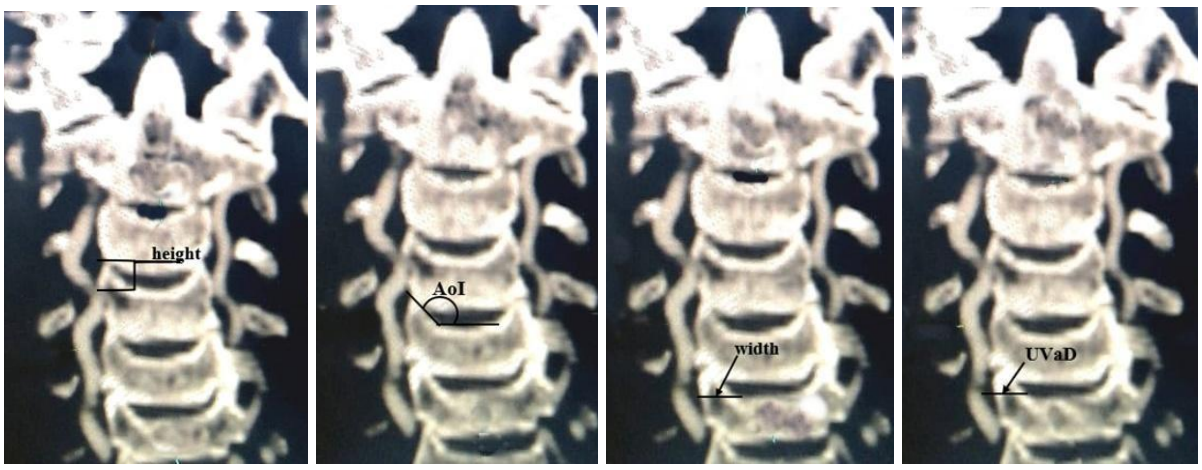


Figure 1-4. 1: Height of the uncinate process. 2: Angle of inclination of uncinate process. (AoI). 3: Width of the uncinate process. 4: Uncovertebral artery distance (UVaD)

Data analysis and presentation

The independent variables included age, sex, and side of the vertebra, while the dependent variables were the length, width, angle of inclination, and uncovertebral artery distance. Frequencies, means, and standard deviations were calculated using SPSS (version 25.0, Chicago, Illinois). The data was expressed in the form of mean ± SD. Normality was checked using the Shapiro-Wilk test ($p > 0.05$). An independent t-test was used for inter-individual comparisons of the dependent variables between the two sexes. A paired t-test was used for intra-individual comparison of the dependent variables on the left and right sides. One-way ANOVA was used for inter-individual comparisons of the dependent variables between the different age groups. A repeated measures ANOVA was used for intra-individual differences among the different vertebral levels. When statistically significant differences were observed, ANOVA was then followed up with a post hoc analysis for pairwise comparisons. A p-value of ≤ 0.05 was considered significant at a 95% confidence interval. The data was presented using tables and graphs.

Results

Out of the 100 CT scan images (500 vertebrae; 1000 uncinate processes) analyzed, 50 (50%) were male and 50 (50%) were female. The sex distribution across the different age groups was as shown in *Table 1* below:

Table 1: Sex distribution across different age groups

		Age Groups				Total
		0-19	**20-39**	**40-59**	**≥60**	
Sex	**Male**	7	13	17	13	50
	Female	4	19	12	15	50
Total		11	32	29	28	100

Extents of the uncinate process

Out of the 100 CT scan images examined for the caudal extents of the uncinate process, the UP was present at C7 level in 100 (100%) of the subjects, at T1 in 49 (49%) of the subjects and at T2 in 1 (1%) of the cases. The different caudal extents of the uncinate process were shown in *Figure 5*.

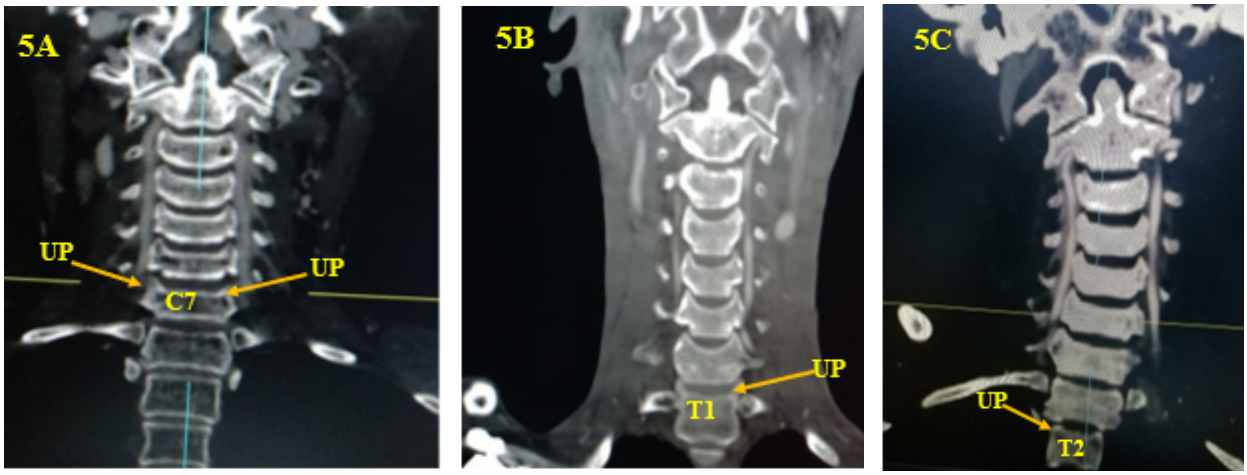


Figure 5: CT scan images showing different caudal extents of the uncinate process. ***5A***: CT scan image showing the UP extending caudally to C7 ***5B***: CT scan image showing the UP extending caudally to T1. ***5C*:** CT scan image showing the UP extending caudally to T2.

The mean height, width, angle of inclination (AoI) and uncovertebral artery distance observed are summarized in the tables below. (*Height, width and UVaD in mm; AoI in degrees).*

Table 2: Mean ± SD of the parameters observed across the age groups.

Age Groups	Mean height ± SD	Mean width ± SD	Mean AoI ± SD	Mean UVaD ± SD
0-19	3.43 ± 1.31	5.20 ± 1.27	136.24 ± 13.41	5.95 ± 1.80
20-39	4.09 ± 1.03	5.62 ± 1.09	132.87 ± 13.86	6.83 ± 1.37
40-59	4.25 ± 1.20	5.60 ± 1.20	135.05 ± 12.90	7.04 ± 1.74
≥ 60	4.70 ± 1.12	5.68 ± 0.99	132.87 ± 12.10	7.19 ± 1.55

Table 3: Means ± SD of the parameters observed along the vertebral levels.

Vertebral level	Mean height ± SD	Mean width ± SD	Mean AoI ± SD	Mean UVaD ± SD
C3	3.71 ± 1.15	5.50 ± 1.19	131.03 ± 13.96	6.55 ± 1.45
C4	4.25 ± 1.24	5.68 ± 1.15	132.77 ± 13.20	6.69 ± 1.44
C5	4.42 ± 1.19	5.58 ± 1.06	133.75 ± 12.81	6.68 ± 1.48
C6	4.49 ± 1.19	5.65 ± 1.03	134.66 ± 12.39	6.80 ± 1.37
C7	4.30 ± 1.22	5.53 ± 1.17	137.14 ± 12.40	7.75 ± 2.00

Table 4: Mean ± SD of the parameters observed in males and females.

Sex	Mean height ± SD	Mean width ± SD	Mean AoI ± SD	Mean UVaD ± SD
Male	4.29±1.27	5.71 ± 1.17	134.35 ± 13.38	7.19 ± 1.76
Female	4.20 ± 1.12	5.47 ± 1.06	133.39 ± 12.80	6.60 ± 1.41

Table 5: Mean ± SD of the parameters observed on the right and left side

Side	Mean height ± SD	Mean width ± SD	Mean AoI ± SD	Mean UVaD ± SD
Right	4.17 ± 1.19	5.64 ± 1.16	134.35 ± 13.38	6.93 ± 1.60
Left	4.31 ± 1.20	5.54 ± 1.09	133.39 ± 12.80	6.86 ± 1.64

The trends observed in the parameters are summarized in the graphs below:

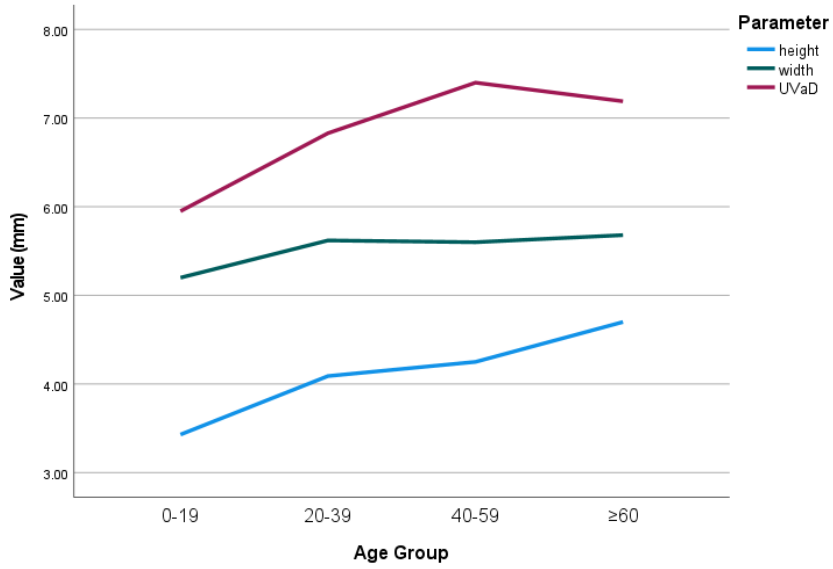


Figure 6A: Multiple line graphs showing age differences in the height, width and uncovertebral distance (UVaD).

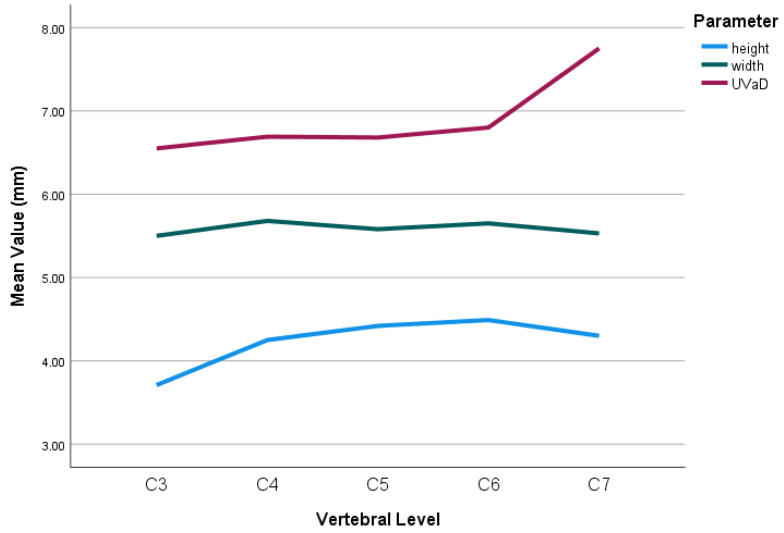


Figure 6B: Multiple line graphs showing vertebral level differences in the height, width, uncovertebral distance (UVaD) and angle of inclination (AoI) of the uncinate process

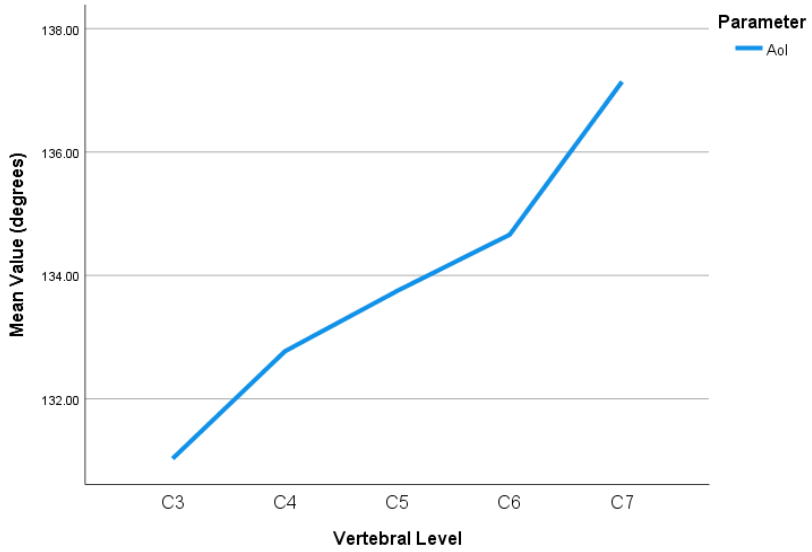
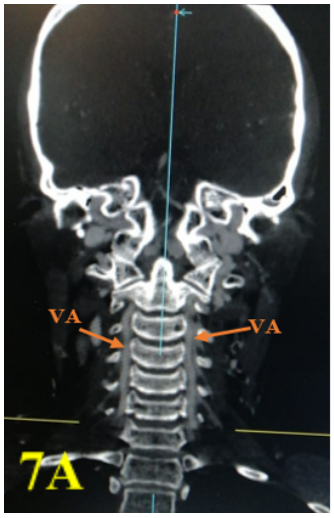


Figure 6C: A simple line graph showing the trend in angle of inclination (AoI) down the vertebral levels.

The course of the cervical segment of the vertebral artery was observed to be straight (*Figure 7A*) in some subjects and tortuous (*figure 7B*) in other subjects.



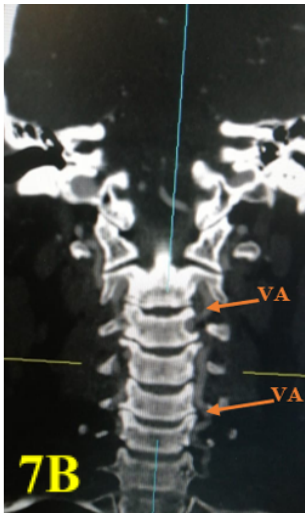


Figure 7A: CT scan image showing straight vertebral artery (VA) course

Figure 7B: CT scan image showing tortuous vertebral artery (VA) course

DISCUSSION

Extents of the uncinate process

In this study, the UP was observed to extend to C7 level in 100% of the cases, T1 level in 49% of the cases and at T2 in 1% of the observed cases. This was in contrast to the report by Tulsi and Perrett (7) that the UP is variably absent at C7 in the Australian population and the report by Hayashi and Yabuki (8) that the UP only rarely extends to T1 in the Japanese population.

Posterolateral disc herniation in the cervical region commonly occurs at C7 level. The cervical UP is important for prevention of posterolateral disc herniation in the lower cervical region (3). The incidence of disc herniation at the cervical region has been reported to be about 8% (9). KW Ongeti et al, (10) reported a relatively lower incidence of cervical disc herniation (1.4%) in the Kenyan population and this may be due to the presence of the UP at C7 in 100% of the subjects as observed in this study.

Height of the uncinate process

This lower height of the UP reported in the Kenyan population compared to other populations could be due to the fact that the other studies only included adult specimens while this study also included subjects below 18 years (11) (12) (13) (14). Differences in accuracy of measurements in this CT study compared to dry bone and cadaveric studies may have also contributed to the difference observed.

The observed increase in the UP height with age may be explained by the developmental changes that take place in the UP from early life to adulthood as well as the spondylotic changes that occur in the uncinate process in the later decades of life (1). The uncinate process has been reported to grow upwards

from the age of 4 and to continue enlarging from age 9 to 14 years (1). The uncinate processes are a common site for osteophytic spurring due to cervical spondylosis that begins in the fourth decade of life and this may explain the increase in height in later decades.

The trend observed in the UP height where it increased gradually from C3 to C6 and then decreased at C7 was consistent with the report by Tulsi and Perrett (7) and in contrast to the study by Güvençer *et al.* (2) that reported a constant increase from C3 to C7 with C7 having the highest height. The decrease in the height that was observed may be due to the fact that C7 is a transitional vertebra hence it may adopt features of the first thoracic vertebrae that typically has a rudimentary uncinate process (16).

The side differences in the UP height could be due to left-right asymmetry in the distribution of Hox genes during the development of the axial column. Hox genes determine vertebral segment identity in terms of proliferation, apoptosis and differentiation (17). Asymmetrical osteoarthritic changes could also play a role in left-right asymmetry since asymmetrical ankylosing spondylitis has been reported to be a feature of asymmetrical polyarthritis that occurs with age (18).

Owing to the remarkable proximity of the UP to the vertebral artery, cervical spinal nerves, radicular arteries and cervical sympathetic chain, the observed increase in height of the uncinate process in older subjects and in males may increase the risk of compression of these neurovascular structures leading to vertebrobasilar insufficiency, radiculopathy and myelopathy (1)(2). A decrease in height of the uncinate process particularly in the lower cervical vertebrae may increase the risk of posterolateral disc herniation since the UP provides stability to the intervertebral disc (3).

Width of the uncinate process

The observed values for the width of the uncinate process from this study were generally similar to those reported by other studies done in other populations despite the inclusion of subjects below 18 years (11) (12) (14). This may be due to the fact that no significant increase in the width of the UP takes place past the ages of 20-39 years as observed in this study.

The changes in UP width with age that were observed were such that it increased from the first decades of life to 20-39 years but did not change significantly past that age. Despite the report by Rudy *et al.* (19) that the odds of uncinate process hypertrophy increase by 1.15 each year after the fourth decade of life, the width may not change because spondylotic changes in the UP mainly manifest through osteophytic spurring which may not increase the width.

The UP width was significantly higher in males and this may be due to the higher levels of androgens in males that have been reported to play a role in increased bone size and density (20).

The statistically significant side differences in the UP height could be due to left-right asymmetry in the distribution of Hox genes during the development of the axial column. Hox genes determine vertebral segment identity in terms of proliferation, apoptosis and differentiation (17).

Excessive resection of the UP width during anterior cervical spine decompression surgeries has been reported to attenuate the stability offered by these joints (14). Owing to the important role of the uncovertebral

joints in limiting lateral flexion and posterior displacement of the cervical spine, surgeons should be aware of the narrower UP width in females and in age group 0-19 years when performing uncinectomy so as to optimize the post-operative quality of life of patients.

Uncovertebral artery distance

The UVaD was observed to be higher than the values observed in the Korean population (21). This may be due to the fact that dry bone studies use the transverse foramina as the surrogate of the vertebral artery which may be inaccurate because they are unable to account for the tortuosity of the vertebral artery in vivo. This CT study was more accurate to dry bone studies since it allowed for visualization of the entire length and tortuosity of the vertebral artery as well as all the intact cervical vertebrae in series.

The UVaD was observed to vary with age. This may be due to increased arterial tortuosity with aging (22). The UVaD was significantly larger in male subjects and this may be due to the greater width of the uncinate process in male subjects compared to female subjects that was observed in this study. An increase in width results in a subsequent increase in UVaD.

The UVaD was fairly constant along C3 to C6 but it increased significantly at C7. This was due to the fact the vertebral segment of the vertebral artery begins at the transverse foramen of C6 and hence at C7 level, the vertebral artery is further away from the C7 vertebra (23).

The uncovertebral artery distance is of clinical importance due to the high risk of iatrogenic injury to the vertebral artery when performing anterior cervical spine surgeries. It is therefore paramount for spine neurosurgeons to be wary of the variability of this distance particularly in older patients so as to avoid iatrogenic injury to the VA which can lead to vertebrobasilar insufficiency and death (4).

Conclusion

The morphometry of the uncinate process and the uncovertebral artery distance in the Kenyan population displays age, sex, vertebral level and side-related variations. These variations emphasize the utility of CT imaging of the UP in order to reduce the incidence of surgical complications as well as in diagnosis of related pathologies. The knowledge of the vertebral artery's proximity to the UP is useful during procedures of the cervical spine in order to reduce the incidence of iatrogenic injury to the artery.

Limitations and delimitations

Measurements were taken twice to reduce intra-observer error. The CT contrast medium in the vertebral artery was intra-luminal and hence the vessel wall thickness was not accounted for when measuring the uncovertebral artery distance. However, the wall of the vertebral artery is ≤ 0.5 mm on average and this can be considered negligible in the practical clinical setting. Also, this error was propagated throughout all the measurements and therefore it did not affect the associations observed.

Strengths of the study

The internal validity of this study was comparatively better due to the use of CT imaging which is more accurate compared to previous studies done on dry bones and cadaveric specimens. The external validity was also comparatively better due to inclusion of all age groups as well as the consideration of several clinically relevant UP parameters.

REFERENCES

1. Hartman J. Anatomy and clinical significance of the uncinate process and uncovertebral joint: A comprehensive review. Clin Anat N Y N. 2014 Apr;27(3):431–40.
2. Güvençer 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 Oct;57(10):570–7.
3. Raveendranath V, Kavitha T, Umamageswari A. Morphometry of the Uncinate Process, Vertebral Body, and Lamina of the C3–7 Vertebrae Relevant to Cervical Spine Surgery. Neurospine. 2019 Dec;16(4):748–55.
4. Smith MD, Emery SE, Dudley A, Murray KJ, Leventhal M. Vertebral artery injury during anterior decompression of the cervical spine. A retrospective review of ten patients. J Bone Joint Surg Br. 1993 May;75(3):410–5.
5. Othman YA, Verma R, Qureshi SA. Artificial disc replacement in spine surgery. Ann Transl Med [Internet]. 2019 Sep
6. Stull KE, Tise ML, Ali Z, Fowler DR. Accuracy and reliability of measurements obtained from computed tomography 3D volume rendered images. Forensic Sci Int. 2014 May;238:133–40.
7. Tulsi RS, Perrett LV. The Anatomy and Radiology of the Cervical Vertebrae and the Tortuous Vertebral Artery. Australas Radiol. 1975 Sep;19(3):258–64.
8. Hayashi K, Yabuki T. Origin of the uncus and of Luschka's joint in the cervical spine. J Bone Joint Surg Am. 1985 Jun;67(5):788–91.
9. Herniated Cervical Disc, herniated disc, ruptured cervical disc, bulging disc, neck surgery, acdf [Internet]. [cited 2021 Jul 7]. Available from: https://mayfieldclinic.com/pe-hcdisc.htm
10. Prolapsed Intervertebral Disc in an African Population: Kenyan Experience | East African Orthopaedic Journal [Internet]. [cited 2021 Jun 16].
11. Pait TG, Killefer JA, Arnautovic KI. Surgical anatomy of the anterior cervical spine: the disc space, vertebral artery, and associated bony structures. Neurosurgery. 1996 Oct;39(4):769–76.
12. Bozbuğa M, Oztürk A, Ari Z, Bayraktar B, Sahinoğlu K, Gürel I. Surgical anatomic evaluation of cervical uncinate process for ventral and ventrolateral subaxial decompression. Okajimas Folia Anat Jpn. 1999 Oct;76(4):193–6.
13. Russo VM, Graziano F, Peris-Celda M, Russo A, Ulm AJ. The V2 segment of the vertebral artery: anatomical considerations and surgical implications: Laboratory investigation. J Neurosurg Spine. 2011 Dec;15(6):610–9.
14. Uğur HÇ, Uz A, Attar A, Tekdemir İ, Egemen N, Elhan A. Anatomical projection of the cervical uncinate process in ventral, ventrolateral, and posterior decompressive surgery. J Neurosurg Spine. 2000 Oct 1;93(2):248–51.
15. Güvençer 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 Oct;57(10):570–7.
16. Post NH, Cooper PR, Frempong-Boadu AK, Costa ME. Unique features of herniated discs at the cervicothoracic junction: clinical presentation, imaging, operative management, and outcome after anterior decompressive operation in 10 patients. Neurosurgery. 2006 Mar;58(3):497–501; discussion 497-501.
17. Christ B, Huang R, Wilting J. The development of the avian vertebral column. Anat Embryol (Berl). 2000 Sep;202(3):179–94.
18. Senthelal S, Li J, Goyal A, Bansal P, Thomas MA. Arthritis. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021
19. Rudy IS, Poulos A, Owen L, Batters A, Kieliszek K, Willox J, et al. The correlation of radiographic findings and patient symptomatology in cervical degenerative joint disease: a cross-sectional study. Chiropr Man Ther. 2015 Feb 9;23(1):9.
20. Clarke BL, Khosla S. Androgens and Bone. Steroids. 2009 Mar;74(3):296–305.
21. Kim S-H, 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 Oct;52(4):300–5.
22. Han H-C. Twisted Blood Vessels: Symptoms, Etiology and Biomechanical Mechanisms. J Vasc Res. 2012 May;49(3):185–97.
23. Magklara E-P, Pantelia E-T, Solia E, Panagouli E, Piagkou M, Mazarakis A, et al. Vertebral artery variations revised: origin, course, branches and embryonic development. Folia Morphol. 2021;80(1):1–12.