

ORIGINAL RESEARCH

MORPHOMETRIC ANALYSIS OF CERVICAL VERTEBRAL PEDICLES AND UNCINATE PROCESSES: CLINICAL IMPLICATIONS IN AN OSTEOLOGICAL SAMPLE FROM THE VINDHYA REGION**Ashish Tiwari¹, Bhaskar Reddy², Chandrababha Choudhary^{3*}, Meghana Mishra⁴, Arjun Singh Parmar⁵**¹ PG Scholar, Department of Anatomy, Shyam Shah Medical College, Rewa, Madhya Pradesh, India.² Professor, Department of Anatomy, Shyam Shah Medical College, Rewa, Madhya Pradesh, India.³ Assistant Professor, Department of Anatomy, Shyam Shah Medical College, Rewa, Madhya Pradesh, India⁴ Professor, Department of Anatomy, Shyam Shah Medical College, Rewa, Madhya Pradesh, India.⁵ Professor, Department of Anatomy, Shyam Shah Medical College, Rewa, Madhya Pradesh, India.

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ABSTRACT

The cervical vertebrae support the skull, permit complex neck movements and protect the spinal cord and vertebral vessels. Precise morphometric knowledge of the cervical pedicle and uncinat process is essential for safe cervical instrumentation, decompression procedures and implant design. Because vertebral dimensions vary across populations, region-specific anatomical data are clinically relevant. Objective: To evaluate the morphometry of subaxial cervical vertebral pedicles and uncinat processes in an adult dry-bone osteological sample from the Vindhya region and to discuss their clinical implications. This cross-sectional descriptive study was conducted in the Department of Anatomy, Shyam Shah Medical College, Rewa, Madhya Pradesh, over 18 months after Institutional Ethics Committee approval. The study included 180 dried adult cervical vertebrae from C3 to C7. Bilateral pedicle width and height and uncinat process length, width and height were measured using a digital vernier caliper with 0.01 mm accuracy. The source data did not provide level-wise specimen counts; therefore, these counts have been flagged for author verification before submission. Data were analysed using SPSS. Mean, standard deviation and analysis of variance were used to compare measurements across cervical levels. Results: Pedicle dimensions increased in a caudal direction. Right pedicle width increased from 4.42 ± 0.55 mm at C3 to 6.08 ± 0.65 mm at C7, while right pedicle height increased from 5.49 ± 0.66 mm at C3 to 6.54 ± 0.60 mm at C7. Left-sided measurements showed a similar pattern. Uncinat process dimensions increased from C3 to C6 and then declined at C7. Right uncinat process width increased from 2.45 ± 0.32 mm at C3 to 3.57 ± 0.43 mm at C6, followed by a reduction to 2.80 ± 0.52 mm at C7. Most measurements showed minimal right-left asymmetry. ANOVA demonstrated highly significant inter-level differences for pedicle parameters ($p < 0.001$) and significant inter-level differences for uncinat process parameters ($p < 0.05$). The study provides regional baseline morphometric data from an osteological sample of subaxial cervical vertebrae from the Vindhya region. The observed progressive enlargement of pedicles from C3 to C7 and the peak uncinat process dimensions around C5-C6 may be useful for cervical pedicle screw placement, anterior cervical decompression, implant selection and avoidance of neurovascular complications, provided that individual preoperative imaging is used for surgical planning.

Keywords: Cervical vertebrae; pedicle morphometry; uncinat process; subaxial cervical spine; cervical instrumentation; Vindhya region.

INTRODUCTION

The cervical spine is a highly specialized segment of the vertebral column. It provides support to the head, allows multidirectional neck movement and protects the spinal cord, spinal nerve roots and vertebral arteries. In the subaxial cervical region, the small size of the pedicles and their proximity to the spinal canal and transverse foramina make screw placement technically demanding. Quantitative knowledge of pedicle dimensions and reliable anatomical landmarks is

therefore necessary to reduce the risk of vertebral artery, nerve root and spinal cord injury during cervical instrumentation [1,2].

Population-specific morphometric data are important because cervical vertebral dimensions differ between ethnic and regional groups. Indian studies have repeatedly emphasized that dimensions of cervical vertebral bodies, pedicles, laminae and related posterior elements may be smaller than values reported in many Western populations, which has implications for screw diameter, trajectory selection and implant design [3-7].

The uncinate processes are paired bony elevations arising from the superolateral margins of the cervical vertebral bodies. They form the uncovertebral joints and are closely related to the intervertebral foramina, cervical nerve roots and vertebral artery. Morphological variation or degenerative enlargement of the uncinate process may contribute to radiculopathy and may increase surgical risk during anterior decompression, uncinectomy and anterolateral approaches. The foramen transversarium, which transmits the vertebral vessels and sympathetic plexus, also shows clinically important variations that may influence preoperative planning [8-10].

Against this background, the present study was undertaken to evaluate the morphometry of dried adult subaxial cervical vertebrae from the Vindhya region, with particular emphasis on pedicle and uncinate process dimensions and their relevance to cervical spine surgery. The aim of the study was to assess the morphometry of subaxial cervical vertebrae (C3-C7), with specific emphasis on cervical pedicle and uncinate process dimensions, and to evaluate their clinical implications for cervical spine instrumentation and decompressive procedures.

MATERIALS AND METHODS

Study design and setting

This cross-sectional descriptive study was conducted over 18 months in the Department of Anatomy, Shyam Shah Medical College, Rewa, Madhya Pradesh, India, after obtaining approval from the Institutional Ethics Committee.

Study material

The study included 180 dried adult cervical vertebrae from C3 to C7 obtained from the osteology section of the Department of Anatomy. Only fully ossified and morphologically intact vertebrae were included. Vertebrae showing fractures, deformity, gross degenerative change, pathological lesions or erosion were excluded.

Specimen distribution by vertebral level: The vertebrae were classified by cervical level (C3-C7) before measurement. The supplied source manuscript reports a total of 180 vertebrae but does not provide exact n values for each vertebral level. These level-wise counts should be verified from the raw osteology records and inserted before final journal submission.

Morphometric assessment

Measurements were recorded using a digital vernier caliper with an accuracy of 0.01 mm. Pedicle width and pedicle height were measured bilaterally. Uncinate process length, width and height were also measured bilaterally. For the uncinate process, length was defined as the distance between its anterior and posterior margins, width as the distance between the medial and lateral margins at its base, and height as the distance from the tip of the process to its base. Measurements were recorded in millimetres.

Pedicle length was not interpreted because the supplied results contained pedicle width and height only. The manuscript therefore reports pedicle width and height for the pedicle component to avoid unsupported conclusions.

All measurements were based on standardized anatomical landmarks. Formal intraobserver and interobserver reliability coefficients were not available in the supplied dataset; this has been acknowledged as a limitation and should be added if repeat-measurement data are available.

Statistical analysis

Data were entered into Microsoft Excel and analysed using SPSS software. Continuous variables were summarized as mean $\pm$ standard deviation. Analysis of variance was used to evaluate inter-level differences across C3-C7. Right-left differences were interpreted descriptively. The available source analysis reported threshold p values rather than exact parameter-wise p values; therefore, the tables retain the reported ANOVA thresholds ($p < 0.001$ for pedicle parameters and $p < 0.05$ for uncinat process parameters). Exact parameter-wise p values should be inserted if available from the original statistical output. A p value < 0.05 was considered statistically significant.

RESULTS

The morphometric data demonstrated distinct level-wise variation in both pedicle and uncinat process dimensions. The pedicle measurements showed a gradual cranio-caudal increase, whereas uncinat process dimensions increased up to C6 and then declined at C7. Because exact level-wise specimen counts were not provided in the supplied source manuscript, the results are presented as level-wise mean $\pm$ standard deviation values without level-specific percentage distribution.

Table 1. Pedicle morphometry of subaxial cervical vertebrae (C3-C7)

Cervical level	Pedicle width right (mm)	Pedicle width left (mm)	Pedicle height right (mm)	Pedicle height left (mm)
C3	4.42 $\pm$ 0.55	4.30 $\pm$ 0.70	5.49 $\pm$ 0.66	5.55 $\pm$ 0.57
C4	4.73 $\pm$ 0.50	4.62 $\pm$ 0.61	5.90 $\pm$ 0.49	5.65 $\pm$ 0.50
C5	5.42 $\pm$ 0.76	5.17 $\pm$ 0.55	6.38 $\pm$ 0.52	6.14 $\pm$ 0.48
C6	5.47 $\pm$ 0.66	5.48 $\pm$ 0.69	6.72 $\pm$ 0.55	6.67 $\pm$ 0.55
C7	6.08 $\pm$ 0.65	5.74 $\pm$ 0.65	6.54 $\pm$ 0.60	6.38 $\pm$ 0.66

Values are expressed as mean $\pm$ standard deviation. ANOVA $p < 0.001$ for inter-level differences in pedicle measurements as reported in the source analysis; exact parameter-wise p values should be inserted if available.

Pedicle width increased from C3 to C7 on both sides, with the greatest values observed at C7. Pedicle height also increased caudally, although the right-sided value peaked at C6 and remained high at C7. Right-left differences were small and did not show a consistent side predominance. These data are clinically relevant for pedicle screw diameter selection and trajectory planning in the subaxial cervical spine.

Table 2. Uncinat process morphometry of subaxial cervical vertebrae (C3-C7)

Cervical level	Width right (mm)	Width left (mm)	Length right (mm)	Length left (mm)	Height right (mm)	Height left (mm)
C3	2.45 $\pm$ 0.32	2.57 $\pm$ 0.39	9.90 $\pm$ 1.05	9.98 $\pm$ 1.02	5.66 $\pm$ 0.68	5.31 $\pm$ 0.71
C4	2.89 $\pm$ 0.31	2.84 $\pm$ 0.36	10.61 $\pm$ 0.91	10.69 $\pm$ 1.02	6.21 $\pm$ 0.56	6.03 $\pm$ 0.73
C5	3.17 $\pm$ 0.35	3.21 $\pm$ 0.38	11.71 $\pm$ 0.83	11.98 $\pm$ 0.93	6.79 $\pm$ 0.53	6.70 $\pm$ 0.68
C6	3.57 $\pm$ 0.43	3.48 $\pm$ 0.47	12.06 $\pm$ 0.86	12.30 $\pm$ 0.85	7.19 $\pm$ 1.00	7.18 $\pm$ 0.92
C7	2.80 $\pm$ 0.52	2.90 $\pm$ 0.43	10.32 $\pm$ 1.05	10.35 $\pm$ 0.99	5.42 $\pm$ 0.76	5.22 $\pm$ 0.66

Values are expressed as mean $\pm$ standard deviation. ANOVA $p < 0.05$ for inter-level differences in uncinat process measurements as reported in the source analysis; exact parameter-wise p values should be inserted if available.

Uncinat process width, length and height increased from C3 to C6 and then declined at C7. The largest dimensions were observed at C6 for most parameters. Bilateral measurements were comparable, with no consistent right- or left-sided predominance. These findings are relevant during anterior cervical decompression, uncinectomy and procedures involving the uncovertebral region.

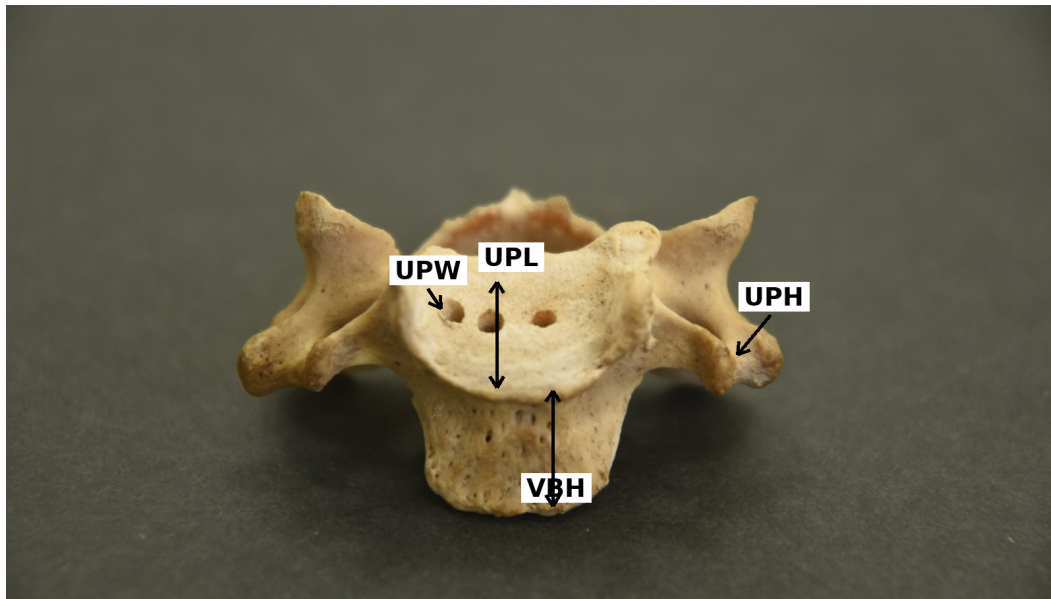


Figure 1. Measurement landmarks on a cervical vertebra.

UPL, uncinate process length; UPW, uncinate process width; UPH, uncinate process height; VBH, vertebral body height. UPL was measured between the anterior and posterior parts of the uncinate process; UPW was measured between the medial and lateral margins of the process at its base; UPH was measured from the tip of the uncinate process to its base; VBH was measured between the superior and inferior margins of the vertebral body at the anterior midline.

DISCUSSION

Pedicle morphometry

The present study demonstrated a highly significant increase in pedicle dimensions from C3 to C7. Pedicle width increased from 4.42 ± 0.55 mm on the right and 4.30 ± 0.70 mm on the left at C3 to 6.08 ± 0.65 mm on the right and 5.74 ± 0.65 mm on the left at C7. Pedicle height showed a similar cranio-caudal increase. This pattern indicates that the lower cervical pedicles provide a comparatively larger osseous corridor for screw placement, whereas upper subaxial pedicles require greater caution because of their smaller dimensions.

These findings are broadly consistent with earlier morphometric and CT-based studies. Gupta et al. reported level-wise variation in typical cervical pedicle dimensions and emphasized the importance of three-dimensional assessment before transpedicular screw placement [4]. Munusamy et al. similarly demonstrated clinically relevant variability in cervical pedicle dimensions in a multi-ethnic Asian population, supporting the need for population-specific planning [7]. Kumar et al. also documented sex- and level-related differences in cervical pedicle geometry in adult Indian subjects and highlighted the importance of CT-based preoperative evaluation [5].

The relatively small pedicle widths recorded in the present study reinforce the need for careful screw selection. Inadequate appreciation of pedicle width and trajectory may increase the risk of pedicle breach, vertebral artery injury and neural injury. Although the present study was based on dry bones rather than CT images, the data provide useful regional osteological reference values for implant sizing and surgical training.

Uncinate process morphometry

Uncinate process dimensions showed a different pattern from pedicle measurements. Width, length and height increased from C3 to C6 and then declined at C7. This finding suggests that the C5-C6/C6 region represents a zone of relatively prominent uncovertebral morphology. Because the uncinate processes form the lateral boundaries of the intervertebral disc and contribute to the uncovertebral joints, their size and orientation are important during anterior cervical decompression and uncinate resection.

The present observations align with previous Indian anatomical studies that reported level-wise variation in subaxial cervical vertebral morphology [3,6]. The clinical relevance of the uncinat process is closely linked to its relationship with the intervertebral foramen and transverse foramen. Yesender et al. measured the relation of the uncinat process to the foramen transversarium and emphasized its importance in anterior approaches to the cervical spine [8]. Recent anatomical work on the foramen transversarium has further reinforced the need to understand regional variations in cervical vertebral anatomy before procedures involving the vertebral artery pathway [9]. CT angiographic assessment of the V2 segment of the vertebral artery also supports the role of preoperative imaging when cervical procedures are planned near the transverse foramina [10].

Clinical implications

The morphometric values obtained in this study have practical implications for cervical spine surgery. First, pedicle width and height guide screw diameter, length and trajectory selection during posterior cervical fixation. Second, uncinat process dimensions are important during anterior decompression, uncinectomy and artificial disc replacement because excessive lateral drilling may endanger the vertebral artery, whereas inadequate decompression may leave residual foraminal stenosis. Third, the regional data may assist in contextualizing implant design and surgical planning for patients from this region, but individual preoperative radiological assessment remains essential.

CONCLUSION

The present study demonstrates significant morphometric variation in subaxial cervical vertebrae from C3 to C7 in a dry-bone osteological sample from the Vindhya region. Pedicle dimensions showed progressive cranio-caudal enlargement, whereas uncinat process dimensions increased up to C6 and then declined at C7. Bilateral differences were minimal and did not show a consistent side predominance.

These findings provide useful anatomical baseline data for cervical spine instrumentation, pedicle screw fixation, anterior cervical decompression, uncinat process surgery and implant design. Accurate knowledge of regional cervical vertebral morphometry is essential for minimizing neurovascular complications and improving the safety of cervical spine procedures.

Declarations

Ethics approval: The study was conducted after approval from the Institutional Ethics Committee, Shyam Shah Medical College, Rewa. Approval No.: S.No/IEC/M.C/2024/3747

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Conflict of interest: Nil

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