Original Article

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Anatomy Section

Prevalence of Fusion Between Adjacent Cervical Spinous Processes in Adult Cadavers: A Cross-sectional Study

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ABSTRACT

Introduction: Cervical spine surgery is associated with a considerable risk of performing procedures at the wrong level. Errors in accurately identifying the appropriate level for spinal interventions can result from various factors, including an inadequate understanding of anatomical variations, such as fusion of the Cervical Spinous Process (CPS), abnormalities at the craniocervical junction, cervical ribs, hemivertebrae, and blocked or fused vertebrae. Furthermore, patient-specific factors, including tumours, infections, previous cervical spine surgeries, obesity, and osteoporosis, significantly contribute to the incidence of surgeries performed at incorrect levels.

Aim: To determine the prevalence of fusion between adjacent CPS.

Materials and Methods: The present cross-sectional study examined the spinous processes of the cervical vertebrae in 30 formalin-preserved adult cadavers (15 males and 15 females), aged between 60 and 95 years, in Smt. BK Shah Medical College and Research Institute, Vadodara, Gujarat, India. Fusion between the CPS of adjacent vertebrae was recorded after the removal of soft-tissue from C1 to T1.

Results: The present study found fusion between adjacent CPS in only 2 male (6.66%) cadavers. whereas none were observed in females.This fusion was exclusively observed between C2-C3 vertebrae The fused spinous processes demonstrated complete osseous continuity without visible fusion lines.

Conclusion: CPS fusion is relatively uncommon in the adult Indian population; however, when it occurs, it is predominantly observed at the C2-C3 level in male cadavers. These findings provide a crucial reference for spinal surgeons to prevent surgical errors. Both preoperative and intraoperative imaging is essential for minimising surgical errors.

Keywords: Anatomical variations, Cervical spine, Cervical vertebra, Spine surgeries, Vertebral column

INTRODUCTION

The cervical region of the spine, situated in the neck, comprises seven cervical vertebrae, referred to as C1-C7, and intervertebral discs. These structures collectively support the cranium and facilitate head and neck movement. The first two cervical vertebrae possess distinct characteristics and functions: the first cervical vertebra (C1), known as the atlas, has a ring-like configuration, whereas the second cervical vertebra (C2), termed the axis, features an upward projection known as the dens. The remaining cervical vertebrae each contain a vertebral body and posterior neural arch. This arch is composed of pairs of laminae and pedicles that encircle the vertebral foramen and include a bifid spinous process [1,2].

Spine surgeries present a particular risk for wrong-level surgeries. The prevalence of incorrect-level spine surgeries ranges from 0.03 to 16%, with the cervical region being the second most common site for such errors [3]. Longo UG et al., estimated that of approximately 1,300,000 spinal procedures, 418 were performed at the incorrect level, with 21%, 71%, and 8% occurring in the cervical, lumbar, and thoracic spines, respectively [4]. Errors in identifying the correct level for spine surgeries stem from various factors, including communication failures, such as inadequate information exchange among the surgical team (preoperative and intraoperative). Inadequate preoperative planning, including insufficient review of imaging, absence of clear surgical plans and markings, and lack of surgeon experience, contributes to these errors [3-5]. Failure to account for anatomical variations of the spine, such as craniocervical junction abnormalities, cervical ribs, hemivertebrae, varying intervertebral disc heights, or fusion of the spinous processes of the cervical vertebrae, can hinder proper localization of the surgical level [6,7]. Furthermore, patient-specific factors, including tumours, infections, previous cervical spine surgeries, obesity, and osteoporosis, significantly contribute to the incidence of surgeries performed at incorrect levels [3,7,8]. Approximately, 5% of surgeons report that anatomical variations have resulted in the selection of wrong levels spinal surgery, adversely affecting patient health and frequently necessitating additional surgical interventions. These errors are among the most litigated, leading to significant financial and professional consequences for the surgeons. Therefore, meticulous attention to cervical spinous fusion is imperative during spinal surgeries [8-10].

The CSP is typically situated at a considerable depth, except for the seventh cervical vertebral (C7) spinous process, which is referred to as the "vertebra prominence" due to its palpable nature at the base of the neck and its resemblance to thoracic spinous processes. The seventh cervical vertebral spinous process is a crucial landmark for surgical treatment [11,12]. CSP fusion predominantly manifests at the C2-C3 vertebral level. This fusion can be congenital, associated with Klippel-Feil syndrome, or acquired through degenerative conditions such as tuberculosis [13-19]. Nevertheless, the fusion of CSP in contiguous cervical vertebrae represents a factor that might induce inaccuracies in the enumeration of cervical vertebrae, potentially leading to surgical interventions at wrong spinal levels [6-8]. Existing research has focused solely on radiographs or dry bones [11-19]. Therefore, the present cadaveric study was conducted to determine the prevalence of fusion between adjacent CPS in adult cadavers. The objective was to provide anatomical insights that may aid spine surgeons in accurate vertebral level identification and assist surgeons in avoiding wrong-level cervical spine surgeries through better preoperative and intraoperative localisation.

MATERIALS AND METHODS

The present observational study was conducted at a teaching Medical Institute from year September 2018-June 2021 at in Smt. BK Shah Medical College & Research Institute, Gujarat, India. After obtaining ethical approval from the Institutional Ethical Committee (IEC) (Reference Letter No.- SVIEC/OW/MEDI/PHD/18005).

Inclusion and Exclusion criteria: The spinous processes of the cervical vertebrae were examined in 30 formalin-preserved adult human cadavers (15 males and 15 females). The cadavers were aged between 60 and 95 years, with an average age of 77.5±10.1. The study exclusively included specimens that exhibited no observable external deformities indications of injury, pathological conditions, or prior surgical interventions.

Study Procedure

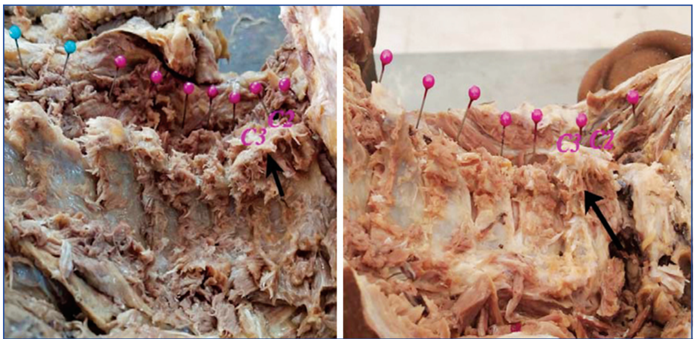
The cadavers were placed in the prone position on a flat table. A midline incision was made in the cervical region, and both the superficial and deep back muscles were identified and excised to reveal the cervical vertebral column. Subsequently, the spinous processes of each cervical vertebra were meticulously cleaned and examined to ascertain the presence of fusion between adjacent CSP. Complete osseous continuity between adjacent spinous processes without any visible or palpable interspinous gap, fibrous tissue, or fusion line was considered CPS fusion. The fusion line or interspinous ligament is typically absent or obliterated and bony contours appear continuous. In uncertain cases, gentle scraping was performed to confirm whether the continuity was osseous or fibrous. The level of fusion and laterality were documented and high-resolution photographs were taken for reference and analyses.

STATISTICAL ANALYSIS

Data collection and analysis were performed using Statistical Package for Social Sciences (SPSS) (version 23). The statistical analysis was primarily descriptive. Continuous variables are summarised as mean±Standard Deviation (SD), and categorical variables are expressed as frequencies and percentages. Because only two specimens demonstrated fusion, no comparative analyses were performed, and the results were limited to descriptive statistics with 95% confidence intervals.

RESULTS

The present study examined the cervical spine in 30 adult cadavers aged between 60 and 95 years, with a mean age of 77.5±10.1 years. Fusion between adjacent CSP was identified in two cadavers (6.66%, 95% CI=0-15.3%). This fusion was exclusively observed between the C2-C3 vertebrae [Table/Fig-1]. Both cases demonstrated complete osseous continuity without visible fusion lines, consistent with bony fusion. The transverse processes of the adjacent vertebrae did not exhibit fusion. Notably, CSP fusion was observed only in male cadavers (13.33%), whereas none of the female specimens showed evidence of fusion. Due to the limited number of fusion cases, the data were analysed descriptively, and no inferential statistical tests were applied.



[Table/Fig-1]: Fusion of the Cervical Spinous Process (CPS) at the C2-C3 (black arrow) vertebral level.

DISCUSSION

Wrong-level Spinal Surgery (WLSS) is not uncommon in the spinal column. The global incidence of WLSS in open spinal surgeries ranges from 0.1 to 17% [7]. According to Ammerman JM and Ammerman MD the incidence of wrong-level cervical diskectomy is reported to be between 6.8 and 7.6 per 10,000 cases annually [20]. Hsiang J (2011) noted that it is essential to understand the congenital abnormal variations in the spinal anatomy of the patient, as identified through pre-operative imaging studies, to prevent wrong-level surgery [6]. Most studies have been conducted on radiographs or dry bones, whereas the present study was conducted on cadavers [11-19]. The present study observed fusion between adjacent CSP in 6.66% of cases, which is similar to the 6.25% incidence reported by Sharma M et al., in the cervical region compare to other regions [13]. Other studies have reported a lower rate of fusion [Table/Fig-2] [13,21-23]. Previous studies have reported a higher prevalence of spinous process fusion in the lumbar region compared to other regions [22,24]. The most prevalent fusion occurs between the C2 and C3 vertebrae, which results in limited movement between them; hence, the C3 vertebra is termed the vertebra critica [13,17]. Sharma M et al., Saminathan S et al., Demeneopoulou E et al., and Vikani SK et al., found most common fusion at C2-C3 level in different cases which is similar with our result [13,17,19,22]. In contrast, Nwosu NC et al., reported fusion at the C6-C7 level, but the present study found fusion only at the C2-C3 level [25]. This fusion may be illusory, as the findings were not confirmed radiographically. The high prevalence of inconsistent fusion patterns of the CSP can make it extremely challenging for clinicians to accurately count the cervical level. This difficulty can easily result in wrong level spinal surgeries, which may have significant medical and legal implications [3,6].

Authors	Place of study	Sample size	Fusion (%)
Present study	Gujarat	30 Cervical spine specimens	6.66
Sharma M et al., (2013) [13]	Punjab	48 Dry vertebral columns	6.25
Sar M et al., (2017) [21]	Odisha	392 Dry vertebrae	1.02
Vikani KS et al., (2019) [22]	Gujarat	259 Dry vertebrae	0.38
Deepa S et al., (2014) [23]	Gujarat	50 Dry vertebral columns	2

[Table/Fig-2]: Comparison of Cervical Spinous Process (CPS) fusion with other studies [13,21-23].

Vertebral fusion may be congenital, arising from the incomplete segmentation of sclerotomes at specific levels, or acquired through various other causes, such as tuberculosis, cardiopulmonary anomalies, renal anomalies, cardiac defects, or trauma. Congenital anomalies, including Klippel-Feil syndrome, are characterised by a triad of a short neck, low posterior hairline, and reduced range of neck motion. Associated anomalies may include scoliosis, spina bifida occulta, renal abnormalities, rib deformity, deafness, synkinesia, congenital heart disease, and craniofacial abnormalities. In this syndrome, cervical vertebra fusion most commonly occurs at the C2-C3 and C5-C6 levels [15,18,26].

Moreover, awareness of this anatomical CSP fusion can help prevent misinterpretation during radiological evaluation and ensure accurate vertebral localisation. Although the small number of fusion cases limits statistical interpretation, these observations contribute valuable baseline data for understanding variations in cervical spine anatomy relevant to both anatomists and neurosurgeons.

Limitation(s)

The study focused on a specific age range (60-95 years, with an average of 77.5 years), which may limit the applicability of the results to other age groups without additional validation. The results were not corroborated by radiographic images of the relevant area, which could mean that the observed higher prevalence is misleading. The present study had a relatively small sample size (n=30), which was primarily dependent on the availability of cadavers for anatomical research purposes. Consequently, the data were analysed descriptively, and the findings should be interpreted with caution. Despite these limitations, the present study provides valuable baseline information that can serve as a reference for future research with larger sample sizes.

CONCLUSION(S)

The fusion of the CSP is relatively uncommon in the adult population; however, when it does occur, it is predominantly observed at the C2-C3 level in male cadaveric specimens. These findings provide a crucial reference for spinal surgeons to prevent surgical errors. Both preoperative and intraoperative imaging is essential for minimising surgical errors. Future studies should include larger and more diverse populations, combine cadaveric and radiological data, and explore possible developmental or genetic causes to better understand the occurrence and importance of CSP fusion.

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