Morphological Characteristics of the Spinous Process of Axis: Clinical Implications for Cervical Spine Manipulation

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Abstract

Objective: The purpose of this study was to evaluate the osseous variation of the axis spinous process as it may relate to palpation by clinicians.

Methods: Morphologies of the bifid spinous process in the intact dry axis of 121 Chinese adult were investigated and classified. The angular deflection of the spinous processes, the bifid spinous processes (the bifid portions of the spinous processes), and the length of the bifid spinous processes were observed and measured.

Results: The bifid spinous process morphologies were classified into 4 types: inverted-V shape (n = 49), inverted-U shape (n = 50), M shape (n = 18), and nonbifid spinous processes (n = 4). The direction of the spinous processes and bifid spinous processes were consistent because they depended on each other's direction of deviation. When the correlation between angular deflection of spinous processes and bifid spinous processes was analyzed, the right deviations of spinous process specimens (29 cases) showed that angular deflections of spinous processes were equal to bifid spinous processes and there was no statistically significant difference seen between them ($t = 0.286$, $P > .05$), whereas in the left deviations of spinous process specimens (49 cases), the angular deflection of spinous processes were not equal in length, but bigger than the bifid spinous processes, which was statistically significant ($t = -3.079$, $P = .003 < .05$).

Conclusion: The anatomical structure of the spinous processes and the bifid spinous processes vary from one another, but they exhibit some regularity. In clinical spinal manipulation practice, the anatomical characteristic of the axis should be taken into account during cervical static palpation, diagnostic imaging, and treatment. (J Manipulative Physiol Ther 2019;42:82-88)

Key Indexing Terms: *Anatomy; Manipulation, Spinal*

Introduction

The cervical spinous process and transverse process, which are the vital osseous marks of the cervical static palpation, play important roles in cervical spinal manipulation.[1] In clinical spinal manipulation practice, the deviation of spinous process is regarded as very important objective evidence of minor misalignments of joints, such as the type I and II atlantoaxial rotatory subluxation and atlantoaxial rotatory fixations.[2] The diseases of the atlantoaxial joint have been a topic of general interest in clinical research owing to the high risk of myelopathy and life-threatening neurologic injuries.[3,4] Cervical spinal manipulation is one of the nonsurgical treatments to treat the diseases of minor misalignments of joints by manual therapists, chiropractors, physical therapists, etc.[5-7] The function of cervical spinal manipulation to correct the atlantoaxial joint is regarded as manipulative reduction.[8-10] In clinical practice, the deviation of spinous processes, which is manually palpable by therapist, is often used to determine atlantoaxial joint derangement.[11-13] However, the structure and function of atlantoaxial vertebral anatomy are quite complex, which results in misdiagnosis and confusion in clinical practice and interventions.[14,15] To improve the accuracy in treatment of minor misalignments of joints, a comprehensive research study has been performed on the anatomical structure of axis to delineate and provide the anatomical basis for accurate positioning of the cervical static palpation.

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Methods

Participants

The Department of Anatomy, School of Basic Medical Science, Southern Medical University, China, provided 134 dry adult axes specimens of Chinese origin for this study. Of these 134, only 121 of them were included in this study because the rest were either damaged or had transverse processes, which were asymmetrical. The information about age and sex of those axes was unknown. Ethical approval to undertake this study was obtained from Southern Medical University's Human Research Ethics Committee.

Anatomical Observation and Measurement

Observation of Bifid Spinous Process Types. On the measuring platform, the shapes of bifid spinous processes were observed from back to front, and then they were classified into categories based on their similarities.

Observation and Measurement of Direction of Spinous Processes and Its Angles. The specimens were fixed horizontally on the protractor during observation and measurement. The line of the 2 apexes of transverse processes was regarded as a horizontal line (because the specimens with asymmetrical transverse processes were omitted from the study) and its midpoint as point "zero." The deviations of the spinous processes and its angles were observed and measured against the superior surface (Fig 1.).

Measurement of Bifid Spinous Processes. Each of the sides of the bifid spinous process is measured independently from point B to the apex of point A with a Vernier caliper (the minimum scale was 0.02 mm; China National Machinery Import & Export Corp, Beijing, China) (Fig 1).

Observation and Measurement of Direction of Bifid Spinous Processes and Its Angles. The specimens were fixed in a similar way as was mentioned earlier for measurement of spinous process and its angles, and the measurements of deviations of bifid spinous processes and its angles were also carried out in a similar way (Fig 1).

Analysis of Data

The statistical analyses were performed with the SPSS 20.0 software (IBM SPSS Statistics for Windows, IBM Corp, Armonk, New York). The measured data (the angles of deviation of spinous processes and bifid spinous processes, the length of bifid spinous processes) were expressed in the form of $\overline{\chi} \pm$ SD (min-max). The direction of deviation of spinous processes and bifid spinous processes were expressed as frequencies and analyzed by the χ^2 test. A paired-samples *t* test was used for the comparison between the angles of deviation of the spinous processes and the bifid spinous processes. When the *P* value was < .05, the difference was considered statistically significant.

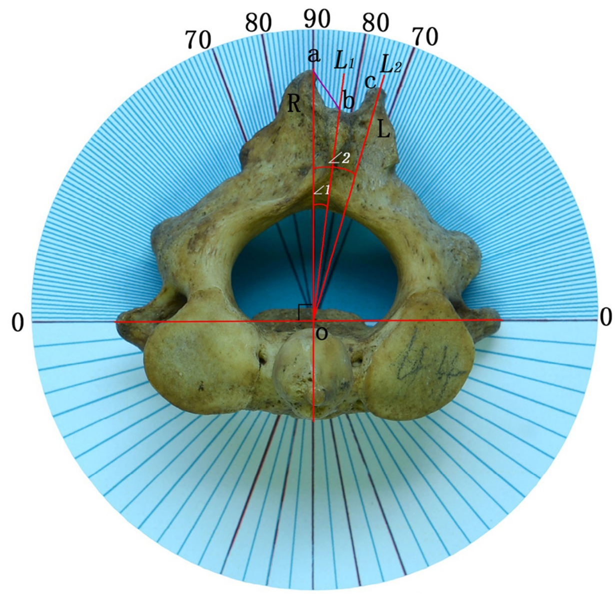

Fig 1. *The apex of bifid spinous process (a and c). The point b is the most posterior point of the ridge that forms the superior surface of the spinous process. The middle line through the spinous process of axis vertebrae (L_1); the line through the apex of left bifid spinous process (L_2); the length of right bifid spinous process (ab); the angle of deviation of spinous process ($\angle_1$); the angle of deviation of the left bifid spinous process ($\angle_2$).*

Results

Structures of Bifid Spinous Processes Types

The bifid spinous process morphologies of 121 specimens (117 cases [96.68%] of bifid spinous processes and 4 cases [3.32%] had no bifurcation, as given in Fig 2) were classified into 4 types: inverted-V shape (n = 49), inverted-U shape (n = 50), M shape (n = 18), and nonbifid spinous processes (n = 4) (Fig 3). Forty-three cases (36%) had no deviation of spinous processes including all nonbifid spinous processes, whereas 78 cases (64%) showed some deviation of a *type*. The average length of 2 bifid spinous processes had no significant difference; however, both arms were not equal (except in 1 case). A left large-angle deviation of the bifid spinous processes was seen in 73 cases (62%), as shown in Figure 2.

The Related Measurements of Spinous Processes and Bifid Spinous Processes

The length of the bifid spinous processes and the angles of deviation of the spinous processes and the bifid spinous processes were expressed as $\overline{\chi}$ ± standard deviation (min-max) as shown in Tables 1-3. The angular deflection of the spinous processes varied within a large range (1°-9°), although the average angle of deflection had no significant difference (Table 1). The average length and angle of the bifid spinous processes decreased orderly as M shape, inverted-U shape, and inverted-V shape, respectively,

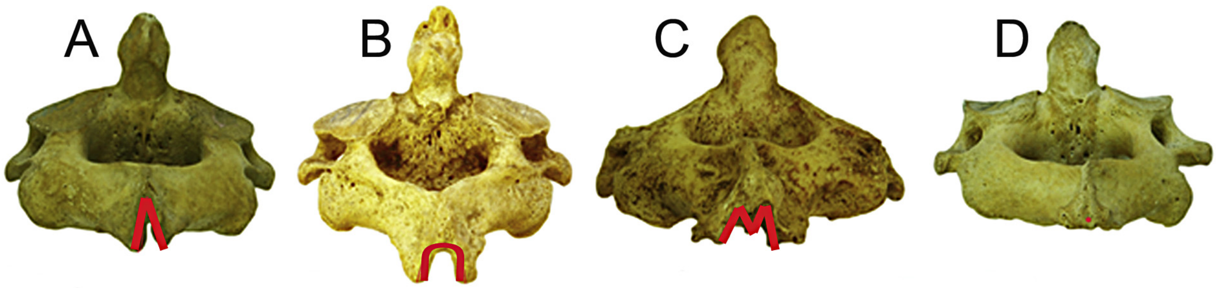

Fig 2. *(A) Inverted-V shape, (B) inverted-U shape, (C) M shape, (D) nonbifid spinous processes.*

as shown in Tables 2-3. There was a statistically significant difference between the right and left angles of deviation of the bifid spinous processes in inverted-V shape (a paired *t* test, $t = -2.780$, $P = .008 < .05$); the left angles of deviation were bigger than the right in inverted-V shape (Table 3).

The Correlation Between the Spinous Processes and the Bifid Spinous Processes

The Correlation Between the Directions of Deviation of Spinous Processes and Bifid Spinous Processes. Of the original 121 specimens considered, only 74 were taken into account here because no deviation of the spinous processes and the same angle of deviation of 2 bifid spinous processes were omitted from the original sample. Directions of deviation of spinous processes and bifid spinous processes were analyzed by the χ^2 test in the 74 specimens that showed the deviations of spinous processes and bifid spinous processes, and it had no significant statistical difference, as given in Table 4 ($\chi^2 = 0.57$, $P > .45$). The directions of deviation of the spinous processes and bifid spinous processes were consistent because they depend on each other's direction of deviation.

The Correlation Between Angular Deflection of Spinous Processes and Bifid Spinous Processes. Of the original 121 specimens that were considered, only 78 were taken into account because no deviation of spinous processes were omitted from the original sample. The right and left deviations of spinous process specimens were 29 and 49 cases, respectively (Fig 2).

The right deviations of spinous process specimens (29 cases) were selected from total axis samples. The angular deflection of spinous processes and bifid spinous processes were analyzed by *t* test. There was no statistically significant difference seen between them ($t = 0.286$, $P > .05$). In the right deviation of the spinous process specimens, the angular deflections of the spinous processes were equal to bifid spinous processes (Table 5).

The left deviations of the spinous process specimens (49 cases) were selected from the total axis samples. The *t* test analysis of the angular deflection of the spinous processes and bifid spinous processes produced statistically significant difference results ($t = -3.079$, $P = .003 < .05$). In the left deviations of the spinous process specimens, the angular deflection of the spinous processes was not equal to bifid spinous processes, and in fact the angular deflection of bifid spinous processes were bigger than spinous processes (Table 5).

Discussion

Previous published studies hardly reported the details related to research on axis spinous processes.[1,16,17] The axis spinous process is one of the osseous marks of the cervical static palpation in cervical spinal manipulations.[1] In the cervical spinal manipulation, the practice of cervical rotation is often performed to correct the deviation of spinous processes, which are regarded as the manipulative reduction.[1] In clinical practice, it is important to judge the direction of deviation of spinous processes by cervical static palpation. The direction of deviation of spinous processes is important information to cervical rotatory manipulation treatment.[13] The cervical rotatory manipulation is one of Feng's spinal manipulative therapies, which was created by Tian-You Feng in the 1970s and now is very popular in China.[18] The manual therapist needs to identify the direction of deviation of the spinous process, with the help of a doctor's thumb steadily and firmly pushed against the spinous process until the end of the cervical rotatory manipulation during the process.[18] In this experiment, the number of right, left, or no deviation of spinous processes was 29, 49, and 43, respectively. The experiment results indicated that approximately one-third of the specimens had no deviation of spinous processes and two-thirds of specimens had the deviation. Congenital deviation of spinous processes is variable. The bony landmark variations of spinous processes are not indicators for spinal manipulation because this variance.

The osseous marks of the cervical static palpation are the tips of bifid spinous processes rather than the spinous process in cervical spinal manipulations.[19] The shape, length, and deviation of the bifid spinous processes were

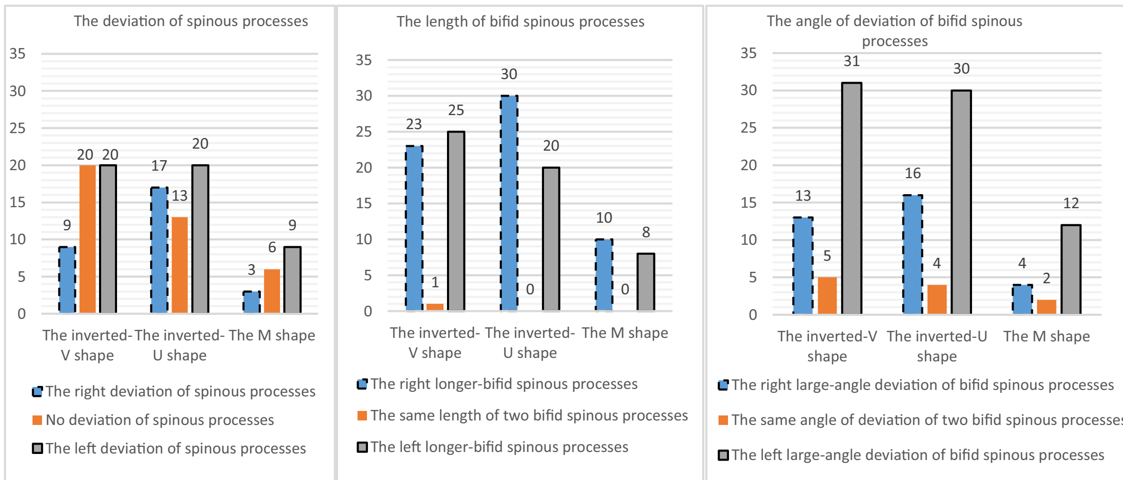

Fig 3. *The numbers and characteristic distribution of spinous processes and bifid spinous processes.*

Table 1. *The Angles of Deviation of the Spinous Processes*

Types	The Angles of Right Deviation of Spinous Processes	The Angles of Left Deviation of Spinous Processes
Inverted-V shape (29 cases)	2.9° ± 1.4° (1°-5°)	3.6° ± 1.6° (1°-9°)
Inverted-U shape (37 cases)	3.6° ± 1.4° (1°-6°)	3.5° ± 1.7° (2°-9°)
M shape (12 cases)	3.7° ± 1.2° (3°-5°)	3.6° ± 1.7° (1°-6°)
Total	3.3° ± 1.4° (1°-6°)	3.6° ± 1.6° (1°-9°)

The table explains the number of specimens, which showed the average angles of deviation of spinous processes in different category of vertebrae. The angular deviation of spinous process is ∠1. Values are mean ± standard deviation.

Table 2. *The Lengths of Bifid Spinous Processes*

	The Lengths of Bifid Spinous Processes		
Types	Right	Middle	Left
Inverted-V shape (49 cases)	7.46 mm ± 2.03 mm (3.20-13.10 mm)	-	7.30 mm ± 2.26 mm (3.18-14.78 mm)
Inverted-U shape (50 cases)	9.10 mm ± 2.37 mm (3.42-14.56 mm)	-	8.83 mm ± 2.66 mm (4.08-14.62 mm)
M shape (18 cases)	10.57 mm ± 2.93 mm (6.78-17.96 mm)	3.10 mm ± 1.09 mm (1.58 -5.40 mm)	9.56 mm ± 1.30 mm (7.00-11.52 mm)
Total	8.30 mm ± 2.48 mm (3.20-17.96 mm)	3.10 mm ± 1.09 mm (1.58 -5.40 mm)	8.64 mm ± 2.57 mm (3.18-14.78 mm)

The number of specimens that showed the average lengths of bifid spinous processes in different category of vertebrae. The length of bifid spinous processes are measured as ab and bc as described in Figure 1. Values are mean ± standard deviation.

not always the same, and these variable morphological characteristics would directly influence the cervical static palpation. The average length of 2 bifid spinous processes had no significant difference. The number of the longer right, left, and same length bifid spinous processes was 63, 53, and 1, respectively. The left large-angle deviation of bifid spinous processes had significant difference; 62% of axis specimens are the left large-angle deviation of bifid spinous processes. The number of the right, left large-angle deviation of bifid spinous processes, and the same angle of deviation of 2 bifid spinous processes was 33, 73, and 11, respectively. No deviation of bifid spinous processes was seen in 10% of cases with the same length and angle of 2 bifid spinous processes. Therefore, the bifid spinous processes (90%) are commonly asymmetrical; the tips of the bifid spinous processes as the osseous marks of cervical static palpation are not reliable. If a clinician palpates the bifid spinous process of axis as “not in the midline,” this

Table 3. *The Angles of Deviation of Bifid Spinous Processes*

Types	The Angles of Deviation of Right Bifid Spinous Processes	The Angles of Deviation of Left Bifid Spinous Processes
Inverted-V shape (49 cases)	8.1° ± 3.7° (2°-22°)	10.1° ± 3.9° (4°-19°)
Inverted-U shape (50 cases)	11.9° ± 4.4° (0°-27°)	13.9° ± 4.6° (4°-25°)
M shape (18 cases)	14.4° ± 4.8° (5°-25°)	16.9° ± 4.9° (12°-30°)
Total	10.7° ± 4.8° (0°-27°)	12.8° ± 5.0° (4°-30°)

There were 2 bifid spinous processes in every axis. Each side of the bifid spinous process was measured independently. The angular deviation of bifid spinous process is ∠2. Values are mean ± standard deviation.

Table 4. *The Directions of Deviation of Spinous Processes and Bifid Spinous Processes*

	Directions of Deviation of Spinous Processes		
Types	Left	Right	Total
Directions of deviation of bifid spinous processes			
Left	47	2	49
Right	5	20	25
Total	52	22	74

The direction of deviation of bifid spinous processes depends on the bigger angle of bifid spinous processes. For example, the angle of deviation of the left bifid spinous process is bigger than the right; the direction of the deviation of the bifid spinous process turns left. There was no statistically significant difference ($\chi^2 = 0.57$, $P > .45$) between the directions of spinous processes and bifid spinous processes.

Table 5. *The Angular Deflection of Spinous Processes and Bifid Spinous Processes*

	The Mean of the Angular Deflection	
Types	Spinous Processes	Bifid Spinous Processes
The angular deflection		
Right (29 cases)	3.3° ± 1.4°	3.1° ± 4.6°
Left (49 cases)	3.6° ± 1.6°	5.8° ± 5.4°

The angular deflections of the bifid spinous processes are the absolute value of the difference between the 2 angles of deviation of the bifid spinous processes. The direction of deviation of the bifid spinous processes depends on the bigger angle of the bifid spinous processes. In the right deviation of the spinous process specimens (29 cases), there was no statistically significant difference between the angular deflection of the spinous processes and the bifid spinous processes ($t = 0.286$, $P > .05$). In the left deviation of spinous process specimens (49 cases), there was a statistically significant difference between the angular deflection of spinous processes and bifid spinous processes ($t = -3.079$, $P = .003 < .05$). Values are mean ± standard deviation.

could readily be because of the variable shapes and angulations of the various parts of the bifid spinous process and not because of any rotary misalignment of the bone.

Previously, most studies of the cervical spinal manipulations were mainly focused on the correlation between the deviation of spinous processes and minor misalignments of joints in China.[9] However, the morphological characteristics of bifid spinous processes have rarely been studied. The directions of deviation of spinous processes and bifid spinous processes were analyzed by the χ^2 test. The experiment indicated that the directions of deviation of the spinous processes and bifid spinous processes were consistent because they depended on each other's direction of deviation. The angular deflection of spinous processes and bifid spinous processes were analyzed by *t* test. As a result, in the right deviation of spinous process specimens, the angular deflection of spinous processes was equal to bifid spinous processes. In the left deviation of spinous process specimens, the angular deflection of spinous processes was not equal to bifid spinous processes; the angles of deviation of bifid spinous processes were greater than spinous processes. According to the statistical results, the direction and angle of deviation of spinous processes and bifid spinous processes have some regularity. In clinical practice, cervical static palpation, diagnostic imaging, and treatment of minor misalignments of joints may be aided by these findings.

Limitations

Measurements were made on dry axis Chinese adult specimens and not in imaging and in vivo, which may have slight variation with the in vivo structures and thus shows discrepancy compared with the clinical data. Because only 121 adult axes were used in this study, the specimens did necessarily reflect the larger patient population. It was possible that the measuring tool used in the study was simple and had some inexplicable defect to cause experimental errors. The measurement tool (vernier caliper) used had a negative error of (0.1-y) cm. To correct the reading, we subtracted the error from the measurement.

Conclusion

According to the findings of this study, the direction of the spinous processes and bifid spinous processes were consistent because they depend on each other's direction of deviation; in the right deviation of spinous process specimens, the angular deflection of spinous processes was equal to bifid spinous processes; in the left deviation of spinous process specimens, the angular deflection of spinous processes was not equal to the bifid spinous processes, and in fact, was bigger than the spinous processes. The impact of the deviation of the spinous processes and the bifid spinous processes should be considered during cervical static palpation.

Funding Sources and Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): Y-K.L.
Design (planned the methods to generate the results): L-Q.L.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): L-Q.L.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): J.Q.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): L-Q.L.
Literature search (performed the literature search): F.Y.
Writing (responsible for writing a substantive part of the manuscript): L-Q.L.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): L-Q.L.

Practical Applications

- According to the findings of this study, the direction of the spinous processes and bifid spinous processes were consistent because they depend on each other's direction of deviation.
- In the right deviation of spinous process specimens, the angular deflection of spinous processes was equal to bifid spinous processes; in the left deviation of spinous process specimens, the angular deflection of spinous processes was not equal to the bifid spinous processes, and in fact, was bigger than the spinous processes.
- The impact of the deviation of the spinous processes and the bifid spinous processes should be considered during cervical static palpation.

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