AXIS FOR ROTATION AT THE INTERVERTEBRAL JOINT IN JAPANESE MONKEYS

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Received December 3, 2003

Abstract : The position of axis for rotation at the intervertebral joint was investigated using ten Japanese monkeys. The position of axis for rotation at the intervertebral joint was shifted from dorsal to ventral direction on the superior and inferior views of the 1st thoracic vertebra and was next shifted from ventral to dorsal direction on the superior and inferior views of the 10th thoracic vertebra, with some exceptions. X-ray examination demonstrated that in the Japanese monkeys, lordosis was seen in both the cervical and lower lumbar (L5–L7) spine, whereas kyphosis was seen in the thoracic and upper lumbar (L1–L4) spine. Therefore, the possibility that the position of axis for rotation at the intervertebral joint was related to the curvature of the spinal column was not supported by the present study.

Key words : intervertebral joint, Japanese monkey, spinal column, accessory process

INTRODUCTION

There are some reports[1,2] on the structure of vertebrae in monkeys. It is known that long and slender accessory processes are present in the range between the lower thoracic and upper lumbar vertebrae of monkeys[1,2]. The authors[3] observed that long and slender accessory processes were present in the range between the 10th thoracic and the 5th lumbar vertebrae of a baboon. However, there were few reports on the axis of rotation at the intervertebral joint of monkeys. Therefore, the authors investigated the axis of rotation at the intervertebral joint using Japanese monkeys. It was found that the position of axis for rotation at the intervertebral joint was shifted from dorsal to ventral direction on the superior and inferior views of the 1st thoracic vertebra and was next shifted from ventral to dorsal direction on the superior and inferior views of the 10th thoracic vertebra, with some exceptions.

MATERIALS AND METHODS

Materials

The animal experiment was carried out in accordance with the US NIH Guide for the care and use of laboratory animals. Japanese monkeys were bred at the Primate Research Institute, Kyoto University. The monkeys were pretreated with intramuscular injection of

ketamine hydrochloride (10 mg/kg) and deeply anesthetized by intravenous administration of pentobarbital sodium (Nembutal; 30 mg/kg). The monkeys were sacrified by severing the common carotid artery. The spinal columns were resected and photographed by a soft X-ray apparatus. Thereafter, the vertebrae were resected from the spinal columns.

X-Ray Examination

Spinal columns were photographed with a soft X-ray apparatus (Softex type E40; Softex Co., Osaka, Japan) as described previously[4].

RESULTS

Structure of Vertebrae

Ten Japanese monkeys ranging in age from 2 to 29 years old were studied. The backbone of the Japanese monkey was composed of 7 cervical, 12 thoracic, 7 lumbar, 3 sacral, and 9–16 coccygeal vertebrae. As shown in Fig. 1, long and slender accessory processes were present

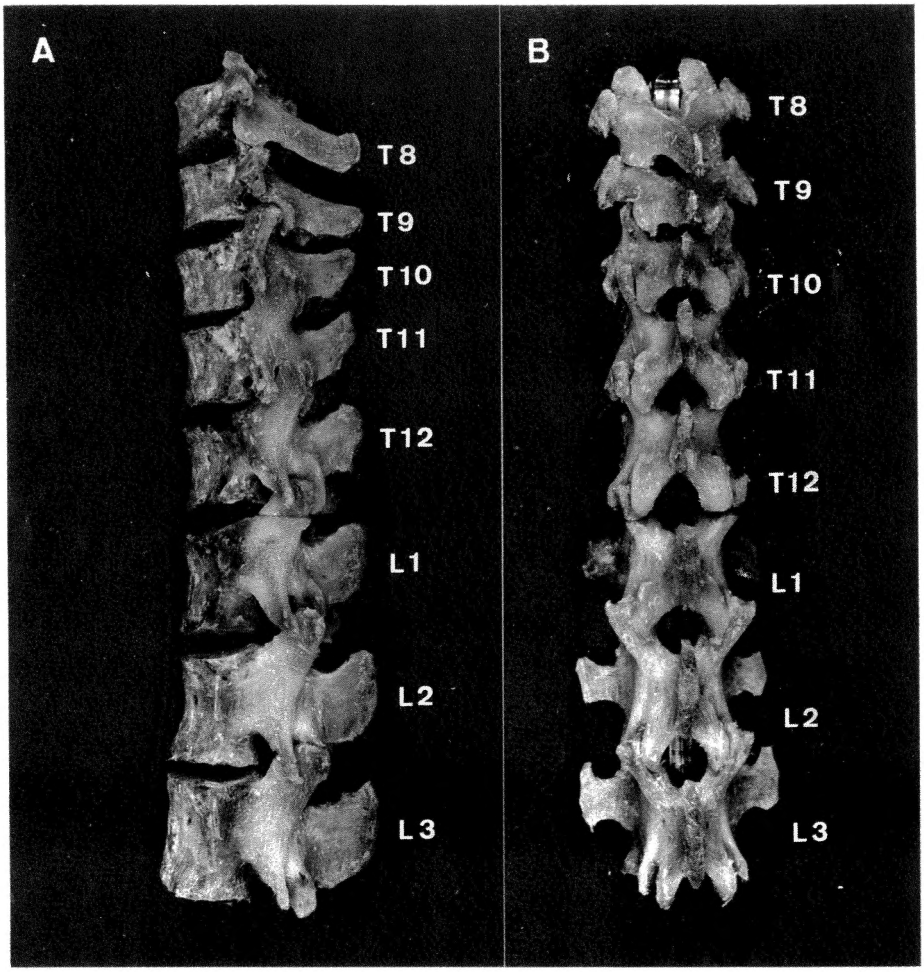

Fig. 1. Lateral (A) and posterior (B) views of the lower thoracic and upper lumbar vertebrae in the Japanese monkey (2 years old).

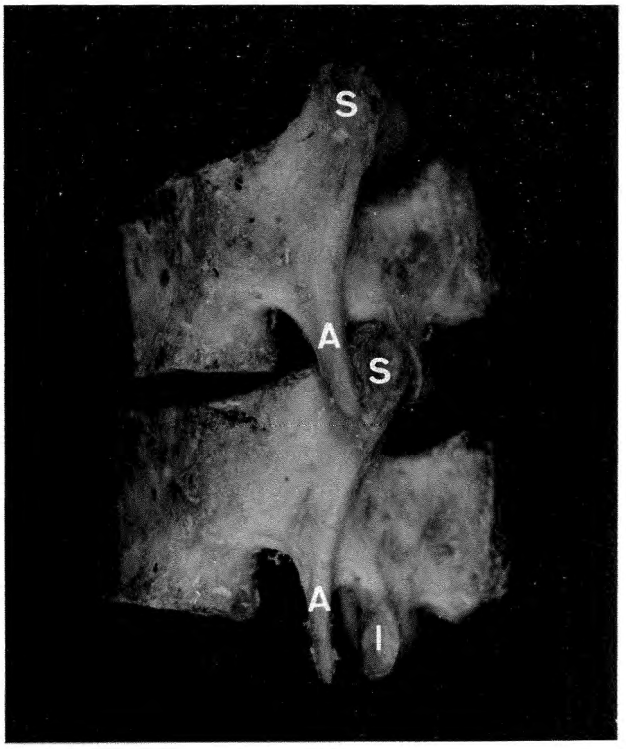

Fig. 2. Lateral view of the 1st and 2nd lumbar vertebrae in the Japanese monkey (2 years old). A, I, and S denote the accessory, inferior articular, and superior articular processes, respectively.

in the range from the 10th thoracic to the 5th lumbar vertebrae. The accessory process was absent from the last two lumbar vertebrae of the 6th and 7th lumbar vertebrae. The transverse processes of the thoracic vertebrae cranial to the 8th thoracic vertebra projected horizontally, but the accessory processes declined at an angle of 60° to 70° to horizontality in the thoracic and lumbar vertebrae caudal to the 8th thoracic vertebra (Fig. 1A). Although the superior articular processes were not tightly held in the 11th and 12th thoracic vertebrae (Fig. 1B), they were tightly held between the accessory and inferior articular processes of the adjacent vertebra in the range between the 1st and 5th lumbar vertebrae (Fig. 2). Therefore, the rotation movement of the spinal column was much restricted in the range between the 1st and 5th lumbar vertebrae.

Rotation Movement of Intervertebral Joint

The axis of rotation at the intervertebral joint was examined in the cervical, thoracic, and lumbar vertebrae of ten Japanese monkeys. Figure 3 indicates that the position of axis for rotation is shifted from dorsal to ventral direction on the superior and inferior views of the 1st thoracic vertebra. The position of axis for rotation was dorsal in the 2nd–7th cervical vertebrae, whereas it was ventral in the thoracic vertebra caudal to the 2nd thoracic vertebra. The same finding was obtained in all of the other nine cases of the Japanese monkeys.

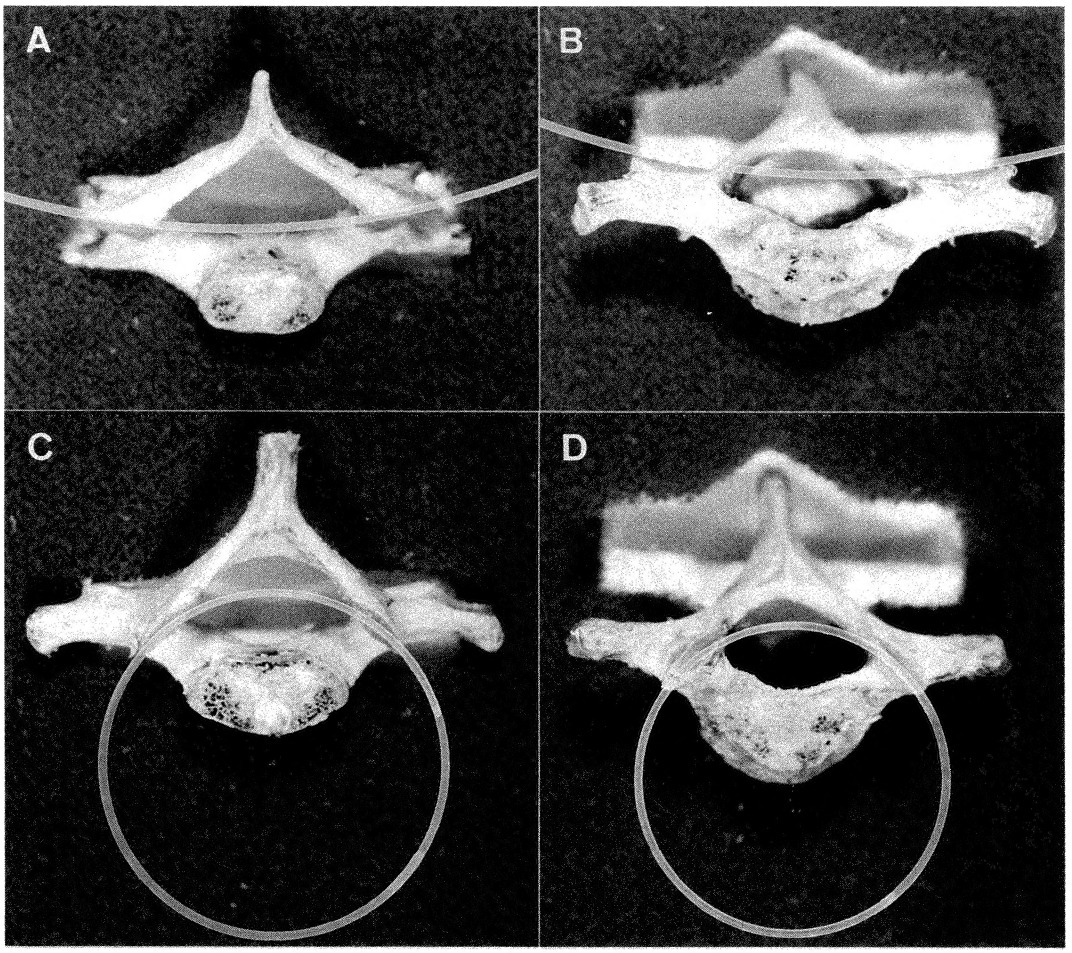

Fig. 3. The upper shift of the position of axis from dorsal to ventral direction for rotation at the intervertebral joint. The white circles show the rotation movement at the intervertebral joint. A, inferior view of the 7th cervical vertebra; B, superior view of the 1st thoracic vertebra; C, inferior view of the 1st thoracic vertebra; and D, superior view of the 2nd thoracic vertebra.

Figure 4 indicates that the position of axis for rotation is shifted from ventral to dorsal direction on the superior and inferior views of the 10th thoracic vertebra in the Japanese monkey. The position of axis for rotation was ventral in the thoracic vertebrae cranial to the 10th thoracic vertebra, whereas it was dorsal in the 11th and 12th thoracic and all of the lumbar vertebrae. The same finding was obtained in seven other cases; in one case each the position of axis for rotation was shifted from ventral to dorsal direction on the superior and inferior views of the 9th thoracic vertebra (9-year-old subject) or the 11th thoracic vertebra (24-year-old subject).

The shift of axial position for rotation at the intervertebral joint occurs suddenly on the superior and inferior views of both the 1st and 10th thoracic vertebrae, but does not occur gradually.

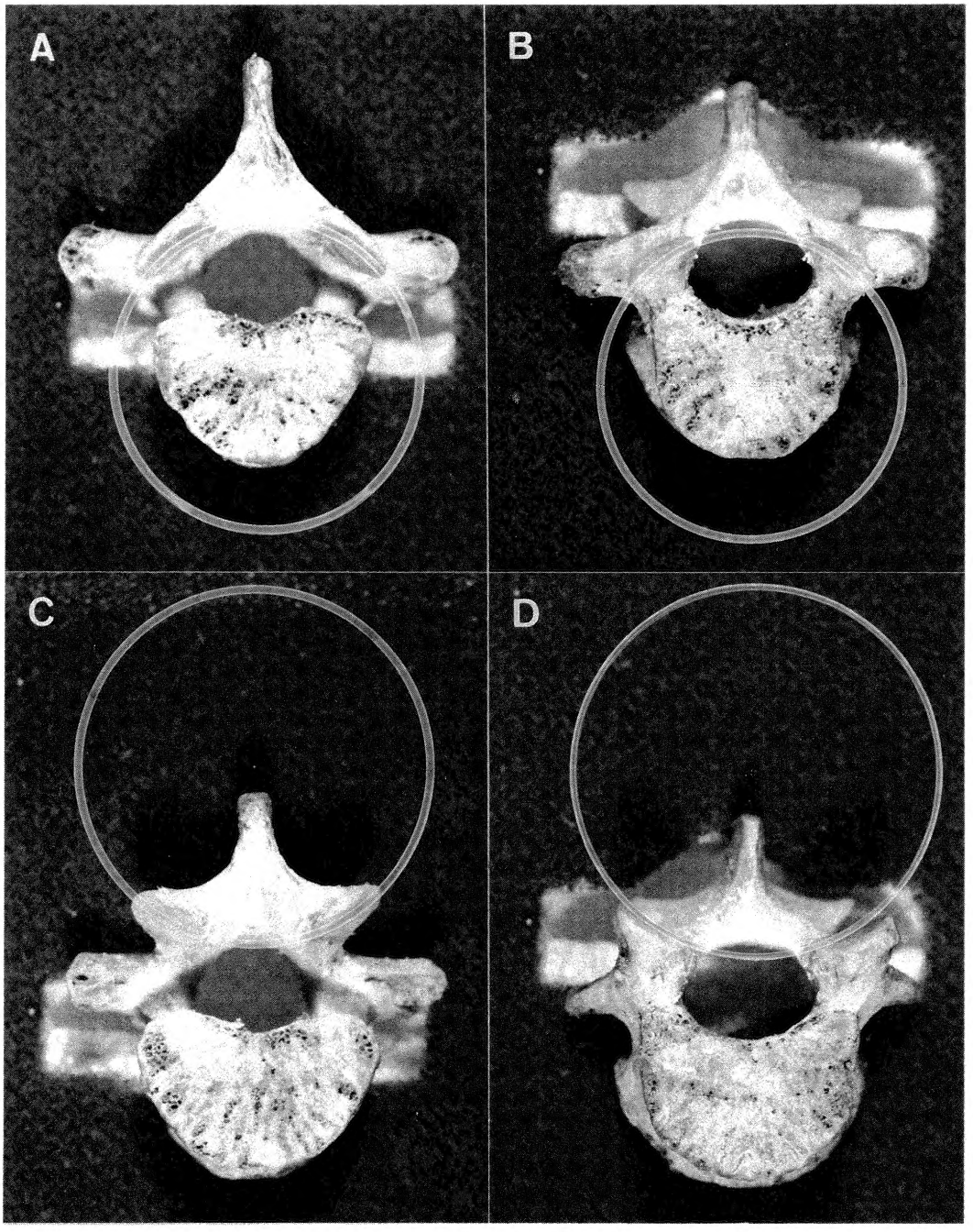

Fig. 4. The lower shift of the position of axis from ventral to dorsal direction for rotation at the intervertebral joint. The white circles show the rotation movement at the intervertebral joint. A, inferior view of the 9th thoracic vertebra; B, superior view of the 10th thoracic vertebra; C, inferior view of the 10th thoracic vertebra; and D, superior view of the 11th thoracic vertebra.

Fig. 5. X-ray photograph of the spinal column in the Japanese monkey (8 years old). T1, the 1st thoracic vertebra; T10, the 10th thoracic vertebra; L5, the 5th lumbar vertebra; and S, sacrum.

Relationship Between the Position of Axis for Rotation and Curvature of Spinal Column

To examine the relationship between the position of axis for rotation at the intervertebral joint and the curvature of the spinal column, the spinal columns were photographed beforehand with a soft X-ray apparatus, and thereafter the vertebrae were resected from the spinal columns. Figure 5 shows an X-ray photograph of the spinal column from an 8-year-old Japanese monkey. The position of axis for rotation at the intervertebral joint was shifted from dorsal to ventral direction on the superior and inferior views of the 1st thoracic vertebra and was next shifted from ventral to dorsal direction on the superior and inferior views of the 10th thoracic vertebra. Lordosis was seen in both the cervical and lower lumbar (L5-L7) spine, whereas kyphosis was seen in the thoracic and upper lumbar (L1-L4) spine. Therefore, the possibility that the position of axis for rotation at the intervertebral joint is dorsal in the spinal site of lordosis, whereas it is ventral in the spinal site of kyphosis, was not supported by the present study.

DISCUSSION

The present study revealed that the position of axis for rotation at the intervertebral joint was shifted from dorsal to ventral direction on the superior and inferior views of the 1st thoracic vertebra and was next shifted from ventral to dorsal on the superior and inferior views of the 10th thoracic vertebra, with some exceptions.

Kimura et al.[1] studied the vertebrae of crab-eating monkeys (Macaca fascicularis) and reported that the last two thoracic and the 1st-5th lumbar vertebrae had a distinct accessory process ventral to the inferior articular process, and the superior articular and mamillary processes were tightly held between the accessory and inferior articular processes of the adjacent vertebra. The accessory processes in the vertebrae of the Japanese monkey were morphologically similar to those of the crab-eating monkey.

In the present study, the backbone of the Japanese monkey was composed of 7 cervical, 12 thoracic, 7 lumbar, 3 sacral, and 9-16 coccygeal vertebrae. Schultz[2] reported that the backbone of Macaca was composed of 7.0 cervical, 19.0 thoracic plus lumbar, 3.0 sacral, and 17.0 coccygeal vertebrae on the average. The coccygeal vertebrae of the Japanese monkey were slightly fewer in number than those of Macaca reported by Schultz[2].

In the case of the crab-eating monkey[1], it was suggested that the position of axis for rotation at the intervertebral joint was shifted from ventral to dorsal direction on the superior and inferior views of the 10th thoracic vertebra. Human vertebrae present in Nara Medical University were examined and it was found that the position of axis for rotation at the intervertebral joint was shifted from ventral to dorsal direction on the superior and inferior views of the 12th thoracic vertebra in 12 out of 17 cases, whereas it was shifted on the superior and inferior views of the 11th thoracic vertebra in 5 out of 17 cases.

Based on clinical observations, Gregersen and Lucas[5] suggested a possible shift of the axial rotation from the disc center of the thoracic vertebra to the pedicle of the lumbar vertebra.

The authors[3] investigated the vertebrae of a baboon and observed that the position of axis for rotation at the intervertebral joint was shifted from dorsal to ventral direction on the

superior and inferior views of the 1st thoracic vertebra and was next shifted from ventral to dorsal direction on the superior and inferior views of the 10th thoracic vertebra.

Preuschoft et al.[6] studied a curvature of the lumbar spine in Japanese Macaques trained for bipedalism and reported that Japanese monkeys gradually acquired a pronounced lordosis of the lumbar spine. They revealed that it was due to a relative increase of the ventral lengths of the vertebral bodies. It is interesting to speculate whether the position of axis for rotation at the intervertebral joint is modified by training for bipedalism.

There is a possibility that the position of axis for rotation at the intervertebral joint is related to the curvature of the spinal column, namely it is dorsal in the spinal site of lordosis, whereas it is ventral in the spinal site of kyphosis. The present study revealed that the position of axis for rotation at the intervertebral joint was dorsal, but not ventral, in the lower thoracic (T11–T12) and upper lumbar (L1–L4) spine of kyphosis. Therefore, the finding of the Japanese monkeys did not support the possibility. Incidentally, slender accessory processes restricted the rotation movement of spinal column in the lower thoracic and upper lumbar spine.

ACKNOWLEDGMENT. This study was conducted under the Cooperation Research Program of the Primate Research Institute, Kyoto University.

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