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Influence of Age and Sex on the Position of the Conus Medullaris and Tuffier's Line in Adults

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Background: **The purpose of this study was to analyze the position of the conus medullaris and Tuffier's line in the same patient population, to correlate this position with age and sex, and to determine an objective guide for the selection of a safe intervertebral space during spinal block.**

Methods: **Magnetic resonance imaging studies of the lumbar spine were reviewed in 690 consecutive patients. The study population consisted of patients older than 20 yr who had been referred for imaging to assess possible causes of low back pain. The position of the conus medullaris was defined as the most distal point of the cord that could be visualized on the sagittal sequence. A line perpendicular to the long axis of the cord was extended to the adjacent vertebra. In the lumbar plain films, the Tuffier's line was defined by drawing a horizontal line across the highest points of the iliac crests. Each vertebral body and intervertebral space was divided into four segments: upper, middle, and lower thirds of a vertebral body, and the intervertebral space. Each segment of a vertebral body or intervertebral space that the lines crossed was identified and recorded. The positions, stratified by decade of age, were compared using analysis of variance. The Tukey test was used for *post hoc* comparisons. Comparisons between sex were performed with the unpaired *t* test.**

Results: **The conus medullaris and Tuffier's line (median [range]) were positioned at L1-lower (T12-upper–L3-upper) and L4L5 (L3L4–L5S1), respectively. The distance between the conus medullaris and Tuffier's line (mean ± SD [range]) was 12.6 ± 1.9 [7–18] segments, which corresponded to the height of approximately three vertebral bodies and intervertebral spaces. In no case did Tuffier's line overlap with the conus medullaris. The distance in segments between the conus medullaris and Tuffier's line was shorter with increased age ($P < 0.001$). The position of the conus medullaris and Tuffier's line was lower in female patients than in male patients ($P < 0.001$) and higher in patients with sacralization than in those with lumbarization or without transitional vertebra ($P < 0.001$). The in-between distances were not significantly different regardless of sex or presence of transitional vertebra.**

Conclusions: **During spinal block, there seems to be a safety margin of 2–4 vertebral bodies and intervertebral spaces between the conus medullaris and Tuffier's line, which is consistent regardless of sex or presence of transitional vertebra. However, because the conus medullaris and Tuffier's line become closer with age and the clinical use of Tuffier's line requires palpation through subcutaneous fat, caution must be exercised regarding selection of the intervertebral space, especially in the aged and obese population.**

MOST typically, Tuffier's line, which connects the highest points of the iliac crests, has been used as a marker of the lumbar spine level. Variation in the position of the conus medullaris follows a normal distribution, with a peak incidence at the lower third of L1 and ranging from the middle third of T12 to the upper third of L3.[1,2] The bony segmental levels, at which Tuffier's line crosses the vertebral column, are distributed in a normal fashion with some overlapping where the spinal cord ends.[3] Thus, in some patients with a high Tuffier's line and a low cord, intrathecal needles and catheters might be directed close to the cord.[3]

It is important to know the level of the lumbar spine where the needle is being inserted. One of the main reasons for counting the intervertebral space before spinal block is the avoidance of cord damage. In addition, the height of the block is related to the level at which the injection is made.[4,5] In two thirds of patients, however, surface palpation resulted in the erroneous localization of intervertebral space; in most cases markers were higher than the level at which the anesthetist believed the space to be.[2] Lumbar radiograph and magnetic resonance imaging (MRI) cannot be routinely recommended to check the conus position and lumbar spinal level for all patients scheduled for spinal anesthesia. Therefore, knowing the margin of safety between the conus medullaris and Tuffier's line is helpful to determine a safe puncture site *via* palpation of the external surface of the back.

To our knowledge, the relationship between the position of the conus medullaris and surface markers (*e.g.*, Tuffier's line) used for identification of a vertebral or intervertebral level has not previously been studied. The purposes of this study were to analyze the position of the conus medullaris and Tuffier's line in the same patient population, correlate this position with age and sex, and determine an objective guide for the selection of a safe intervertebral space.

Methods

After institutional review board approval (Seoul National University Hospital, Seoul, Korea), previous MRI images and plain lumbar films in the same patients were reviewed. The study population consisted of consecutive patients older than 20 yr of age who had been referred for MRI imaging to assess the possible causes of

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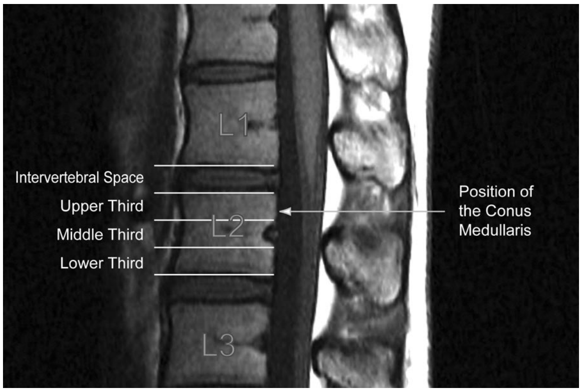

Fig. 1. Magnetic resonance image demonstrating the method for determining the conus medullaris position, defined as the most distal point of the cord that can be visualized on the sagittal sequence. Each vertebra and intervertebral space was divided into four segments: upper, middle, and lower thirds of the vertebral body, and intervertebral space. L = lumbar vertebra.

low back pain with or without sciatica for the past 4 yr, although a minority of patients had been assessed for metastatic disease. Patients with previous spinal operation history, kyphoscoliosis, or congenital anomalies such as syringomyelia or dural cyst were excluded, so that those in the study would have no known abnormality of the vertebrae or cord.

T1-weighted sagittal MRI studies of the lumbar spine were reviewed to evaluate the position of the conus medullaris and dural sac. The positions of the conus medullaris and the dural sac were defined as the most distal point of the cord and dura that could be visualized on the sagittal sequence. A line perpendicular to the long axis of the cord and the dura was extended to the adjacent vertebra, and the position was defined in relation to the vertebra. According to the method of Saifuddin *et al.*,[1] each unit of a vertebra and intervertebral space was divided into four segments. The vertebral body was divided into three equal portions [upper (U), middle (M), lower (L) thirds], and the intervertebral disc was defined as a separate region (fig. 1). For the purpose of statistical analysis, each potential level was assigned a segmental number, such that the lower third of S3 (S3L) = 1, the lower third of L4 (L4L) = 17, and the upper third of T12 (T12U) = 35, with a range of 4 from the top of each vertebral body to the next. The L5 vertebral body was determined by counting downward from T12 on the plain films and, in the absence of transitional vertebrae, was confirmed *via* MRI by a complete intervertebral disc separated from the sacrum. Axial sequences were evaluated for the presence of any thickening of the filum terminale.

Lumbar anteroposterior radiographs taken in the supine position were reviewed for checking the position of the Tuffier's line, which was formed by drawing a horizontal line across the highest points of the iliac crests using an electronic ruler on the digital picture archiving communication system. The segment or point of the vertebral body or intervertebral space at which this line was crossed was identified and noted. The level was determined by identifying T1, considered to be the vertebra articulated with a normal first rib,[6] or T12, as the lowest vertebra that was associated with a rib,[7] and counting down from this vertebra. This method was used instead of counting up from the sacrum, so that there would be no uncertainty from abnormal sacralization of the lumbar vertebrae.[6,7] All available plain films from each patient were also reviewed and assessed for the presence of a lumbosacral transitional vertebra, which was classified as lumbarization of S1 or sacralization of L5. In the former, T12 vertebra and six lumbar vertebrae were identified, and the lowermost vertebra was considered as an S1 partially or fully detached from the sacrum. In the latter, only four vertebrae were identified, because the theoretical L5 was partially or fully attached to the sacrum or articulated to it by the transverse processes.[6] The L5 vertebral body, which was determined by counting down from T1 or T12 in the plain film, was reconfirmed by checking whether it corresponded to the L5 vertebral body in the MRI sagittal image where this vertebra was separated from the sacrum by a complete intervertebral disc.

The vertical distances in segments from the conus medullaris to the Tuffier's line were calculated by subtracting the assigned segmental number of the Tuffier's line from that of the conus medullaris. The same assessor, blinded to the study purpose, performed each measurement.

The relationships between age and positions of the conus, Tuffier's line, or dural sac were analyzed by Pearson correlation analysis. The study population was divided into subgroups of age in decades from the twenties to eighties to determine whether the position of the conus medullaris or the Tuffier's line and the in-between distance change with age. One-way analysis of variance was used to identify any difference among the subgroups with regard to age and presence or type of transitional vertebrae. The Tukey test was used for *post hoc* comparisons. Comparisons between sex were performed with the unpaired t test; results were considered significant at $P < 0.01$.

Supplementary Study

A supplementary study was performed to validate the method to define the Tuffier's line on lumbar plain films. After obtaining institutional review board approval and informed consent, 20 male volunteers, whose age (mean ± SD [range]) was 22 ± 1 [21–24] yr, height 174 ± 6 [165–188] cm, and weight 68 ± 8 [56–87] kg, were enrolled. With the patient seated on a table with the legs hanging down, radiopaque markers were attached to the uppermost point of the iliac crests on both flanks in the same manner as when delineating the Tuffier's line during spinal block. On lumbar anteroposterior radiographs

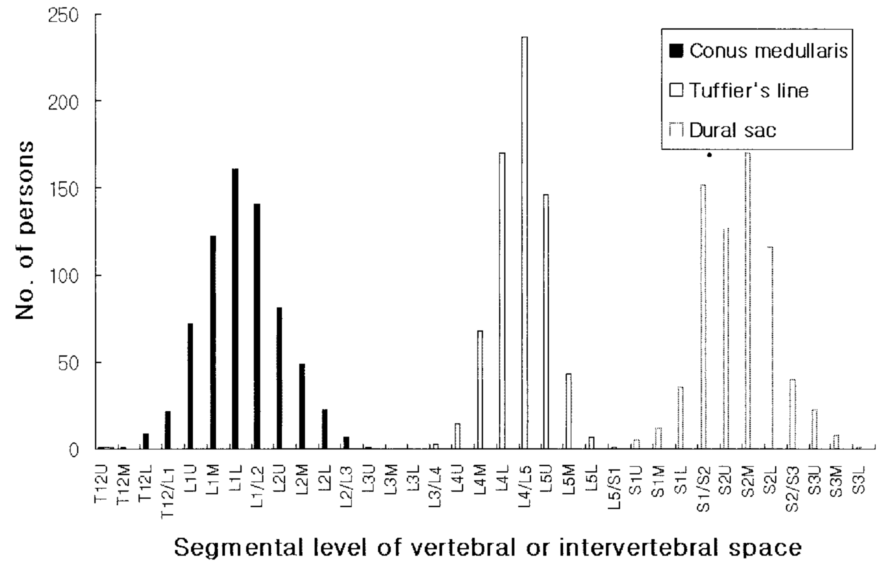

Fig. 2. Distribution of the vertebral levels in segments at which the conus medullaris, Tuffier's line, and dural sac cross. The segmental levels where the spinal cord ends, the Tuffier's line crosses, and the dural sac ends followed normal distribution, respectively. Each vertebra and intervertebral space was divided into four segments: upper (U), middle (M), and lower (L) thirds of the vertebral body, and the intervertebral space. L1–5 = lumbar vertebra, S = sacrum, T = thoracic vertebra.

taken in the supine position, the Tuffier's line was formed twice by connecting the highest points of the ilium and the two radiopaque markers, respectively. The segment of a vertebral body or intervertebral space that the lines crossed was identified and recorded in the same way as in the main study. The same assessor, blinded to the study design and purposes, delineated the Tuffier's line and identified the segment in each patient. The segmental position of the two lines (median [twenty-fifth to seventy-fifth percentiles]) that was compared by the Wilcoxon signed rank test was not different (L4L5 [L5U–L4L5] each; $P = 0.25$). In no case was there a discrepancy of more than one segment between the two lines. Thus, formation of the Tuffier's line on radiographs does not seem to be different from the bedside determination of the line in adults with a normal body build.

Results

Images from 690 patients (347 male, 343 female) were assessed for the study. The age of the patient group (mean ± SD [range]) was 51 ± 17 [20–90] yr, height 163 ± 9 [143–186] cm, and weight 63 ± 11 [34–106] kg.

The conus medullaris, Tuffier's line, and dural sac (median [range] and mean of the segment number ± SD [range]) were L1L (T12U–L3U) and 28.7 ± 1.8 [23–35], L4L5 (L3L4–L5S1) and 16.2 ± 1.2 [12–20], and S2M (S1U–S3L) and 6.5 ± 1.6 [1–11], respectively (fig. 2). The calculated distance (mean ± SD [range]) between the conus medullaris and Tuffier's line was 12.6 ± 1.9 [7–18] segments, which corresponded to about 2–4 units of the vertebral body and intervertebral space (fig. 3). In no case did the Tuffier's line overlap the conus medullaris. The position of the conus and Tuffier's line was correlated with age (Pearson correlation coefficient = −0.137 [$P < 0.001$] and 0.243 [$P < 0.001$], respectively). The position of the conus medullaris was lower ($F = 2.98$, $P = 0.007$), and that of the Tuffier's line was higher ($F = 8.80$, $P < 0.001$), with age, such that the in-between distances in segments was shortened with age ($F = 10.27$, $P < 0.001$) (fig. 4).

The conus medullaris and Tuffier's line (median [range] and mean of the segment number ± SD [range]) were positioned, respectively, at L1L (T12U–L2L) 29.1 ± 1.7 [25–35] and at L4L5 (L3L4–L5S1) 16.4 ± 1.2 [12–20] in men, and at L1L2 (T12L–L3U) 28.3 ± 1.8 [23–33] and L4L5 (L4U–L5L) 15.9 ± 1.2 [13–19] in women. The positions of the conus medullaris and Tuffier's line were lower in women than in men ($P < 0.001$), but the in-between distances in segments were the same regardless of sex.

The study group included 12 patients with sacralization and 29 patients with lumbarization. In the patients with sacralization, the conus medullaris, Tuffier's line, and dural sac (median [range] and mean of the segment number ± SD [range]) were positioned at L1M (T12U–L1L2) 30.8 ± 2.0 [28–35], at L4U (L3L4–L4L) 18.7 ± 1.2 [17–20], and at S1L/S1S2 (S1M–S2M) 8.2 ± 1.3 [6–10], respectively. In the patients with lumbarization, the conus medullaris, Tuffier's line, and dural sac (median [range] and mean of the segment number ± SD [range])

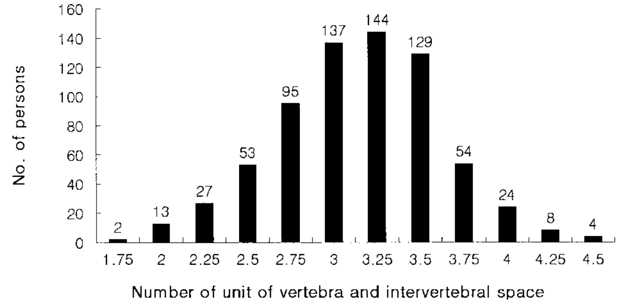

Fig. 3. Distribution of the vertical distance between the conus medullaris and Tuffier's line. The number of units of vertebra and intervertebral space corresponds to the height of one vertebral body and intervertebral disc space.

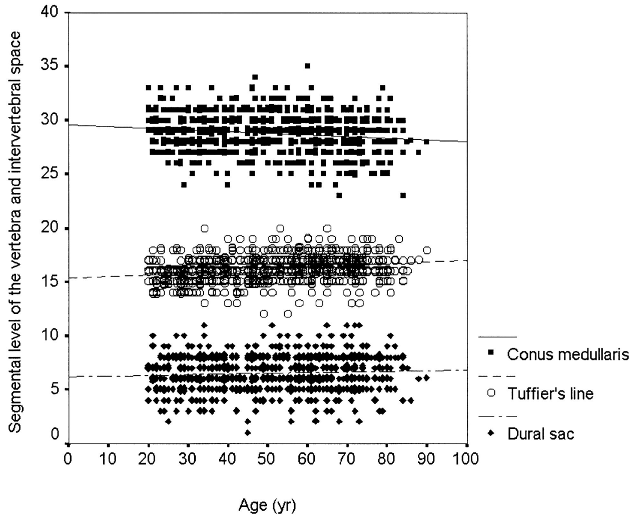

Fig. 4. Correlation between age and segmental levels at which the conus medullaris, Tuffier's line, or dural sac cross. Position of the conus medullaris was lower with age (r = −0.137, *P* < 0.001); position of Tuffier's line was higher with age (r = 0.243, *P* < 0.001). The vertical distance between the conus medullaris and Tuffier's line decreased with age (r = −0.286, *P* < 0.001), and the position of the dural sac was constant regardless of age. Numbers of the segmental level of vertebra or intervertebral space are: 5 = lower portion of S2, 10 = midportion of S1, 15 = upper portion of L5, 20 = L3L4 intervertebral space, 25 = lower portion of L2, 30 = midportion of L1, and 35 = upper portion of T12.

were positioned at L2U (L1U–L2L3) 27.3 ± 1.8 [24–31], L5M (L4L5–L5S1) 14.3 ± 0.9 [12–16], and S2L (S1S2–S3M) 5.2 ± 1.4 [2–8], respectively. The positions of the conus medullaris, Tuffier's line, and dural sac of the patients with sacralization were higher than in those with lumbarization or without transitional vertebrae ($P < 0.001$). However, the vertical distance between the conus medullaris and Tuffier's line (mean ± SD) was not different among the patients with sacralization (12.1 ± 2.0 segments), with lumbarization (13.1 ± 1.9 segments), or without transitional vertebrae (12.5 ± 1.9 segments).

Discussion

The positions of the conus medullaris, Tuffier's line, and dural sac measured in the same patients corresponded well to results of previous studies.[1,2,7,8] Our findings reveal that the safety margin between the conus medullaris and Tuffier's line may be less than two vertical heights of a vertebral body and intervertebral space. The distance between the conus medullaris and Tuffier's line decreases with age regardless of sex.

The most common method of identifying lumbar interspaces is to use the Tuffier's line that joins the two iliac crests, or half of the Tuffier's line, by dropping a perpendicular line from the iliac crest to the lumbar spine[9]; the former method is probably more accurate than the latter.[4] Other approaches, such as counting down from C7 or finding the vertebra that is attached to the twelfth rib, are usually less practicable. The former approach is tedious and may be inaccurate because of the difficulty in reliably counting and palpating all interspaces between C7 and L5.[10] Finding the vertebra that is attached to the twelfth rib is not at all helpful in obese patients.[9] Because clinical use of the Tuffier's line requires palpation through a variable amount of subcutaneous fat, high placement of Tuffier's line is especially likely in the obese.[3] Term parturients with preeclampsia accompanied by generalized edema may also have high placement of the Tuffier's line.[11] Because older patients with osteoporosis or age-related vertebral deformity usually have a reduced height of the vertebral body,[12–14] the segmental position of the conus could be lower with that of the Tuffier's line higher but relatively less so, so that the in-between distance appears to be shortened with age, as proved in this study.

Palpating the upper iliac crest and drawing a vertical line seemed to be unreliable in determining intervertebral space, which tended to be one or two spaces higher than the anesthetist believed it to be.[15] When anesthetists tried to identify intervertebral space by palpation, their identification was correct in only 29% of cases, with the actual space being higher than assumed in 68%.[2] In another study, palpation was successful in only 30% of cases, and intervertebral spaces in up to 27% of cases were wrongly identified by more than one level.[16] While performing spinal anesthesia with isobaric bupivacaine, injection at the higher lumbar space produces a higher spread of analgesia.[5] The temptation to use less of a "potentially neurotoxic" spinal anesthetic drug may force the anesthesiologist to choose a higher intervertebral space, such as the L2–L3 interspace.[11] Thus, the practice of selecting the highest possible intervertebral space may be unwise because of the possibility of inaccuracy.

Determination of whether the lumbosacral transitional vertebra is a sacralized L5 or a lumbarized S1 remains a perplexing problem in the absence of plain films.[17] The prevalence of transitional vertebrae has been reported to range between 8% and 15%.[17,18] Without plain film, identification of a lumbosacral vertebral level is difficult, which reflects a potential source of error in the determination of conus level by MRI alone.[1] In our study, however, there was no significant problem with identification of lumbosacral vertebrae, because both plain film and MRI were available. The presence of transitional vertebrae has an effect on the position of the conus medullaris and Tuffier's line. However, because the margin of safety between their positions was not different, counting up from the apparent lumbosacral junction seems to be a reasonable way to select an intervertebral space regardless of the presence of transitional vertebra.

Radiologic studies exclude the thickness of the subcutaneous tissue, so that more uniform results can be drawn regarding the correlation between the positions of the conus medullaris and Tuffier's line. In practice, subcutaneous thickness may be estimated by pinching the skin in the same way as in checking degree of obesity. Before the patient flexes the spinal column, checking and marking the corresponding vertebral level on the Tuffier's line may be helpful to select a safe intervertebral level. As shown in this study, it would be practical to know the distance from the conus medullaris to the Tuffier's line in the same patient population, because lumbar radiograph and MRI cannot be routinely recommended for all patients scheduled for spinal block.

MRI studies and plain films were performed on supine patients with their legs elevated. With maximal hip and lower spine flexion, the distance between the lumbar spinous processes will be increased. For radiography, each patient's back was not as flexed as in spinal puncture, but this did not greatly affect the study results because with flexion there is little distraction of the lower vertebrae from the sacrum.[4]

In conclusion, during spinal block, the safety margin between the conus and Tuffier's line may be less than two heights of a vertebral body and intervertebral space. Because the clinical use of Tuffier's line requires palpation through subcutaneous fat, we may not select an intervertebral space more than one level higher than the Tuffier's line, especially in old and obese patients. Nonetheless, we should be aware that there remains another potential mechanism of nerve lesion—damage to the nerves in the cauda equina—during spinal block.

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