Incidence of lower thoracic ligamentum flavum midline gaps

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Background. Lower thoracic epidural anaesthesia and analgesia (EDA) has gained increasing
importance in perioperative pain therapy. The loss-of-resistance technique used to identify the
epidural space is thought to rely on the penetration of the ligamentum flavum. Investigations
at the cervical and lumbar regions have demonstrated that the ligamentum flavum frequently
exhibits incomplete fusion at different vertebral levels. Therefore, the aim of this study was to
directly investigate the incidence of lower thoracic ligamentum flavum midline gaps in embalmed
cadavers.

Methods. Vertebral column specimens were obtained from 47 human cadavers. Ligamentum
flavum midline gaps were recorded between the vertebral levels T6 and L1.

Results. The incidence of midline gaps/number of viable specimens at the following levels was:
T6–7: 2/45 (4.4%), T7–8: 1/47 (2.1%), T8–9: 2/45 (4.4%), T9–10: 7/39 (17.9%), T10–11: 12/34 (35.2%),
T11–12: 10/35 (28.5%), T12/L1: 6/38 (15.8%).

Conclusions. In the present study we have determined the frequency of lower thoracic liga-
mentum flavum midline gaps. Gaps are less frequent than at cervical levels, but more frequent than
at lumbar levels. Peak incidence was found in the region between T10 and T12. Using a strict
midline approach, one cannot therefore rely on the ligamentum flavum to impede entering the
epidural space in all patients.


Keywords: anaesthetic techniques, extradural; anatomy; model, cadaver; spinal cord,
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The loss-of-resistance (LOR) technique is most commonly used to identify the epidural space in the lower thoracic and
lumbar region. This technique depends fundamentally on the resistance to injection of saline and needle advancement
offered by spinal ligaments, which abruptly decreases once the tip of the needle has penetrated the ligamentum flavum,
and reached the epidural space. Previous cryomicrotome investigations concluded that ligamentum flavum midline
fusion could be absent ‘to a variable degree’, although no exact incidences were given. Recent investigations at cer-
vical, high thoracic, and lumbar levels have confirmed and extended this finding, indicating that, depending upon the vertebral level, up to 74% of ligamenta flava may fail to fuse in the midline. No investigations concerning the detailed incidence of ligamentum flavum midline gaps at lower thoracic levels have been performed. Therefore, the aim of the present study was to directly investigate lower thoracic ligamentum flavum midline gaps in embalmed cadavers.

Methods
Following institutional approval, vertebral column specimens were obtained from 47 human cadavers in legal prop-
erty of the Institute of Anatomy, Histology and Embryology, Innsbruck Medical University. Cadavers were preserved in a
mixture of formaldehyde and carbol.

Vertebral arches were detached at the pedicles of Th6–L1 and removed en bloc. The dural sac and epidural connective
tissue were removed by blunt dissection, and the ligamentum flavum was directly examined anteriorly.

At each dissected level, the ligamentum flavum was thoroughly investigated for signs of midline gaps and
then probed gently using a blunt needle with a diameter of 1 mm. Two investigators (P.L. and J.C.), blinded to
each other’s results, recorded the frequency of midline gaps.

Statistics

Descriptive statistics were used for analysis. Inter-observer reliability was analysed using intra-class correlation coefficient (ICC). Scores for statistical measurements with the ICC range from 0 to 1, where the former shows no reliability and the latter perfect reliability.

Results

Mean (range) cadaver age was 81 (39–100) yr. The tissues within the spinal canal were removed easily, with only minimal adherence between adipose tissue and the inner surface of the ligamentum flavum. The ligamentum flavum appeared as a rigid but pliable structure easily distinguishable by its yellowish color and smooth surface. Gaps as a result of lack of fusion in the midline were readily visible, and confirmed by gentle probing. Ligamentous structures in a number of specimens were damaged during harvesting from the cadavers, or during dissection, and were excluded from analysis.

Out of the 47 harvested lower thoracic vertebral columns, the numbers of intact specimens allowing for unambiguous interpretation of ligamentum flavum anatomy at different levels were as follows: T6–7: 45, T7–8: 47, T8–9: 45, T9–10: 39, T10–11: 34, T11–12: 35, T12/L1: 38.

The following variations were encountered: complete fusion of the ligamentum flavum in the midline, and midline gap throughout the entire height (Fig. 1). The incidence of midline gaps/number of viable specimens at the following levels was (Fig. 2): T6–7: 2/45 (4.4%), T7–8: 1/47 (2.1%), T8–9: 2/45 (4.4%), T9–10: 7/39 (17.9%), T10–11: 12/34 (35.2%), T11–12: 10/35 (28.5%), T12/L1: 6/38 (15.8%). ICC between the two investigators was 1.

Discussion

The present study investigated the incidence of lower thoracic ligamentum flavum midline gaps. Depending on the vertebral level, up to 35% of lower thoracic ligamenta flava are discontinuous in the midline. The incidence of discontinuous ligaments was highest in the region between T10 and T12, gaps being less frequent above and below this level.

During epidural anaesthesia, the needle traverses three main ligamentous structures, the supraspinous and intraspinous ligaments, and the ligamentum flavum. Whereas the first two are composed of collagenous fibres, the ligamentum flavum consists of 80% elastin, and its dense homogenous texture is readily appreciated as a needle passes through it. There is considerable tension in the ligamentum flavum as it spans from the upper rim of the anterior surface of the cephalad lamina of an adjacent pair of vertebrae to the posterior aspect of the lower lamina. Ligamenta flava are thinnest at cervical levels, and increase in strength towards the lumbar spine. In a transverse plane, it extends from the midline to the roots of the articular processes, where it reinforces the anterior capsules of the zygapophyseal joints. Imaging studies describe ligamenta as most frail in the midline, the most plausible reason being that the ligamentum flavum embryologically consists of a left and right lateral portion. These lateral parts of the ligamentum flavum may fuse in the midline, or remain separate. Between the left and right half of the ligamentum flavum, frequent intervals for the passage of veins connecting the posterior external vertebral venous plexus with the posterior internal vertebral venous plexus have been described.
The incidence of ligamentum flavum midline gaps has been controversially discussed (summarized in Table 1). In general, there seems to be agreement that gaps most regularly occur in the cervical region, and decrease in frequency at high thoracic and lumbar levels.2 3 Most investigations have been carried out in the lumbar region using diverse techniques. Here, reported midline gap incidences range from ‘never’9 to ‘always’.10 11 More congruence exists for the upper thoracic region, where the incidence is roughly between one-third2 and one-half8 of cases. In the cervical region, incidences between 50 and 74% have been described. Results from this investigation support and substantially widen the latter findings, in as much as the incidence of midline gaps in the lower thoracic region was described for the first time. Gaps appear to be less frequent than at cervical levels, but more frequent as compared with lumbar levels.

It has been reported previously that the superficially located supraspinal and interspinal ligaments do not offer the same elastic resistance to injection of saline as the ligamentum flavum, and the perceptible resistance to needle advancement may therefore be blunted.13 12 In cases of failed ligamentum flavum midline fusion, the superficial ligaments may offer some resistance to the advancing needle and injection.12 However, the latter ligaments are composed of collagenous fibres, and thus the actual loss of resistance may be blunted. Using a strict median approach, the midline gaps described in the present study could be responsible for a considerable proportion of failures to recognize the epidural space.

In principle, a midline gap could thus impede the LOR encountered using the median approach, whereas the para-median approach should, in all instances, rely safely upon the penetration of the ligamentum flavum. Therefore, the anatomic variations encountered in the present study may offer one possible explanation for impaired epidural space detection during midline puncture.13 However, it is not known how often strict ‘midline’ punctures are actually midline, rather than actually slightly paramedian. In clinical practice, cervical and high thoracic epidural punctures are classically performed using the ‘hanging-drop’ technique, while the ‘LOR’ is more commonly used to determine needle position in the lower thoracic and lumbar region. The reasons for this can only be speculated upon. First, this obviously, at least in part, reflects the excellent reliability of cervical epidural subatmospheric pressure as an indicator of epidural needle placement, which is by far less pronounced in the lumbar region. Secondly, ligamenta flava are thinnest at cervical, and thickest at lumbar levels, increasing the resistance to needle advancement the more caudally puncture is performed.2 3 Thirdly, the findings from this and previous studies suggest that using a strict midline approach, one cannot always rely on the ligamentum flavum as a perceptible barrier to epidural needle placement, and, moreover, that this effect is more likely to occur at cervical and high thoracic than at lower thoracic and lumbar levels.2 3

Finally, some potential limitations of this study should be addressed briefly. We chose direct dissection of embalmed specimens to investigate ligamentum flavum anatomy. Therefore, we cannot exclude a potential artifact resulting from the embalming or dissection processes. This, however, is unlikely to be a significant factor as we performed dissections with great care to avoid any damage to the ligamentum flavum. Moreover, if such damage was noted, the specimen was excluded from evaluation. Furthermore, results from anatomic dissections2 3 are congruent with previous investigations on non-embalmed specimens.18 There are no reports that midline gaps of the ligamentum flavum are degenerative in nature, which is relevant to the present study, since the cadavers represented a distinct sub-population owing to their high average age. In previous investigations in patients suffering from, for example low back pain, no midline fusion defects were described as characteristic or etiologic for degenerative disease.10 11

In conclusion, in the present study we determined the frequency of lower thoracic ligamentum flavum midline gaps. The latter are most frequent in the region between T10 and T12. Using a strict midline approach, one cannot therefore rely on the ligamentum flavum to impede entering the epidural space in all patients.

### References

Ligamentum flavum midline gaps


