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# Morphometric Evaluation of $T_{13}$-$L_1$ and $L_1$-$L_2$ Interarcuate Space for Subarachnoid Introduction in Simmental and Brown Swiss Cattle: A Cadaver Study

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### Abstract

This study aimed to reveal the probable anatomic differences of the $T_{13}$–$L_1$ or $L_1$–$L_2$ vertebrae in Simmental and Brown Swiss cattle during surgeries, such as subarachnoid anesthesia and cerebrospinal fluid aspiration, and thus determine a reference value. This study was conducted in 30 cows, of which 15 were Brown Swiss cattle and 15 were Simmental, aged 5–6 years, and having a live weight of 400–450 kg. The region from the $T_{13}$–$L_1$ vertebrae to the sacrum was taken from each animal and divided into 2 equal parts throughout the long axis. The distance between the spinous processes of the $T_{13}$–$L_1$ and $L_1$–$L_2$ vertebrae, spinous processes length of the $T_{13}$ and $L_1$ vertebrae, sagittal length of interarcuate spaces between the $T_{13}$–$L_1$ and $L_1$–$L_2$ vertebrae, and vertical length of vertebral canals of the $T_{13}$ and $L_1$ vertebrae were measured using an electronic digital caliper. Statistical results showed that although there was no significant difference within the groups ($p > .05$), there was a significant difference between the groups in terms of the sagittal length of interarcuate space between the $T_{13}$–$L_1$ vertebra ($p < .05$). We believe that this result is because of the anatomical and genetic differences between the 2 cattle breeds.

***Keywords*****:** Cattle, interarcuate space, morphometry

## Introduction

Intrathecal anesthesia is preferred nowadays for paralumbar, perineal, posterior extremities, and other surgeries in cattle owing to the adverse effects of general anesthesia. Examination of the cerebrospinal fluid (CSF) can be done via CSF aspiration through the subarachnoid entrance using radio-diagnostic procedures (Kılıç et al., 2015; Yayla et al., 2012; Yayla & Kılıç, 2010). Therefore, acknowledging the anatomic structure of the region according to the breed will contribute to more effective anesthesia and other procedures.

All vertebrae, except the atlas, involve the vertebral body and vertebral arch in mammals. The 2 neighboring vertebrae are connected to each other from their vertebral body through the intervertebral disc and ventral and dorsal longitudinal ligaments. In addition, neighboring vertebrae are connected to each other from their vertebral arch by means of the interarcuate ligament, intertransverse ligament, interspinous ligament, and supraspinous ligament. The vertebral arch and vertebral body are merged through the pedicle of the vertebral arch. The lamina of the vertebral arch, an enlarged part, is located on the pedicle of the vertebral arch. The 2 laminae of the vertebral arch of a vertebra unite in a median line to form the spinous process (Dursun, 2000; König & Liebich, 2007; Sharshar et al., 2015).

Although the atlanto-occipital, lumbosacral, or thoracolumbar space is preferred for CSF aspiration in cattle, only the lumbosacral space is used for spinal anesthesia (Aksoy et al., 2012;

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De Lahunta & Glass, 2009; Hiraoka et al., 2007; Lee et al., 2004; Skarda et al., 1989; Vandevelde et al., 2001). However, thoracolumbar introduction is not recommended in the surgery of the paralumbar fossa or flank, and Cesarean, rumenotomy, and abomasopexy are preferably conducted in the standing position; therefore, subarachnoid introduction should be done through the $T_{13}$–$L_1$ vertebrae or alternatively through the $L_{1-2}$ vertebrae (Caulkett et al., 1993; De Rossi et al., 2003; Lee & Yamada, 2005; Seyrek-İntaş et al., 2001; Yayla et al., 2013).

In a previous study (Aksoy et al., 2012), subarachnoid entries were performed through the $T_{13}$–$L_1$ or $L_{1-2}$ vertebrae in different animal breeds by the same doctor, and it was detected that this procedure was more difficult in the Simmental breed than in other breeds. In addition, the fact that the clinicians at our university had difficulty entering the subarachnoid space of Simmental breed cattle brought to our hospital, but could do so easily in Brown Swiss breeds encouraged us to perform this study. This problem also bring about the question of whether the spaces $T_{13}$–$L_1$ or $L_{1-2}$ will show morphometric changes according to different breed or not. This study aimed to find answers to these questions also measure the intervertebral space distances between $T_{13}$–$L_1$ and $L_{1-2}$ vertebrae in Simmental and Brown Swiss cattle, to determine whether there is any difference between the two cattle breeds, and thus to establish a reference for surgical operations such as subarachnoid anesthesia or CSF aspiration.

## Method

The use of the animals in this study was allowed by the local ethics committee of animal experiments of Kafkas University (KAU-HADYEK/2015-025/08.01.2015). This investigation was performed in 30 cows, of which 15 were Brown Swiss cattle (group I) and 15 were Simmental (group II). They were aged 5–6 years, with 400–450 kg live weight, did not have any disorder or trauma complaint, and were ethically slaughtered in the Kars slaughter house. The vertebral column, with its soft tissues, till the tail vertebra and $T_{13}$ of each cow was excised (Figure 1, 2) and divided into 2 equal parts and moved to the anatomy laboratory of the Kafkas University. Following this, the distance between the spinous processes of the $T_{13}$ and $L_1$ vertebrae (Figure 1 "a"), distance between the spinous processes of the $L_1$–$L_2$ vertebrae (Figure 1 "b"), lengths of spinous processes of the $T_{13}$ (Figure 1 "c") and $L_1$ vertebrae (Figure 1 "d"), sagittal length of the interarcuate spaces between the $T_{13}$–$L_1$ (Figure 1 "e") and $L_1$–$L_2$ (Figure 1 "f"), and vertical lengths of the vertebral canals of the $T_{13}$ (Figure 1 "g") and $L_1$ vertebrae (Figure 1 "h") were measured using an electronic digital caliper (.01 mm, BTS, England). The obtained data were analyzed statistically using Minitab packaged software (Trialware, Pennsylvania, USA) and then evaluated within groups and between groups comparatively using one-way analysis of variance (Tukey's test). To compare variables between the groups, *t* test was used.

## Results

According to the results of the study, there was no statistically significant difference within the groups in terms of the distance between the spinous processes of the $T_{13}$ and $L_1$ vertebrae, distance between the spinous processes of the $L_1$–$L_2$ vertebrae, lengths of spinous processes of the $T_{13}$ and $L_1$ vertebrae, sagittal length of the interarcuate spaces between the $T_{13}$–$L_1$ and $L_1$–$L_2$ vertebrae, and vertical lengths of the vertebral canals of the $T_{13}$ and $L_1$ vertebrae ($p > .05$) (Figure 1). However, a significant difference was found between the groups in terms of the sagittal length of interarcuate space between the $T_{13}$–$L_1$ ($p < .05$). There was no statistically significant difference within the groups (Table 1).

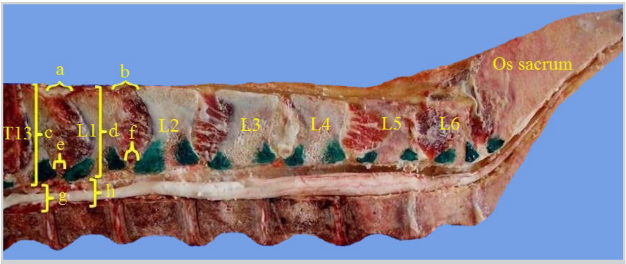


**Figure 1**
*Sagittal Section of the Thoracolumbal and Os Sacrum in Brown Swiss Cattle. (a) Distance between the Spinous Processes of $T_{13}$–$L_1$ Vertebrae, (b) Distance between the Spinous Processes of $L_{1-2}$ Vertebrae, (c) The Spinous Process Length of $T_{13}$ Vertebra, (d) Length of Spinous Processes of $L_1$ Vertebra, (e) Sagittal Length of Interarcuate space between $T_{13}$–$L_1$ Vertebrae, (f) Sagittal Length of Interarcuate Space Between $L_{1-2}$ Vertebrae, (g) Vertical Length of Vertebral Canal $T_{13}$ Vertebra, (h) Vertical Length of Vertebral Canal $L_1$ Vertebra.*

**Table 1**
*Comparison between the Groups of Morphometric Measurement Results Obtained from the Study*

| | **Distance between the spinous processes (mm)** | | **Spinous processes length (mm)** | | **Sagittal length of interarcuate space (mm)** | | **Vertical length of vertebral canal (mm)** | |
|---|---|---|---|---|---|---|---|---|
| **Groups** | **$T_{13}$-$L_1$** | **$L_1$-$L_2$** | **$T_{13}$** | **$L_1$** | **$T_{13}$-$L_1$** | **$L_1$-$L_2$** | **$T_{13}$** | **$L_1$** |
| ($n = 15$) | 19.17 ± 5.72 | 18.59 ± 5.14 | 59.88 ± 5.07 | 54.63 ± 5.48 | 5.12 ± 1.20 | 5.47 ± 1.35 | 18.78 ± 2.28 | 19.82 ± 2.49 |
| ($n = 15$) | 18.86 ± 3.08 | 19.13 ± 4.22 | 60.15 ± 7.49 | 55.59 ± 6.12 | 4.15 ± 1.0* | 4.79 ± 1.34 | 19.07 ± 1.26 | 19.82 ± 1.91 |

*Note*. *: Statistical significance between groups in each column ($p < .05$). Values are presented as mean ± standard deviation

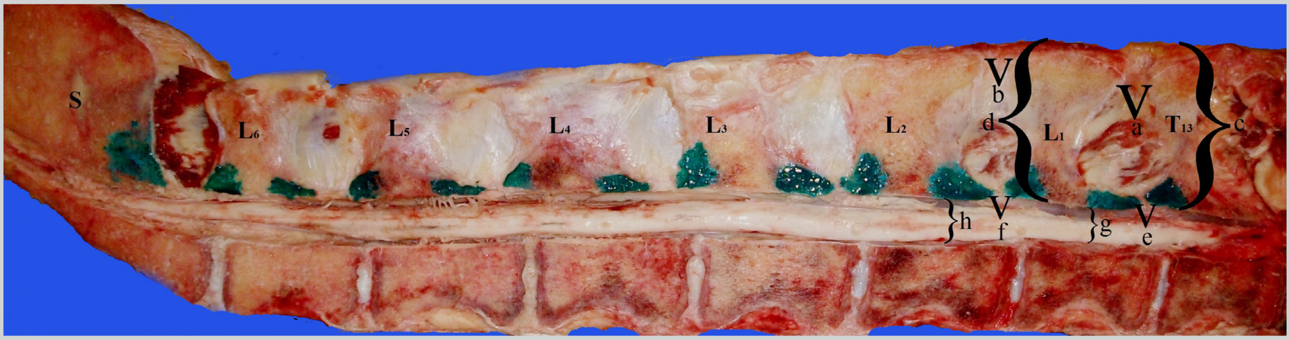


**Figure 2**

*Sagittal Section of the Thoracolumbar and Os Sacrum in Simmental Cattle. (a) Distance between the Spinous Processes of $T_{13}$–$L_1$ Vertebrae, (b) Distance between the Spinous Processes of $L_{1-2}$ Vertebrae, (c) The Spinous Process Length of $T_{13}$ Vertebra, (d) Length of Spinous Processes of $L_1$ Vertebra, (e) Sagittal Length of Interarcuate Space between $T_{13}$–$L_1$ Vertebrae, (f) Sagittal Length of Interarcuate Space between $L_{1-2}$ Vertebrae, (g) Vertical Length of Vertebral Canal $T_{13}$ Vertebra, (h) Vertical Length of Vertebral Canal $L_1$ Vertebra.*

## Discussion, and Conclusion and Recommendations

Subarachnoid or intrathecal administration is necessary primarily for intrathecal anesthesia, radio-diagnostic procedures, and CSF aspiration. Although lumbosacral space is favored for intrathecal anesthesia in many animal breeds, cisternal or lumbosacral injections are used for myelography (Aksoy et al., 2012; Yayla et al., 2012). Many surgeries need to be performed in the standing position because of the known complications of surgeries, especially in adult cattle (Aksoy et al., 2012; Caulkett et al., 1993; De Lahunta & Glass, 2009). Therefore, there are many studies on intrathecal or subarachnoid anesthesia and analgesia, which do not let the animals lie down (Aksoy et al., 2012; Yayla & Kılıç, 2010); some researchers have recommended thoracolumbar administration along with lumbosacral (Caulkett et al., 1993; Ferheller et al., 2004; Lee et al., 2006; Levis et al., 1999). Moreover, there are studies on entering via the lumbosacral line, then advancing the spinal catheter cranially or caudally after having entered through the thoracolumbar space for the blockage of nerves in the $L_{2-5}$ level, and administering the anesthetic drug to this part (Aksoy et al., 2012; Özaydın & Kılıç, 2003; Skarda et al., 1989). These studies have also reported that $T_{13}$–$L_1$ intrathecal entrance was difficult; thus, $L_{1-2}$ may be an alternative for $T_{13}$–$L_1$ introduction. However, studies on morphometric measurements of the mentioned regions for subarachnoid introduction in cattle are limited. In a previous study (Aksoy et al., 2012), subarachnoid analgesia was performed in different cattle breeds, but the subarachnoid introduction in Simmental cows was determined to be problematic. This prompted us to conduct this study, and the intervertebral distance was measured between the $T_{13}$–$L_1$ and $L_{1-2}$ vertebrae of Simmental and Brown Swiss cattle (the 2 common breeds in cultural breeding). We aimed to determine a reference value for surgical operations, such as subarachnoid anesthesia or CSF aspiration, from this region. We believe that the results of this study will contribute to the literature by providing further information on subarachnoid surgeries.

Although there are no studies conducted on morphometric measurements in cattle, several studies reported the distance till the subarachnoid gap on the skin during intrathecal attempts. Lee et al. (2004) found the distance between the skin and subarachnoid space to be 84–93 mm in 8 cows and 85–95 mm in 10 cows; they did not find any statistically significant difference in the effect on analgesia in these 2 groups. Another study (Lee et al., 2006) found this distance to be 82–91 mm in adult animals and 57–65 mm in young animals, whereas another study (Lee et al., 2004) found this to be 89 mm. Hiraoka et al. (2007) reported this distance to be 81–90 mm. Our study dealt with the length of spinous processes, except for the skin. This length was determined as 59.88 ± 5.07 mm for $T_{13}$ vertebra in Brown Swiss cattle and 60.15 ± 7.49 mm in Simmentals, whereas it was found to be 54.63 ± 5.48 mm for $L_1$ vertebra in Brown Swiss cattle and 55.59 ± 6.12 mm in Simmentals. In addition, there was no statistically significant difference both within the group and between group measurements.

Sinding and Berg (2010)carried out a study dealing with similar data in warmblood foals, and no interspinous space width less than 4 mm was found. The width between $T_{16-17}$ was determined to be 5.9 ± 1.2 mm, and the widest interspinous space was reported as 8.9 ± 2.6 mm between $T_{10-12}$. However, the researchers did not conduct any study in cattle to investigate the spinous processes of $T_{13}$–$L_1$ and $L_{1-2}$ vertebrae in terms of morphometric values. In the present study, the distance between the spinous processes of $T_{13}$-$L_1$ vertebrae was determined as 19.17 ± 5.72 mm in Brown Swiss cattle and 18.86 ± 3.08 mm in Simmentals; the distance between the spinous processes of $L_{1-2}$ vertebrae was 18.59 ± 5.14 mm in Brown Swiss cattle and 19.13 ± 4.22 mm in Simmentals. Furthermore, there was no statistically significant difference in measurements both within the group and between the groups. Therefore, it can be assumed that these 2 breeds have substantial similarities.

In a study carried out in water buffalo by using computed tomography (Sharshar et al., 2015), the interarcuate space between the last thoracic spine and initial lumbar vertebra and within all the lumbar vertebrae were determined, although not between the last 2 thoracic spines. However, there was no study regarding the sagittal length of interarcuate space in cattle. Therefore, to the best of our knowledge, this is the first study investigating the sagittal length of interarcuate space in Brown Swiss and Simmental cattle. This length was found to be 5.12 ± 1.20 mm in Brown Swiss cattle and 4.15 ± 1.0 mm in Simmental in $T_{13}$–$L_1$, whereas it was 5.47 ± 1.35 mm in Brown Swiss cattle and 4.79 ± 1.34 mm in Simmental in $L_{1\text{-}2}$. There was no statistically significant difference in these data within the groups. Although there was no statistically significant difference in the sagittal length of $L_{1\text{-}2}$ interarcuate space, a statistically significant difference was determined for $T_{13}$–$L_1$ ($p < .05$). Therefore, we assume that $T_{13}$–$L_1$ intrathecal introduction would be easier for Brown Swiss cattle than Simmental ones.

The diameter of spinal canal of $L_1$ vertebra was specified as 16.89, 8.83, and 11.81 mm for human, sheep, and deer, respectively (Bai et al., 2012). The diameter of the spinal canal of $T_{13}$ vertebra was found to be 9.4 and 9.8 mm for $L_1$ vertebra (Mageed et al., 2013). This study revealed that the vertical length of the vertebral canal of $T_{13}$ vertebra was 18.78 ± 2.28 mm in Brown Swiss cattle and 19.07 ± 1.26 mm in Simmentals, whereas the vertical length of the vertebral canal of $L_1$ vertebra was 19.82 ± 2.49 mm in Brown Swiss cattle and 19.82 ± 1.91 mm in Simmentals. Furthermore, they were statistically similar both within the group and between groups.

In conclusion, this study was designed to compare the intervertebral space distances between the $T_{13}$–$L_1$ and $L_{1\text{-}2}$ vertebrae in Brown Swiss cattle and Simmentals. There may be difficulties in subarachnoid entry in Simmentals as the sagittal length of $T_{13}$–$L_1$ interarcuate space and sagittal length of interarcuate space between $L_{1\text{-}2}$ vertebrae is narrower than Brown Swiss cattle. We think that this difference is the result of the Simmental cattle breed genetically being more muscular and having higher milk production.

**Ethics Committee Approval:** The use of the animals in this study was allowed by the local ethics committee of animal experiments of Kafkas University (KAU-HADYEK/2015-025/08.01.2015).

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept - İ.Ö., Ö.A.; Design – S.Y., Y.A.; Supervision - Ö.A., İ.Ö.; Resources - U.A., S.Ö.; Materials - Y.A., U.A.; Data Collection and/or Processing - Y.A., U.A.; Analysis and/or Interpretation - S.Y., Y.A., U.A.; Literature Search – Ö.A., S.Y., Y.A.; Writing Manuscript – Y.A., S.Y.; Critical Review - İ.Ö., S.Y., S.Ö.

**Conflict of Interest:** The authors have no conflicts of interest to declare.

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