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Prone positioning improves surgical access to the thoracolumbar junction – An MRI pilot study

Mohammed Hasanain [a], Colya N. Englisch [b], Thomas Tschernig [b,*], Ralf Ketter [a], Diana Hell [c], Arno Bücker [c], Joachim Oertel [a]

[a] Department of Neurosurgery, Saarland University Medical Center, Homburg/Saar, Germany
[b] Institute for Anatomy and Cell Biology, Saarland University, Homburg/Saar, Germany
[c] Diagnostic and Interventional Radiology, Saarland University Medical Center, Homburg/Saar, Germany

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ABSTRACT

Background: The lateral decubitus position is the standard position for a lateral approach of the thoracolumbar junction, but prone positioning has been observed to increase the distance of abdominal organs from the spine in comparison to lateral decubitus position and gives a safe exposure to the lumbar spine.
Purpose: To compare distances between the thoracolumbar spine junction and abdominal structures between lateral decubitus and prone position.
Methods: Magnetic resonance imaging was conducted in two positions, lateral decubitus and prone, in six volunteers with no previous spine injury or complaints. Distances of abdominal structures from the spine were measured from Th10 to S1.
Results: In lateral decubitus position, abdominal structures shifted away from the thoracolumbar junction on the left side but became nearer to the spine on the right side. The distance of abdominal structures from the spine was highest in prone position, particularly on the right side.
Conclusions: These anatomical descriptions suggest that prone position can improve surgical access to the thoracolumbar junction in comparison to the standard lateral decubitus position, from the right side as well as from the left side.

1. Introduction

The spine is accessible by three main approaches (Araujo Ono et al., 2024). The lateral approach allows for dorsal and ventrolateral instrumentation of the lumbar spine (Araujo Ono et al., 2024). Lateral decubitus positioning of the patient is most commonly used for lateral surgical approach to the lumbar spine. Surgeons often prefer the lateral approach owing to its simplicity, low blood loss, short surgery duration, and the ability to correct deformity and insert large implants in comparison to the posterior approach. In complex cases, the lateral approach is often complementary to the posterior approach. The main disadvantage is the need to reposition the patient.

Intraoperative complications include severe vascular and visceral injuries (Araujo Ono et al., 2024). Recently, the concept of prone positioning of the patient in the context of single position combined posterior and lateral approaches has emerged (NaPier, 2023; Patel et al., 2023; Pimenta et al., 2023). Indeed, prone position permits a lateral approach on both sides without the need for repositioning. We observed that visceral and vascular structures are more distant from the spine than in lateral decubitus position.

To study this observation, we performed magnetic resonance imaging of the lumbar spine including the thoracolumbar junction in lateral decubitus and prone positions in six probands. Previous studies investigated the supine and lateral decubitus position (Alluri et al., 2023; Ouchida et al., 2019). They showed that, lateral decubitus position allows for safer organ–spine distances than supine. The aim of this study was to compare the distance of the abdominal organs from the thoracolumbar junction in lateral decubitus and prone position. Focusing on the analysis of intraindividual comparisons is requested as the exact anatomy of the abdomen varies among individuals.

* Correspondence to: Institute for Anatomy and Cell Biology, Faculty of Medicine, Saarland University, Kirrberger Strasse, Building 61, 66421 Homburg/Saar, Germany.
E-mail address: Thomas.Tschernig@uks.eu (T. Tschernig).

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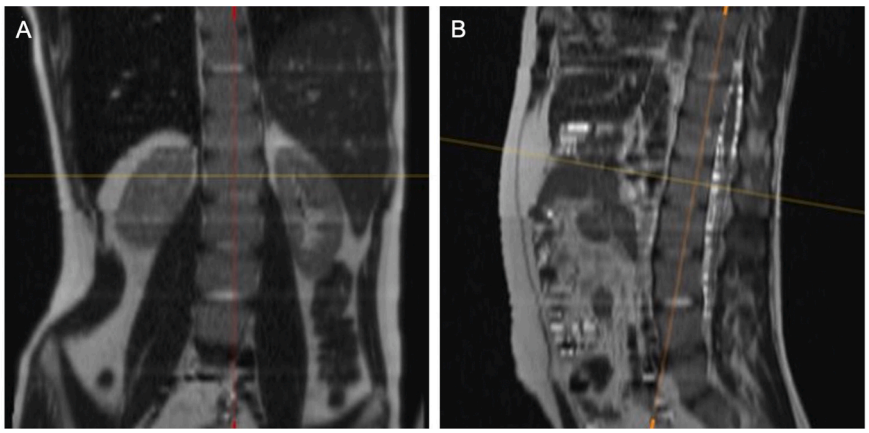

Fig. 1. Magnetic resonance imaging scans in the frontal plane (A) and median plane (B).

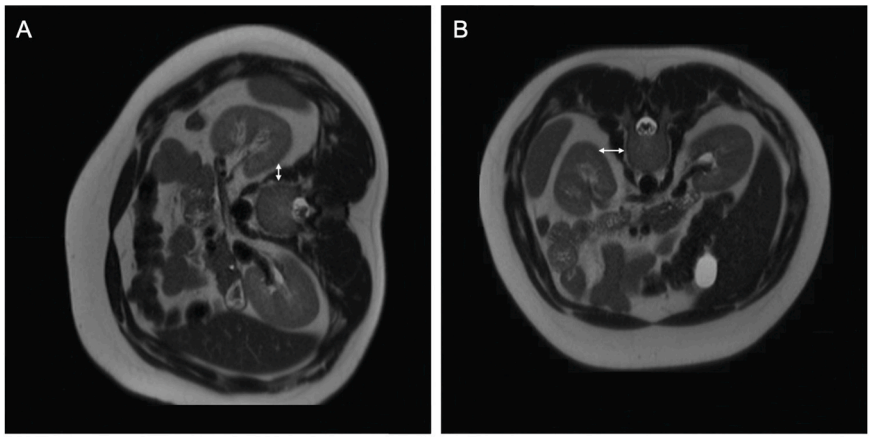

Fig. 2. Magnetic resonance imaging scans in the transversal plane at L1 in lateral decubitus position (A) and prone position (B). Arrows demark the measurement from the vertebral body to the first intercepting organ border.

2. Material and methods

2.1. Study design

Magnetic resonance imaging (MRI) was performed in six candidates. They were placed in right and left lateral decubitus, and prone position on the MRI table. MR scans were performed using a 1.5 Tesla scanner (Magnetom Aera, Siemens Healthineers, Erlangen, Germany). In all volunteers, T2 weighted single shot sequences were obtained (HASTE; TR = 1000 and TE = 92 ms). For the lateral decubitus position, probands were placed in combined 30° hip and knee flexion to facilitate posture maintenance during imaging. For prone positioning, pads and pillows were used to facilitate a stable and pleasant position.

Exclusion criteria were pregnancy, age under 18, previous abdominal, chest, or spine surgery, congenital spine deformity, chronic obstructive pulmonary disease, and claustrophobia. All candidates gave their informed consent to participate in this study and to have their MRI-associated data and images published anonymously. The local Institutional Review Board (Ethikkommission bei der Ärztekammer des Saarlandes) gave its approval (91/22).

2.2. Measuring

The abdominal organ–spine distances were measured in a frontotransversal axis in mm. Starting point: The midpoint of the lateral border of the vertebral body or intervertebral disc in the sagittal and in the longitudinal axis (Fig. 1). Endpoint: The border of the first intercepting organ. Measurements were performed for both sides and from Th10 to S1, as exemplarily displayed in Fig. 2.

2.3. Statistical analysis

Statistical analysis and graphs were performed using the GraphPad Prism software package (Version 10.0.3). Descriptive analysis was provided using mean ± standard deviation. Data were comparatively analyzed using a Wilcoxon–signed–rank test. P was two-tailed and considered statistically significant when < 0.05.

3. Results

Of the six investigated volunteers, three were female, and three male. The focus of this investigation was the thoracolumbar junction. Data and descriptive statistics are provided in Fig. 3, for the right side, and Fig. 4, for the left. Of note, none of the proband had lumbosacral transitional vertebrae (Paton et al., 2024).

On the right side, the prone position showed overall larger organ–spine distances than in the right lateral decubitus position (Fig. 3). This was significant at the thoracolumbar junction levels Th10 (107 ± 6.5 vs. 49 ± 42 mm), Th10–Th11 (97 ± 19 vs. 27 ± 34 mm), Th11 (97 ± 27 vs. 30 ± 35 mm), Th11–12 (73 ± 38 vs. 13 ± 15 mm), Th12 (60 ± 37 vs. 19 ± 19 mm), Th12–L1 (41 ± 35 vs. 10 ± 9 mm), L1–L2 (27 ± 11 mm vs. 15 ± 9 mm), and L2 (53 ± 34 vs. 26 ± 11 mm).

Beginning at the Th12 level the liver and the right kidney increasingly crossed the frontotransversal axis in prone position which

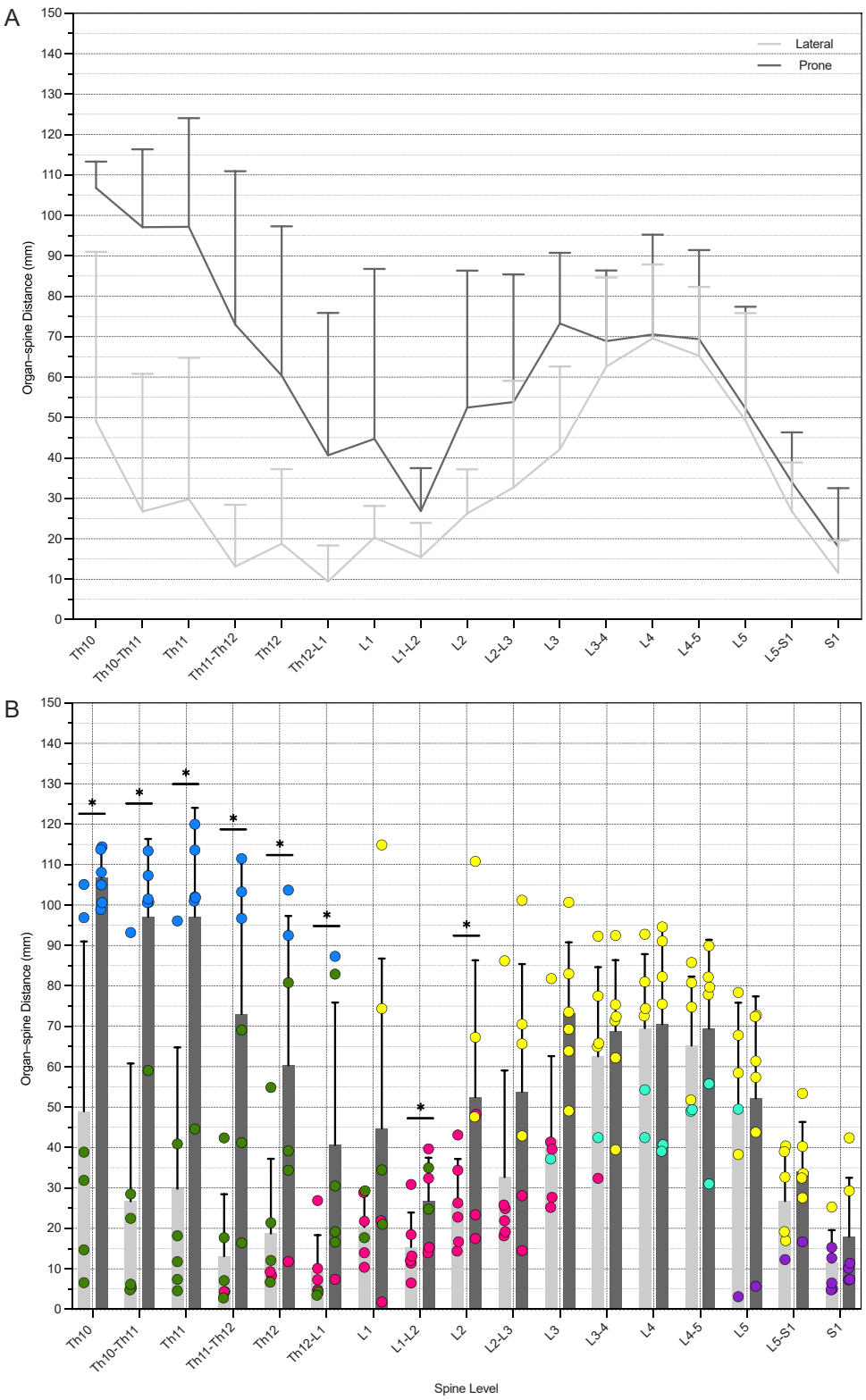

Fig. 3. Organ–spine distances depending on proband position from the Th10 to the S1 level on probands' right side in the analyzed transversal plane. (A) shows mean values and standard deviations, and (B) individual data. Light and dark grey colored columns/lines represent the mean value in mm and the standard deviation from measurements obtained from lateral-decubitus- and prone-positioned probands, respectively. (B) Singular points represent individual data. The color code of each point indicates the intercepting organ/structure. Blue: ribcage, dark green: liver, magenta: right kidney, turquoise: peritoneum, yellow: abdominal wall, purple: right iliac vessels.

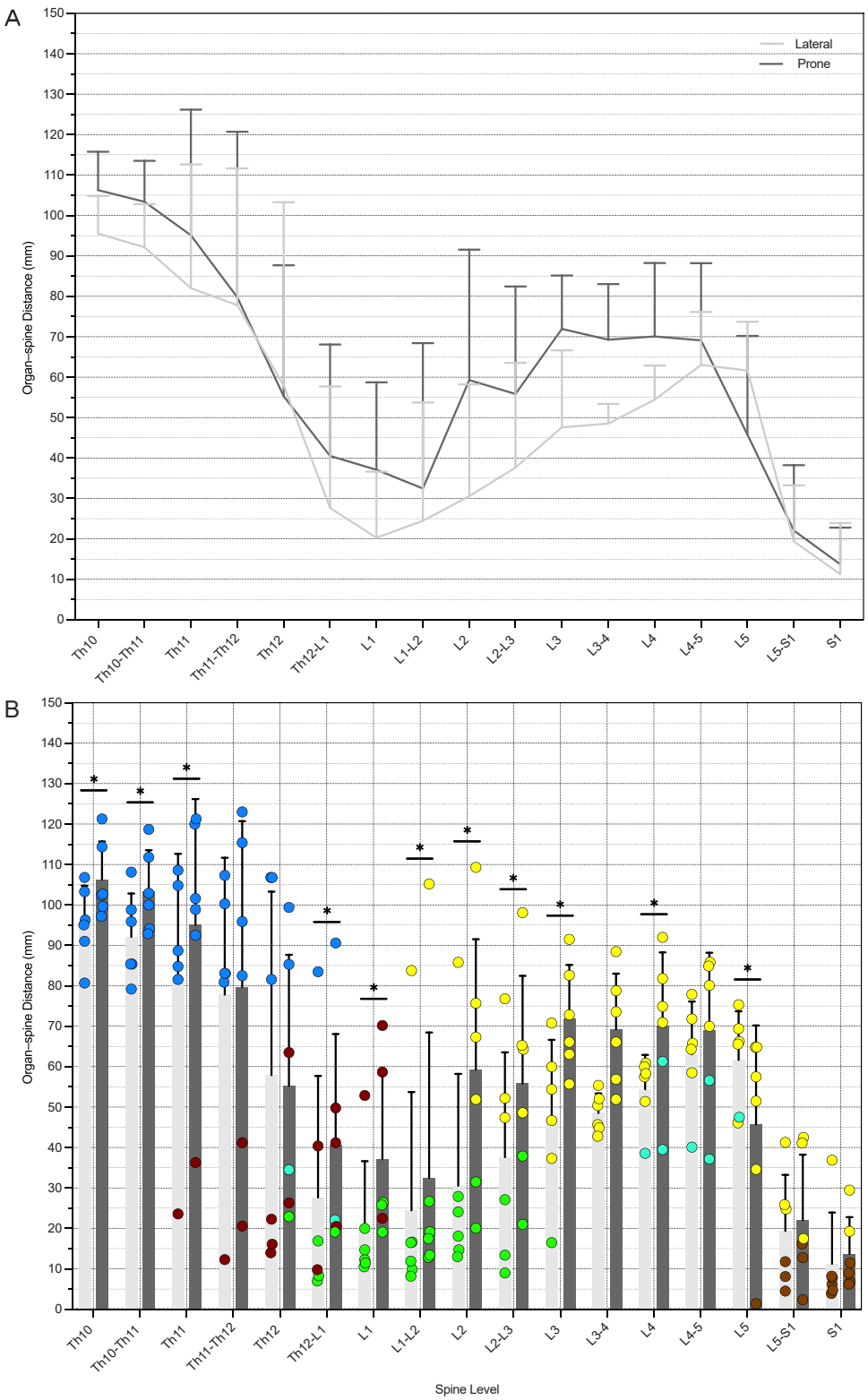

Fig. 4. Organ–spine distances depending on proband position from the Th10 to the S1 level on probands' left side in the analyzed transversal plane. (A) shows mean values and standard deviations, and (B) individual data. Light and dark grey colored columns/lines represent the mean value in mm and the standard deviation from measurements obtained from lateral-decubitus- and prone-positioned probands, respectively. (B) Singular points represent individual. The color code of each point indicates the intercepting organ/structure. Blue: ribcage, red: spleen, turquoise: peritoneum, green: left kidney, yellow: abdominal wall, brown: left iliac vessels.

decreased the respective organ–spine distances. At the Th12–L1 level and in right lateral decubitus position, the right kidney and the liver intercepted the frontotransversal axis in four and two cases, respectively. In contrast, at the same level and in prone position, the liver intercepted in four cases, the ribcage in one, and the right kidney in one, respectively. At the L1 level and in lateral decubitus position the right kidney intercepted in four cases, and the liver in two, with an overall organ–spine distance of 20 ± 8 mm. At the same level and in prone

position, the abdominal wall, the liver, and the right kidney intercepted the frontotransversal axis in two cases each, with an overall organ–spine distance of 45 ± 42 mm. At the L1–L2 level and in lateral decubitus position, the right kidney crossed the frontotransversal axis in all six cases, whereas in prone position the right kidney intercepted in four cases and the liver in two. Below the L1–L2 level, the liver no longer crossed the frontotransversal axis, although larger amounts of interceptions with the abdominal wall at L2, L2–3, and L3 and particularly in prone position enlarged the gap in overall organ–spine distances between the prone and the lateral decubitus position. Beyond the thoracolumbar junction, the variation between the two positions became decreasingly relevant up to S1, with structures such as the peritoneum and the right iliac vessels crossing the frontotransversal axis at similar distances from the spine regardless of the subject's position (Fig. 3).

On the left side, the prone position also showed overall larger organ–spine distances than in the left lateral decubitus position (Fig. 4). However, this variation was less pronounced than on the right side. Nevertheless, this was significant at the thoracolumbar junction levels Th10 (106 ± 10 vs. 96 ± 9 mm), Th10–Th11 (103 ± 10 vs. 92 ± 11 mm), Th11 (95 ± 31 vs. 82 ± 31 mm), Th12–L1 (41 ± 28 vs. 28 ± 30 mm), L1 (37 ± 22 vs. 20 ± 16 mm), L1–L2 (33 ± 26 mm vs. 25 ± 29 mm), and L2 (59 ± 32 vs. 31 ± 28 mm).

At the Th10 level, the ribcage intercepted in all six cases regardless of prone or left lateral decubitus positioning. At the Th10–Th11 and Th11 levels, the ribcage was the first structure to intercept the frontotransversal axis in most cases in prone and lateral decubitus position. At the Th11–12 level, the spleen intercepted once in lateral and twice in prone position. At the Th12 level, the peritoneum and the left kidney each joined once as interceptions in the frontotransversal axis in prone but not in lateral decubitus position. There was no significant variation between prone and left lateral decubitus position at the Th11–Th12 and Th12 levels. At the Th12–L1 level and in in prone position, a heterogenous picture emerged with the spleen intercepting in three cases, the left kidney, the peritoneum, and the ribcage each in one case. At the same level in left lateral decubitus position, the left kidney intercepted in three cases, the spleen in two cases, and the ribcage in one case. At the L1 level and in prone position the left kidney and the spleen intercepted the frontotransversal axis in three cases each, whereas in left lateral decubitus position the left kidney intercepted in five cases and the spleen only once. In contrast, at the L1–L2 level, the left kidney intercepted the frontotransversal axis in 5 cases in both positions. The abdominal wall was the intercepting structure in the last case. At the L2 level and in prone position, the abdominal wall intercepted the frontotransversal axis in four cases and the left kidney in two cases, whereas in left lateral decubitus position the left kidney intercepted in five cases and the abdominal wall only once.

Caudally of these levels, the variation between both positions was significant at the L2–L3, L3, L4, and L5 levels (Fig. 4).

4. Discussion

This MRI study shows that prone position is associated with an increased distance between the thoracolumbar spine and the abdominal structures as compared to lateral decubitus position. This was particularly the case for the right side. Lateral surgical approach in prone position may therefore be a safe option for accessing the thoracolumbar junction which was increasingly reported in the last years (Alan et al., 2022; Alluri et al., 2023; Brown et al., 2023; Patel et al., 2023; Pimenta et al., 2023). In contrary to a previous study that compared lateral decubitus with prone position using different cohorts for each, we incorporated individual anatomical factors which is a strength of our study (Alluri et al., 2023). A limitation of our study is the low case number. With respect to the latter, the variations we observed are even more remarkable. Although we took measures to simulate the operating conditions to obtain the most accurate measurements, there are many other factors that reduce the representativity of our findings compared to real life scenarios. For example, patients under anesthesia are commonly administered muscle relaxants, which accentuates the anterior organ shifting away from the spine as the respiration is artificially controlled. Breathing maneuvers which are necessary during MRI also affect abdominal organs' position. Thus, future research on larger patient groups is necessary to validate the findings of this study and to consider the advantages and disadvantages of prone positioning, including the anesthesiologic point of view.

Relevant variations between prone and lateral decubitus position were observed. The measurements show that depending on the position, paraspinal organ movement is mostly observed along the thoracolumbar junction in contrast to the lumbosacral analogue. The data indicate that thoracic and abdominal organs are moving in both longitudinal and frontal planes. The wide standard deviations reflect the large individual body-mass-index-dependent paraspinal organ mobility range. While the approach in the lateral decubitus position is only suitable from the left side because of the absence of the liver, the approach in prone position can be performed from both sides, even with in relation additional space on the right side because of the liver shifting ventrally. Interestingly, pressure-controlled ventilation with volume guaranteed mode has been shown to be favorable for prone position (Lee et al., 2019). In addition, airway pressure can serve as a predictor of cardiac output reduction during surgery in prone position which may help in patients with hemodynamic instability (Wang et al., 2025). The prone position seems to have not only advantages for the surgery of the thoracolumbar junction but also for the surgery of the lower lumbal spine (Smith et al., 2021). The group of Juan S. Uribe has published a feasibility study and early clinical experiences with the prone single-position for lateral approach as well as a recent "Technical Guide for Mastery" of this approach to the spine (Giraldo et al., 2025; Godzik et al., 2020).

In conclusion, the prone position facilitates the lateral approach to the thoracolumbar spine bilaterally.

Ethical statement

Healthy probands were investigated using MRI. Every proband gave informed consent. The study was approved by the local Institutional Review Board (Ethikkommission bei der Ärztekammer des Saarlandes, 91/22).

CRediT authorship contribution statement

Hasanain Mohammed: Writing – original draft, Investigation. **Tschernig Thomas:** Writing – original draft, Investigation, Conceptualization. **Englisch Colya N.:** Writing – original draft, Investigation. **Hell Diana:** Investigation. **Ketter Ralf:** Writing – review & editing. **Oertel Joachim:** Writing – review & editing, Supervision, Conceptualization. **Buecker Arno:** Supervision, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no competing interests.

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