

The Diagonal Vector (DIVE) Approach for Lumbar Plexus Block – A Comparison with Chayen’s Technique

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Purpose: Substantial understanding of anatomic landmarks remains mandatory for regional anesthesia procedures of the lower limbs, even in times of ultrasound-guided techniques. Theoretically, applying a diagonal vector (DIVE) from the posterior superior iliac spine towards the spinous process of lumbar vertebra 3 leads to a higher error tolerance and closer nerve approximation when compared to Chayen’s approach. The purpose of this study was to compare both techniques regarding clinical applicability, accuracy and risk profile.

Patients and Methods: Lumbar plexus block was performed bilaterally according to Chayen’s technique and the DIVE method in embalmed bodies donated to science. The posterior medial half of the psoas major muscle was predefined as the puncture target area. Essential anatomical landmarks were labelled, photographed and a computer-aided analysis of the images was conducted. Both approaches were compared regarding the puncture success rate, spatial nerve approximation and complications such as vessel or kidney punctures.

Results: Both techniques were applied bilaterally on 34 embalmed bodies (50% male, mean age \pm standard deviation 82 ± 8 years, height 167 ± 10 cm) and led to similar success rates of a psoas muscle hit (Chayen vs DIVE 86.3% vs 82.8%). DIVE punctures were more often localized in the medial third of the psoas ($p < 0.001$), whereas the risk for vessel or kidney punctures was similar ($p = 0.473$; $p = 0.367$, respectively).

Conclusion: Punctures according to the DIVE method resulted in a higher puncture accuracy compared to Chayen’s technique with comparable practicability and risk profile. When using the DIVE Block, a window for a successful puncture can be expected between a quarter and a third of the PSIS- L3SP distance.

Keywords: regional anesthesia, lumbar plexus block, lower limb surgery, peripheral nerve block, local anesthetics

Introduction

Peripheral nerve block (PNB) techniques such as the posterior lumbar plexus block (LPB) play a crucial role in postoperative pain management after hip procedures such as total arthroplasty.^{1–5} Regional anesthesia enables early mobilisation active support in therapy, faster rehabilitation with good functional outcome and comparable pain control with fewer side effects, including neurologic and opioid-induced complications^{6–12} The LPB, also referred to as “psoas compartment block”, represents the most proximal peripheral approach for blocking the lumbar plexus (femoral, obturator and lateral cutaneous femoral nerve) mandatory for anesthesia of the lower extremity by a single puncture or injection.^{13,14} After Winnie first described an anterior perivascular (“3 in 1”) approach to the lumbar plexus in 1973 and later a posterior approach at the level of L4/L5, Chayen introduced a posterior L4 approach based on a loss of resistance in 1976.^{15–17} Even though several ultrasound-based approaches have been reported in body donors as well as

in patients since then,^{18,19} broad understanding of relevant anatomical landmarks remains a fundamental aspect of all regional anaesthesia procedures, as this can prove beneficial when ultrasound guided approaches reach their limits.^{20–22} In 2009, Heller et al implemented the DIVE method by constructing a diagonal vector (DIVE) from the posterior superior iliac spine (PSIS) towards the spinous process (SP) of L3 (L3SP). In theory, the DIVE method is less dependent on individual anatomical variations and might lead to a higher error tolerance as well as closer spatial nerve approximation compared to previous approaches.²³ However, there is currently no direct comparison of this method with one of the landmark-based approaches such as Chayen's technique.

Thus, the objective of this prospective, experimental study was to evaluate the applicability, accuracy and risk profile of the DIVE method compared to Chayen's clinically established approach to the LPB in human anatomical specimens.

Materials and Methods

Ethical Aspects

The bodies had been donated to the Department of Anatomy of the Medical Faculty Carl Gustav Carus of the Technical University Dresden under the Anatomical Donation Program, approved by the Technical University of Dresden. All body donors provided written informed consent to the conduct of studies and the use of the generated data for research purposes during their lifetime. The study was conducted in accordance with the Declaration of Helsinki adopted by the World Medical Association in October 2024.²⁴

Preparation of Body Donors

Bodies were eviscerated, postured in a strict right lateral position and the LPB punctures were carried out bilaterally from posterior. To provide standardized spatial conditions and minimize projection errors or unwanted needle deviations, the bodies were positioned so that the body-related frontal plane was aligned exactly perpendicular to the horizontal plane of the table surface. Essential anatomical reference points were marked at the ventral and dorsal side of the bodies for photo documentation and subsequent analysis. LPB punctures were performed bilaterally with Chayen's technique and with the DIVE method in each prepared body. The puncture sites were identified according to the respective landmarks in the lumbar region as originally described by Heller et al and Chayen et al^{16,23} The puncture depth was recorded with a centimeter-scaled (Contiplex Braun® 18G 110mm) needle at its exit point from the ventral surface of the psoas major muscle. For both approaches, the target area was predefined as the posterior medial half of the psoas major muscle in the frontal plane, since the true position of the lumbar plexus can be approximated at the border between the medial and the medium psoas third.²³ Details regarding the puncture method, marking of essential anatomical reference points, photo documentation and the calculation of spatial distances are available in the [Supplementary](#).

Statistical Analysis

All values are presented as mean \pm standard deviation (SD). For comparisons of continuous variables between the two approaches of a posterior LPB two tailed, paired t-tests were performed. Levene's test was used to check continuous variables for Gaussian distribution. Categorical variables were compared with the Chi²-test or, in case of expected cell frequencies <5, with the Fisher's exact test. A polynomial fit procedure was performed to create an approximation curve and to calculate the closest proximity of the DIVE vector to the path of the nerve as represented at the respective curve minimum. SPSS software (IBM SPSS statistics, version 21.0.0.0, Armonk, NY, USA) was used for all calculations. A p-value of <0.05 was considered statistically significant.

Results

Body Donors

34 bodies donated to science and embalmed with 10% standard formalin solution were dissected and investigated. One body was excluded from further analysis due to severe scoliosis. A total of 132 punctures were carried out bilaterally in the remaining 33 bodies, with 66 according to Chayen's approach and 66 by applying the DIVE method. General biometric data as well as parameters describing the anatomical configuration of the 33 specimens (17 female/ 16 male)

were collected from both sides of the body to gain 66 side-specific anatomical datasets. The overall mean (\pm standard deviation) age was 82.1 ± 8.0 years (range 65–99 years), the mean body height was 167.2 ± 9.5 cm (range 148–183cm). There was no difference regarding sex, height and age between the groups.

Comparison of the DIVE Method and Chayen’s Approach

We developed a two-dimensional scheme of the average anatomical configuration within a Cartesian coordinate system by integrating the mean positions of the SPs of L3, L4 and L5 the PSIS, the psoas major muscle and the caudal kidney pole in relation to the median longitudinal body axis and the intercrystal line (Tuffier’s line, ICL). The average proximity of the needle insertion points on the DIVE vector to the lumbar plexus nerves was then calculated based on the acquired measurements (Figure 1a). The range of highest spatial approximation (< 9 mm), given as the relation of the actual puncture vector to the DIVE vector was 0.1 to 0.33, corresponding to an average distance of the needle insertion point

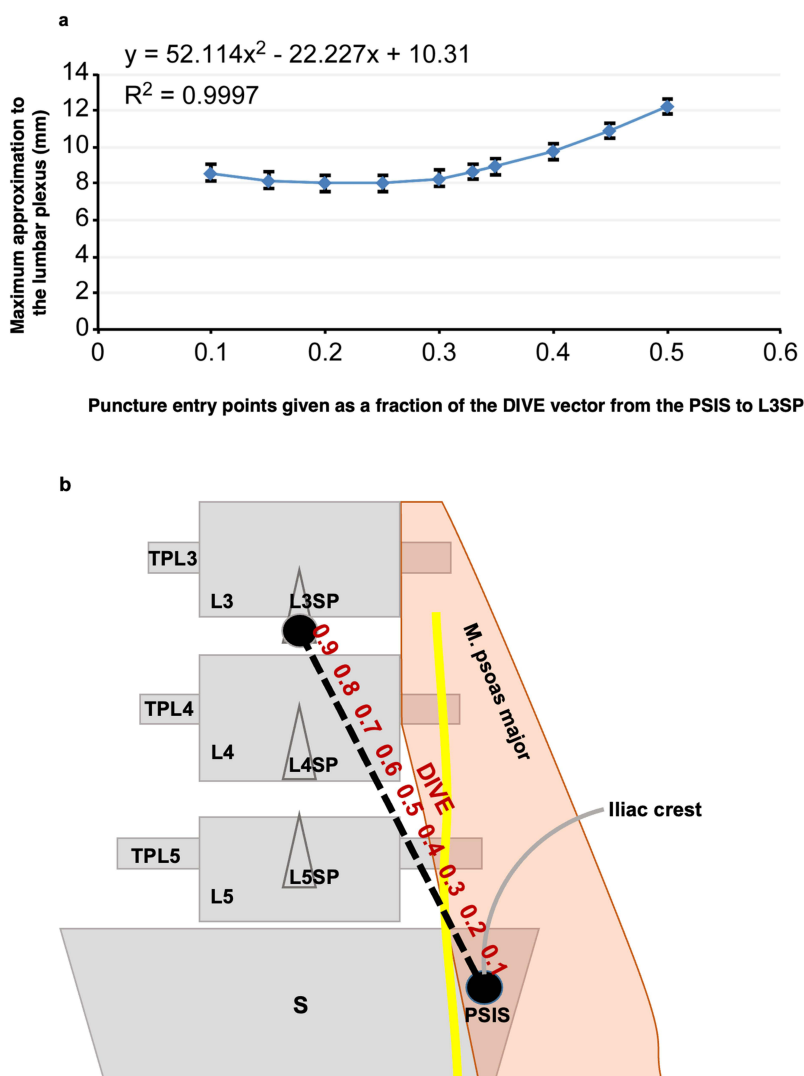


Figure 1 Theoretical and graphical representation of the DIVE vector. (a) Approximation curve of the DIVE vector to the lumbar plexus. Data are presented as mean \pm standard error of the mean. The line connecting the posterior superior iliac spine (PSIS) with the tip of the spinous process of L3 is called DIVE vector (shown in Figure 1b). The x-axis depicts puncture entry points on the DIVE vector, given as a fraction from 0.1 to 0.5 (for example: if the total line measures 10 cm, 0.3 corresponds to a puncture point on this line at 3 cm from PSIS in direction to the spinous process of L3). The y-axis depicts the resulting distance of the needle tip to the presumed path of the lumbar plexus measured in mm. The calculated curve shows that punctures between 0.1 to 0.4 of the DIVE vector result in close proximity (8–9 mm) of the needle tip to the lumbar plexus. (b) Graphical representation of the DIVE vector. The DIVE vector (black dashed line) runs from the posterior superior iliac spine (PSIS) to the spinous process of lumbar vertebra 3 (L3SP). The red numbers depict puncture entry points on the DIVE vector, given as a fraction from 0.1 to 1.0 starting from the PSIS. **Abbreviations:** SP; spinous process; TP; transverse process. TPL3, transverse process of lumbar vertebra 3; TPL4, transverse process of lumbar vertebra 4; TPL5, transverse process of lumbar vertebra 5; S, sacrum; L4SP, spinous process of lumbar vertebra 4; L5SP, spinous process of lumbar vertebra 5.

from the PSIS of 10–29mm. Unsuccessful punctures due to hitting osseous structures occurred in 21.2% of Chayen’s punctures and in 12.1% of DIVE punctures. Successful needle passages passing by osseous structures as well as potential osseous hindrances in the path of the DIVE vector are presented in Figures 1b and 2. An overview of the average DIVE vector length documented in case of a successful needle passage as well as the distances from the needle insertion point to relevant anatomical reference points is given in Table 1. All needle insertion points according to Chayen’s technique and their relation to anatomical reference points are shown in Figure 3a, those according to the DIVE method in Figure 3b. Figure 4a and b each show a dorsal view of a cadaver specimen with the needle insertion points according to the DIVE method and Chayen’s approach. Figure 4c presents a ventral view of the anatomical landmarks and puncture sites according to the DIVE and Chayen approaches, illustrated on a cadaver specimen. Punctures according to both techniques showed some degree of variability in relation to the median longitudinal body axis and the average ICL position. There was no difference in passing the needle into any part of the psoas muscle (Chayen vs DIVE: 78,8% vs 87,9%, $p=0.243$), however the DIVE punctures were more often localized within the medial third (33.3% vs 65.5%, $p<0.001$) as well as the medial half (47.1% vs 69.0%, $p=0.032$) of the psoas major muscle (see Table 2). For both methods, neither the side of the body nor sex had a significant influence on whether a puncture was placed within any part of the psoas major muscle. The mean approximation of the needle to the lumbar plexus was $7.1 \pm 5.5\text{mm}$ with the DIVE method and $7.8 \pm 6.4\text{mm}$ with Chayen’s approach ($p=0.560$). No accidental puncture of the kidneys occurred with the DIVE method. All five cases (4 according to DIVE, 1 according to Chayen) of unintentional paravertebral vessel punctures were located on the right side of the body. The average distance of the needle towards the parenchyma of the kidney was $52 \pm 16\text{mm}$ with the DIVE method, which is larger than the average distance for Chayen’s punctures of $46 \pm 16\text{mm}$ ($p=0.019$).

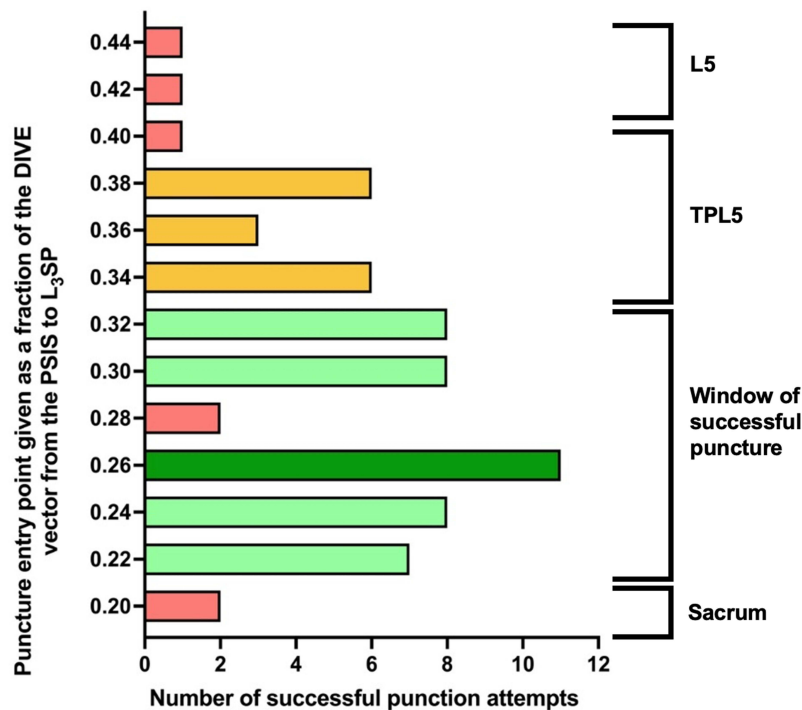


Figure 2 DIVE vector puncture points and corresponding osseous hindrances. The line connecting the posterior superior iliac spine (PSIS) with the tip of the spinous process of L3 (L3SP) is called DIVE vector (shown in Figures 1b and 3b). The y-axis depicts puncture entry points on the DIVE vector, given as fraction from 0.1 to 0.5 (for example: if the total line measures 10 cm, 0.3 corresponds to a puncture point on this line at 3 cm from PSIS in direction to L3SP). Red and Orange vertical chart bars show low success rates at these needle entry points due to osseous hindrances. Green bars demonstrate the numbers of successful punctures without osseous contact. L5: lumbar vertebra 5; TPL5: transverse process of lumbar vertebra 5.

Table 1 Average DIVE Vector Lengths and Distance to Anatomical Reference Points

	Total (n=58)	Left (n=29)	Right (n=29)	Male (n=17)	Female (n=16)
DIVE vector lengths					
PSIS–L3SP	97.0 ± 10.5	96.1 ± 11.3	96.9 ± 10.3	98.5 ± 13.1	94.6 ± 7.5
PSIS–IS	27.2 ± 6.8	25.4 ± 6.0	28.2 ± 7.0	26.4 ± 7.8	27.3 ± 5.5
PSIS–IS _{relative}	0.28 ± 0.1	0.26 ± 0.1	0.29 ± 0.1	0.27 ± 0.1	0.29 ± 0.1
Distance from needle insertion points to anatomical reference points					
to the longitudinal median body axis	37.4 ± 8.8	35.0 ± 8.5	37.7 ± 8.1	38.0 ± 8.8	34.9 ± 7.7
to the ICL (Tuffier's line)	-20.3 ± 13.4	-21.8 ± 14.0	-20.0 ± 13.2	-26.8 ± 13.5	-15.4 ± 11.2
puncture depth	96.2 ± 12.1	96.5 ± 12.5	95.4 ± 11.7	101.2 ± 11.1	91.1 ± 10.9

Notes: Data are given as mean ± standard deviation in millimetres. The average DIVE vector lengths of the 58 successful punctures are presented for the length of the DIVE vector from the PSIS to the L3SP (PSIS-L3SP), from the PSIS to IS (PSIS-IS), from the PSIS to the insertion site in relation to the length of the DIVE vector (PSIS-IS_{relative}).

Abbreviations: DIVE, diagonal vector; IS, needle insertion site; L3SP, spinous process of lumbar vertebra of L3; PSIS, posterior superior iliac spine.

Discussion

This prospective experimental study is the first to examine the practicability and accuracy of the DIVE method in human specimens. The main finding of the present study is that an LPB puncture according to the DIVE method results in

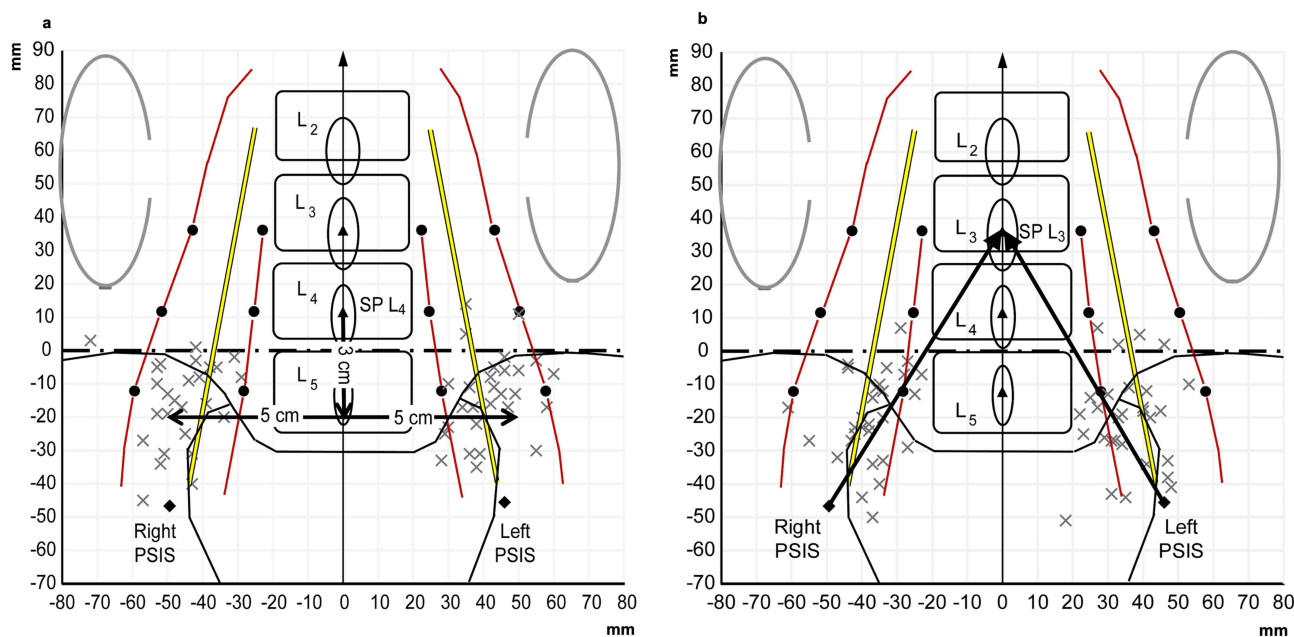


Figure 3 Distribution of Punctures Using Chayen's Approach and the DIVE Method. (a) Dispersion of punctures according to Chayen's approach. Dispersion of the particular ventral exit sites of the needle with a successful puncture (x) in full frontal plane following Chayen's approach (n = 52) with a depiction of the corresponding fixed metric measurements as well as the presumed path of the targeted neuronal structure (yellow lines) at the borderline between the medial and the medium third within the psoas major muscle (red lines). The dashed-dotted horizontal line represents the intercrystal line, the vertical line the median longitudinal body axis. The grey ovals represent the left and right kidney. (b) Dispersion of punctures according to the DIVE method. Dispersion of the particular ventral exit sites of the needle with a successful puncture (x) in full frontal plane following the diagonal vector method (n=58) with a depiction of the corresponding fixed metric measurements as well as the presumed path of the targeted neuronal structure (yellow lines) at the borderline between the medial and the medium third within the psoas major muscle (red lines). The diagonal vector (DIVE vector), ie the line connecting the posterior superior iliac spine (PSIS) with the tip of the spinous process of L3, is indicated by a black arrow. The dashed-dotted horizontal line represents the intercrystal line, the vertical line the median longitudinal body axis. The grey ovals represent the left and right kidney.



Figure 4 Anatomical views of LPB puncture sites: DIVE method vs Chayen's approach in cadaver specimens. **(a)** Dorsal view of the LPB puncture using the DIVE method. Dorsal view of a cadaver torso in a craniocaudal orientation, positioned on its left side with the lateral side of the body at the top and the spine at the bottom. The blue needle on the left side towards the cranium represents the spinous process of the vertebral body of L3 and the blue needle on the right side towards the caudal pole represents the right posterior superior spina iliaca on the right side of the body. The yellow line represents the DIVE vector from PSIS to L3SP and the needle insertion point demonstrates a puncture according to the DIVE method. **(b)** Dorsal view of of LPB puncture using Chayen's approach. Dorsal view of a cadaver torso (specimen No. 3) with the lateral side positioned at the top and the spine at the bottom in craniocaudal position with the cranium towards the right side and the caudal pole towards the left side of the picture. The blue needles represent the spinous processes of the vertebral bodies of L5 (L5SP), L4 (L4SP) and L3 (L3SP, left to right). The yellow arrows demonstrate the approach to the needle insertion point by marking a point 3 cm caudad (horizontal line) to L4 and from there 5 cm lateral. The insertion point of the green needle demonstrates a puncture according to Chayen's approach. **(c)** Ventral view of the puncture sites according to the DIVE and Chayen's approaches as well as relevant anatomical landmarks. Ventral view of a specimen's abdominal retroperitoneal cavity with the cranium at the top and the lower body towards the bottom of the picture. The anatomical lancet represents the intercrystal line. The aorta abdominalis anterior lies behind the lancet, dividing into the common iliac arteries below. The left and right lower kidney Poles are marked with blue needles. The green cannulas represent the projection of the posterior superior iliac spine (PSIS) on both sides and the yellow cannulas represent the vertical and horizontal borders of the promotorium of the sacral bone. The relevant anatomical landmarks are shown at the levels of L3 (red), L4 (yellow), and L5 (green), each from medial to lateral: the spinous process of L3 (L3 SP), L4 (L4 SP) and L5 (L5 SP), the lateral border of the vertebral body, and the lateral edge of the psoas muscle. Puncture sites according to the DIVE technique are marked in black, and those according to Chayen's approach are marked in white. Note that a puncture following Chayen's approach was not possible on the right side of the body due to persistent bony contact.

a higher spatial approximation to the lumbar plexus as well as a higher puncture accuracy with a similar risk profile and practicability compared to Chayen's technique.

The DIVE method is based on the concept that using two anatomical reference points instead of just one as in Chayen's technique increases lumbar plexus approximation and reduces errors in determining the correct insertion point as well as any associated complications due to interindividual anatomical variability and methodical imprecision.^{25–31} This theoretical advantage of the DIVE method was validated by the significantly higher precision and puncture accuracy within the target area being the medial half and median third of the psoas muscle (Figure 3a and b) as well as a lower failure rate due to a hit of osseous hindrances.²³ Approximately 80% of successful punctures without any bone contact were localized within a range of 0.2 to 0.33 on the average DIVE vector in relation to its total length from PSIS to L3SP, as shown in Figure 3b, which coincidentally lay within the area of highest spatial approximation (< 9mm) of the DIVE vector towards the lumbar plexus, between 0.1 and 0.33 (Figure 1a). Based on these results, conducting a posterior LPB

Table 2 Comparison of Hit-Rates of Chayen's and DIVE Approach

	Chayen (n=66)	DIVE (n=66)	p-value
<i>Unsuccessful punctures due to hit of osseous structures</i>	14 (21.2)	8 (12.1)	0.243
	Chayen (n=52)	DIVE (n=58)	
<i>Psoas muscle hit</i>	44 (86.3) *	48 (82.8)	0.792
<i>Hit of the medial half of the Psoas muscle</i>	24 (47.1)	40 (69.0)	0.032
<i>Hit of the medial third of the Psoas muscle</i>	17 (33.3)	38 (65.5)	<0.001
<i>Accidental renal puncture</i>	1 (1.9)	0 (0.0)	0.473
<i>Accidental puncture of central vessel</i>	1 (1.9)	4 (6.9)	0.367
<i>Distance to kidney (mm)</i>	46 ± 16	52 ± 16	0.019
<i>Distance to LP (mm)</i>	7.8 ± 6.4	7.1 ± 5.5	0.506

Notes: Continuous variables are presented as mean ± standard deviation, categorical variables as absolute (relative frequencies). P-values were calculated with a two tailed, paired t-test for continuous variables and with the exact Fisher's test for categorical variables. A p<0.05 is considered statistically significant and marked in italics. *n=51.

Abbreviations: DIVE, diagonal vector; LP, lumbar plexus.

by using the DIVE method should be attempted primarily between 0.2 and 0.33 on the DIVE vector with a strictly perpendicular needle advancement.

When comparing the DIVE method with the established Chayen's technique in terms of clinical practicality, aspects such as safety, complication potential and feasibility have to be considered. As the main nerves arising from the lumbar plexus relevant to lumbar plexus block run in the medial half of the psoas muscle, a more medial puncture according to the DIVE method potentially results in a higher success rate and a lower probability of organ damage compared to the more lateral Chayen's approach. We observed a higher frequency of accidental major iliac and lumbar vessel punctures with the DIVE method, which run medial to the psoas muscle and supply paravertebral and back muscles. Even though the accidental vessel puncture rates in both approaches were not significantly different, it should be noted that LPB according to the DIVE method potentially increases the risk of accidental vessel punctures, especially on the right side, or unintended epidural local anesthetic spread due to the medial needle trajectory and the close anatomical relation to the intervertebral neuroforamina.³² The greater approximation of the DIVE vector to the path of the lumbar plexus in comparison with Chayen's approach further implies that the lumbar plexus may be successfully localized within less time when applying the DIVE method under clinical circumstances in combination with ultrasound guidance. The higher proximity of the needle tip to the lumbar plexus nerves could potentially result in a more rapid onset of anesthesia after local anesthetic injection with a reduced amount of required local anesthetic. When combined with color doppler or power doppler ultrasound, the risk of accidental vessel punctures should, at least in theory, be minimized. However, since this study was carried out in body donors, we could not verify such a hypothesis.

Owing to recent technological advancements and widespread availability, ultrasound-based techniques are increasingly preferred in clinical practice. While ultrasound-guided techniques rightfully hold a prominent position when it comes to PNB techniques, previous studies have also pointed out important limitations, including the inability to visualize target nerves due to their intramuscular course and the limited spatial resolution associated with the low ultrasound frequencies required for these techniques.^{33,34} Therefore, landmark-based PNB techniques might offer several advantages and are essential, particularly in settings where ultrasound guidance reaches its limitations and is not feasible.³⁵ They do not require specialized equipment, can often be performed more quickly by experienced practitioners and are not affected by poor image quality, which can be a major limitation in patients with obesity, altered anatomy or for unexperienced anesthesiologists. In this context, landmark-based techniques may present a steeper learning curve for

trainees, allowing them to focus on anatomical and palpation skills before engaging with the complexity of ultrasound image interpretation.³⁶ The present cadaveric study demonstrates the expected theoretical superiority of the DIVE method in terms of higher puncture accuracy, with a similar risk profile and practicability compared to Chayen's technique, thereby contributing to improved patient care and safety.

There are some limitations to this experimental study. The clinical applicability of the results is limited by the three-dimensional tissue shrinkage caused by the chemical fixation of the bodies and the advanced mean age of 82 years which goes along with tissue trophism, increased calcification levels and size reduction of the psoas muscle.^{37,38} Additionally, the tissue layers of the cutis and subcutis had already been removed within the lumbar region, hence the presented puncture depths on the DIVE vector might be somewhat lower than they would be in living patients. Along with age and age-related changes of tissue composition, anatomical variations should be considered and systematically evaluated in a larger, broader and more diverse cohort of living subjects to assess the clinical applicability of the DIVE method. Regarding the anatomical limitations of the DIVE method, unsuccessful puncture attempts at the inferior limit of the DIVE vector are most probable due to contact with either the iliac crest or the sacrum. Punctures closer to L3SP occur due to osseous contact with the transverse process of L5 or potentially the vertebral body L5 (Figures 1b and 2). Punctures between 0.22 and 0.32, ie between a quarter and a third of the PSIS- L3SP distance, therefore, represent a window for a successful puncture. The lower success rate, which was observed at exactly 0.28 of the DIVE vector length, can only be explained as a random observation.

Conclusion

LPB by means of a puncture on the DIVE vector resulted in a closer approximation to the lumbar plexus and higher puncture accuracy with similar practicability and risk profile compared to Chayen's technique. A window for successful puncture can be expected between a quarter and a third of the PSIS- L3SP distance. The DIVE method might offer the advantage of a higher success rate in patients or situations where ultrasound-guided approaches reach their limits and overall contribute to an improved quality, effectiveness and efficiency of this regional anesthetic procedure within modern perioperative patient care regimens.

Abbreviations

DIVE, diagonal vector; ICL, intercrystal line (Tuffier's line); L3SP, spinous process of the third lumbar vertebra; LPB, lumbar plexus block; PNB, peripheral nerve block; PSIS, posterior superior iliac spine; SP, spinous process.

Disclosure

The authors report no conflicts of interest in this work.

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