Lumbar Plexus in Children

A Sonographic Study and Its Relevance to Pediatric Regional Anesthesia

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Background: Pediatric regional anesthesia has gained increasing interest over the past decades. The current study was conducted to investigate the lumbar paravertebral region and the lumbar plexus at L3–L4 and L4–L5 by means of sonography to obtain fundamentals for the performance of ultrasound-guided posterior lumbar plexus blocks.

Methods: Thirty-two children (12 boys, 20 girls) with American Society of Anesthesiologists physical status I or II were enrolled in the current study. The lumbar paravertebral region was visualized at L3–L4 and L4–L5 on two corresponding posterior sonograms (longitudinal, transverse). The lumbar plexus had to be delineated, and skin-plexus distances were measured. In a series of five pediatric patients undergoing inguinal herniotomy, ultrasound-guided posterior lumbar plexus blocks at L4–L5 were performed.

Results: The children were stratified into three age groups (group 1: > 3 yr and ≤ 5 yr; group 2: > 5 yr and ≤ 8 yr; group 3: > 8 yr and ≤ 12 yr). The lumbar plexus could be delineated at L3–4 and L4–5 in 19 of 20 cases in group 1, 17 of 20 cases in group 2, and 16 of 24 cases at L4–5 in group 3. In all patients, the lumbar plexus was situated within the posterior part of the psoas major muscle. Skin-plexus distances showed statistical significant differences between groups 1 and 3 and between groups 2 and 3. The strongest positive correlation existed between skin-plexus distances and the children’s weight. Ultrasound guidance enabled safe and successful posterior approaches to the lumbar plexus, thus resulting in effective anesthesia and analgesia of the inguinal region.

Conclusions: Sonography of the lumbar plexus in children proved to be feasible. Skin-plexus distances correlated with the children’s weight rather than with their age. The sonographic findings were fundamental for the performance of successful ultrasound-guided posterior approaches in a small group of pediatric patients.

PERIPHERAL nerve blocks in children have gained increasing interest over the past few decades.1–5 One of the major benefits of these techniques is that they are directed to the site of surgery, thus minimizing undesirable side effects.1,5

Unilateral anesthesia and analgesia for operations in the groin area and on the hip and thigh, as well as for postoperative pain relief, can be obtained by means of a posterior lumbar plexus block at the L4–L5 level.1,3–8 Nevertheless, little is known about the topographic anatomy of the lumbar paravertebral region and the lumbar plexus in children relevant to regional anesthesia. In contrast to anatomical studies in adults,9–11 the exploration of pediatric anatomy by means of dissections is nearly impossible; hence, literature is rare and incomplete. Moreover, recommendations for depth of needle insertion are mainly based on clinical4 but not on anatomical or imaging studies. Dudare et al9 made an attempt to explore lumbar plexus anatomy in children by means of computed tomography, but direct visualization of neural structures failed in the majority of cases.

High-resolution sonography has been established as the first line modality for imaging of peripheral nerves.12,13 Accordingly, the current study was conducted to investigate the topographic anatomy of the lumbar plexus in children and to measure skin-plexus distances at the L3–L4 and L4–L5 levels by means of sonography. Further, an ultrasound-guided technique for posterior lumbar plexus blocks at L4–L5 in children had to be developed.

Materials and Methods

The current study was designed as an observational, cross-sectional study. Institutional approval was obtained by the local ethics commission (Innsbruck Medical University, Innsbruck, Austria), and parental written informed consent was required for all patients. According to regional directions, patients aged older than 8 yr had to provide written informed consent, whereas patients aged younger than 8 yr had to give informed consent, if possible, to be included in this study. Criteria for exclusion were missing written or informed consent, age younger than 3 yr or older than 12 yr, American Society of Anesthesiologists physical status greater than II, developmental retardation, and any malformations, injuries, and previous operations at the lumbar region. Thirty-two children (12 boys, 20 girls) with American Society of Anesthesiologists physical status I or II scheduled for follow-up sonography of the urinary tract because of vesicoureteral reflex were enrolled in the study.
All examinations were performed in a convenient atmosphere under parental presence, and no sedation was required.

An HDI 5000 (ATL/Philips, Bothell, WA) ultrasound device with a curved array transducer (C 8-5; ATL/Philips) providing an ultrasound frequency of 5–8 MHz was used. All sonograms were obtained in the SonoCT mode (ATL/Philips) to enhance sharpening of tissue interfaces. During examination, patients were lying prone with a cushion placed under the abdomen to minimize lumbar lordosis.

The lumbar paravertebral region was examined at the L3–L4 and L4–L5 levels bilaterally. The relevant levels could be localized by depicting the respective transverse processes on posterior longitudinal paravertebral sonograms. The reflex of the cephalad portion of the sacrum was used as a landmark from which the lumbar transverse processes could be counted upward. After the L3–L4 and L4–L5 levels had been localized, posterior transverse sonograms were obtained. By this means, the lumbar paravertebral region could be examined in two perpendicular echo planes (longitudinal and transverse) at the mentioned levels. The landmarks were the psoas major muscle, the quadratus lumborum muscle, and the erector spinae. Finally, the lumbar plexus had to be visualized within the substance of the psoas major muscle on transverse (figs. 1A and B) as well as on longitudinal sonograms (figs. 2A and B) at each level. The shortest (skin-plexus distance A) and longest (skin-plexus distance B) distances to the skin surface were recorded (fig. 3). Pressing against the skin surface with the transducer was avoided and measurements were computed in the center of the respective transverse sonograms14 to minimize measurement errors.

In a series of five male pediatric patients with American Society of Anesthesiologists physical status I or II undergoing inguinal herniotomy, ultrasound-guided posterior lumbar plexus blocks were performed. A portable ultrasound device (SonoSite 180 plus; SonoSite, Bothell, WA) with a 10–5 MHz linear array transducer (“hockey stick,” HST/10-5; SonoSite) was used. The children were premedicated using 1 mg/kg midazolam rectally. General anesthesia was induced with sevoflurane. After insertion of a laryngeal mask airway, patients were placed in the lateral decubitus position with the operative side superior and the thighs flexed. Two anesthesiologists experienced in ultrasound-guided pediatric nerve blocks performed the procedures under sterile conditions. The lumbar plexus was delineated at the L4–L5 level in the above-described manner. An insulated 25-gauge Sprotte needle of 35-mm length (UPS 3/35; Pajunk, Geisingen, Germany) was introduced perpendicular to a transverse echo plane and advanced under ultrasound guidance close to the lumbar plexus (figs. 4A and B). The needle position was verified in a longitudinal echo plane (figs. 5A and B) and adjusted if necessary under ultrasound guidance. After negative aspiration, a volume of 0.3 ml/kg ropivacaine, 0.33%, was slowly injected. Spreading of the local anesthetic solution within the posterior part of the psoas major muscle was traced sonographically. Finally, the patients were placed in a supine position for the following inguinal herniotomy.

**Statistical Analysis**

Statistical analysis was performed with SPSS for Windows 10.0 (SPSS Inc., Chicago, IL). Data were tested for normality by using the Kolmogorov-Smirnov test. Patient data are presented as median ± range. Skin-plexus distances are expressed as mean ± SD and were analyzed for between-group differences by means of a one-way analysis of variance with the Bonferroni post hoc test. Sex-dependent differences were evaluated with the Student t test for unpaired samples. The Spearman coefficient was calculated to assess correlations between skin-plexus distances and the patients’ age, height, and weight. P values less than 0.05 were considered to indicate statistical significance.
Results

A total of 32 patients (12 boys, 20 girls) were studied. They were stratified into three groups with regard to their age (group 1: > 3 yr and ≤ 5 yr; group 2: > 5 yr and ≤ 8 yr; group 3: > 8 yr and ≤ 12 yr). Patient data are presented in table 1.

In all examined patients, sonography of the lumbar paravertebral region was feasible. The lumbar plexus could be delineated and measured successfully at L3–L4 and L4–L5 in 19 of 20 cases in group 1 and in 17 of 20 cases in group 2. In group 3, sonography of the lumbar plexus was feasible in 22 of 24 cases at L3–L4 and in 16 of 24 cases at L4–L5. In all cases, the lumbar plexus was situated within the posterior part of the psoas major muscle. The measured skin-plexus distances are presented in table 2.

All measured data were distributed normally according to the Kolmogorov-Smirnov test. Both skin-plexus distances (A, B) showed statistical significance between groups 1 and 3 (P < 0.001) and between groups 2 and 3 (P < 0.001) at the L3–L4 and L4–L5 levels. The Student t test indicated no significant differences of the measured skin-plexus distances between boys and girls at either level. The Spearman coefficient revealed significant positive correlations (at a level of
among the measured skin-plexus distances and the patients' weight (L3–L4: 0.68; L4–L5: 0.64), age (L3–L4: 0.58; L4–L5: 0.63), and height (L3–L4: 0.51; L4–L5: 0.52).

Ultrasound-guided posterior approaches (three right, two left) to the lumbar plexus were performed in five male patients. Their ages were 0.7, 0.9, 1.3, 1.8, and 2 yr; their heights were 0.67, 0.74, 0.77, 0.88, and 0.90 m; and their weights were 7.5, 9, 10, 13, and 14 kg. Sonography of the lumbar paravertebral region was feasible in all cases, and the lumbar plexus was delineated clearly in both echo planes. The ultrasound-guided approaches could be performed successfully in the five patients, and all lumbar plexus blocks provided effective anesthesia and analgesia of the inguinal region during surgery and for postoperative pain relief. None of the patients showed unwanted side effects or any complications associated with posterior lumbar plexus block.

### Discussion

This study represents the first investigation of the lumbar plexus in children by means of sonography and describes a technique for ultrasound-guided posterior lumbar plexus block. A reliable visualization of the lumbar plexus was feasible in the majority of cases, and imaging of the remaining lumbar paravertebral region could be performed in all cases. The current results are in contrast to a previous study dealing with ultrasound imaging of the lumbar paravertebral region in adults, which showed detailed sonographic anatomy but failed in visualizing neural structures. This fundamental difference can be explained by the more superficial position of the lumbar plexus in children; hence, less tissue penetration of ultrasound is required. As a consequence, higher frequencies (5–8 vs. 3–5 MHz) could be applied, thus resulting in a better spatial resolution of the obtained images.

In general, the sonographic appearance of the lumbar plexus corresponded to the typical and well-established echotexture of peripheral nerves. On transverse sonograms, the lumbar plexus appeared as an ovoid structure consisting of hypoechoic dots—the fascicles or

### Table 1. Patient Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group 1: &gt; 3 yr and ≤ 5 yr (n = 10)</th>
<th>Group 2: &gt; 5 yr and ≤ 8 yr (n = 10)</th>
<th>Group 3: &gt; 8 yr and ≤ 12 yr (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>4.2 ± 0.6</td>
<td>6.5 ± 1.3</td>
<td>9.4 ± 1.4</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.04 ± 0.04</td>
<td>1.24 ± 0.15</td>
<td>1.36 ± 0.13</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>16.6 ± 2.3</td>
<td>20.0 ± 5.0</td>
<td>29.0 ± 10.5</td>
</tr>
</tbody>
</table>

Data are presented as median ± range.
fascicle groups\textsuperscript{15}—enveloped by hyperechoic elements resembling connective tissue—the epineurium.\textsuperscript{15} Longitudinal sonograms showed the respective “fascicular” echotexture—hypoechoic parallel bands bordered by hyperechoic striations.\textsuperscript{12,13} On the transverse as well as on the longitudinal sonograms, the hyperechoic structures appeared more prominent compared with other nerves. It is unclear whether this is specific for the lumbar plexus, possibly age specific, or both. It should be mentioned that descriptions regarding the echotexture of peripheral nerves in the current literature are based on adult studies.\textsuperscript{12,15} High-frequency linear array transducers (10–15 MHz) are state of the art for detailed imaging of superficially located peripheral nerves.\textsuperscript{13} Nevertheless, curved array transducers proved to be superior for sonography of the lumbar paravertebral region.\textsuperscript{15} Frequencies of 5–8 MHz had to be applied to gain enough penetration depth at the expense of spatial resolution compared with superficial nerves.

In adults, the psoas major muscle shows a typical sonographic pattern. On transverse sonograms, it has a hypoechoic background interspersed with hyperechoic speckles that represent fibrous structures within the muscle.\textsuperscript{16} Longitudinal sonograms reveal the corresponding “fibrillar” pattern.\textsuperscript{16} The presence of these fibrous structures impaired the visualization of the lumbar plexus in adults substantially.\textsuperscript{15} In the examined children, the psoas major muscle appeared more hypoechoic, with less fibrous structures. This feature facilitated the delineation of the lumbar plexus within the substance of the psoas major. Further, on longitudinal sonograms, the latter showed a more posteroanterior course within the muscle compared with the mentioned fibrous structures. This was of additional help in identifying the lumbar plexus. In all cases, the lumbar plexus was found to be situated within the posterior part of the psoas major muscle, which is in accordance with recent investigations of adult topographic anatomy.\textsuperscript{10,9}

Nevertheless, the clear delineation of the lumbar plexus failed in a few cases. In particular, at the L4–L5 level, sonography might be difficult in males as well as in females because of tall iliac crests that disturb the spread of ultrasound.\textsuperscript{15} This was most evident in group 3. Moreover, skin-plexus distances were greatest in this group, resulting in a decline of spatial resolution. At the L3–L4 level, sonography of the lumbar plexus failed in six cases across all groups (one in group 1, three in group 2, two in group 3) for unknown reasons, although imaging of the remaining lumbar paravertebral region was proper.

The mean skin-plexus distances showed an increase from group 1 to group 3 (table 2) at both investigated levels. The differences were statistically significant between groups 1 and 3 and between groups 2 and 3. Dalens et al.\textsuperscript{4} studied two similar posterior approaches to the lumbar plexus at L4–L5 (modified Chayen technique vs. Winnie technique) in cohorts of 25 children ranging in age from 7 months to 16 yr and determined the depth of the lumbar plexus by means of nerve stimulation. In the current investigation, skin-plexus distances were measured at the L4–L5 level. This corresponds to the site of needle insertion used for the more recommended Winnie approach\textsuperscript{4} (intersection of the intercristal line with a perpendicular line through the posterior superior iliac spine). Remarkably, the current skin-plexus distances are more consistent with the data of Dalens derived from the modified Chayen approach that represents an approach below the level of L5 (midpoint of a line from the spinous process of L5 to the posterior superior iliac spine). Sciard et al.\textsuperscript{5} performed a posterior lumbar plexus block at L4–L5 in a 4 yr-old-male patient and located the lumbar plexus \textit{via} Winnie approach at a depth of 3 cm, which is consistent with the mean skin-plexus distance at L4–L5 in group 1. However, in the mentioned studies, distances were measured by using a one-dimensional method based on electrophysiologic principles. In contrast, sonography as a sophisticated imaging modality allowed direct visualization of the lumbar plexus.

Dadure et al.\textsuperscript{8} recently investigated the anatomy of the lumbar paravertebral region by means of computed tomography and assessed the depth of the lumbar plexus at L4–L5. In their comparable group of children (aged 5–8 yr), the median value of lumbar plexus depth is noticeable higher compared with the present data. Even the youngest patients (aged 1–4 yr) showed a median lumbar plexus depth that exceeds the mean skin-plexus distance of group 1 (aged 3–5 yr) in the current study. This discrepancy might be explained by the failure of direct lumbar plexus delineation on computed tomography scans in the majority of patients. In the remaining cases, the position of the lumbar plexus had to be estimated in the posterior part of the psoas major muscle.

Dalens et al.\textsuperscript{4} correlated the depth of needle insertion with the patients’ age in their original publication. In more recent guidelines, Dalens\textsuperscript{17} also reported a weight dependence of needle insertion depth. This is in accord with the results of the current study because the strongest positive correlation existed between skin-plexus distances and the children’s weight. A similar but less positive correlation could be detected between the skin-plexus distances and the children’s age, and the least correlation was found between the skin-plexus distances and the children’s height. Dadure et al.\textsuperscript{8} also stated an age dependence of lumbar plexus depth. However, because of an increasing number of obese children, a weight-dependent approach to the depth of needle insertion seems more suitable.

Ultrasound-guided posterior approaches to the lumbar plexus at L4–L5 were performed successfully in five pediatric patients undergoing inguinal herniotomy by means of a portable ultrasound device. The latter enabled appropriate imaging quality combined with a max-
demonstrate detailed sonographic imaging of the lumbar plexus as well as the neighboring retroperitoneal structures, could be delineated clearly in all cases. It is well-known that the lower poles of both kidneys reach the level of the iliac crests in infants and the L4–L5 level in young children. Thus, the kidneys might be at risk during a “blind” approach at L4–L5 in these patients. Real-time needle guidance enabled safe approaches to the lumbar plexus at L4–L5 and helped to avoid inadvertent puncture of adjacent structures.

Originally, an “in-line” technique (introducing the needle in the echo plane) was proposed for an ultrasound-guided approach to the lumbar plexus in adults because it represents a deep block. In the current study, the needles were introduced and guided perpendicularly to the echo plane because it is a common practice for superficial blocks. Nevertheless, the needles’ positions were verified in two perpendicular echo planes to obtain the maximum spatial information.

One of the major benefits of ultrasound-guided techniques is the monitoring of local anesthetic spread as a reliable predictor of success. In the described procedures, spreading of the injected local anesthetic solution around the lumbar plexus was achieved by keeping a certain distance between the needle tips and the neural structures to avoid their injury. The distribution showed a flow-like pattern that seems to correlate with the distribution of contrast medium within the psoas major muscle observed in radiographic investigations.

The ultrasound-guided lumbar plexus blocks could be performed within 10 min and showed rapid onset times. Effective anesthesia and analgesia of the inguinal region during the surgical procedure as well as for postoperative pain relief could be provided. However, intraoperative stress responses occurred during manipulations on the scrotum. This can be explained by missing anesthesia of the pudendal nerve derived from the sacral plexus that innervates the posterior part of the scrotum. In the five patients, there was no evidence of epidural spread as reported by Dalens et al. and no bilateral motor blockade of the femoral nerve was recognized postoperatively.

In conclusion, in the current study, we were able to demonstrate detailed sonographic imaging of the lumbar paravertebral region and the lumbar plexus in children. The obtained skin-plexus distances might be valuable for posterior approaches to the lumbar plexus according to the technique of Winnie. Skin-plexus distances correlated slightly stronger with the children’s weight than with their age. Furthermore, these results represent fundamentals for ultrasound-guided posterior lumbar plexus blocks. Imaging of individual anatomy, real-time needle guidance, and monitoring of the local anesthetic spread were the key features that allowed safe and successful ultrasound-guided blocks in this series of pediatric patients.

References