The causes for failed conversion of epidural labor analgesia to epidural surgical anesthesia: A controlled before-after study

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Research Article

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Abstract

**Background:** There are few specific reports on the possible reasons for the failure of epidural labor analgesia (ELA) conversion to epidural surgical anesthesia (ESA). We designed this study to investigate the possible reasons for the failure of ELA conversion to ESA by comparing the changes in the spinal canal of parturients after continuous epidural analgesia during delivery and 24 hours after drug withdrawal through lumbar magnetic resonance imaging (MRI) examination.

**Methods:** The parturients who delivered vaginally with ELA were included. Lumbar MRI examination was performed 2 hours after delivery and 24 hours after delivery. All data were transferred to a Siemens PACS workstation for measurement. The results of the MRI examinations 2 and 24 hours after delivery were compared. The primary outcomes were the area of the dural sac (DS) and epidural space (ES), and the secondary outcomes were the apparent diffusion coefficient (ADC) values of bilateral spinal ganglion and the longitudinal diameter and transverse diameter of the dural sac. Data related to ELA were also recorded.

**Results:** MRI examination was completed at 2 hours after delivery in 11 parturients with ELA, and two of them refused a second MRI. Among the 11 parturients, two were found to have obvious drug liquid accumulation in the epidural space, but one of the two refused the second MRI examination. Comparing the MRI examination completed at 2 hours with that completed at 24 hours after delivery, the area of the dural sac and the longitudinal diameter and transverse diameter (except L1-2) of the dural sac decreased at the L4-5, L3-4, L2-3 and L1-2 levels, while the area of the epidural space increased at the L4-5, L3-4, L2-3 and L1-2 levels. There were no significant differences in the bilateral ADC values between 2 and 24 hours after delivery.

**Conclusion:** ELA may lead to dilation of the epidural space, compression of the epidural sac, and even accumulation of epidural fluid. The reason for the failure of epidural conversion might be that the low concentration of local anesthetics retained in the epidural space during labor analgesia diluted the high concentration of local anesthetics during cesarean section. It might also be that ELA leads to epidural expansion and dural sac compression, which affect the diffusion of high concentrations of local anesthetics during cesarean section.

**Trial registration:** Chictr.org, ChiCTR2200059311. Registered on 28/04/2022.

Introduction

Severe labor pain can have adverse effects on both the mother and the fetus. Epidural labor analgesia (ELA) is the preferred analgesic method, and it is widely believed that ELA does not increase the risk of cesarean section. However, with the increasing rate of ELA, the total number of cesarean sections has increased accordingly. Most anesthesiologists prefer to directly administer high-concentration local anesthetics through an indwelling epidural catheter to convert ELA to ESA. However, clinical observers
have found that the failure rate of epidural conversion was high, which would lead to increased intraoperative pain and perioperative risk.

Many studies have reported the various factors affecting the failure of epidural conversion, including obstetric-related factors (urgency of cesarean section), maternal-related factors (age, height, weight and gestational age), and ELA-related factors (frequency of explosive pain and times of rescue analgesia, pain score at 2 hours before cesarean section, duration of labor analgesia and anesthesia performed by nonobstetric anesthesiologists) [1–6]. There are few specific reports on the possible reasons for the failure to convert ELA to ESA. It is speculated that ELA may lead to nerve root edema, thus affecting the efficacy of anesthetic drugs. In addition, the epidural space may retain a certain amount of low concentrations of local anesthetics, which may dilute the high concentrations of local anesthetics during cesarean section. In addition, with the prolongation of ELA, the risk of epidural catheter displacement or shedding increases.

MRI examination provides a high resolution of soft tissue, which can clearly display the anatomical structure of the vertebral canal. It is obviously superior to other examinations in displaying the soft tissue inside the vertebral canal (such as intervertebral discs, ligaments and lumbar spinal nerve roots). MRI examination involves no radiation and does not affect the lactation of parturients, so maternal acceptance is high. We designed this study to investigate the possible reasons for the failure of ELA conversion to ESA by comparing the changes in the spinal canal of parturients in vaginal delivery after continuous epidural analgesia during delivery and 24 hours after drug withdrawal through lumbar MRI examination.

**Methods**

**Ethical approval**

This controlled before-after study was approved by the China Ethics Committee of Registering Clinical Trials (ChiECRCT20210029) and was registered in the Chinese Clinical Trial Registry (ChiCTR2100047772). Written informed consent was obtained from all included parturients. The study was conducted from May 2022 to August 2022.

**Study design and participants**

Parturients with ASA physical status I–II, age ≥ 20 years, gestational age ≥ 37 weeks, who delivered through the vagina with ELA were enrolled. Exclusion criteria included withdrawal of the drug during ELA for more than 30 minutes, epidural catheter displacement or shedding, complication with severe cardiopulmonary disease, or refusal to participate. The parturients who delivered through the vagina with ELA were observed in the delivery room for 2 hours. They were transferred back to the ward after there was no postpartum hemorrhage, no urinary retention and good uterine contraction. Then, the parturients were transferred to undergo lumbar MRI examination, and the labor analgesia pump was
stopped just before the MRI examination. After 24 hours, the lumbar MRI examination was performed again.

The chief anesthesia resident who had more than 3 years of obstetric anesthesia experience administered the labor analgesia. The parturients were placed in the left lateral position, a convenient lumbar epidural space was located, and a multiorifice epidural catheter was inserted 3-5 cm into the epidural space. After a test dose of 3 mL 1.5% lidocaine with epinephrine 1:200,000 was given, a bolus of 8-10 ml 0.1% ropivacaine and 0.5 μg/ml sufentanil was administered. When the sensory block was attained to T10 or higher, the ELA pump was connected with a continuous infusion rate of 8-10 ml/h.

MRI scans were performed using a Siemens ultra-high definition 3.0T magnetic resonance imaging system (Siemens skyra 3.0T). Sagittal T1WI, T2WI and transverse T2WI scans of the lumbar spine were routinely performed, and the scanning range included L1-L5. The L1-L5 spinal cord was imaged with 3D hydrography imaging using the sequence parameters of 3D-T2-Space-stir-iso, and the images were reconstructed by maximum-intensity projection (MIP). Continuous diffusion-weighted imaging (DWI) was performed for L1-L5 on the transverse axis. The anterior and posterior lines of the lower edge of the vertebral body were taken as the scanning angle for transverse scanning.

**Data collection and outcomes**

All images were transmitted to a Siemens PACS workstation (syngo.via VB10B) for measurement, and the apparent diffusion coefficient (ADC) of DWI images was automatically formed. In the DWI image, regions of interest (ROIs) were placed at the anatomical position of the corresponding spinal nerve ganglion. The spinal nerve ganglion was located by spinal cord hydrography imaging combined with T1 images generated by DWI. The ROI should be smaller than that of the nerve root to avoid volume effects. The size and shape of the ROI on both sides should be consistent, and the two measurements before and after should be consistent. Each ADC value was measured three times to obtain the average value. All data measured on axial T2WI images were positioned at the same level on median sagittal T1WI or T2WI images. The area of the dural sac (DS) and epidural space (ES) and the longitudinal diameter and transverse diameter of the dural sac were measured on the T2WI axial image at the level of the intervertebral disc. The DS area was delimited by the edge of the dural sac, the ES area was delimited by the edge of the epidural fat, and the longitudinal diameter and transverse diameter of the DS were delimited by the maximum longitudinal diameter and transverse diameter of the DS. All measurements were carried out by experienced attending physicians in the radiology department. Each data point was measured three times to determine the average value.

The primary outcomes were the area of the DS and ES, and the secondary outcomes were the ADC values of the bilateral spinal ganglion and the longitudinal diameter and transverse diameter of the DS. Data related to ELA were also recorded.

**Statistical analysis**
The sample size was estimated by PASS based on the change in the L2-3 DS area before and after. It was expected that after continuous pumping of ELA, the difference in the DS area before and after pumping was 0.1 cm², the standard deviation was 0.1, and the statistical efficiency was α = 0.05 - β = 0.8. The sample size of paired data was used to calculate the sample size. The calculated sample size was 8 cases, and the estimated lost to follow-up rate was 20%. Finally, 10 participants were included in this study. SPSS 21.0 software was used for data analysis, and P < 0.05 was considered significant. Normally distributed data was expressed as the mean ± standard deviation (SD), and the paired sample T test was used for statistical analysis. Nonnormally distributed data was expressed as the median (interquartile interval), and the rank-sum test of paired samples was used for statistical analysis.

Results

Clinical characteristics of patients

Thirteen parturients were eligible for screening; however, two parturients were excluded for withdrawing the ELA pump before MRI examination. Finally, 11 parturients were included, and 2 parturients withdrew for refusing the second MRI examination. Finally, only 9 parturients were included in the statistical analysis. Maternal demographic characteristics and data related to ELA are shown in table 1.

Primary outcome analysis

Eleven parturients completed the first MRI examination, and two of had significant fluid accumulation in the epidural space. However, one of the two refused a second MRI examination. In her MRI image, significant fluid accumulation was widely found in the L1-2, L2-3, L3-4, and L4-5 epidural spaces. [Fig. 1, 2] The area of the dural sac was decreased at the L4-5, L3-4, L2-3 and L1-2 levels when comparing 2 hours after delivery to 24 hours after delivery [Fig. 3]. The area of epidural space was increased at the L4-5, L3-4, L2-3 and L1-2 levels when comparing 2 hours after delivery to 24 hours after delivery [Fig. 4].

Secondary outcome analysis

The longitudinal diameter and transverse diameter of the dural sac were decreased at the L4-5, L3-4, L2-3 and L1-2 levels (except the transverse diameter of the DS) when comparing 2 hours after delivery to 24 hours after delivery [Fig. 5]. There was no significant difference in the bilateral ADC values of the L4, L3, L2 and L1 spinal ganglia between 2 hours after delivery and 24 hours after delivery [Fig. 6].

Discussion

Failure of epidural anesthesia to general anesthesia increases the risk of parturients and fetuses. Because the parturients do not fast during ELA, emergency general anesthesia could increase the risk of reflux and aspiration. In addition, the obstetric population has a higher risk of intubation difficulty and failure than the average person in the population under general anesthesia. Despite the continuous improvement of modern tracheal intubation equipment, the difficulty of obstetric intubation remains an
ongoing concern [7]. The investigative report 'Saving Mothers Lives' highlighted the importance of rapid epidural conversion, in which one woman died due to inability to ventilate during general anesthesia for cesarean section [8]. In addition, general anesthesia for cesarean section is related to maternal complications, including serious anesthesia-related complications such as surgical site infection and venous thromboembolic events, as well as a higher incidence of severe maternal pain and postpartum depression requiring hospitalization [9]. The Royal College of Anaesthetists recommends a general anesthesia rate lower than 1% for elective cesarean section and less than 5% for those classified as emergent [10]. Furthermore, intraoperative pain during caesarean section under neuraxial anesthesia has replaced intraoperative awareness under general anesthesia as the most common successful negligence claim against obstetric anesthesiologists [11,12].

However, the reasons for the failure of the conversion of ELA to ESA remain unclear. It is speculated that ELA may lead to nerve root edema, thus affecting the efficacy of anesthetic drugs. In addition, the epidural space may retain low concentrations of local anesthetics, which may dilute the high concentrations of local anesthetics during cesarean section. In addition, with the prolongation of ELA, the risk of epidural catheter displacement or shedding increases.

This study was the first to perform lumbar MRI examination on parturients who delivered vaginally with ELA and found that continuous ELA may lead to the dilation of the epidural space, compression of the epidural sac, and even accumulation of epidural fluid. A total of 11 parturients in this study completed the first MRI examination, and two of them showed significant fluid accumulation in the epidural space. Many scholars generally believe that the failure of epidural conversion might be related to the low concentration of local anesthetics retained in the epidural space during labor analgesia diluting the high concentration of local anesthetics during cesarean section [13]. In addition, it might also be that continuous ELA leads to epidural dilation and dural sac compression, which affect the diffusion of high concentrations of local anesthetics during cesarean section. Higuchi et al. reported a controlled before-after study of lumbar MRI examination for a single epidural saline injection (5 ml vs 10 ml vs 15 ml). They found that saline injection through an epidural catheter compresses the epidural sac, the degree of compression of the dural sac was injection-volume dependent, and the dural sac compression lasted at least 30 min after epidural saline injection [14].

This study found that there were no significant changes in the bilateral ADC values of the lumbar ganglion at 2 hours and 24 hours after delivery. This might indicate that with the prolonged duration of ELA, no significant edema was observed in the lumbar ganglion. Diffusion-weighted imaging (DWI) can monitor the random movement of water molecules and provide information on organizational microstructure. The increase in ADC values of the nerve root are considered to be related to edema or compression of the nerve root [6,15]. In recent years, many studies have found that DWI can be used to evaluate and diagnose lesions, such as multiple sclerosis, lumbar foraminal stenosis and lumbar disc herniation, and carpal tunnel syndrome [16-18]. Increased ADC values were observed in these lesions.
There were some limitations in this study. First, the ELA maintenance method in our study was continuous epidural infusion combined with patient-controlled epidural analgesia, and the new technology of programmed intermittent epidural bolus was not discussed. Different administration methods, injection speeds or pressures might result in different distributions and diffusion of epidural solution, thus resulting in different compression of the epidural sac and different expansion of the epidural space. Second, the reasons were inferred indirectly because our research was performed on the vaginal parturients, not on the parturients who had a cesarean section.

In conclusion, our research demonstrated that continuous ELA may lead to the dilation of the epidural space, compression of the epidural sac, and even accumulation of epidural fluid. The reason for the failure of epidural conversion might be related to the low concentration of local anesthetics retained in the epidural space during labor analgesia diluting the high concentration local anesthetics during cesarean section. It might also be that ELA leads to epidural expansion and dural sac compression, which affect the diffusion of high concentration local anesthetics during cesarean section.

**Abbreviations**

ELA epidural labor analgesia

ESA epidural surgical anesthesia

MRI magnetic resonance imaging

DS dural sac

ES epidural space

ADC apparent diffusion coefficient

DWI diffusion-weighted imaging

ROIs regions of interest

**Declarations**

**Acknowledgements**

Not applicable.

**Authors’ contributions**

LSY designed the study and drafted/revised the manuscript. LSY, GJ and ZY made contributions to the acquisition of clinical study data. LXS and XX made substantial contributions to the analysis and interpretation of the data. LXS designed the study and revised the manuscript.
Funding

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Availability of data and materials

The datasets used and analyzed during the study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

Ethical approval was obtained from China Ethics Committee of Registering Clinical Trials (ChiECRCT20210029), address: West China Hospital, Sichuan University, NO. 37, Guo Xue Xiang, Chengdu, Sichuan, China. The trial was registered in the Chinese Clinical Trial Registry (ChiCTR2200059311, date of registration: 28/04/2022) prior to patient enrollment. The study protocol was performed in the relevant guidelines. Written informed consent was obtained from all patients.

Consent for publication

Not applicable.

Competing interests

The authors report no competing interest.

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References


**Table 1**

Table 1 Maternal demographic characteristics and data related to epidural labor analgesia.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>30±2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>161±6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>67±5</td>
</tr>
<tr>
<td>Gestational week (w)</td>
<td>40±0.8</td>
</tr>
<tr>
<td>Duration of ELA (min)</td>
<td>570(515,780)</td>
</tr>
<tr>
<td>Dosage of ELA (ml)</td>
<td>99(79,157)</td>
</tr>
<tr>
<td>Number of PCEA (n)</td>
<td>0(0,1)</td>
</tr>
<tr>
<td>Baseline cervical dilatation (cm)</td>
<td>2(2,2.5)</td>
</tr>
<tr>
<td>Duration of first stage of labor (min)</td>
<td>580(450,760)</td>
</tr>
<tr>
<td>Duration of second stage of labor (min)</td>
<td>51(41,62)</td>
</tr>
</tbody>
</table>

ELA: epidural labor analgesia; PCEA: patient-controlled epidural analgesia.

**Figures**
Figure 1

Lumbar MRI images 2 hours after delivery at the L1-2, L2-3, L3-4 and L4-5 levels. Figure A: L1-2 level, Figure B: L2-3 level, Figure C: L3-4 level, Figure D: L4-5 level.

There was found a significant fluid accumulation in the epidural space.
Figure 2

Lumbar MRI images at the L1-2, L2-3 levels compared at 2 hours after delivery to 24 hours after delivery.

Figure A and B at L2-3 level compared at 2 hours after delivery to 24 hours after delivery. Figure A: The dural sac was obviously compressed, the area of dural sac was reduced to 2.28 cm². The epidural space was dilated, the area of epidural space was increased to 0.5 cm². The epidural space was found a significant fluid accumulation. Figure B: The dural sac was recovered, the area of dural sac was increased to 2.64 cm². The epidural space was recovered, the area of epidural space was reduced to 0.34 cm². Figure C and D at L1-2 level compared at 2 hours after delivery to 24 hours after delivery. Figure C: The dural sac was obviously compressed, the area of dural sac was reduced to 2.26 cm². The epidural space was dilated, the area of epidural space was increased to 0.36 cm². The epidural space was found a significant
fluid accumulation. Figure D: The dural sac was recovered, the area of dural sac was increased to 2.64cm². The epidural space was recovered, the area of epidural space was reduced to 0.26cm².

Figure 3

The area of the dural sac at the L4-5, L3-4, L2-3 and L1-2 levels was compared at 2 hours after delivery to 24 hours after delivery.

*: P<0.05, There was a statistically significant difference.
Figure 4

The area of the epidural space at the L4-5, L3-4, L2-3 and L1-2 levels was compared at 2 hours after delivery to 24 hours after delivery.

* : P<0.05, There was a statistically significant difference.
Figure 5

The longitudinal diameter and transverse diameter of the dural sac at the L4-5, L3-4, L2-3 and L1-2 levels was compared at 2 hours after delivery to 24 hours after delivery.

*: P<0.05, There was a statistically significant difference.
Figure 6

The left and right ADC values of the L4, L3, L2 and L1 spinal ganglia was compared at 2 hours after delivery to 24 hours after delivery.