

Advances in Epidural Labor Analgesia for Obese Parturients

Zunyi Liu, Jiang Zhu

Department of Anesthesiology, The Second Affiliated Hospital of Soochow University, Suzhou City, Jiangsu Province, People's Republic of China

Correspondence: Jiang Zhu, Tel +8613962153438, Email zhujiangsz@126.com

Abstract: With the development of society and economy, and the improvement of people's living standards, obesity has gradually become a significant issue not only in China but globally. Epidural anesthesia, being the most commonly used method for labor analgesia in clinical practice, has significantly reduced the pain experienced by parturients during childbirth and decreased the cesarean delivery rate. However, due to the anatomical and physiological differences between obese and non-obese parturients, the effectiveness and techniques of labor analgesia may vary. This review focuses on the anatomical characteristics and drug differences in obese parturients, the methods of epidural labor analgesia in this population, the application of ultrasound in epidural puncture for obese parturients, and the complications associated with labor analgesia. The goal is to provide a guidance for clinical practice.

Keywords: labor analgesia, obese parturients, intrathecal block

Prevalence of Obesity

The global prevalence of overweight and obesity represents a significant public health burden. According to the World Health Organization's 2022 Obesity Atlas, the global adult obesity rate is projected to rise from 15.5% (696 million) in 2010 to 25.1% (1.469 billion) by 2030, with one in five women expected to be obese by that time.¹ The proportion of overweight and obese women of reproductive age is also rapidly increasing.² It is estimated that in 2014, there were 38.9 million overweight and obese pregnant women globally, including 14.6 million obese pregnant women. The number of overweight and obese pregnant women has increased sharply in both high- and middle-income countries as well as low- and middle-income countries.³ In 2014, the percentage of overweight and obese women in India was 21.7%, with India having the highest number of overweight and obese pregnant women (4.3 million), accounting for 11.1% of the global total.⁴ A survey from China revealed that between 2004 and 2015, the prevalence of overweight among women aged 15–49 years rose from 32.1% to 43.1%, while the obesity rate increased from 5.3% to 10.0%.⁵ Another study indicated that, as of 2012, the overall prevalence of overweight and obesity among Chinese women of reproductive age was 43.7%.⁶ In the United States, it was reported that 29.0% of women giving birth in 2019 had pre-pregnancy obesity, an increase of 11% from 2016.⁷ In France, from 1998 to 2016, the proportion of mothers with a high BMI steadily increased, with the percentage of overweight mothers rising from 13.2% to 20.0%, and obese mothers increasing from 6% to 12%.⁸ Pre-pregnancy overweight and obesity often lead to gestational obesity, contributing to prenatal obesity. Due to changes in dietary habits and reduced physical activity during pregnancy, the rates of overweight and obesity are typically higher among term pregnant women compared to the general adult female population.

Anatomical Characteristics and Medication Differences in Epidural Anesthesia for Obese Parturients

The epidural space, situated between the dura mater and the periosteum lining the inner surface of the vertebral canal, contains the dural sac, spinal nerves, blood vessels, lymphatics, connective tissue, and fat. In obese parturients,

differences in epidural anatomy lead to variations in the effectiveness of epidural blockade compared to non-obese parturients.

Research has shown that the surface area of the dura mater is the main determinant of the peak sensory block of epidural anesthesia and is also the primary factor affecting the onset time to reach the peak block level. In obese parturients, increased abdominal pressure and dilated epidural veins compress the dural sac, leading to a reduced surface area of the dura mater. A smaller surface area facilitates the diffusion, onset, and peak effect of local anesthetics.⁹ A study using MRI to observe intrinsic factors affecting the diffusion and action time of local anesthetics found that the surface area of the dura mater has a significant impact on the diffusion and action time of these drugs. The surface area of the dura mater is negatively correlated with the longitudinal distribution of local anesthetics. Injected fluid in the epidural space will diffuse and cover the surface of the cylindrical dural sac; if the cylindrical dural sac is reduced, it will promote the longitudinal diffusion of local anesthetics.¹⁰ Therefore, the smaller surface area of the dura mater in obese parturients reduces the need for local anesthetics.

Obesity and pregnancy can reduce the volume of cerebrospinal fluid (CSF) in the lumbosacral region, and this reduction decreases the dilution effect of local anesthetics in the subarachnoid space. Quinn H and colleagues measured CSF volume in volunteers and used MRI to assess the impact of obesity and abdominal pressure on CSF volume.¹¹ They found that relatively obese subjects (42.9 ± 9.5 mL) had a significantly smaller CSF volume (measured from the T11-T12 disc to the sacral terminus of the dural sac) compared to non-obese subjects (53.5 ± 12.9 mL). Abdominal compression, achieved by inflating an empty 5-l irrigation solution bag to 20 mmHg and securing it against the subject's abdomen with a 36 cm-wide circumferential binder, reduced CSF volume by 3.6 ± 3.2 mL. Hideyuki and colleagues calculated CSF volume by multiplying the area of the dural sac by its length and found a significant correlation between lumbosacral CSF volume and the peak sensory block level during spinal anesthesia. And they used MRI to confirm the negative correlation between lumbosacral CSF volume and peak sensory block levels.¹² Although it is unclear to what extent local anesthetics maintain the block through the subarachnoid space after initial neural blockade via the epidural space, it is generally believed that they can still act through the dura mater in the subarachnoid space. The smaller CSF volume in obese pregnant women, caused by both pregnancy and the higher intra-abdominal pressure compared to non-obese individuals, amplifies this effect.

In healthy individuals, a certain amount of fat tissue is present in the epidural space, providing support and protection to the spinal cord. In obese patients, there is a higher content of epidural fat, although this is somewhat controversial.¹³ The volume of epidural fat not only affects the efficacy and onset of local anesthetic blockade but also influences the pharmacokinetics of the drug through its lipophilicity. According to relevant studies, the volume of epidural fat is negatively correlated with motor block scores and the time to reach the maximum block. In other words, a larger volume of epidural fat is associated with a higher degree of motor block and a faster onset of the block.¹⁴ Therefore, individual differences in epidural fat content may explain the varying spread and intensity of local anesthetic blockade.

The compression of the inferior vena cava by the uterus in parturients forces venous blood from the lower extremities to reroute through the paravertebral venous plexus, with some of the blood returning to the superior vena cava via the azygos vein. This results in increased pressure within the vertebral venous plexus and venous engorgement. In obese parturients, the higher fat content exacerbates this venous engorgement, leading to even greater epidural space pressure. These factors collectively reduce the need for local anesthetics in obese parturients.^{15,16}

Epidural Analgesia Techniques for Obese Parturients

Intrathecal analgesia techniques for labor in obese parturients can be categorized into several methods: epidural analgesia (EA), spinal analgesia, combined spinal-epidural analgesia (CSEA), and dural puncture epidural analgesia (dural puncture EA). Based on the mode of analgesic infusion, they can further be divided into continuous epidural infusion and programmed intermittent epidural bolus (PIEB).

Currently, EA is one of the most widely used methods for labor analgesia.¹⁷ There is a lack of literature on the use of spinal analgesia and CSEA specifically for obese parturients, and their comparative advantages over EA remain to be explored.

During the maintenance of analgesia, clinical studies have indicated that PIEB provides more effective analgesia for obese parturients compared to continuous epidural infusion; however, it is associated with a significant prolongation of the three stages of labor.¹⁸ The study's conclusion was derived from a retrospective analysis conducted in China, which included a total of 586 obese parturients. A study by Yueli Ye et al also supports this finding, noting that although labor duration is extended, it remains within the clinically normal range.¹⁹ Conversely, George et al found that intermittent epidural bolus shortened the second stage of labor in non-obese parturients. This difference may be attributed to the unique physiological characteristics of obese parturients or possibly to the method of labor induction and the adoption of new labor management protocols.²⁰ However, there is a limited amount of literature concerning PIEB for obese parturients, which presents certain limitations in our understanding. While PIEB may provide better analgesia for obese parturients during labor, it is essential to carefully evaluate its potential impact on labor duration. Further research is needed to fully assess the efficacy and safety of this approach, particularly in this specific population.

Dural puncture epidural analgesia (DP-EA) involves puncturing the dura mater with a spinal needle without administering intrathecal medication, followed by the administration of analgesics via an epidural catheter.²¹ The primary advantage of DP-EA over standard epidural analgesia (EA) is the precise confirmation of catheter placement by the presence of cerebrospinal fluid (CSF). This confirms the midline position of the Tuohy needle and may facilitate the spread of local anesthetics into the subarachnoid space, potentially accelerating the onset of analgesia and enhancing its quality.^{21,22} Theoretically, DP-EA could be particularly beneficial for obese parturients, given the higher failure rates associated with catheter placement in this population. DP-EA effectively mitigates this issue by ensuring accurate placement.²³ Additionally, since obese parturients are at higher risk for cesarean delivery during labor, having a well-functioning epidural catheter in place is crucial for providing regional anesthesia in case of an emergency cesarean section. However, recent research by Hon Sen Tan et al found no significant differences in the quality of analgesia or the incidence of adverse effects between DP-EA and standard EA in obese parturients.²⁴ It has been suggested by Weijia Du et al that the lack of observed differences in Tan's study may be due to the small volume of local anesthetic used.²⁵ In Tan's study, the analgesic regimen consisted of a 6 mL bolus of 0.1% ropivacaine with 2 µg/mL fentanyl every 45 minutes. This small volume might have masked the analgesic effects of the local anesthetic entering the subarachnoid space. In contrast, a clinical study in China used a regimen of 0.1% ropivacaine combined with 0.5 µg/mL sufentanil, with a background infusion rate of 4 mL/h and a patient-controlled analgesia (PCA) bolus of 6 mL/h.²⁶ This study found that the DP-EA group had superior analgesia and fewer adverse effects compared to the standard EA group. Despite these findings, the benefits of DP-EA for obese parturients require further investigation to determine its efficacy and safety in this specific population.

The Application of Ultrasound in Epidural Puncture for Obese Parturients

Obese parturients often present challenges for epidural catheter placement due to thicker adipose layers, poorly defined surface anatomical landmarks, and softened ligaments. These factors contribute to a higher failure rate of epidural catheter placement compared to non-obese parturients. Ultrasound guidance has proven beneficial in overcoming these challenges, significantly improving the success rate of epidural catheterization in this population.

Assisting in Accurate Localization

During neuraxial puncture, anesthesiologists typically rely on palpation of surface anatomical landmarks to identify the L3-4 interspace. However, the accuracy of this method is often limited, particularly in obese parturients where palpation of the iliac crest and spinous processes is difficult. The enlarged uterus and excessive abdominal weight further restrict lumbar flexion, complicating the process. Studies have reported a significant reduction in the accuracy of locating the L3-4 interspace in obese parturients.²⁷ Ultrasound can clearly visualize critical landmarks, such as the sacrum, spinous processes, and intervertebral spaces, potentially improving the accuracy of lumbar segment localization in obese patients. According to Pancaro, the accuracy of ultrasound in identifying lumbar interspaces is about 49%, compared to just 8% when relying solely on surface anatomical landmarks.²⁸ While ultrasound localization is not considered the "gold standard", its accuracy significantly surpasses that of palpation.

Predicting Puncture Depth

In addition to obscuring surface landmarks, obesity also complicates the identification of the epidural space due to softened ligaments caused by pregnancy. This softening reduces the tactile feedback that typically signals entry into the epidural space, leading to a higher rate of false positives, increased puncture attempts, failure rates, and unintended dural punctures.²⁹ Ultrasound is effective in predicting the skin-to-epidural space depth in obese parturients. The average epidural space depth in obese women is approximately 6.6 cm (range 4.5 to 8.5 cm), with 17% of obese patients having an epidural depth exceeding 8 cm. Weiniger et al noted that women with a higher BMI (around 40 kg/m²) are expected to have a deeper epidural space, and those with a depth greater than 6 cm may experience greater difficulty during puncture.³⁰ Balki et al found a strong correlation between ultrasound-assisted transverse median plane measurements of epidural space depth and the actual needle distance in obese parturients, with an average depth discrepancy of only 0.3 cm.³¹ However, the transverse median plane might compress subcutaneous tissue, leading to an underestimation of the actual depth. Sahota JS and colleagues compared the transverse median plane with the paramedian sagittal oblique plane in obese parturients, finding that the paramedian sagittal oblique plane provided better image quality and visibility of relevant structures.³² The estimated and actual needle distances in both planes were 6.5 cm and 6.6 cm, respectively, showing an average difference of just 0.05 cm. Yu et al successfully performed epidural anesthesia in a morbidly obese patient using the paramedian approach under ultrasound guidance, significantly reducing procedure time.³³ Additionally, the new Accuro handheld ultrasound device can automatically identify key neuraxial landmarks in real time, significantly improving the accuracy of epidural depth measurements in obese parturients.³⁴ With the advancement of these technologies, the ease and success rates of neuraxial punctures in obese parturients are expected to continue to improve.

Real-Time US-Guided Technique

Real-time ultrasound-guided (RTUSG) spinal anesthesia is a technique that integrates multiple ultrasound scanning approaches to guide needle insertion. This method allows for real-time observation of the needle's angle and depth during spinal puncture, enabling a fully visualized procedure. The most common approach within RTUSG is the combination of a paramedian sagittal oblique view and an in-plane needle insertion technique (PSO-IP).³⁵ In a study by Chong et al involving 60 non-obese patients, RTUSG was compared to the traditional paramedian approach based on palpation. The RTUSG technique showed a higher first-attempt success rate (87% vs 47%), a higher single-attempt success rate (47% vs 20%), and a shorter procedure time (41 vs 96 seconds).³⁶ Conversely, Elsharkawy et al compared RTUSG with the traditional midline approach in patients with a BMI > 30 kg/m² or with difficult-to-palpate spinous processes. Both techniques were performed by experienced anesthesiologists. The RTUSG technique resulted in longer needle insertion times (median 256 vs 117 seconds) without a significant difference in the number of puncture attempts (mean 1.4 vs 1.6). Despite not specifying the particular difficulties encountered, RTUSG was considered to be much more challenging.³⁷ Therefore, in obese patients or those with complex anatomy, RTUSG does not appear to offer significant advantages over conventional techniques. Even though Chong et al's study highlighted some benefits, these advantages seem minimal in patients with easily identifiable landmarks.

In summary, ultrasound guidance enables anesthesiologists to accurately locate the epidural space and predict puncture depth, thereby significantly increasing the success rate of epidural puncture in obese parturients while reducing the number of puncture attempts and associated complications.

Impact of Obesity on Labor Analgesia Complications

Labor Duration

First Stage of Labor

A 2010 analysis by Cambic CR et al in the *British Journal of Anaesthesia* reviewed existing research on the impact of labor analgesia on the first stage of labor, concluding that the overall evidence suggests that labor analgesia does not affect the duration of this stage. However, numerous studies indicate that labor analgesia significantly prolongs the first stage of labor in obese patients.³⁸ Lundborg L et al found that the median duration of the first stage of labor was increased by 25 minutes in obese young women compared to non-obese women, with a 90th percentile difference

exceeding one hour. This difference in the duration of active labor between obese and non-obese parturients also varies with maternal age, consistent with many studies.³⁹ Carlhall et al also supported the finding that increased BMI is associated with prolonged labor in nulliparous women.⁴⁰

Second Stage of Labor

It is commonly believed that neuraxial analgesia prolongs the second stage of labor. This is also true for obese parturients, although some studies suggest that obesity might actually shorten this stage. Carlhall et al included 63,829 women who received labor analgesia and found that, compared to women with normal BMI, obese women had slower labor progression but a shorter duration of the second stage.⁴⁰ This finding aligns with the study by Østborg TB et al.⁴¹ Furthermore, Østborg TB et al compared the second stage of labor in obese parturients with and without epidural analgesia, revealing that epidural analgesia prolonged the second stage in obese parturients. Overall, an increased BMI is associated with a shorter median duration of the second stage, but epidural analgesia tends to extend the duration of this stage in obese parturients.

Post-Dural Puncture Headache (PDPH)

PDPH is a common complication of epidural analgesia in obstetric patients. Studies have shown a negative correlation between obesity and the incidence of PDPH. Peralta et al included 518 patients with accidental dural puncture and found that the overall incidence of PDPH was 51% (95% CI, 46% to 55%), which was significantly negatively correlated with BMI. Although the incidence of PDPH is lower in obese patients, the severity and treatment needs of PDPH are not influenced by weight.⁴² The lower incidence of PDPH in obese patients may be related to anatomical changes in the epidural space. Compared to non-obese individuals, obese patients have higher epidural pressure and smaller cerebrospinal fluid volume, which may reduce cerebrospinal fluid leakage and consequently lower the incidence of PDPH. However, Song J et al found that BMI did not significantly correlate with PDPH incidence ($P > 0.05$) and there was no association between BMI and the intensity of post-dural puncture headache ($P = 0.29$).⁴³ Therefore, whether obesity reduces the incidence of PDPH remains controversial and requires further investigation with larger-scale studies.

Summary

In summary, obese parturients experience changes in anatomical and physiological structures that affect labor analgesia. They typically require lower doses of analgesics, have more diverse options for pain management, and benefit from more accurate ultrasound guidance. The outcomes of labor also differ compared to non-obese parturients. Therefore, research on labor analgesia for obese parturients should receive increasing attention. Future research should focus on identifying appropriate analgesic medications for obese parturients, determining optimal dosages, developing efficient puncture techniques, reducing cesarean rates, and minimizing complications.

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Disclosure

The authors report no conflicts of interest in this work.

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