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PERSPECTIVES

Neuraxial Homeostasis – Optimizing Neuraxial Labor Analgesia

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Abstract: At present, few studies on labor analgesia focus on preventing and managing neurological complications, and there is a lack of specific operational guidelines for clinical practice. This study aims to compare spinal analgesia–epidural analgesia (SA-EA) and combined spinal–epidural analgesia (CSEA) in reducing neurological complications during labor analgesia. SA-EA group: A standard spinal needle (0.5 × 113mm) was first inserted to perform a dural puncture, and 2mL of 0.1% ropivacaine + 1μg/mL sufentanil was injected intrathecally. After the spinal needle was withdrawn, a standard epidural needle (1.6 × 80mm) was used to perform an epidural puncture, and an epidural catheter (1.0mm) was inserted approximately 4cm into the epidural space. Twenty minutes later, an epidural analgesia pump was connected. CSEA group: A standard epidural needle (1.6 × 80mm) was first inserted for epidural puncture. A spinal needle was then passed through the epidural needle to perform a dural puncture, and 2mL of 0.1% ropivacaine + 1μg/mL sufentanil was injected intrathecally. After the spinal needle was removed, an epidural catheter (1.0mm) was inserted approximately 4cm into the epidural space. Twenty minutes later, an epidural analgesia pump was connected. We hypothesize that there may be differences in the incidence of neurological complications between the two groups. It is pioneering and significant as it starts from actual clinical operations. By in-depth comparing SA-EA and CSEA techniques, the study is expected to provide important references for clinical practice, improving the safety and efficacy of labor analgesia and reducing neurological complications. Additionally, it is the first time to propose the concept of neuraxial homeostasis in the anesthesia field, which is of great importance to the development of the discipline.

Keywords: neuraxial homeostasis, neuraxial labor analgesia, spinal analgesia–epidural analgesia, combined spinal–epidural analgesia

Natural childbirth is a painful process that consumes the parturient's physical and mental energy over a long period. Labor pain not only increases the parturient's suffering, negatively impacts the childbirth experience, and causes fear of natural childbirth but also has adverse effects on the fetus. Thus, labor pain management is a key focus in obstetric anesthesia. To control and manage labor pain, medical professionals have explored non - pharmacological and pharmacological labor analgesia methods. Neuraxial block is now universally recognized as the preferred method.[1] Neuraxial labor analgesia effectively alleviates the parturient's pain and provides a rapid, excellent anesthetic effect for instrumental delivery or intrapartum cesarean-section.[2]

Neurologic complications during labor analgesia are rare. The most common include post-dural-puncture headache (PDPH),[3] epidural hematoma,[4] transient neurologic syndrome (TNS),[1] cauda equina syndrome (CES),[5] nerve-root injury, and other neurologic sequelae such as permanent neurologic deficit or infectious complications.[6] PDPH results from cerebrospinal fluid leakage and occurs in approximately 0.8–1.5% of cases, usually following inadvertent dural puncture or repeated needle insertions.[3] TNS presents as lower-limb pain or dysesthesia and may be related to local-anesthetic neurotoxicity or mechanical needle trauma. Studies suggest that hormonal changes during pregnancy could increase neural sensitivity to local anesthetics, yet the incidence of TNS does not differ significantly from that in non-pregnant populations.[1] CES is rare but serious. It has been linked to high local-anesthetic concentrations or catheter compression, with a reported incidence in China of less than 0.01%.[5] Nerve-root injury may occur when the needle directly damages a root or when excessive local-anesthetic concentration causes chemical injury. The incidence is about 0.1–0.5%. Manifestations include localized pain, sensory changes, or motor deficits, which are generally transient.

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Neuraxial labor analgesia methods include epidural (EP), dural puncture epidural (DPE), CSE, and single-shot spinal (SSS) analgesia. Since Abouleish et al[7] introduced CSEA for labor analgesia, it has become a standard technique. With rapid onset, reduced breakthrough pain frequency,[8] decreased local anesthetic use, reduced motor block (especially in prolonged labor),[9] and the speed and reliability of spinal anesthesia combined with the flexibility of epidural catheter techniques for prolonged anesthesia/analgesia,[10] CSEA has become a popular clinical choice. The needle-through-needle technique is commonly used for CSEA. After identifying the epidural space via the epidural needle, a fine (25 or 27G) spinal needle is introduced into the subarachnoid space for spinal anesthesia with a local anesthetic injection. After removing the spinal needle, the epidural catheter is placed in the epidural space.[11]

But in clinical practice, during classic CSEA labor analgesia, when inserting the spinal needle through the epidural needle to puncture the dura and arachnoid mater, about 25% of parturients exhibit neurological symptoms, like unilateral limb or lower back spasms, and some even experience permanent numbness in areas such as the ipsilateral lumbar abdomen or lateral thigh. However, when performing spinal analgesia first, followed by epidural catheterization, the neurological symptom incidence drops to approximately 1%. Here, we introduce the concept of "neuraxial homeostasis disruption". Currently, "neuraxial homeostasis" lacks a clear academic definition. The neuraxis, formed by vertebral bodies and ligaments, contains the spinal cord, nerve roots, CSF, blood vessels, and connective tissues. The subarachnoid space is filled with CSF, in which the spinal cord and nerve roots float. It is hypothesized that during classic CSEA, when the epidural needle first enters the epidural space, breaking the neuraxis's sealed structure may cause slight dura and arachnoid mater tremors. These tremors, in turn, agitate the nerve fibers floating in the CSF. When the spinal needle is inserted through the epidural needle to puncture the dura and arachnoid mater to enter the subarachnoid space, it may contact these agitated nerve fibers, triggering neurological symptoms in parturients. However, spinal needle puncture, with a much smaller diameter than the epidural needle, does not disturb the CSF's nerve fibers, thus reducing the risk of neurological symptoms. Therefore, as shown in Figure 1, we define the relatively stable state of neuraxis structures when

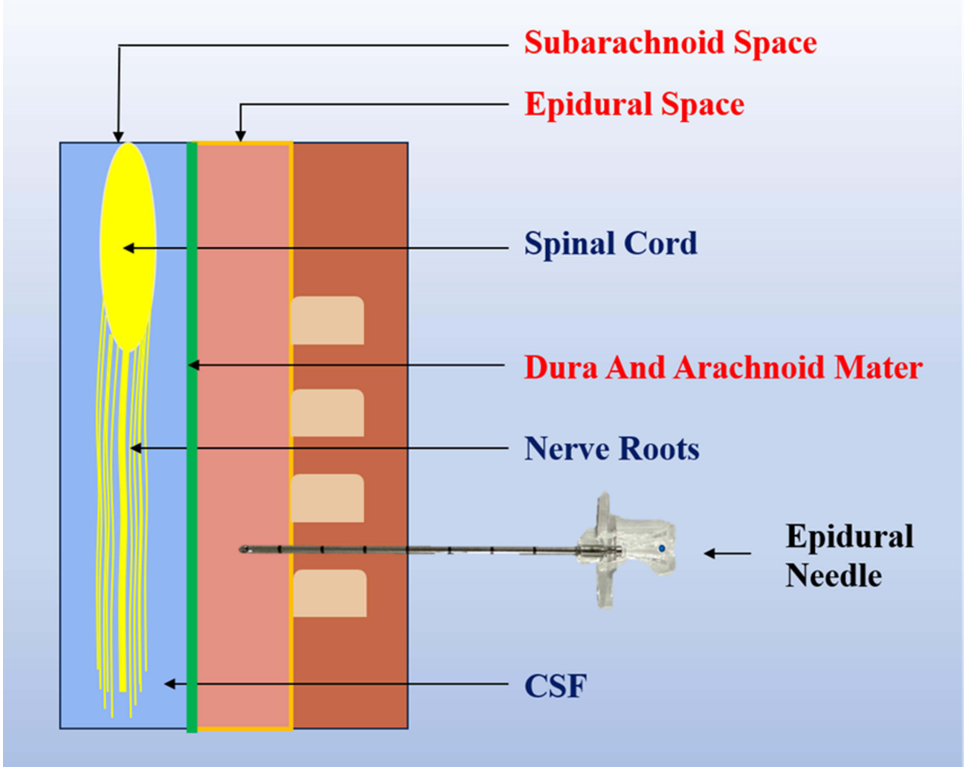

Figure 1 Neuraxial homeostasis and neuraxial homeostasis disruption.
Notes: We define the relatively stable state of neuraxis structures when the neuraxis is sealed as "neuraxial homeostasis". In CSEA, when the epidural needle reaches the epidural space, breaking the neuraxis's sealed structure and possibly causing slight dura and arachnoid mater tremors, which agitate the CSF-floating nerve fibers, this is termed "neuraxial homeostasis disruption".

the neuraxis is sealed as "neuraxial homeostasis". In CSEA, when the epidural needle reaches the epidural space, breaking the neuraxis's sealed structure and possibly causing slight dura and arachnoid mater tremors, which agitate the CSF-floating nerve fibers, this is termed "neuraxial homeostasis disruption". When neuraxial homeostasis is disrupted during the process of inserting the spinal needle through the epidural needle to puncture the dura and arachnoid mater, patients may experience neurological symptoms. These symptoms, and possible neurological sequelae, can severely impact parturients' health,[12] causing psychological stress, anxiety, and affecting their emotional and mental well-being, potentially prolonging recovery and delaying their return to normal life and work.

Currently, research on labor analgesia mainly focuses on common complications like hypotension, post-dural puncture headache (PDPH), epidural-related maternal fever (ERMF), breakthrough pain, inadequate analgesia, uterine atony, transient fetal heart rate abnormalities, urinary retention, and itching, with studies on their prevention and management.[3,13] However, research on neurological complication prevention and management is scarce, especially regarding specific operational levels, making it hard to offer practical clinical guidance. Thus, starting with neuraxial homeostasis-optimizing neuraxial labor analgesia, a prospective multicenter study comparing SA-EA and CSEA for labor analgesia in preventing neurological complications is proposed.

This study intends to enroll 624 parturients receiving labor analgesia at our hospital. The study subjects are limited to patients with an ASA (American Society of Anesthesiologists) classification of I or II. The exclusion criteria include the following: ① Patients with platelet dysfunction and/or coagulation disorders; ② Patients with infections, whether local (eg, near the injection site) or systemic; ③ Patients with spinal problems, such as severe spinal deformities, intervertebral disc protrusion, or a history of spinal surgery; ④ Patients who explicitly refused spinal anesthesia. Using a random-number table, participants will be allocated into SA-EA group and CSEA group (n=312 each). The following data will be recorded: presence of neurologic symptoms during the procedure, adverse events related to neuraxial analgesia (Hypotension within 20min, ERMF, Pruritus within 48h, NAVO, Urinary retention, Chills, Toxicity, Extensive block, Nerve damage within 48h, Back pain, PDPH, Paresthesia within 1week), analgesic efficacy (VAS 0min, VAS 1min, VAS 5min, VAS 10min, VAS 30min, VAS 60min, VAS complete cervical dilation, VAS fetal head delivery, VAS placental delivery), quality of analgesia (Asymmetric blockage, S_2 blockage, Bromage scores, PCEA bolus, Manual epidural bolus, Epidural catheter adjustment), maternal outcomes (Vaginal birth, Instrumental delivery, Cesarean delivery), and fetal outcomes (Fetal bradycardia, Apgar scores).

This study, pioneering in focusing on clinical operations themselves, aims to compare SA - EA and CSEA techniques in preventing neurological complications. It is expected to offer crucial references for labor analgesia practice, enhancing safety and efficacy, reducing neurological complications, and safeguarding maternal health. From practical clinical perspectives, this study first proposes the concept of neuraxial homeostasis in the anesthesia field, holding significant value for the discipline's development.

Declaration of Generative AI in Scientific Writing

Generative AI was not used in scientific writing upon submission of the paper.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors have no conflicts of interest to declare for this work.

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