REVIEW ARTICLE

Ultrasound-guided Neuraxial Analgesia in Obstetrics

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Abstract

Analgesia in obstetrics has an essential place during childbirth. Pain during childbirth has two components, sensory and emotional. Adequate analgesia affects the course of labor, reducing the cardiovascular, respiratory, and gastrointestinal effects of catecholamines. The use of ultrasound in anesthesia has its advantages as it enables accurate determination of the lumbar interspaces in neuraxial analgesia techniques. This review aims to show the advantage of using ultrasound-guided neuraxial analgesia in obstetrics compared to the conventional blind approach.

Keywords: Analgesia, Childbirth, Pain.

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Introduction

Labor (childbirth) is a natural phenomenon, but for most women, it is an unpleasant and extremely painful experience.[1] Although it is highly ranked in comparison to other causes, the intensity of labor pain is difficult to measure. Many parturients, especially primiparous, rate labor pain as very strong and unbearable. The definition of pain, according to the International Association for the Study of Pain (IASP) and the World Health Organization (WHO), is an unpleasant sensory and emotional experience associated with actual or potential tissue damage.[2] Acute pain, which includes labor pain, has two components: sensory and emotional.[3] The sensory component involves the transmission of painful stimuli from a peripheral receptor to the brain,[3] while the emotional component depends on the interaction of emotional, social, and cognitive factors, making it unique to each person. Adequate labor analgesia can affect the course of labor by reducing the cardiovascular, respiratory, and gastrointestinal effects of catecholamines, which are amplified as part of the mother's stress response to severe pain.[4] Pain treatment during labor improves uteroplacental perfusion and reduces the incidence of postpartum depression and post-traumatic stress syndrome. The American Society of Anesthesiologists (ASA) recommends that maternal requests are a sufficient indication for starting pain treatment during labor.[5]

Optimal distribution of local anesthetic around nerve structures is the key requirement for successful regional anesthetic blocks. Ultrasound visualization of anatomical structures is the only method offering safe blocks of superior quality by optimal needle positioning. It enables the anesthetist to secure an accurate needle position and to monitor the distribution of the local anesthetic in real-time. Recent studies have shown that direct visualization of the distribution of local anesthetics with high-frequency probes can improve the quality and avoid the complications of neuraxial techniques.[6] Ultrasound equipment is portable and does not carry the risk of ionizing radiation. Considering their enormous potential, these techniques should have a role in the future training of anesthetists.

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Neuraxial Labor Analgesia

The most effective analgesia for labor is neuraxial analgesia.[7] Neuraxial analgesia blocks T10 to L1 segments for the first stage of labor and extend to S2–S4 during the late first stage and the beginning of the second stage.[7] Labor often progresses faster in multiparous women; therefore, a faster onset of a neuraxial block, which will also cover the sacral nerves, must be enabled. Neuraxial analgesia may be initiated at any stage of labor, from the first stage of labor to the complete dilation of the cervix.[8] The most common techniques of neuraxial analgesia are epidural, single-shot spinal, and combined spinal-epidural (CSE) analgesia.

Ultrasound Guidance in Regional Anesthesia

The use of ultrasound in defining anatomical structures before neuraxial analgesia is essential in modern medical practice. Ultrasound is routinely used in adipose patients, with the altered anatomical structure of the lumbar spine or when it is difficult to determine traditional anatomical indicators of a safe puncture site by palpation.[7,8] The ultrasound imaging can assist in two unique ways for the placement of central neuraxial block: ultrasound scanning before skin puncture and real-time ultrasound guidance.

By pre-procedural scan of the spine, one can obtain useful information such as identification of the midline, correct vertebral level, and open and wide intervertebral space for needle insertion, the assessment of depth for needle length selection and angulation of the needle for successful access to the epidural or intrathecal space, as well as the identification of the best place for needlepoint entry. Moreover, it enables the assessment of abnormal spine anatomy and adjusting the needle insertion angle, for example, in scoliosis.[9]

In a systematic review of randomized controlled trials with meta-analyses based on 32 trials (3439 patients) pre-procedural lumbar ultrasounds, in various clinical settings, were compared with the conventional palpation method for the identification of landmarks for neuraxial procedures. It was concluded that pre-procedural ultrasound reduced the failure rate and the number of needle redirections, and the first-attempt success rate was significantly increased by a pre-procedural ultrasound. It does not prolong overall procedure time and might shorten needling time. One in five patients in any clinical setting, and one in three patients with difficult or impalpable landmarks due to obesity or other factors, would benefit from its use. Thus, a preprocedural ultrasound is recommended to avoid serious complications associated with increased attempts and traumatic techniques used to identify the epidural or subarachnoid space, such as spinal hematoma, traumatic cord injury, or postdural puncture headache.[10]

Pregnant women mostly belong to the group of patients who find it difficult to perform neuraxial anesthesia because proper positioning makes it difficult due to uterus and labor. The anesthesiologist relies on anatomical landmarks and tactile sensors when performing the procedure (palpation of the processus spinosus, altered pressure when placing the needle), which is often not easily performed in obstetric patients. Preprocedural ultrasonography increases the success of the block because it reduces the number of failed puncture attempts. Patients spend less time in a forced position and are more satisfied with the method, especially because ultrasound-controlled neuraxial analgesia enables a more frequent first needle pass.[7,8]

Although there are studies that failed to show improvement in normal-weight patients (regarding the number of puncture attempts, necessary puncture levels, and time of epidural catheterization), that is, in parturients with palpable anatomical landmarks,[11,12] recent meta-analyses revealed that there is enough evidence to support the lumbar ultrasound for neuraxial procedures in the obstetric population, in particular for women with special risks (obesity, scoliosis, dorsal instrumentation) where ultrasound may lower the rate of procedure-related adverse events.[13,14]

Preparations for Neuraxial Anesthesia

Before applying any labor pain relief technique, it is necessary to evaluate the mother and obtain consent for the procedure. The mother will often be frightened and upset due to pain, so information about potential risks may further affect her condition. It is recommended that pregnant women be introduced to the aspects of labor pain relief during their preparation for labor and that maternity hospitals have information on the risks of labor pain relief procedures in written form. The risks and benefits of using the neuraxial block during labor are assessed on a case-by-case basis. Contraindications to this type of anesthesia include coagulopathies, hypovolemia, infection at the injection site, sepsis, certain cardiovascular conditions, neurological disorders (e.g., increased intracranial pressure), a noncooperative patient, patient refusal, and a lack of equipment or staff to perform anesthesia.[15] As part of the anesthesia evaluation, an insight is made into the patient's medical history, including their obstetric history. The clinical examination includes an assessment of the patient's cardiorespiratory condition and an examination of the injection site. In laboratory parameters, the reference values of activated partial thromboplastin time (APTT) and platelet count are used as the parameters for safe neuraxial anesthesia.[16] All patients undergoing neuraxial analgesia must have an intravenous route established. Maternal blood pressure, heart rate, and pulse oximetry are continuously monitored. Fetal monitoring is performed according to obstetric assessment. Intermittent assessments of pain control, motor function, and sensory blocks are performed to determine the adequacy of analgesia.

Preprocedural Ultrasonography

There have been described multiple variations of the scanning technique in the literature, but core principles are the same:[9,17]

- A sitting position is preferable, though a lateral decubitus position is acceptable, with forwarding flexion of the lumbar spine which opens up the lumbar interspinous spaces, and improves the acoustic window.
- A low-frequency curved-array probe (2–5 MHz) is selected, ultrasound gel is used as a coupling medium, and the screen depth is set to 9–11 cm and adjusted after the initial assessment.

- The scanning is started in the para-sagittal transverse process view, 3–4 cm lateral from the midline on the lumbar spine, slightly cranial to the sacrum to identify the finger-like acoustic shadows of the transverse processes (“trident sign”).
- The probe is slid medially while maintaining a strictly parasagittal orientation to obtain a para-sagittal articular process view identified as “camel humps.”
- The probe is then tilted medially to obtain a para-sagittal oblique view (PSO view). The laminae appear as a “sawtooth” or “horsehead”, and medially, the posterior complex, anterior complex, and thecal sac are subsequently identified.
- The probe is slid caudal until the sacrum is identified as a long horizontal hyperechoic line. Starting at this point, in the PSO view, the interlaminar spaces (acoustic windows) are counted up from the sacrum, each interspace is centered on the ultrasound screen and a corresponding skin mark is made at the midpoint of the long edge of the probe to indicate its location.
- The probe is then rotated 90° to obtain a transverse spinous process view at the desired interspace. The midline (vertical marking) is marked with the aid of the M-mode midline marker.
- The transverse interspinous view (TI view) is obtained by sliding the probe slightly cranial or caudal. This enables the identification of the posterior complex, anterior complex, and thecal sac. The interspaces are marked laterally (transverse marking). The cranial tilt of the probe and beam may improve the quality of the view, especially where spaces are narrow.
- The intersection of the vertical and transverse skin markings is the needle entry point for ultrasound-assisted neuraxial procedures.

The needle insertion depth is estimated by measuring the distance from the skin to the deep aspect of the posterior complex. Needle insertion and re-direction should be guided by tactile feedback. If a satisfactory TI view (i.e., one in which the posterior complex is visible) cannot be obtained, the location of the interlaminar space may be instead determined from the PSO view, which usually offers a larger and better window into the vertebral canal.

Real-time Ultrasound Guidance for Neuraxial Procedures

One of the main disadvantages of pre-procedural scanning is that the actual procedure is still blind. Furthermore, measurements which are provided by pre-procedural scanning are specific at the time and patient position and become inaccurate with patient movement, needle insertion, needle angle adjustment, and distortion of tissue.[18] With real-time ultrasound, it is possible to visualize the complete procedure of the needle placement through the paramedian acoustic window including the application of intrathecal drugs and flow of the local anesthetic solution into the epidural space.[19] The adjustment of needle trajectory and confirmatory tip location can be easily done since active needle tracking allows visualization of the needle as it travels through tissue layers. Additionally, active scanning allows for readjustment without having to remap when a patient moves from their prescanned position. The real-time ultrasound guidance for midline neuraxial blockade is complicated by the acoustic shadows from the vertebrae. The paramedian longitudinal approach provides superior quality images compared to classical ultrasound planes used for preprocedural “mapping.” Due to the possibility of neurotoxicity of ultrasound gel, saline is commonly used as a coupling medium for real-time imaging, reducing image quality.[20] Recent studies testing the feasibility and success of real-time ultrasound for neuraxial block placement have been promising; however, real-time ultrasound scanning is currently a challenging technique with limited clinical utility.[9]

Neuraxial Techniques

The most common neuraxial techniques for labor pain relief are epidural analgesia, spinal analgesia, and combined spinal-epidural analgesia.[21] Combined spinal-epidural analgesia during labor is used in highly developed countries for the majority of patients. Single-shot spinal analgesia is used in individual clinical cases.[21] The choice of technique depends on the clinical condition of the patient, the course of labor, the institution’s equipment and staff, and adequate conditions for the safe performance of the selected technique. Single-shot spinal and combined spinal-epidural analgesia enable the quicker onset of analgesia when compared to epidural analgesia alone.[22] Epidural and combined spinal-epidural analgesia provide analgesia throughout labor, with the possibility of increasing the dose and converting it to anesthesia for surgical termination of labor. Epidural analgesia does require higher doses of anesthetic when compared to spinal analgesia.[22] High or total spinal anesthesia can occur if an epidural dose is administered in an unrecognized spinal catheter. The ideal local anesthetic for labor analgesia should provide reliable sensory blocks, not cause motor blockage, and have no side effects if accidentally injected intravascularly or overdosed.

Amide local anesthetics are used in obstetrics and other cases of regional anesthesia. The recommendation of the ASA is to use the lowest concentration of local anesthetic that will achieve effective analgesia with minimal side effects.[5] The goal is to achieve adequate analgesia with the preserved ability to push and the minimization of placental anesthetic transfer. Bupivacaine is an amide local anesthetic that has long been used in obstetrics and provides an excellent sensory block.[23] Levobupivacaine is from the group of amide anesthetics; it provides better sensory-motor separation and therefore has less effect on a motor blockade of the lower extremities.[24] Opioids in combination with local anesthetics have a synergistic effect, which makes them very popular in obstetrics; applied intrathecally and epidurally, they act directly on opioid receptors in the spinal cord.

Fentanyl is the opioid of choice. It is administered in a dose of 5–25 µg.[25] Higher doses can cause fetal bradycardia, in particular when the mother is relieved of pain quickly. Fetal bradycardia is deemed to be caused by a sudden drop in circulating catecholamines due to the rapid onset of analgesia.[26] The level of adrenaline decreases as well as its tocolytic effect on the uterus. This bradycardia is transient and can be stopped with nitroglycerin (200–400 µg iv).[26]

Epidural Analgesia

Before epidural analgesia, pregnant women should be informed about the risks and benefits of this type of analgesia, as well as the impact on the course of labor. Epidural analgesia has no effect on the first stage of labor and does not increase the risk of cesarean section, but it can prolong the second stage.[27] Unlike cases of classical labor, neuraxial analgesia techniques require a higher level of monitoring. Epidural analgesia or anesthesia is performed by positioning the epidural needle below the L2–L3 lumbar interspace (Fig. 1).[28] An epidural catheter is inserted through the epidural needle. The needle is removed and the catheter is fixed and connected to the perfusion pump. All neuraxial procedures are performed under strict aseptic conditions.[28] Having the patient in a good position before performing anesthesia is the main condition for a successful blockade — even the most experienced obstetric anesthesiologist will not be able to identify the epidural space if the mother is not in an adequate position. A patient moving in pain, difficulty in positioning due to gravide uterus, or adiposity are all factors that can lead to failure of the procedure. An epidural needle (Touhy, Hustead, Weiss) is 17–18G in diameter and 8.89 cm long, with markers on every 1 cm. A test dose is given to check for unintentional intravascular or subarachnoid position of the epidural catheter.[29] Epidural analgesia is achieved with 5–10 mL of epidural solution (0.1% bupivacaine + 2 µg/mL fentanyl).[29] Maintaining epidural analgesia can be achieved by manual bolus, continuous infusion, patient-controlled analgesia, and programmed intermittent epidural bolus. In practice, each dose is considered to be a test dose.

Fig. 1: Epidural analgesia or anesthesia is performed by positioning the epidural needle below L2 to L3 lumbar interspace

The loss-of-resistance technique is the standard approach to identifying the epidural space during epidural anesthesia. Only about 60% of punctures are successful at the first attempt.[30] This high failure rate has been attributed to the quality of anatomical landmarks and of patient positioning along with the degree of personal experience. A 2008 guideline by the National Institute for Health and Care Excellence (NICE) recommended the routine use of neuraxial ultrasound for epidural catheterization, concluding that ultrasound might help achieve correct catheter placement.[31]

Single-shot Spinal Analgesia

Single-shot spinal analgesia is used in the second stage of labor in multiparous women with advanced cervical dilation (8–9 cm) as the time needed for insertion and activation are both shorter.[32] The expected duration of this analgesia is up to 2 hours and is performed in the L3–L4 intervertebral space. A combination of a local anesthetic and fentanyl (bupivacaine 2.5 mg and fentanyl 25 µg) is used. Technically easier than epidural analgesia, single-shot spinal provides good pelvic muscle relaxation due to the sacral block. To avoid post-puncture headaches, small-diameter pencil-point spinal needles (25–27G) are used. Maternal monitoring and continuous cardiotocography are mandatory. Disposable single-shot spinal analgesia is the method of choice in third-world countries.

Combined Spinal-epidural Analgesia for Labor

Combined spinal-epidural analgesia (CSE) for labor combines the advantages of spinal analgesia (rapid analgesia) and epidural analgesia (the possibility of prolonging analgesia through an epidural catheter). During the first phase of labor, due to the spinal dose, the patient quickly became pain-free.[33] The most common technique of CSE analgesia is the needle-through-needle technique. Special kits enable the performing of labor analgesia and the insertion of an epidural catheter through a single puncture on the skin. Following identification of the epidural space, a spinal needle with a pencil-point tip is inserted into the subarachnoid space through the epidural needle. A spinal dose of anesthetic is administered through the spinal needle, which is then removed from the epidural needle, and an epidural catheter is placed. After achieving adequate analgesia, analgesia is maintained through the epidural catheter. The average period from spinal injection to the first epidural dose is about 90 minutes.

Anesthesia for Cesarean Section

The most common surgical intervention in obstetrics is a cesarean section. The high maternal mortality rate in the past was one of the reasons why the percentage of cesareans was very small at the beginning of the 20th century (1% in the United States of America).[34] By application of regional anesthesia in obstetrics, better conditions for patients in labor were provided; consequently, the percentage of surgical delivery increased (32% in the United States of America).[34] Although complications after cesarean section outweigh complications after vaginal delivery, the total number of cesarean deliveries is constantly increasing. The fact that obstetricians are frequently afraid of being accused of professional error in case of complications during vaginal delivery also contributes to the increase in cesarean sections. Research has shown that maternal mortality is mostly caused by impossible intubation during induction of general anesthesia, which is why regional anesthesia has taken precedence in obstetrics.

Neuraxial anesthesia is used for >95% of cesarean deliveries in the United States and Canada.[35] The benefits of regional anesthesia are: minimizes maternal morbidity, allows the parturient to be awake for birth, minimizes intraoperative systemic medication and transfer to the fetus, avoids airway instrumentation, facilitates multimodal postoperative analgesia with low-dose neuraxial opioids, and it may be associated with a reduced incidence of perioperative venous thromboembolism and surgical site infection.[36] Neuraxial techniques used during labor, such as epidural analgesia and CSE, can be converted to operative anesthesia a dose increase. When a patient is at high risk of requiring surgical termination of labor, a neuraxial catheter is placed during labor to avoid the risks of general anesthesia and to take care of possible postpartum hemorrhage.[37] Conditions that require early initiation of neuraxial anesthesia are twin gestation, preeclampsia, attempting of vaginal birth after previous cesarean delivery, category II fetal heart rate tracing, history of prior PPH, obesity with body mass index (BMI) > 40 or with sleep apnea, anticipated or known difficult airway, and history of malignant hyperthermia. Complications of neuraxial anesthesia are shown in Table 1.[38]

Conclusion

The current evidence supports the ultrasound-assisted approach to the central neuraxial blockade. Preprocedural ultrasound has been proven to help to identify lumbar intervertebral levels and allows precise measurement of depth to the epidural space, it improves the efficacy and safety of block by facilitating more accurate needle placement and decreasing the number of needle redirections and skin punctures, and it reduces the risk of serious complications associated with increased attempts and traumatic techniques. Although the conventional surface landmark-guided technique is simple and effective in the majority of patients, when technical difficulty is anticipated or when increased precision is desired, neuraxial ultrasound is an advanced tool to be used. Taking that into consideration, preprocedural neuraxial imaging should be used routinely to acquire and maintain the imaging skills to enable success for challenging neuraxial procedures.

Table 1: Complications of neuraxial anesthesia

Insertion	*Drug related*	*Late*
Trauma	Incomplete block	Postdural puncture headache
"Wet tap"	High block	Arachnoiditis
Bloody tap	Cranial nerve palsy	Cauda equina syndrome
Shearing of the catheter	Local anesthetic systemic toxicity	Cord ischemia
Knotting of the catheter	Hypotension	Meningitis
	Pruritus	Epidural abscess
	Shivering	
	Allergic reaction	

Declaration of Patient Consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given their consent for their images and other clinical information to be reported in the journal.

Author's Contributions

AM, EM, AK, ZB, and SJP gave substantial contribution to the conception or design of the article as well as in the acquisition, analysis, and interpretation of data for the work. Each author had a role in the drafting and revision of the article. Additionally, each author gave final approval of the version to be published and agree to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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