Challenge Journal of Perioperative Medicine

Review

Neuraxial anesthesia in pregnant patients with neurological disorders – Safety and practice strategies: A review

Mehmet Akif Yilmaz [a,*], Nuray Uzun [a]

[a] *Department of Anesthesiology and Reanimation, Atatürk University School of Medicine, Erzurum, Türkiye*

ABSTRACT

Pregnant patients with neurological disorders face multifaceted challenges arising from both the physiological changes of pregnancy and the underlying neurological conditions. In this unique patient population, anesthesia management requires meticulous planning to ensure maternal and fetal safety while minimizing the risk of neurological complications. Neuraxial anesthesia emerges as a safe and effective option when implemented with appropriate patient selection, a multidisciplinary approach, and individualized anesthesia protocols. This review comprehensively evaluates the clinical benefits of neuraxial anesthesia in pregnant patients with neurological disorders, highlighting critical considerations in its application and potential risks. Drawing upon the existing body of evidence, it aims to promote the safe use of neuraxial techniques and enhance awareness of the challenges inherent in managing this patient group. Additionally, the review underscores the importance of anesthesiologists adopting individualized strategies that address the specific risks associated with neurological pathologies, optimizing the advantages of neuraxial anesthesia in obstetric care.

ARTICLE INFO

Article history:
Received – December 16, 2024
Revision requested – February 6, 2025
Revision received – February 7, 2025
Accepted – February 10, 2025

Keywords:
Neurologic disorder
Pregnancy complications
Anesthesia obstetrical
Anesthesia epidural
Anesthesia spinal

Citation: Yilmaz MA, Uzun N. Neuraxial anesthesia in pregnant patients with neurological disorders – Safety and practice strategies: A review. *Chall J Perioper Med.* **2025**; 3(1):14–20.

1. Introduction

Obstetric patients can present with a broad range of neurological disorders. Most of the literature on anesthesia management in such cases consists of case reports or retrospective analyses involving a limited number of patients. In this article, we will review the literature and try to give a general summary about pregnant women with neurological disorders. After discussing labor analgesia and cesarean section anesthesia, general considerations for pregnant women with neurological disorders will be discussed and anesthetic management will be summarized.

2. Anesthetic Considerations and Neurologic Disorders

2.1. Labor pain

Pain perception is influenced by a person's emotional state, motivations, cognitive processes, and social and cultural context [1]. Many women, particularly those experiencing childbirth for the first time, describe labor pain as intolerable [2]. In the 2019 obstetric analgesia and anesthesia guidelines published by the American College of Obstetricians and Gynecologists, it is stated that maternal request alone is a valid medical indication for labor analgesia. Additionally, they concluded that neuraxial labor analgesia does not lead to a higher rate of cesarean deliveries [3]. Pain during the first stage of

* *Corresponding author*. E-mail address: mehmetakifyilmaz025@gmail.com (M. A. Yilmaz)
ISSN: 2980-292X / DOI: https://doi.org/10.20528/cjpm.2025.01.003

labor is classified as visceral pain. It is caused by the stretching of mechanoreceptors in the uterus and cervix, as well as tissue ischemia. The visceral pain signals are carried to the spinal cord through the T10, T11, T12, and L1 nerve roots. The pain experienced during the second stage of labor is more intense than that of the first stage. The pain during the second stage of labor is a combination of visceral pain from uterine contractions and cervical distension, along with somatic pain caused by the stretching of the vaginal and perineal tissues. The somatic pain signals are transmitted to the spinal cord through the pudendal nerve (S2, S3, and S4) [4].

2.2. Effects of labor pain

Labor causes a neuroendocrine stress response that has effects on multiple maternal and fetal organ systems. Labor pain increases oxygen consumption, so pregnant women who hyperventilate may experience respiratory alkalosis due to hypocarbia [5]. The resulting hypocarbia can inhibit ventilatory drive and cause maternal and fetal hypoxemia in the absence of supplemental oxygen [6]. Respiratory alkalosis shifts the oxyhemoglobin curve to the left, increasing the affinity of oxygen for maternal hemoglobin and thus reducing the transfer of oxygen from the placenta to the fetus. Severe maternal alkalosis can cause uteroplacental vasoconstriction, leading to decreased fetal blood flow and oxygen delivery [7]. Epidural analgesia reverses the adverse ventilatory effects of pain, resulting in increased oxygen tension in both mother and fetus [8]. Increased plasma catecholamines secondary to pain increase peripheral vascular resistance and reduce uteroplacental perfusion [9]. Using analgesia during labor reduces the endocrine stress response of the mother and baby [10].

2.3. Labor analgesia

Multiple pharmacologic and nonpharmacologic options are available to help women manage pain during labor. Neuraxial analgesic techniques [i.e., epidural, spinal, and combined spinal-epidural] are the most effective way to alleviate labor pain [11]. The use of neuraxial analgesia is recommended to manage labor pain when there are no contraindications [12]. The most commonly used systemic labor analgesics are opioids and opioid agonist-antagonists [13]. These include fentanyl, remifentanil, meperidine, morphine, nalbuphine, butorphanol, and pentazocine [14]. In addition to opioids, antihistamines, phenothiazine derivatives, benzodiazepines, or anesthetic gases can be used. These are promethazine, hydroxyzine, ketamine, midazolam, diazepam, and nitrous oxide [15].

2.4. Neuraxial analgesia and anesthesia in patients with neurological disorders

Neuraxial analgesia and anesthesia techniques are the preferred options for providing labor pain relief and anesthesia during cesarean delivery in obstetric patients. Neurological disorders affect the choice of technique in anesthesia management. We have some general concerns for all patients with neurological or neuromuscular disorders. For instance, in patients with elevated intracranial pressure caused by an intracarinal mass or other factors, there is a risk of a rapid drop in cerebrospinal fluid (CSF) pressure and potential brain herniation following neuraxial anesthesia. Additionally, distorted anatomy may complicate both neuraxial anesthesia and airway management.

2.5. When should we perform premedication? What should we pay attention to?

Patients with neurological disorders should be premedicated well before delivery. Previous records, including imaging studies, should be examined, and a multidisciplinary management plan should be developed if needed. For obstetric patients, this plan should address labor analgesia or anesthesia for cesarean delivery. The preanesthetic consultation provides the patient with an opportunity to weigh the risks and benefits of different anesthesia options. It is also important to review the current treatment regimen, including medications that might impact anesthesia management. Neurological symptoms such as cognitive dysfunction or seizures should be questioned for frequency and severity. The effects of neurological disease on other organs and systems (e.g. heart, lung) should be evaluated.

2.6. Intracranial mass

Patients with brain tumors may require anesthesia for procedures other than craniotomy. The primary concern is that a reduction in lumbar cerebrospinal fluid (CSF) pressure, caused by a dural puncture—whether intentional with a spinal needle or accidental with an epidural needle—can increase the risk of brain tissue herniation. There is also a risk of a potentially dangerous increase in intracranial pressure after the administration of large volumes or bolus doses of epidural fluid [16]. In a retrospective study conducted by Girault et al. [16], 20 women with intracranial masses [primary or metastasis] were examined. They underwent vaginal delivery or cesarean section with neuraxial analgesia and anesthesia. It has been shown that the type of birth is not associated with maternal mortality. The case report published by Finder et al. [17] reported three patients managed with epidural anesthesia: two with vaginal birth and one with cesarean section. No complications were observed related to the anesthesia technique. A 29-week-old pregnant woman with giant intracranial meningioma, reported by Kasper et al. [18], was admitted to the hospital with speech disorder. In the imaging performed, an intracranial mass covering more than 50% of the right hemisphere was detected in the transverse section. As a result of a multidisciplinary approach, a cesarean section was performed with epidural anesthesia to monitor consciousness. No complications related to the anesthesia method were observed.

A neurological or neurosurgical consultation should be obtained whenever possible before administering neuraxial anesthesia in patients with intracranial masses. The consultant should be specifically asked

whether a dural puncture could cause brain herniation. Neuroimaging should be reviewed to assess for mass effect, hydrocephalus, and potential obstruction of cerebrospinal fluid (CSF) flow. If there is clinical and radiological evidence of significant mass effect or CSF flow obstruction, the patient may be at an elevated risk of brain herniation following a dural puncture, and neuraxial anesthesia should be avoided. For patients considered to be at a lower risk of brain herniation, the risks and benefits of neuraxial anesthesia should be discussed among the neurologist, obstetrician, anesthesiologist, and the patient.

In patients with intracranial masses, general anesthesia may be necessary for an emergency or elective cesarean section when neuraxial anesthesia is contraindicated. In patients with elevated intracranial pressure, opioids are commonly given alongside anesthesia induction agents during endotracheal intubation to prevent hypertension and increased intracranial pressure that may result from sympathetic discharge [19]. During anesthesia induction for a cesarean section, the advantages of using opioids must be weighed against the risk of neonatal respiratory depression, as all opioids pass through the placenta [20]. Remifentanil is a desirable option due to its rapid onset and ultra-short duration of action, which allow for quick emergence and smooth extubation. In the prospective, randomized, controlled study titled Effects of remifentanil on mother and newborn during the induction of general anesthesia, conducted by Kee et al. [21] on 40 cesarean section patients: 2 newborns in the study group required naloxone administration due to respiratory depression. Kee says remifentanil crosses the placenta and may cause neonatal depression and recommends using remifentanil when adequate facilities for neonatal resuscitation are available. In addition, during general anesthesia, $PaCO_2$ (partial carbon dioxide) should be kept within the normal range. Increases in PaCO2 will cause increased cerebral blood flow, and hypercarbia should always be prevented in patients with increased ICP [22]. Hyperventilation and hypocarbia should also be avoided, as severe hyperventilation can lead to cerebral vasoconstriction and reduced cerebral perfusion. In pregnant patients, it can also cause uterine artery vasoconstriction, leading to decreased blood flow to the fetus [23].

2.7. Idiopathic intracranial hypertension (IIH)

Also referred to as pseudotumor cerebri, this condition is characterized by high intracranial pressure without the presence of a space-occupying lesion or ventriculomegaly. Idiopathic intracranial hypertension (IIH) can get worse during pregnancy. The most serious outcome is the risk of permanent vision loss. There is generally no risk of brain herniation after dural puncture in patients with IIH, and in fact CSF drainage can be used therapeutically in patients with IIH [24]. In the case report published by Gragasin et al. [25], while epidural anesthesia was applied to a pregnant woman with IIH diagnosis for labor analgesia, the catheter sent to the intrathecal space after involuntary dural puncture was used both for labor analgesia and for CSF aspiration in the treatment of severe postpartum headaches. In the case report published by Moore et al. [26], an intrathecal catheter was placed to treat postoperative intracranial hypertension in a pregnant woman diagnosed with IIH. In the case reports published by Palop et al. [27], it was presented that epidural anesthesia technique was chosen for labor analgesia in two pregnant women diagnosed with IIH. They suggested that especially epidural bolus doses should be given slowly to avoid increasing intracranial pressure. In the case report published by Bedson et al. [28], they presented the combined spino-epidural technique for cesarean section anesthesia to a pregnant woman diagnosed with IIH. No complications related to the choice of anesthesia technique were observed in all of these case reports. In the case report published by Estevez et al. [29], they presented a patient with IIH who experienced acute vision loss while applying an epidural blood patch, and attributed the bilateral vitreal and retinal hemorrhage to the increased intracranial pressure caused by the rapid application of the epidural blood patch. As a result, neuraxial anesthesia can be applied carefully in pregnant women with IIH. The advantage of continuous spinal anesthesia is that it reduces the increased intracranial pressure that becomes symptomatic through CSF aspiration. Continuous spinal anesthesia is not typically used for labor analgesia, but it may be considered for patients IIH who are at high risk for cesarean delivery. The use of a small volume of spinal anesthetic enables rapid, titratable surgical anesthesia, removing the need for a large, quick epidural bolus in the event of an urgent operative delivery. Additionally, it can be utilized to drain cerebrospinal fluid (CSF) in patients who develop symptoms of increased intracranial pressure (ICP) during or after labor. In the case report by Aly et al. [30], a pregnant woman diagnosed with IIH presented to the hospital for delivery and presented with symptoms of intracranial hypertension such as severe headache, nausea and vomiting. After a voluntary intrathecal catheter was placed and 25 cc CSF aspiration was performed, the patient's symptoms were relieved and intrathecal labor analgesia was started.

2.8. Cerebrovascular disorders (CVD) (ischemic or hemorrhagic stroke)

Ischemic or hemorrhagic stroke occurs in 30 per 100,000 women during pregnancy. In the case of acute stroke, surgery should be postponed whenever possible because adverse outcomes are likely to increase [31]. There is limited data to predict the risks in pregnant patients with a recent stroke. Management is based on the patient's clinical condition and the urgency of delivery. Neuraxial anesthesia techniques are preferred for pain management during delivery, unless contraindicated due to anticoagulation or the effects of a cerebrovascular disorder (CVD) on intracranial anatomy and physiology. For cesarean delivery, neuraxial anesthesia should be considered whenever feasible to reduce circulating catecholamines and minimize blood pressure fluctuations associated with intubation and extubation [32]. In a case report published by Wang et al. [32], a cesarean section is indicated for a pregnant woman with hemorrhagic

stroke after a multidisciplinary approach and the patient is administered epidural anesthesia. No procedure-related complications are observed. In the review titled "Stroke in Pregnancy" published by Miller et al. [31] in 2020, it was suggested that vaginal delivery should be the first choice for delivery, and neuraxial methods were also recommended as the first choice for labor analgesia. It has been suggested that neuraxial anesthesia should be the first choice anesthesia method for patients who are indicated for cesarean section with a multidisciplinary approach. It is emphasized that general anesthesia should be performed if therapeutic anticoagulants are used, neurosurgical surgery is planned, or neuraxial anesthesia is contraindicated. In patients with ischemic stroke who need antithrombotic or anticoagulant therapy for prevention or treatment, neuraxial anesthesia techniques must be coordinated with the timing of drug administration. In some cases, neuraxial anesthesia should be avoided due to the risk of epidural hematoma.

2.9. Intracranial aneurysm and arteriovenous malformation (AVM)

There is no need to alter the standard anesthesia management for patients who have undergone complete surgical repair of an intracranial aneurysm or arteriovenous malformation (AVM). For patients with residual or untreated lesions, a multidisciplinary plan for obstetric anesthesia management should be developed, aiming to prevent rupture of the lesion [33]. The main concern in anesthetic management is to prevent hypertension, as it can raise the pressure gradient across the lesion wall and lead to rupture. This increase in pressure gradient and potential rupture can occur after a dural puncture during a neuraxial procedure, but could also theoretically result from a sudden drop in cerebrospinal fluid (CSF) pressure [34]. In a retrospective study published by Elwood et al. [33] in 2020, 16 pregnant women with arteriovenous malformation were screened; 13 of them required anesthesia for cesarean section and one required anesthesia for labor pain. Of these, 11 pregnant women received spinal anesthesia and 2 received epidural anesthesia. One pregnant woman received epidural anesthesia as labor analgesia. In their case series of 16 births, no complications were seen directly resulting from neuraxial procedures. The decision to use neuraxial techniques for labor analgesia or cesarean delivery should weigh the risks and benefits of these methods in comparison to alternatives. For obstetric patients, neuraxial techniques are typically recommended for those with known intracranial aneurysms and arteriovenous malformations (AVMs). Neuraxial labor analgesia is more effective in reducing the rise in blood pressure during labor compared to alternative methods of pain relief [34]. Neuraxial anesthesia facilitates instrumental vaginal delivery and reduces the need for general anesthesia during cesarean delivery. The risk of significant intracranial hypotension after a dural puncture can be minimized by using a small-bore, pencil-point spinal needle. Epidural analgesia typically prevents dural puncture, but if an inadvertent dural puncture occurs with the larger epidural needle, cerebrospinal fluid (CSF) leakage may be more significant compared to a small-bore spinal needle. General anesthesia eliminates the risk of dural puncture but necessitates endotracheal intubation, which can be complicated by hypertension during both intubation and extubation. Additionally, the risks associated with general anesthesia apply to all obstetric patients [33]. In patients with intracranial vascular lesions who develop a headache following a neuraxial anesthesia procedure, there should be a strong suspicion of intracranial hemorrhage when assessing the patient for a potential post-dural puncture headache (PDPH). For these patients, intracranial hemorrhage should be ruled out before performing an epidural blood patch to treat a PDPH. In the case report published by Egger et al., intracranial hemorrhage was detected in the imaging performed after severe headaches following spinal anesthesia in a pregnant woman with known AVM diagnosis [35].

2.10. Spinal cord anomalies

2.10.1. Chiari malformation

Chiari malformations are congenital conditions marked by abnormalities at the craniocervical junction, leading to the downward displacement of cerebellar structures and the potential for partial or intermittent obstruction of cerebrospinal fluid flow [36]. Most pregnant patients have Chiari type 1, characterized by the displacement of an abnormally shaped cerebellum below the level of the foramen magnum [37]. Key anesthesia-related concerns include the extent of obstruction or potential obstruction of cerebrospinal fluid (CSF) flow between the cranial and spinal compartments, as well as the risk of herniation following a dural puncture [38]. Twelve pregnant women with type 1 Chiari malformation were followed by Chantigan et al. [37]; general anesthesia was applied to 3 pregnant women, epidural anesthesia was applied to 6 pregnant women, and spinal anesthesia was applied to 3 pregnant women. It was stated that neuraxial anesthesia is safe in pregnant women with type 1 Chiari malformation. Landau et al.'s [38] published case report emphasized that spinal anesthesia was applied to a pregnant woman with surgically corrected Chiari type 1 malformation without any complications. In a study titled "Management of Anesthesia and Delivery in Women with Chiari I Malformations" published by Waters et al. [39] in 2018, they showed that no complications associated with neuraxial anesthesia developed. In this article, the author stated that there should be no complications in patients who receive epidural or spinal anesthesia, and that the neuraxial option should be offered to women with Chiari malformation.

2.10.2. Spinal abnormalities

Patients with cervical spine disorders may face an increased risk of airway management difficulties during general anesthesia, due to factors such as progressive kyphosis or limited mobility following corrective spine surgery [40]. Patients with spinal abnormalities may have difficult neuraxial procedures, increasing the risk of inadvertent dural puncture during epidural anesthesia

[41]. Patients with these disorders should have radiological imaging to assess the relevant anatomy if neuraxial anesthesia is being considered. The feasibility of neuraxial anesthesia was demonstrated in the case report titled "A Pregnant Woman with Spina Bifida: Need for a Multidisciplinary Labor Plan" published by O'neal [41].

2.10.3. Syringomyelia

Patients with syringomyelia are theoretically at risk of syrinx dilation from a rapid epidural bolus injection or from increased intracranial pressure during intubation [42]. In a review titled "Anesthetic and Obstetric Management of Syringomyelia during Labor and Delivery" published by Garvey et al. [42], 70% of 43 pregnant women who underwent cesarean section received general anesthesia, and 69% of those who gave birth vaginally received epidural anesthesia. All anesthesia techniques were successfully performed without permanent complications.

2.10.4. Spinal stenosis or lumbar disc herniation

In a retrospective study published by Hebl et al. [43], titled "Neuraxial Anesthesia in Patients with Spinal Stenosis, Lumbar Disc Herniation or Previous Spinal Surgery", a total of 937 pregnant women were screened for neurological complications. The primary limitation of this study is that the effects of neuraxial anesthesia could not be fully evaluated, as there was no control group with similar pathology that received general anesthesia. The study indicates that patients with spinal stenosis or lumbar disc herniation may have an increased risk of neurological complications following neuraxial anesthesia. In a retrospective study by Moen et al. [44], approximately 1.7 million patients who underwent neuraxial anesthesia were screened for postoperative neurological complications, and spinal stenosis was determined to be a risk factor for postoperative neurological complications. Of the 1.7 million patients screened, only 85 patients developed permanent neurological complications.

2.10.5. Patients with shunts

Patients with functional CSF shunts may undergo general anesthesia or neuraxial anesthesia [45]. In the case report published by Bedard et al. [45], epidural anesthesia was applied to a pregnant woman with a shunt without any complications. In patients with lumboperitoneal shunts, the effect of intrathecal local anesthetic may be unpredictable and its duration of effect may be shorter due to leakage of the local anesthetic into the peritoneal cavity through the shunt. An insufficient or failed block may occur [46]. In a case report by Kaul et al. [46], on accidental spinal analgesia in an obese woman with a lumboperitoneal shunt, it was noted that the duration of the local anesthetic's effect was reduced to 10-12 minutes when labor analgesia was administered with intrathecal local anesthetic.

Table 1. Summary of diseases and neuraxial procedures.

Illness	Single dose spinal anesthesia	Epidural anesthesia	Combined spinoepidural anesthesia	Continuous spinal anesthesia	Complications	Precautions or key recommendations
Intracranial mass	Reported [47]	Reported [16–18]	No reported	No reported	Hydrocephalus due to brainstem herniation and infratentorial mass [47].	Beware of brain herniation and potential obstruction of CSF flow.
IIH	Reported [48]	Reported [27] Epidural boluses should be administered gradually and slowly [29].	Reported [28]	Reported [25,26,30]	Acute vitreous hemorrhage after rapid, high-volume epidural [29].	Continuous spinal anesthesia can be used for analgesia, anesthesia, and headache caused by IIH.
Cerebrovascular disorders	Reported [31]	Reported [31,32]	Reported [31]	Reported [31]	No complications were observed directly resulting from neuraxial procedures.	Caution with the use of therapeutic or prophylactic anticoagulants.
Intracranial aneurysm or AVM	Reported [33,35]	Reported [33]	Reported [33]	No reported	SAH after spinal anesthesia [35]	Neuraxial anesthesia is safe in the operated patient. The risk of lesion rupture should always be kept in mind.
Chiari malformation	Reported [37,39]	Reported [37,39]	Reported [5,36]	Reported [37]	No complications were observed directly resulting from neuraxial procedures.	Safety of neuraxial anesthesia in the operated patient [38].
Syringomyelia	Reported [49]	Reported [42,50]	No reported	No reported	No complications were observed directly resulting from neuraxial procedures.	High doses and rapidly administered epidural boluses may dilate the syrinx.

IIH: Idiopathic Intracarinial Hypertension; AVM: Arterio Venous Malformation; CSE: Combined Spino-Epidural; SAH: Subarachnoid Hemorrhage.

3. Conclusions

Pregnant women with neurological disorders require a multidisciplinary approach during both pregnancy and delivery. The coordinated work of the neurologist, obstetrician and anesthesiologist can ensure optimal results for both the mother and the fetus. The neurologist; to evaluate how the patient's current neurological condition will be affected by pregnancy and to monitor the disease. To determine the risk of neurological complications during pregnancy or delivery and to take the necessary precautions. In pregnant women with neurological diseases, the neurosurgeon has an important role in the management of diseases that may require surgical intervention or may lead to critical neurological conditions such as increased intracranial pressure. He/she can determine surgical risks in patients who are planned to undergo neuraxial anesthesia. Emergency surgical intervention may be recommended by the neurosurgeon. He/she plays an active role in the management of neurological disorders that develop especially in the postpartum period. The obstetrician; to monitor the course of pregnancy, evaluate maternal and fetal health, and determine the method of delivery in pregnant women with neurological diseases. To create the most appropriate birth plan for patients. The anesthesiologist; to determine the safest anesthesia method suitable for the patient's neurological condition. To evaluate the applicability of neuraxial anesthesia and consider contraindications. If general anesthesia is required, to plan the anesthesia management in a way that minimizes the effects of neurological diseases. The coordinated work of these three branches can prevent possible complications and make the birth process safe for both the mother and the baby. This review aims to demonstrate that neuraxial anesthesia can be used safely in these patient groups and may offer various advantages. With appropriate patient selection, careful evaluation and individualized anesthesia planning, neuraxial anesthesia applications can provide optimal results for both mother and baby. We aim to encourage anesthesiologists to be informed on this subject and not hesitate to apply neuraxial anesthesia to pregnant women with neurological disorders.

Acknowledgements
None declared.

Funding
The authors received no financial support for the research, authorship, and/or publication of this manuscript.

Conflict of Interest
The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this manuscript.

Author Contributions
All of the authors made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; were involved in drafting the manuscript or revising it critically for important intellectual content; and gave final approval of the version to be published.

Data Availability
The datasets created and/or analyzed during the current study are not publicly available, but are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate
Not applicable.

REFERENCES

1. Lowe NK. The nature of labor pain. *Am J Obstet Gynecol*. **2002**;186(5 Suppl Nature):S16-24.
2. Ranta P, Spalding M, Kangas-Saarela T, Jokela R, Hollmén A, Jouppila P, et al. Maternal expectations and experiences of labour pain--options of 1091 Finnish parturients. *Acta Anaesthesiol Scand*. **1995**;39(1):60-6.
3. ACOG Practice Bulletin No. 209: Obstetric Analgesia and Anesthesia. *Obstet Gynecol*. **2019**;133(3):e208-e25.
4. Brownridge P. The nature and consequences of childbirth pain. *Eur J Obstet Gynecol Reprod Biol*. **1995**;59 Suppl:S9-15.
5. Minnich ME, Brown M, Clark RB, Miller FC, Thompson DS. Oxygen desaturation in women in labor. *J Reprod Med*. **1990**;35(7):693-6.
6. Rooth G. Maternal hypoxaemia during labor. *Padiatr Padol*. **1982**;17(2):231-6.
7. Tomimatsu T, Kakigano A, Mimura K, Kanayama T, Koyama S, Fujita S, et al. Maternal carbon dioxide level during labor and its possible effect on fetal cerebral oxygenation: mini review. *J Obstet Gynaecol Res*. **2013**;39(1):1-6.
8. Hägerdal M, Morgan CW, Sumner AE, Gutsche BB. Minute ventilation and oxygen consumption during labor with epidural analgesia. *Anesthesiology*. **1983**;59(5):425-7.
9. Shnider SM, Wright RG, Levinson G, Roizen MF, Wallis KL, Rolbin SH, et al. Uterine blood flow and plasma norepinephrine changes during maternal stress in the pregnant ewe. *Anesthesiology*. **1979**;50(6):524-7.
10. Vogl SE, Worda C, Egarter C, Bieglmayer C, Szekeres T, Huber J, et al. Mode of delivery is associated with maternal and fetal endocrine stress response. *Bjog*. **2006**;113(4):441-5.
11. Traynor AJ, Aragon M, Ghosh D, Choi RS, Dingmann C, Vu Tran Z, et al. Obstetric Anesthesia Workforce Survey: A 30-Year Update. *Anesth Analg*. **2016**;122(6):1939-46.
12. Jones L, Othman M, Dowswell T, Alfirevic Z, Gates S, Newburn M, et al. Pain management for women in labour: an overview of systematic reviews. *Cochrane Database Syst Rev*. **2012**;2012(3):Cd009234.
13. Olofsson C, Ekblom A, Ekman-Ordeberg G, Hjelm A, Irestedt L. Lack of analgesic effect of systemically administered morphine or pethidine on labour pain. *Br J Obstet Gynaecol*. **1996**;103(10):968-72.
14. Smith LA, Burns E, Cuthbert A. Parenteral opioids for maternal pain management in labour. *Cochrane Database Syst Rev*. **2018**;6(6):Cd007396.
15. Likis FE, Andrews JC, Collins MR, Lewis RM, Seroogy JJ, Starr SA, et al. Nitrous oxide for the management of labor pain: a systematic review. *Anesth Analg*. **2014**;118(1):153-67.
16. Girault A, Dommergues M, Nizard J. Impact of maternal brain tumours on perinatal and maternal management and outcome: a single referral centre retrospective study. *Eur J Obstet Gynecol Reprod Biol*. **2014**;183:132-6.
17. Finfer SR. Management of labour and delivery in patients with intracranial neoplasms. *Br J Anaesth*. **1991**;67(6):784-7.
18. Kasper EM, Hess PE, Silasi M, Lim KH, Gray J, Reddy H, et al. A pregnant female with a large intracranial mass: Reviewing the evidence to obtain management guidelines for intracranial meningiomas during pregnancy. *Surg Neurol Int*. **2010**;1:95.
19. Bédard JM, Richardson MG, Wissler RN. General anesthesia with remifentanil for Cesarean section in a parturient with an acoustic neuroma. *Can J Anaesth*. **1999**;46(6):576-80.
20. Draisci G, Valente A, Suppa E, Frassanito L, Pinto R, Meo F, et al. Remifentanil for cesarean section under general anesthesia: effects

on maternal stress hormone secretion and neonatal well-being: a randomized trial. *Int J Obstet Anesth*. **2008**;17(2):130-6.
21. Ngan Kee WD, Khaw KS, Ma KC, Wong AS, Lee BB, Ng FF. Maternal and neonatal effects of remifentanil at induction of general anesthesia for cesarean delivery: a randomized, double-blind, controlled trial. *Anesthesiology*. **2006**;104(1):14-20.
22. Imarengiaye C, Littleford J, Davies S, Thapar K, Kingdom J. Goal oriented general anesthesia for Cesarean section in a parturient with a large intracranial epidermoid cyst. *Can J Anaesth*. **2001**;48(9):884-9.
23. Van de Velde M, Teunkens A, Kuypers M, Dewinter T, Vandermeersch E. General anaesthesia with target controlled infusion of propofol for planned caesarean section: maternal and neonatal effects of a remifentanil-based technique. *Int J Obstet Anesth*. **2004**;13(3):153-8.
24. Scott C, Kaliaperumal C. Idiopathic intracranial hypertension and pregnancy: A comprehensive review of management. *Clin Neurol Neurosurg*. **2022**;217:107240.
25. Gragasin FS, Chiarella AB. Use of an Intrathecal Catheter for Analgesia, Anesthesia, and Therapy in an Obstetric Patient with Pseudotumor Cerebri Syndrome. *A A Case Rep*. **2016**;6(6):160-2.
26. Moore DM, Meela M, Kealy D, Crowley L, McMorrow R, O'Kelly B. An intrathecal catheter in a pregnant patient with idiopathic intracranial hypertension: analgesia, monitor and therapy? *Int J Obstet Anesth*. **2014**;23(2):175-8.
27. Palop R, Choed-Amphai E, Miller R. Epidural anesthesia for delivery complicated by benign intracranial hypertension. *Anesthesiology*. **1979**;50(2):159-60.
28. Bedson CR, Plaat F. Benign intracranial hypertension and anaesthesia for caesarean section. *Int J Obstet Anesth*. **1999**;8(4):288-90.
29. Pagani-Estévez GL, Chen JJ, Watson JC, Leavitt JA. Acute Vision Loss Secondary to Epidural Blood Patch: Terson Syndrome. *Reg Anesth Pain Med*. **2016**;41(2):164-8.
30. Aly EE, Lawther BK. Anaesthetic management of uncontrolled idiopathic intracranial hypertension during labour and delivery using an intrathecal catheter. *Anaesthesia*. **2007**;62(2):178-81.
31. Miller EC, Leffert L. Stroke in Pregnancy: A Focused Update. *Anesth Analg*. **2020**;130(4):1085-96.
32. Wang A, Saad AF. Hemorrhagic Stroke in Pregnancy. *Clin Obstet Gynecol*. **2023**;66(1):223-30.
33. Ellwood SJ, Mootz AA, Carabuena JM, Farber MK, Reale SC. Management of sporadic intracranial vascular malformations in pregnancy: a retrospective analysis. *Int J Obstet Anesth*. **2024**;58:103989.
34. von Knobelsdorff G, Paris A. Intracerebral hemorrhage after cesarean section under spinal anesthesia. Coincidence or causality? *Anaesthesist*. **2004**;53(1):41-4.
35. Eggert SM, Eggers KA. Subarachnoid haemorrhage following spinal anaesthesia in an obstetric patient. *Br J Anaesth*. **2001**;86(3):442-4.
36. Choi CK, Tyagaraj K. Combined spinal-epidural analgesia for laboring parturient with Arnold-Chiari type I malformation: a case report and a review of the literature. *Case Rep Anesthesiol*. **2013**;2013:512915.
37. Chantigian RC, Koehn MA, Ramin KD, Warner MA. Chiari I malformation in parturients. *J Clin Anesth*. **2002**;14(3):201-5.
38. Landau R, Giraud R, Delrue V, Kern C. Spinal anesthesia for cesarean delivery in a woman with a surgically corrected type I Arnold Chiari malformation. *Anesth Analg*. **2003**;97(1):253-5, table of contents.
39. Waters JFR, O'Neal MA, Pilato M, Waters S, Larkin JC, Waters JH. Management of Anesthesia and Delivery in Women with Chiari I Malformations. *Obstet Gynecol*. **2018**;132(5):1180-4.
40. Yamada S, Won DJ, Yamada SM, Hadden A, Siddiqi J. Adult tethered cord syndrome: relative to spinal cord length and filum thickness. *Neurol Res*. **2004**;26(7):732-4.
41. O'Neal MA. A Pregnant Woman with Spina Bifida: Need for a Multidisciplinary Labor Plan. *Front Med (Lausanne)*. **2017**;4:172.
42. Garvey GP, Wasade VS, Murphy KE, Balki M. Anesthetic and Obstetric Management of Syringomyelia during Labor and Delivery: A Case Series and Systematic Review. *Anesth Analg*. **2017**;125(3):913-24.
43. Hebl JR, Horlocker TT, Kopp SL, Schroeder DR. Neuraxial blockade in patients with preexisting spinal stenosis, lumbar disk disease, or prior spine surgery: efficacy and neurologic complications. *Anesth Analg*. **2010**;111(6):1511-9.
44. Moen V, Dahlgren N, Irestedt L. Severe neurological complications after central neuraxial blockades in Sweden 1990-1999. *Anesthesiology*. **2004**;101(4):950-9.
45. Bédard JM, Richardson MG, Wissler RN. Epidural anesthesia in a parturient with a lumboperitoneal shunt. *Anesthesiology*. **1999**;90(2):621-3.
46. Kaul B, Vallejo MC, Ramanathan S, Mandell GL, Krohner RG. Accidental spinal analgesia in the presence of a lumboperitoneal shunt in an obese parturient receiving enoxaparin therapy. *Anesth Analg*. **2002**;95(2):441-3, table of contents.
47. Metterlein T, Kuenzig H, Bele S, Brawanski A, Graf BM. Coma after spinal anaesthesia in a patient with an unknown intracerebral tumour. *Acta Anaesthesiol Scand*. **2010**;54(9):1149-51.
48. Alves S, Sousa N, Cardoso L, Alves J. Multidisciplinary management of idiopathic intracranial hypertension in pregnancy: case series and narrative review. *Braz J Anesthesiol*. **2022**;72(6):790-4.
49. Hönemann C, Moormann S, Hagemann O, Doll D. Spinal anesthesia for cesarean delivery in a patient with syringomyelia. *Int J Gynaecol Obstet*. **2014**;125(2):172-4.
50. Margarido C, Mikhael R, Salman A, Balki M. Epidural anesthesia for Cesarean delivery in a patient with post-traumatic cervical syringomyelia. *Can J Anaesth*. **2011**;58(8):764-8.