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Large intrathecal volume: a cause of true failed spinal anesthesia

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Abstract
A 37-year-old woman scheduled for postpartum tubal ligation received two intrathecal doses of 2% hyperbaric mepivacaine (44 mg and 40 mg) and a subsequent single dose of 5% hyperbaric lidocaine (62.5 mg). Her sensory level never extended beyond S1. She subsequently underwent an uneventful general anesthetic, and had no residual sensory or motor deficits. An examination of the patient's lumbosacral magnetic resonance imaging (MRI) scan revealed an unusually large thecal volume. A large lumbosacral intrathecal volume may result in significant dilution or poor redistribution of hyperbaric local anesthetic. The final sensory level may be reduced or absent as a result. Intrathecal volume may be the most important non-modifiable factor affecting intrathecal distribution of local anesthetics; however, it cannot be easily measured or predicted. True failed spinal anesthesia should be distinguished from technical mishap, i.e., failing to introduce the anesthetic into the intrathecal space. The differential of a truly failed single-injection spinal anesthetic may include a large thecal volume, dural ectasias, cysts, and simple anatomic sacral restriction. To minimize maldistribution and neurotoxicity, the sum dose of all intrathecal local anesthetics administered for a single procedure should not significantly exceed the maximum recommended single-dose amount.

Key words Spinal anesthesia · Spinal failure · Intrathecal volume · Postpartum · Local anesthetic

Introduction

The failure to achieve adequate levels of anesthesia via a single-injection spinal has been attributed largely to technical errors, dosage miscalculations, or the use of inert local anesthetic [1]. The incidence of failed spinal anesthetics in both private and teaching hospitals varies greatly, and has been reported to be as low as 0.46% and as high as 16%, but ultimately depends on how the term "failure" is defined [1]. We define true failed spinal anesthesia as one not attributed to preventable causes. Reports of true failures of intrathecal analgesia have been largely associated with spinal catheter use rather than with single-injection spinals; the catheter-related failures are believed to be secondary to malposition of the catheter (caudad placement) with maldistribution of local anesthetic. Although there are different theories to explain true failures of spinal anesthesia, most failures are actually due to technical mishaps with failure to actually introduce the local anesthetic into the cerebrospinal fluid (CSF) [2–5]. Anatomic malformations and enlarged thecal volumes, that lead to sacral restriction and spinal failure, are rarely observed or reported. Considering all etiologies of failed spinal analgesia may prevent inadvertent local anesthetic overdose and nerve injury to the cauda equina.

Case report

A 37-year-old, healthy, American Society of Anesthesiologists (ASA) 1, gravida$_2$para$_2$ female presented for tubal ligation on post-partum day 1 after vaginal delivery of a healthy infant. She had not requested neuraxial analgesia for labor and had no prior surgical or anesthetic history. Height and weight were 167 cm and 80 kg, respectively. Airway exam revealed a Mallampati 2 with adequate mouth opening. In the sitting position, the patient was sterilely prepped and draped, and 44 mg of 2% hyperbaric mepivacaine (0.2 cc 10% dextrose in 2.6 cc total volume) and 10 μg fentanyl were injected into CSF at the L4–L5 interspace via a 25-gauge Sprotte needle (with the needle orifice in the cranial direction). Birefringence was present before and after injection of the local anesthetic. The patient was then placed immediately in the supine position. After 10 min, the patient reported some numbness in the ventral aspect of her left foot. A left-sided sensory level to S1 was docu-

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mented. An additional 40 mg (2 cc) of hyperbaric (0.2 cc 10% dextrose) mepivacaine was drawn from a new vial, to which 10 µg of fentanyl was added. Again, in the sitting position, local anesthetic was injected into CSF at L3–L4, one level above the previous attempt with free flow of CSF through the 25-gauge Sprotte needle. At 10 min, there was still no appreciable dermatomal sensory level above S1 despite trendelenburg positioning. A third spinal anesthetic was attempted, using 1.25 cc of a hyperbaric (7.5% dextrose) 5% lidocaine (62.5 mg) solution into an adjacent lumbar interspace (L2–L3) with slow and repeated dilution of the anesthetic with free-flowing, birefringent CSF. Again, the patient had no change in the dermatomal sensory level and no appreciable motor deficits after 10 min. The patient subsequently underwent an uneventful general anesthetic, and reported no sensory or motor changes upon awakening from her anesthetic or upon discharge from the postoperative care unit.

On postoperative day 1, the patient denied numbness and difficulty walking or urinating, and had no symptoms of post-dural puncture headache. Physical examination was unremarkable. Magnetic resonance imaging (MRI) was performed (compare images in Fig. 1a & Fig. 1b) to rule out lumbosacral anatomic malformations, after patient consent was obtained. The MRI revealed normal disk spaces and no evidence of unusual epidural anatomy. The patient's thecal sac volume, however, was estimated, on sagittal view, to be greater than the 95th percentile for size (Steve Reddy, MD, 2005, personal communication), although specific volumetric analysis could not be performed. The patient was discharged from the postpartum unit on postoperative day 2 without incident.

Discussion

True failed single-injection spinal anesthesia may be the result of dilution of the local anesthetic within a large CSF volume, poor CSF distribution from the caudal region, use of an inert local anesthetic, and rare anatomic malformations. Volume—and its influence upon the final distribution of intrathecal local anesthetic distribution—has been suspected for at least a quarter of a century, but the assertion was not substantiated until Carpenter and colleagues did so in 1998, using a novel, but not routinely available, MRI technique capable of accurately measuring CSF volumes [6]. They suggest that lumbosacral CSF volume is the *primary* determinant of the sensory block extent and duration of a spinal anesthetic. Unfortunately, it is inconvenient to measure CSF volumes in every patient by volumetric MRI analysis. Correlating CSF volume and easily measured body characteristics, such as height, weight, and body mass index (BMI), is difficult [8]. Using volumetric MRI

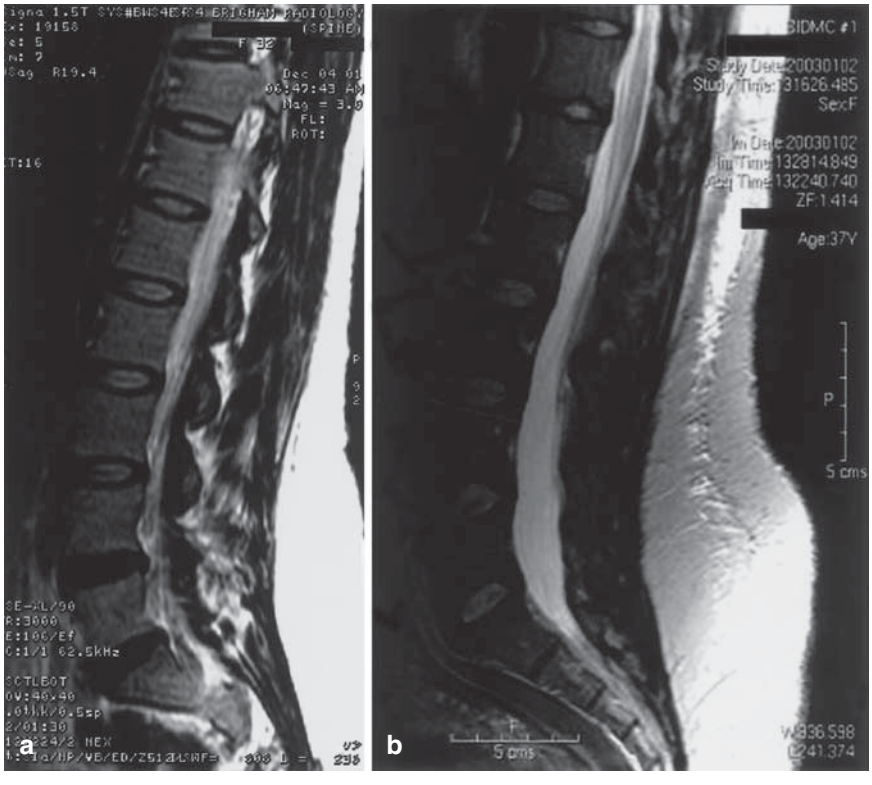

Fig. 1a,b. Magnetic resonance images of the lumbosacral spine. **a** Patient with usual thecal dimensions. **b** Patient with large thecal dimensions. Compare the intrathecal dimensions of the patient in **b** (our patient) to the patient in **a**

analysis would have been a more convincing modality to more accurately assess CSF volume in our patient, and despite the appearance of an enlarged lumbar thecal area, the calculation of volume from a two-dimensional (2-D) MRI sequence may have been inaccurate. Furthermore, the precise behavior of intrathecal hyperbaric local anesthetics in such an environment is speculative; we cannot conclude definitively that the failures of the spinals in our patient were from excessive sacral restriction, dilution, poor redistribution, or a combination thereof.

The prevalence of clinically meaningful thecal enlargement is unknown. Our case is only the second clinical report documenting large lumbosacral CSF volumes in association with severely restricted spinal anesthesia. The first was by Hirayabashi et al. [9], in 1996, who reported a severely restricted level of spinal anesthesia following a single dose of hyperbaric tetracaine (12.5 mg). A subsequent dose of hyperbaric tetracaine (12.5 mg) was successful. The same patient failed another dose of 12.5 mg tetracaine for a separate procedure, but again was rescued with a second 12.5-mg spinal dose. The patient suffered no permanent neurologic deficits despite the large total dose of spinal tetracaine administered. The failed spinals were thought to be the result of a very large lumbar CSF volume, as calculated by MR images of the dural sac area [9].

The normal flow of CSF in the caudal portion of the subarachnoid space is estimated to be less than 10% of the 500 cc produced daily, a physiologic trait which could explain occasional sacral restriction of local anesthetic when deposited in the lumbosacral region, even in the absence of large CSF volumes [7]. Therefore, ineffective redistribution of local anesthetic from the caudal region, in the setting of a large CSF volume is, perhaps, a more precise explanation for the restricted sensory level observed in our patient. In 1991, Rigler and Drasner [3] demonstrated with in-vitro experiments that a partially or completely failed spinal anesthetic may represent maldistribution, an exaggerated but potentially dangerous form of "sacral" restriction of the local anesthetic within the intrathecal space that leads to excessive local anesthetic deposition onto caudal nerves. The maldistributed anesthetic is hindered by ineffective spread throughout the CSF, a phenomenon largely explained by the (low) speed of intrathecal injection, baricity and position of the spinal catheter or needle through which the anesthetic is injected [3]. When local anesthetic is maldistributed within the cauda equina, repeat dosing via either intrathecal catheter or via another single-injection spinal can result in permanent nerve damage [3,10].

Mepivacaine was used for our spinals because of a reportedly reduced incidence of transient neurologic symptoms following spinal anesthesia compared to lidocaine, and they have a similar duration of action [11]. The maximum safe dose of a single intrathecal mepivacaine dose is probably not known, although 80 mg of mepivacaine as a single dose has been used safely in many patients [12]. The use of an additional 62.5 mg of hyperbaric lidocaine was done with caution, i.e., with repeat barbotage of the solution. It remains unclear if the maximum safe total dose of separate amides used is equivalent to a single amide maximum safe dose. Had the intrathecal local anesthetic been maldistributed, the total dose of the amide used (150.5 mg) would probably be considered excessive, and it is perhaps fortuitous that our patient had a large, and therefore, protective, thecal volume. When our patient failed the second dose of hyperbaric mepivacaine, we also considered the possibility that the mepivacaine was inert; however, this was unlikely given that the doses were from separate vials and that the drug had not exceeded its expiration date, and the patient did report some sensory changes. Epidural anesthesia was considered after the third failure; however, because we could not rule out an unusual anatomic malformation in the lumbar region, we chose to avoid additional attempts at regional anesthesia. Unusual anatomic variations or abnormalities of the caudal-spinal area, such as dural ectasia and cysts, can be potential causes of failed spinal anesthesia, but these are rarely encountered [13]. Dural ectasias represent abnormal balloonings of the thecal sac, which can be seen in a high percentage of patients with Marfan's syndrome, but have been reported in just two parturients (without Marfan's) undergoing cesarean section. Both parturients had failed spinal anesthetics [14].

Physiologic resistance to an intrathecal local anesthetic as an explanation for failed spinal anesthesia has been included among the etiologies for a true failed spinal [2,4]; however, as "resistant" sodium channel conformations to local anesthetics have yet to be discovered in the Caucasian population, it should not be seriously considered in the etiology of failed spinal anesthesia. One case of true failed spinal anesthesia in 2004 describes failed spinal anesthesia in a parturient following an intrathecal bupivacaine injection. Unfortunately, these authors assumed the failure to be due to physiologic resistance, and did not image her lumbosacral spine [15].

If what appears to be a true failed spinal anesthetic is encountered, the question of how to alter the characteristics of the second spinal solution arises. Spread of local anesthetic within the CSF can be altered by baricity (and patient position following injection); however, increasing the baricity beyond that which renders the anesthetic hyperbaric does not significantly alter its final distribution. For example, lidocaine in 5% dextrose will distribute in a fashion similar to that of lidocaine in 7.5% glucose [7]. Conversely, local anesthetic may dis-

tribute more uniformly within the CSF if the baricity is very near isobaric (yet technically hyperbaric), as demonstrated by in vitro experiments [3]. This suggests that when repeating a failed spinal, using a solution that is isobaric, rather than less hyperbaric, may be preferable. The concentration of glucose we used for the mepivacaine was approximately 0.78% (7.8 mg/ml), a percentage that is closer to isobaric. Intrathecal glucose (dextrose), in and of itself, does not appear to be neurotoxic [16,17].

In an effort to reduce the possibility of neurotoxicity following repeat spinal injections of local anesthetic, the following guideline has been suggested: (1) attempt CSF aspiration before and after injection of local anesthetic, (2) evaluate sacral dermatomes, (3) do not greatly exceed the overall maximum local anesthetic dose recommended for a single dose, (4) modify the technique used on subsequent injections (e.g., change baricity, alter patient position), and (5) when CSF cannot be aspirated, repeat injection should not be considered unless there is clearly no evidence of sensory blockade. One should also be observant of the total amount of intrathecal opioids and epinephrine used [16].

In conclusion, there are a number of anatomic variations or malformations that can result in complete or nearly complete failed spinal anesthesia by virtue of sacral restriction or dilution of local anesthetic. A very large thecal volume in the lumbosacral region is one such rare example. Because maldistribution of the intrathecal anesthetic during a failed spinal anesthetic cannot be ruled out, the clinician must be cautious when repeating intrathecal injections, and should pay particular attention to the total dose of local anesthetic administered [10,18–20].

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