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Spinal anesthesia for pediatric urological surgery: Reducing the theoretic neurotoxic effects of general anesthesia

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Summary

Background
Spinal anesthesia (SA) is an effective technique that has been used in children for years. With growing concern with regard to the risks of general anesthesia (GA), we developed a SA program to provide an alternative option. We present our initial experience with this program.

Objective
To implement a SA program at a large tertiary care pediatric center and assess the safety and efficacy of the technique as an alternative to GA for urologic surgery.

Study design/methods
We prospectively collected data on all children undergoing SA at our institution. We recorded demographics, procedure, time required for placement of the SA, length of surgery, success of lumbar puncture, success of attaining adequate surgical anesthesia, need for supplemental systemic sedation, conversion to GA, and perioperative complications.

Results
SA was attempted in 105 consecutive children (104 boys, 1 girl) with a mean age of 7.4 ± 4.3 months (range 19 days–24 months) and mean weight of 8.3 ± 1.7 kg (range 3.5–13.7). Placement of the SA was successful in 93/105 children (89%). Inability to achieve lumbar puncture (cerebrospinal fluid was not obtained) meant that SA was abandoned in seven (7%) patients and GA was administered. In five patients in whom SA was successful and surgery was begun, 5/93 (5%) required conversion to GA: two because of evisceration of intestine through large hernia defects related to coughing and abdominal irritation, two because of lack of motor blockade despite an adequate sensory block, and one because of an inability to place an intravenous catheter in the lower extremities (required per SA protocol). If necessary, an intravenous catheter can be placed in the upper extremity, but this must be weighed against the fact that the block has already been placed and is of limited duration. Overall, SA was successful (SA was placed and surgery was completed without conversion to GA) in 88/105 children (84%). No additional sedation and no systemic anesthetic agents were required in 75/88 children (85%). The average time required to place the SA was 3.8 ± 2.7 min (range 1–12). The average time for the surgical procedure was 38.3 ± 23.1 min (range 10–122). No patient required conversion to GA because of recession of block. There were no surgical complications.

Discussion/conclusions
SA is a safe and efficacious technique for routine pediatric urological procedures. SA should be considered for cases such as neonatal torsion or patients with significant cardiac or pulmonary comorbidities when the risks of GA are often weighed against the risks of non-intervention.

[1] Clinical prize winner.

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Introduction

Spinal anesthesia (SA), also known as intrathecal or subarachnoid block, is the deposition of local anesthetic directly into the cerebrospinal fluid, resulting in dense surgical anesthesia inferior to the T8-9 dermatome. This technique is used widely in adult anesthesia and surgery as an alternative to general anesthesia (GA), but its use in infants and children has waxed and waned despite an established safety record.

Over the past 10 years, concern has mounted that anesthetics may have deleterious effects on the developing brain. This concern has arisen primarily from studies in neonatal and juvenile animals, which have consistently shown increases in apoptosis after anesthesia exposure [1—3]. In addition, parental anxiety with regard to a surgical procedure is often directed more at the idea of GA as opposed to the surgical procedure itself. Many urologic procedures are elective in nature and tend to be short in duration. Thus, patients presenting for urologic surgery represent an ideal population in which alternative options to potentially decrease the morbidity of GA should be investigated.

As a result of these concerns, we began a SA program at our institution and herein we present our initial experience.

Materials and methods

With the start of the spinal anesthesia program, a prospective data base was initiated as part of a departmental QI project. The current study was based on a retrospective review of that data base and hence was considered IRB-exempt. We then queried this database to determine demographics, procedure performed, time required for placement of the spinal anesthetic, length of surgery, success of lumbar puncture, success of attaining adequate surgical anesthesia, need for supplemental systemic sedation, conversion to GA, and perioperative complications.

Patient selection

Patients were considered to be potential candidates for SA if they required urological surgery expected to last less than 90 min. We initially restricted SA to children younger than 6 months of age, but with experience, increased to 12 months of age and higher.

Technique for SA

In general, patients undergoing SA do not require an intravenous catheter before the spinal block is placed. Local anesthetic cream (LMX cream) is applied to the lumbar spine approximately 30—45 min prior to the needle procedure to minimize patient discomfort. The procedure is performed under sterile conditions with the child in the sitting position. The child is gently restrained as shown in Fig. 1.

We use a pre-prepared, sterile SA kit that was manufactured specifically for infant and child SA (Cardinal Health, Dublin, OH, USA). The kit contains sterile preparation solution, a fenestrated drape, and syringes that are used to draw up medications required for SA. The intrathecal space is accessed using either a 1.5 inch, 22-gauge or a 1 inch, 25-gauge spinal needle (Becton Dickinson, Franklin Lakes, NJ, USA), depending on the anesthesiologist's preference and the size of the patient. Access to the intrathecal space is confirmed when cerebrospinal fluid is returned. Local anesthetic alone can be used successfully for SA in infants and children; however, we used a cocktail of medications designed to maximize block duration and postoperative analgesia. The local anesthetic used in this series was preservative-free bupivacaine, 0.5%, 0.2 mL/kg (1 mg/kg). We recommend a maximum dose of 1 mL (5 mg) bupivacaine in most patients. For longer procedures or larger children, a higher total volume can be used (1.2 mL, or 6 mg). When using larger volumes, the anesthesiologist must be even more vigilant as to the signs of high block. Signs of high block include respiratory compromise, lack of arm movement, and bradycardia. To prolong the surgical block and maximize postoperative analgesia, each syringe was washed with 1:1000 epinephrine prior to filling with local anesthetic (with the goal of providing an epinephrine dose of 5 mcg/mL), and clonidine, 1 mcg/kg. Two syringes are prepared in the event that one is dropped or becomes contaminated.

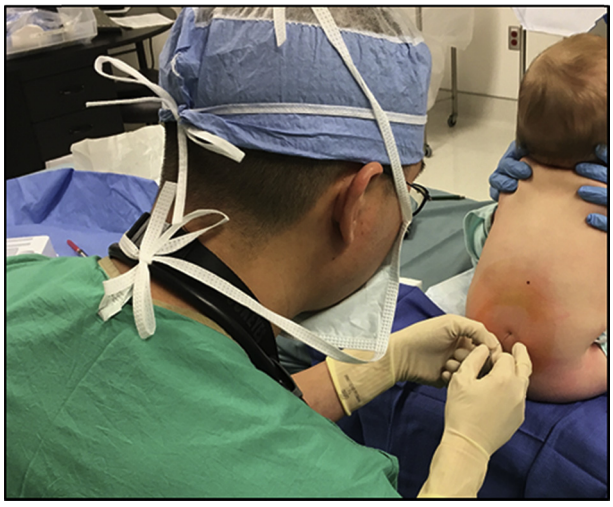

Figure 1 Positioning for spinal anesthetic.

Following the block, the patient is placed in the supine position, taking care not to elevate the legs and back. Although the injected agent is isobaric, there is the potential it may migrate more proximally leading to a higher anesthetic level than desired. Monitors are applied (lower extremities) and a peripheral intravenous catheter is placed in the lower extremity, taking advantage of the sensory block. Most children exhibit dense sensory and motor blockade, but we occasionally place a piece of tape across the distal thighs to minimize leg movement that may compromise operating conditions. The child is then prepped and draped as per routine and the surgical procedure performed.

As a result of deafferentation caused by SA, many children will fall asleep on their own shortly after the block takes effect. If the child is fussy, a pacifier dipped in Sweet-

Ease (sucrose 24%) can be provided. In cases when soothing measures fail, small doses of intravenous sedatives, such as fentanyl and dexmedetomidine, can be administered with very little risk of excess respiratory depression. Usually these measures suffice, but if the surgeon deems the operative conditions suboptimal for satisfactory completion of the operation, the procedure may be easily converted to GA.

Patients typically also received a surgeon-administered penile, ilioinguinal block, or field infiltration as appropriate with 0.25% bupivacaine for postoperative pain management. In the majority of cases, the SA itself contains less than 1 mg/kg bupivacaine, so at least 1.5 mg/kg more can be administered without concerns about local anesthetic systemic toxicity.

Postoperatively, children who do not require sedation can safely bypass the post-anesthesia care unit (PACU) and proceed to phase II/step-down care, unless the child requires hospital admission for another reason. Of note, significant controversy exists regarding whether ex-premature infants should be discharged after SA without sedation given the risk of postoperative apnea. At present, our institution requires any ex-premature infant who does not meet conventional discharge criteria for post-gestational age to be admitted for overnight observation, even when SA alone was used. Children are discharged home on alternating doses of ibuprofen and acetaminophen.

Ethics statement

With the start of the spinal anesthesia program, a prospective data base was initiated as part of a departmental QI project. The current study was based on a retrospective review of that data base and hence was considered IRB-exempt.

Results

SA was attempted in 105 consecutive children (104 boys, 1 girl) with a mean age of 7.4 $\pm$ 4.3 months (range 19 days—24 months) and mean weight of 8.3 $\pm$ 1.7 kg (range 3.5—13.7). Procedures performed (all patients) included circumcision/circumcision revisions (31), hidden penis repair/circumcision (22), chordee release/circumcision (9), distal hypospadias (8), orchidopexy (12), hernia/hydrocele repair (15), inguinal exploration for cryptorchidism (2), scrotal exploration for perinatal torsion (4), and labial abscess drainage (1). Placement of the SA was successful in 93/105 children (89%). Inability to achieve lumbar puncture (cerebrospinal fluid was not obtained) meant that SA was abandoned in seven (7%) patients and GA was administered. In five patients in whom SA was successful and surgery was begun, 5/93 (5%) required conversion to GA: two because of eviscer-ation of intestine through large hernia defects related to coughing and abdominal irritation, two because of lack of motor blockade despite an adequate sensory block, and one because of an inability to place an intravenous catheter in the lower extremities (required per SA protocol). If necessary, an intravenous catheter can be placed in the upper extremity, but this must be weighed against the fact that the block has already been placed and is of limited duration. Overall, SA was successful (SA was placed and surgery was completed without conversion to GA) in 88/105 children (84%). No additional sedation and no systemic anesthetic agents were required in 75/88 children (85%). The average time required to place the SA was 3.8 $\pm$ 2.7 min (range 1—12). The average time for the surgical procedure was 38.3 $\pm$ 23.1 min (range 10—122). No patient required conversion to GA because of recession of block. As a result of the success of the program, we offered SA to five patients older than 12 months of age. Two of these five received sedation (oral midazolam premedication and intravenous sedation) for the spinal procedure itself specifically because of their age (both were 24 months of age). There were no surgical complications. One child underwent successful SA and was discharged home after surgery, but was readmitted the following day with decreased oral intake. The admitting physician noted that the child appeared to have a sunken fontanelle. His neurologic exam was normal, but given the history of recent SA, a spinal ultrasound was ordered, which revealed a small cerebrospinal fluid leak. These leaks are common after lumbar puncture, with radiological studies confirming their presence up to 100% of the time [4]. In most cases, these fluid collections are asymptomatic and require no treatment. This patient received intravenous fluid therapy and was discharged the following day without further management. We speculate that the patient's postoperative presentation was unrelated to the spinal anesthetic.

Discussion

In this series, we have shown that many of the more commonly performed procedures done by pediatric urologists can be undertaken under SA alone. Indeed, 81% of our patients received no systemic agents during the course of their operation. The operative conditions were adequate for successful completion in 84% of the procedures and we did not find having an "awake" child to be a hindrance.

This has immense ramifications. First, our impression is that parents are enthusiastic about the SA as an alternative to GA. Although GA is very safe, we have found that offering an alternative that obviates the need for airway management and sedation relieves much of their anxiety. Second, it may eliminate age as a factor when making a decision to perform an operation or not. As an example, neonatal torsion is a controversial issue, where one traditionally has had to weigh the risk of GA in a newborn with the risks of non-intervention. In this series, we had four boys with delayed referrals for neonatal torsion and surgical exploration was performed at less than 2 months of age. The use of SA may tip the controversy in favor of early intervention as the risks of neonatal GA may be obviated. Third, there are major advantages with regard to resource utilization. Multiple studies have suggested significant benefits with respect to cost and operating room (OR) resources used. The average time to induce SA was found to be 10 min in one large series, with an average time from completion of surgery until the patient left the operating room of 6 min [5]. OR times have been shown to be significantly shorter when SA was used compared with GA [6]. In addition, SA is associated with a 54% reduction in cost when compared with GA and a more rapid patient

turnover rate, which was associated with further reduction in costs [7].

The first use of SA in a pediatric patient was reported by August Bier in 1899, when the technique was used in an 11-year-old for excision of a thigh mass [8]. In 1901, Bainbridge reported a case series of infants in children in whom SA had been successfully used [9]. Despite the widespread use of SA in adults, the technique never gained great popularity in pediatric patients until the 1980s when it was shown to be a suitable alternative to GA in the high-risk, former preterm neonate [10—15]. In this population, SA was used as a means of reducing the incidence of postoperative complications, particularly apnea and respiratory insufficiency, which were noted following general inhalational anesthesia [16]. However, once again the enthusiasm waned as the risk of apnea was shown to be less likely when newer inhalational anesthetic agents were introduced into clinical practice [17,18].

SA has an extensive and consistent record of safety and efficacy. Generally speaking, it can be used as the sole anesthetic in many elective procedures that are performed in neonates, infants, and children. Because SA produces reliable anesthesia inferior to the T6-8 dermatome, it is primarily used in procedures involving the lower body (lower extremities, genitalia, lower abdomen). However, SA has been used for upper abdominal procedures, and has even been used successfully for repair of patent ductus arteriosus in intubated intensive care unit patients [19]. The nature of this "single-shot" technique means that the duration of anesthesia is limited. Available evidence suggests that the duration of SA blockade in children is highly variable. Generally, however, surgical anesthesia can be provided for 70—80 min in most patients. However, when adjuncts such as epinephrine or clonidine are added to the local anesthetic, the block can be extended to as long as 110—120 min [10,20—22]. Our experience in this series confirms these results.

A major benefit of SA is safety as it can be performed in children with few if any of the adverse effects that are seen in adults, such as hypotension, bradycardia, and respiratory insufficiency leading to oxygen desaturation and the need for airway intervention. It is likely that this is because neonates and infants possess a relatively underdeveloped autonomic nervous system and a relatively high per-kilogram cerebrospinal fluid volume. Available evidence supports the perceived low incidence of cardiorespiratory adverse events in infants undergoing SA. One large series (>1500 patients) in which SA was used exclusively showed extremely low rates of bradycardia (1.6%) with no other adverse systemic effects [5]. A systematic review of the literature showed "moderate-quality" evidence that SA without sedation decreases the risk of postoperative apnea by up to 47% [23]. Finally, "high spinal," or unintentionally excessive height of spinal block level, also has been shown to be extremely rare (0.6%) [5].

Recently, based on results from preclinical studies and retrospective cohort studies in children, concern has been expressed on the potential impact of various anesthetic agents on future neurocognitive development. Many of these studies suggest long-term neurocognitive effects of GA during the neonatal period and in infancy [24—26]. In addition, studies in neonatal and juvenile animals have consistently shown increases in apoptosis after anesthesia exposure [1—3]. Although newly published prospective trials in children are reassuring [27,28], the data are far from conclusive. As data in humans have proved equivocal, it is not yet possible to draw clear conclusions as to whether anesthetics are neurotoxic in children.

For this reason, alternatives to prototypical anesthetic regimens have been actively sought. SA is ideal for this purpose as it usually requires little or no sedation, and is most easily implemented in children younger than 12 months of age, who are likely to be the most vulnerable to putative neurotoxic insults. SA is more effective than GA or epidural anesthesia at blunting the neuroendocrine response to surgery, which has been implicated in the pathogenesis of anesthesia-induced neurotoxicity [29]. Because of the unique characteristics of infants (minimal stranger anxiety, ease of performance of SA, lack of hemodynamic instability after block placement), SA can be used to perform surgery on awake infants, thereby limiting or eliminating the need for sedative medications that may be neurotoxic.

Age is one of the primary determinants of risk in children undergoing GA, with age being inversely related to anesthetic risk [30]. Additionally, airway management is often required in this population when GA is used. Failure of airway management in infants has been associated with severe complications, including cardiac arrest and death [31]. SA, in most cases, allows avoidance of GA, sedation, and airway management entirely.

Although SA is not a difficult technique to perform, the care of an awake child in the operating room and the perioperative care of a child who has had neuraxial anesthesia without sedation can present difficulties. For example, while most children fall asleep immediately after placement of the SA, some do not. In our experience, the older the child, the more likely he or she is to be fussy despite an excellent block. In this instance, a patient surgeon and anesthesiologist are paramount. In most cases, the passage of time is all that is required to allow the child to become calm. Of course, one must balance patience with the knowledge that SA produces surgical anesthesia of limited duration. Even in the case when a child needs mild sedation, SA offers the alternative of avoidance of airway management, avoidance of supplemental oxygen, and a significant reduction in the need for systemic sedatives. In rare instances, SA produces an excellent sensory block, but an inadequate motor block, leading to leg movement that can interfere with operative conditions. Even when this occurs, however, gentle restraint with a strap or tape often allows the operation to proceed without difficulty. Finally, our opinion is that implementation of a significant change in practice requires a multidisciplinary approach that allows concerns from all involved parties to be considered. In our experience, collaboration and education in advance prevent this, and allow all participants to appreciate the obvious advantages that SA affords.

Conclusions

We have demonstrated that many of the typical pediatric urological procedures performed may ideally be performed

under SA. These procedures include those taking place below a T8-9 level and of relatively short duration (<90 min). Families are relieved to avoid GA and the procedures may be performed more safely, obviating the need for airway management and often avoiding any systemic agents whatsoever.

Conflict of interest

None.

Funding

None.

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