Regional anaesthesia in paediatric practice

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There are several advantages to using regional anaesthesia alone or combining a light general anaesthetic with a regional technique in the paediatric patient. The most significant advantage, as demonstrated by several authors, is postoperative pain relief.¹⁻⁷ Other postoperative advantages include: earlier ambulation and discharge,¹ decreased narcotic requirements,^{1,2,7} decreased need for non-narcotic analgesics following discharge,⁵ and a more rapid return to the child's usual bright and alert state.⁷ On the other hand, there are some possible disadvantages to regional anaesthesia. Such techniques require special skills and training which are not available to all anaesthetists. Furthermore, when used in conjunction with a general anaesthetic many of the regional techniques require the help of an associate. One anaesthetist is responsible for maintaining a safe general anaesthetic while the other is responsible for block placement. Finally, by combining a regional technique with a general anaesthetic one may be exposing the child to the risks and complications inherent in both. This fear, however, may be more a theoretical consideration than a practical one.

Application, complications, and parental acceptance of regional anaesthesia techniques in children

We reviewed the anaesthetic records from Children's Hospital National Medical Center of all children who had had a regional technique as a part of their total anaesthetic management between July 1, 1982 and June 30, 1984. The 687 children studied ranged in age from neonates to young adults. More than ten per cent were less than one year of age and 60 per cent were less than six years old. Ninety per cent of the children had both a general anaesthetic and a regional block; the remainder had a block technique alone or in combination with intravenous sedation. The most popular block was the "kiddie caudal," which was used in 491 cases (71 per cent). The majority of these caudals were used to provide supplemental operative anaesthesia and postoperative analgesia for male genitourinary procedures, such as circumcisions, orchidopexies, hypospadias repairs, and hydrocoelectomies. Postoperative interviews or chart reviews failed to detect any complications resulting from the 687 regional blocks.

More than half of the regional blocks had been administered to ambulatory surgical patients whose total recovery time was frequently less than four hours. In order to

exclude the possibility that block-related complications occurred at home following discharge, we selected at random 200 families from this pool of 687 children for a follow-up telephone interview. The interview was held from three to nine months after completion of the anaesthetic. Not a single latent complication was detected. Furthermore, 96 per cent of the parents were satisfied with the anaesthetic management which their child had received, and 90 per cent would allow their child to have another regional anaesthetic.⁸

Spinal anaesthesia for high-risk neonates, infants, and children

The use of spinal anaesthesia in children is not new. The largest published series of spinal anaesthetics in infants and children was reported by Tyrrell-Gray in 1910.⁹ He reported one intraoperative death in a gravely ill child in this series of 300 spinal anaesthetics. The child appeared to have sustained a respiratory arrest secondary to the combination of a high level of a spinal anaesthesia and parenterally administered morphine. Most of Tyrrell-Gray's patients underwent procedures involving the abdomen and lower extremities. Based on this experience, he concluded: "The advantages to be gained by the use of spinal anaesthesia have so far impressed me that I am convinced it will occupy an important place in the surgery of children in the future."

Spinal anaesthesia, however, fell into disuse until around 1970, when Eather recognized the advantages of regional anaesthesia in children.¹⁰ Abajian has recently pioneered the use of spinal anaesthesia as the anaesthetic of choice in high risk neonates.¹¹ He has performed over 225 such anaesthetics in infants and neonates without major complications.¹¹

Welborn, Liu, and Steward have shown recently that preterm infants are more prone to life-threatening apnoea, bradycardia and periodic breathing following general anaesthesia than are full-term infants.¹²⁻¹⁴ It has not been demonstrated in a controlled manner that these high-risk neonates are less likely to develop apnoea or bradycardia when spinal anaesthesia is used; however, such compli-

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cations have not been detected by Dr. Linda Rice (Portsmouth Naval Hospital), Dr. J. Christian Abajian (University of Vermont), or by this author following spinal anaesthesia. This unpublished cooperative series involved more than 400 spinal anaesthetics, 200 of which were administered to high-risk infants and neonates (personal communication). In addition, these researchers have not noted any hypotensive episodes nor have they detected any long-term complications.

How to perform a spinal block in infant and neonates

Ketamine as an adjunct agent

We use ketamine $1\text{--}2\text{ mg}\cdot\text{kg}^{-1}$ IM and atropine $0.015\text{--}0.02\text{ mg}\cdot\text{kg}^{-1}$ as adjunct agents in infants older than 52 weeks conceptual age. Conceptual age is defined as the sum of the gestational age and the post-birth age of an infant; e.g., a three-week-old preterm neonate who had a gestational age of 28 weeks, would have a conceptual age of 31 weeks. Children less than 52 weeks conceptual age usually do not receive ketamine sedation.

Patient positioning, needle selection, and lumbar puncture

The child is turned into the lateral position and the neck is extended. Gleason has shown that the optimal positions for spinal tap in preterm infants are either the lateral position with neck extension or the sitting position.¹⁵ Flexion of the neck in the lateral position caused a 28 mmHg decrease in transcutaneous PO_2 .¹⁵ We use a standard 22-gauge 1.5-inch disposable stylet spinal needle. Blaise and Roy have suggested that the 27-gauge hollow unstylet needle from a 24-gauge Angiocath® set can be used in place of a stylet spinal needle.¹⁶ Skin plugs can be transplanted into the subarachnoid space if one uses a non-stylet needle.^{17,18} One must weigh the risk to benefit ratio of using a 27-gauge needle, which minimizes the risk of a post-lumbar puncture headache, against the remote possibility that the puncture will result in the formation of an epidermoid tumour. The spinal cord should not extend below the level of $\text{L}_3\text{--}\text{L}_4$ in either the infant or neonate; therefore, a mid-line approach at $\text{L}_4\text{--}\text{L}_5$ or $\text{L}_5\text{--}\text{S}_1$ is recommended to minimize the risk of spinal cord injury. One may not feel a "pop" with dural puncture. The needle is advanced slowly, and the stylet is frequently removed in order to watch for the free-flowing return of cerebrospinal fluid.

Drug selection, dosage and duration of blockade

The dosage required to produce a predictable level of spinal anaesthesia remains controversial. Abajian suggests 0.2 ml of one per cent tetracaine in 0.2 ml of ten per cent dextrose with 0.02 ml of epinephrine $1:1000$.¹¹ Rice¹⁹ recommends tetracaine $0.4\text{ mg}\cdot\text{kg}^{-1}$ in 0.04 ml

kg^{-1} of ten per cent dextrose for infants weighing from 800 gm to 10 kg. The Rice mixture contains a "wash" of epinephrine. This mixture produces between 75 and 95 minutes of surgical anaesthesia.¹⁹ Spinal anaesthesia produces venous dilatation and analgesia in the lower extremities, which facilitates catheter placement in either a saphenous or foot vein.

Monitoring and helpful hints

Vital signs are monitored with a blood pressure cuff, precordial stethoscope, and ECG monitor. In addition, we routinely use a pulse oximeter to detect hypoxia and, if supplemental oxygen is being used, to prevent hyperoxia. One may find it helpful to restrain the infant's arms by applying loosely tied gauze to his/her wrists and securing the other end to the operating table. Frequently, a pacifier is all one needs to keep the infant entertained and cooperative during surgery. Older and more vigorous infants will occasionally require ketamine sedation. In such instances, we suggest 0.5 to $1.0\text{ mg}\cdot\text{kg}^{-1}$ of ketamine IV.

Patient follow-up

The parents of all children who receive spinal anaesthesia for surgery at Children's Hospital National Medical Center are contacted by telephone 24–48 hours following surgery to ensure that the child is free of latent complications and to assess parental satisfaction with the anaesthetic. To date we have not detected any latent complications, nor have any parents reported dissatisfaction with their child's spinal anaesthetic.

An introduction to caudal anaesthesia in infants and children

Caudal anaesthesia is the most useful regional technique for postoperative pain relief in children. We have found the caudal block to be useful for providing intraoperative anaesthesia and postoperative analgesia in children undergoing circumcision, orchidopexy, hernia repair, hydrocoelectomy, rectal dilatation, and lower extremity orthopaedic procedures when used in conjunction with a light general anaesthetic. The block is easy to perform and does not usually require the help of an assistant. Only a light plane of general anaesthesia is required in conjunction with a caudal block to maintain adequate surgical anaesthesia. The time spent performing the block prior to surgery will be regained at the completion of surgery because the patient awakens more quickly from the light general anaesthetic. If not otherwise indicated, intubation is not necessary in children over one year of age as long as the caudal block is functioning. This will certainly obviate the need to be concerned about the possibility of developing postintubation croup.

Kay reported the use of caudal anaesthesia as an adjunct

to general anaesthesia in over 300 boys having outpatient circumcision.²⁰ The local anaesthetic used in this study was bupivacaine 0.5 per cent with epinephrine 1:200,000. Excellent pain relief was obtained following surgery in all but a dozen boys. McGowen reported 500 cases of caudal anaesthesia for children under ten years of age.²¹ In his series he reports complications secondary to lidocaine toxicity and high caudal blocks (total body caudals).²¹ He also reported four perioperative deaths.²¹ Most of McGowen's complications occurred in children who were undergoing upper abdominal operations. In reviewing this article one must remember that the series is from Salisbury, Zimbabwe, and that almost all the children were African. Many were gravely ill prior to surgery, and many became hypothermic during surgery. Even more complications and perioperative deaths might have occurred if general anaesthesia had been used.

A recent study at Children's Hospital National Medical Center documents the safety of "kiddie caudals." In this study both short- and long-term complications were scrutinized following caudal block placement in 1150 consecutive cases.²² The children in this study ranged in age from one month to 18 years. All blocks were performed following the induction of general anaesthesia either prior to the onset of surgery or at its completion. Bupivacaine hydrochloride solution (maximum dose 3 mg·kg⁻¹) was used in all cases. Frequent aspiration was used to reduce the risks of either inadvertent intravascular or subarachnoid injections. Epinephrine was not routinely used and test-dosing was not employed. Sixty-five per cent of the blocks were performed on ambulatory surgery patients. Caudal blocks were used most frequently in conjunction with genitourinary procedures (81 per cent) that included: orchidopexy, circumcision, hydrocoelelectomy, and hypospadias repair. All children had a post-anaesthetic visit or record review within 48 hours of their surgery. In addition, 130 randomly selected parents were surveyed one to several months following surgery in order to determine if their child had sustained any latent block-related complications. No intravascular injections, toxic drug reactions, hypotension or other perioperative complications were detected in any patient in this series. No latent anaesthesia related complications were reported.

How to perform a "kiddie caudal"

Patient position, landmarks and needle placement

Following the induction of general anaesthesia the child is turned into the lateral position. Palpation of the sacral hiatus reveals its upper concave margin bounded by the two prominent sacral cornua.²³ After preparation of the skin with an antiseptic solution, a 23-gauge hypodermic needle is inserted at a 60° angle until the sacrococcygeal membrane is pierced.²³ A distinct "pop" should be felt as

the needle enters the sacral canal. The needle is then advanced an additional 2.0 mm in a plane parallel to the spinal axis. Following aspiration the local anaesthetic is introduced into the epidural space.

Drug selection, dosage and toxic limits

There are several formulae for determining the volume-to-level relationship for caudal anaesthesia in infants and children. We prefer the dosage schedule reported by Takasaki which is 0.05 ml/kg/spinal segment.²⁴ This formula was derived from Takasaki's experience with caudal blockade in 250 children, of whom 163 were less than two years of age. The surgeries performed required anaesthesia at levels ranging from L₁ to T₅. There were no total body caudals. We have used this formula in over 1150 caudals,²² and 86 per cent of our blocks provided satisfactory postoperative analgesia.⁸ Eyres has established a safe dosage of bupivacaine in infants and children.²⁵ He found that caudally administered bupivacaine 0.25 per cent in a dosage of 3 mg·kg⁻¹ produced plasma levels which were well below accepted toxic limits.²⁵ We have performed more than 1150 caudal blocks with bupivacaine and we have not detected any toxic side effects.²²

Furthermore, we have shown in a recent study that caudally administered 0.25 per cent bupivacaine provided just as effective postoperative analgesia as did two more concentrated solutions which contained 0.30 and 0.375 per cent bupivacaine.²⁶ This double-blind study involved 53 ASA physical status I or II children, ages 4–11 years undergoing ambulatory circumcision, orchiopexy, hydrocoelelectomy, and inguinal hernia repair. The caudal blocks were placed after the induction of general anaesthesia, but prior to the onset of surgery. Forty-eight of the blocks met the study criterion for satisfactory intraoperative analgesia. The five blocks which failed to meet the study criterion were repeated by an attending anaesthetist at the completion of surgery, and these five cases were eliminated from data analysis. All 48 blocks provided effective postoperative analgesia; however, there was a tendency for the more concentrated solution, 0.375 per cent, to delay discharge from the hospital by an average of 41 ± 29 minutes. Therefore, there does not appear to be any advantage to using more concentrated solutions such as 0.30 and 0.375 per cent bupivacaine.

Monitoring and helpful hints

We monitor all children with a precordial stethoscope, blood pressure cuff and ECG. In order to ablate swallowing and subsequent gastric distension we maintain an inspired halothane concentration of 0.5 per cent in conjunction with 70 per cent nitrous oxide throughout all mask cases in which the caudal block is functioning properly. Children usually awaken from this light general an-

aesthetic prior to arrival in the recovery room and remain free of pain and discomfort for three to four hours.

Extremity blocks

The basic techniques used in performing extremity blocks in infants and children are similar to those used in adults; however, there are two major differences. Children are less likely to cooperate with block needle placement while they are awake than are adults, and it is highly unlikely that they will be able to understand the concept of reporting a paraesthesia. Infants cannot be expected to cooperate at all. The nerve stimulator is a useful, if not an essential means of providing feedback in these circumstances. The principles of its use have been described by Wright.²⁷

Indications

Arm blocks can provide muscle relaxation and analgesia for the reduction of simple fractures and anaesthesia for the repair of lacerations and compound fractures. A femoral nerve block, alone or in conjunction with a lateral femoral cutaneous nerve block, can provide anaesthesia for muscle biopsies in children suspected of having either malignant hyperthermia or a glycogen storage disease.²⁸ Similarly, the inguinal paravascular approach (three-in-one block) can provide anaesthesia for diagnostic muscle biopsies with just a single needle stick. In addition, the paravascular block can be used for operations such as split thickness skin grafting to the thigh. In conjunction with a sciatic nerve block it can provide anaesthesia for all lower extremity surgery.

Agents

A combination of lidocaine 0.5 per cent, tetracaine 0.12–0.2 per cent and epinephrine 1:200,000 provides effective anaesthesia and analgesia for six to eight hours. The long duration of neuroblockade is due to the tetracaine. This combination works well when performing blocks with a nerve stimulator because of the rapid onset of the lidocaine; this is not true when one performs the blocks with bupivacaine. Individual drugs can also be used. When compounding, one must remember that the toxicities of the two agents are additive, and dosages must be appropriately reduced.

Techniques

The approaches are similar to the adult methods. They are generally done under intravenous sedation or light general anaesthesia with the aid of a nerve stimulator. The positive lead of the stimulator is placed on the chest wall in order to avoid direct muscle stimulation. The negative lead is placed on the shaft of the block needle.

1 The brachial plexus is best approached with the axillary technique. No paraesthesia is needed as the nerve

stimulator is used to locate the nerves. The appropriate volumes of local anaesthetic agents required to perform this block are outlined in the Table.

- 2 The sciatic nerve can be blocked using the classical posterior approach, but a more peripheral block is much easier to perform in children.²³ The patient is placed in the lateral (Sim's) position. One locates the greater trochanter and the ischial tuberosity by palpation. The sciatic nerve lies midway between these two points in the intramuscular notch. A 22-gauge 3.5-inch spinal needle connected to a nerve stimulator and inserted midway between these landmarks should rapidly elicit dorsi-flexion or plantar-flexion of the foot. In order to confirm that the observed motor activity is due to the tip of the stimulating needle lying in close proximity to the sciatic nerve one injects 1.0 cc of local anaesthetic solution. If all flexion is abolished, it may be assumed that the needle tip is in the correct fascial plane. The block is completed by injecting the total volume of local anaesthetic solution listed in the Table. Motor activity above the knee is most likely the result of direct muscle stimulation and is not a reliable indication that the needle tip is in the correct position.

TABLE Local anaesthetic volumes for peripheral blocks in children

Block	Volume (ml·kg ⁻¹)
Interscalene brachial plexus	0.25
Axillary brachial plexus	0.33
Sciatic nerve	0.15–0.2
Inguinal paravascular (three-in-one block)	0.5

- 3 The femoral nerve lies immediately lateral to the femoral artery. If the femoral pulse cannot be palpated, a doppler probe can be used. The nerve also can be located by delivering a maximal transcutaneous stimulus with a blockade monitor. The probe is placed along the inguinal ligament between the anterior superior iliac spine and the pubic tubercle. A twitch of the quadriceps muscle reveals the approximate location of the underlying femoral nerves; by gradually reducing the voltage, one can accurately determine its location. The femoral nerve block is performed with a 22-gauge 1.5-inch needle and a nerve block stimulator that has been set on a low voltage output. As the needle is advanced at a 45 degree angle, the twitching of the quadriceps muscle group increases dramatically as the needle "pops" through the fascia of the femoral nerve compartment. If the injection of 1 to 2 ml of local anaesthetic solution abolishes the quadriceps motor activity, it can be assumed that the block needle is in the correct fascial plane. The block is completed by

injecting the appropriate volume of local anaesthetic solution for either the femoral nerve block or the paravascular plexus block (Table). If one is performing the paravascular plexus block, digital pressure is applied over the femoral sheath distal to the point of needle insertion. This promotes cephalad spread of the local anaesthetic agent and ensures adequate blockade of the obturator and lateral femoral cutaneous nerves as well as the femoral nerve.

Complications

The major risk is systemic toxicity if maximum dosages are exceeded.

Infiltration blocks

Two other regional techniques, the ilioinguinal/iliohypogastric nerve block and the ring block of the penis, are particularly useful in children.

Ilioinguinal and iliohypogastric nerve block

This block is used as an alternative to caudal anaesthesia for inguinal hernia repair and orchidopexy. The nerves to the groin can be blocked by infiltrating the abdominal wall muscles medial to the anterior superior iliac spine with 0.25 per cent bupivacaine. This is done in conjunction with general anaesthesia and substantially reduces intraoperative anaesthetic requirements and virtually eliminates postoperative pain. In a recent prospective study, 44 boys who were having ambulatory surgery were randomly assigned to one of three groups for control of postoperative discomfort: (1) ilioinguinal/iliohypogastric block with 0.25 per cent bupivacaine, (2) caudal block with 0.25 per cent bupivacaine, and (3) control (no block). All surgery was performed under halothane, N₂O–O₂ anaesthesia; the blocks were placed after completion of the orchidopexy, and while the child was still anaesthetized. In the recovery room a research assistant unaware of group assignment evaluated the severity of postoperative pain and the subsequent need for the narcotic analgesic fentanyl.² In the early phase of recovery, which could apply to either inpatients or ambulatory surgical patients, children who had had a caudal or ilioinguinal/iliohypogastric block had less pain and discomfort than did those who had only general anaesthesia.² In addition, they required significantly less narcotic analgesia.² Children who had received a caudal or ilioinguinal/iliohypogastric block subjectively had less pain and discomfort during their entire postoperative course; however, they did not have less nausea and vomiting.²

Ring block of the penis

A dorsal nerve block of the penis with 0.25 per cent bupivacaine provides excellent pain relief following circumcision or hypospadias repair. However, this block

requires special skill, and may cause haematoma formation if either the dorsal arteries or vein are inadvertently punctured while injecting deep to Buck's fascia. An excellent alternative is simply to inject a subcutaneous ring of 0.25 per cent bupivacaine around the base of the shaft of the penis.¹ This requires no special skills, and intravascular injections can be avoided by using a 23-gauge needle and making frequent aspirations. The block provides excellent adjunct operative anaesthesia and postoperative analgesia for circumcisions.¹

Suggested discharge criteria for in and out surgery

Following ambulatory surgery at the Children's Hospital National Medical Center the same discharge criteria are applied to children who have had a pure regional anaesthesia technique, a combination of regional and general anaesthesia, or only a general anaesthetic. The following criteria must be met prior to all routine discharge, irrespective of the anaesthetic management: all children must ambulate with minimal assistance, consume clear liquids, have minimal nausea and vomiting, and have stable vital signs. If the child has had an upper or lower extremity limb block it is not necessary for sensory or motor function to return prior to discharge. The involved extremity is immobilized in a splint or sling and the parents are informed that the child is unable to feel pain in the blocked arm or leg. Children who have had caudal anaesthesia are also eligible to be discharged prior to the regression of their sensory blockade; however, they must be able to ambulate with minimal assistance and be free of postural hypotension. Voiding is not a criterion for discharge at our institution. Prior to the discharge of any child who has residual sensory blockade, parents are told to take the child directly home and keep the child inside until all sensation returns. In addition, contact with either sharp or warm objects must be avoided while the child still has sensory blockade.

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