Adequacy of caudal analgesia in children after penoscrotal and inguinal surgery using 0.5 or 1.0 ml·kg⁻¹ bupivacaine 0.125%

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To determine the optimal volume of bupivacaine 0.125% for postoperative caudal analgesia, we compared the effectiveness of 0.5 ml·kg⁻¹ and 1 ml·kg⁻¹ of bupivacaine 0.125% with 1:200,000 epinephrine in 80 children undergoing penoscrotal and inguinal surgery. The adequacy of caudal analgesia and supplemental analgesic requirements did not differ between the two groups at any time during the first 12 hr after surgery. We conclude that 0.5 ml·kg⁻¹ of bupivacaine 0.125% with 1:200,000 epinephrine is as effective as 1 ml·kg⁻¹ of the same solution and recommend its use for penoscrotal surgery. The evidence for ss of 0.5 ml·kg⁻¹ of bupivacaine 0.125% for inguinal owever, is inconclusive because of an insufficient patients studied.

terminer le volume optimal de bupivacaine 0,125% lgésie caudale, nous avons comparé l'efficacité de 0,5 ml·kg⁻¹ et de 1 ml·kg⁻¹ de bupivacaine 0,125% phrine 1:200 000 chez 80 enfants devant subir une nguinale et pénoscrotale. L'efficacité de l'algésie insi que le besoin d'analgésiques supplémentaires nblables dans les deux groupes à tout moment pmières 12 heures post-opératoires. En conclu-sion, une dose de 0,5 ml·kg⁻¹ de bupivacaine 0,125% avec

épinéphrine 1:200 000 est aussi efficace qu'une dose de 1 ml·kg⁻¹, et nous recommandons son utilisation dans la chirurgie pénoscrotale. Cependant, l'efficacité d'une dose de 0,5 ml·kg⁻¹ de bupivacaine 0,125% dans la chirurgie inguinale est non concluante à cause d'un nombre insuffisant de patients étudiés.

The volume of anaesthetic solution is an important determinant of the level of analgesia achieved with caudal blockade. Although several mathematical formulae have been developed to predict the volume of solution required for a specific level of caudal blockade,¹⁻⁷ we found that the following simpler regimens could also be used: (a) a smaller volume, 0.5 ml·kg⁻¹, for penile surgery and (b) a larger volume, 1.0 ml·kg⁻¹, for inguinal surgery. Armitage reported the use of similar volumes of local anaesthetic without toxicity in over 1,100 cases.⁸ However, we are unaware of any randomized, double-blind studies establishing the efficacy of these volumes of local anaesthetic to provide adequate postoperative analgesia after penile and inguinal surgery. In our initial experience with caudal blockade, we found that 0.75 ml·kg⁻¹ bupivacaine (0.125% solution) with epinephrine was satisfactory for both penile and inguinal surgery (where up to 12 roots were blocked) although 55% of the patients required codeine within the first 12 hr after surgery.⁹ More recently, we noted that a volume as small as 0.5 ml·kg⁻¹ was effective for penile surgery, where a lower sensory level provided adequate analgesia. To determine whether our clinical observations were accurate, we compared the extent and duration of analgesia after the administration of bupivacaine 0.125% in volumes of 0.5 and 1.0 ml·kg⁻¹ in children undergoing penile and inguinal surgery.

Key words

ANAESTHESIA: paediatric – bupivacaine;
POSTOPERATIVE ANALGESIA, CAUDAL: codeine;
PROCEDURES: penoscrotal, inguinal.

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Methods

This prospective, randomized, double-blinded study was approved by the institutional ethics committee. Informed

TABLE Demographic data

	Volume of bupivacaine*	
	0.5 ml · kg ⁻¹	1.0 ml · kg ⁻¹
Age (yr)	3.69 ± 1.94	3.91 ± 1.89
Weight (kg)	16.7 ± 4.7	16.2 ± 4.18
Procedures (number)		
– Orchidopexy or hernia repair	13	12
– Hypospadias or circumcision	27	28

Data are mean ± S.D.

*Bupivacaine 0.125% with 1:200,000 epinephrine.

written consent was obtained from the parents of 80 children between one and ten years of age scheduled for penoscrotal and inguinal surgery (as inpatients). Patients were excluded from the study if they had a history of an allergic reaction to local anaesthetics, bleeding diathesis, acetylsalicylic acid ingestion in the preceding week or preexisting neurological or spinal cord diseases. All patients were of ASA physical status 1 or 2, fasting and unpremedicated. Anaesthesia was induced with an intravenous technique and maintained with a volatile anaesthetic with or without a muscle relaxant. Narcotics were not administered before or during surgery.

A caudal block was administered at completion of surgery using a technique described previously.⁹ The patients were randomized to receive either 0.5 ml · kg⁻¹ or 1.0 ml · kg⁻¹ of bupivacaine 0.125% with 1:200,000 epinephrine. The 0.125% solution was prepared by diluting plain bupivacaine 0.25% with normal saline without preservatives. Epinephrine was added to each solution to provide a final concentration of 1:200,000. After awakening from anaesthesia the patient was transferred to the recovery room.

Postoperative pain, lower extremity motor function and urinary retention were evaluated at 1, 2, 4 and 12 hr by blinded observers. Pain was assessed with a scoring system described previously.¹⁰ This scoring system assigns a score of zero one or two to each of six variables: blood pressure, crying, movement, agitation, posture and complaints of pain. The pain score is the sum of these six values. Analgesics were administered according to the surgical standing orders at the discretion of the nurses if the pain score exceeded 3. The time intervals from caudal block to administration of supplemental analgesia and to first micturition during the 12 hr following the caudal block were recorded. Motor strength was evaluated on a four-point scale: paralysis (score = 1), movement with gravity (score = 2), passive movement against gravity (score = 3) and forced movement against gravity (score = 4).

Power analysis was performed to determine the number

FIGURE 1 Opioid administration after caudal analgesia.

of patients required in each group. The minimum number of patients required in each group was based on four assumptions: $\alpha_2 = 0.05$; $\beta = 0.20$; $P_1 = 0.65$; $P_2 = 0.90$, where P_1 and P_2 are the proportion of patients who were expected to be analgesic with 0.5 ml · kg⁻¹ and 1.0 ml · kg⁻¹ respectively.¹¹ The number of patients was determined to be 40 per group. Statistical significance ($P < 0.05$) was determined through chi-square analysis with the Yates correction for continuity for nominal data and Student's *t* test for parametric data.¹² Randomization was performed with random number tables.¹²

Results

Eighty patients were studied; 40 received 0.5 ml · kg⁻¹ and 40 received 1.0 ml · kg⁻¹ of bupivacaine 0.125% with 1:200,000 epinephrine. The mean age, weight and type of surgery did not differ significantly between the two groups (Table). One patient in the 0.5 ml · kg⁻¹ group was excluded from the analysis because he required a second surgical procedure within six hours of the caudal block. Four patients did not receive caudal blocks because of aspiration of blood following traumatic entry into the caudal space. These patients were removed from the study and their trial numbers were reassigned to subsequent patients.

The requirement for supplemental analgesia did not differ between the two groups at any time during the 12 hr after the block ($P > 0.05$) (Figure 1). The adequacy of caudal analgesia (i.e., pain score ≤ 3 and no codeine required) did not differ between the two groups at any time (Figure 2). The adequacy of caudal analgesia with 0.5 ml · kg⁻¹ and 1 ml · kg⁻¹ bupivacaine solution did not differ after either penoscrotal or inguinal surgery (Figure 3).

FIGURE 2 Duration of analgesia after caudal block.

FIGURE 4 Return of motor function.

FIGURE 3 Opioid administration and site of surgery.

Thirty-seven of the 39 patients in the $0.5 \text{ ml} \cdot \text{kg}^{-1}$ group and 31 of the 40 patients in the $1 \text{ ml} \cdot \text{kg}^{-1}$ group were able to stand with minimal assistance one hour after administration of bupivacaine ($P = \text{NS}$) (Figure 4). No patient in either group had detectable weakness at 12 hr after the caudal block. The mean ($\pm$ SD) time to first micturition after surgery did not differ between the two groups: $3.6 \pm 1.3 \text{ hr}$ with $0.5 \text{ ml} \cdot \text{kg}^{-1}$ of bupivacaine 0.125% and $4.2 \pm 2.6 \text{ hr}$ with $1 \text{ ml} \cdot \text{kg}^{-1}$ of bupivacaine 0.125%. There were no complications attributed to either the technique or the administration of bupivacaine with the caudal blocks.

Discussion

The effectiveness of caudal blocks for postoperative analgesia is determined by the specific local anaesthetic used, its concentration as well as its volume. It is prudent to use the minimal effective dose of local anaesthetic solution for caudal blockade, since this dose provides a greater margin of safety in case of inadvertent intravascular or subarachnoid injection. In a previous study, we demonstrated that $0.75 \text{ ml} \cdot \text{kg}^{-1}$ of bupivacaine 0.125% with 1:200,000 epinephrine was as effective as the same volume of bupivacaine 0.25% with 1:200,000 epinephrine for postoperative analgesia after urologic surgery.⁹ In the present study we attempted to determine whether we could provide adequate postoperative analgesia with a smaller volume of bupivacaine 0.125%, i.e., $0.5 \text{ ml} \cdot \text{kg}^{-1}$ ($0.625 \text{ mg} \cdot \text{kg}^{-1}$). The maximum serum concentration of bupivacaine after the caudal administration of $2.5\text{--}3 \text{ mg} \cdot \text{kg}^{-1}$ bupivacaine is well below the toxic blood concentration of bupivacaine.^{13,14} However, with unrecognized intravascular injection, toxic blood levels may be achieved with doses of bupivacaine smaller than $2.5 \text{ mg} \cdot \text{kg}^{-1}$.¹⁵ Although the threshold dose of bupivacaine that produces central nervous system side effects after rapid intravascular injection in humans has been reported as $1.6 \text{ mg} \cdot \text{kg}^{-1}$,¹⁵ the dose that produces toxicity in children may be less since the free fraction of bupivacaine may be greater in neonates and infants than it is in adults.¹⁶

A recent study demonstrated that the administration of $1.25 \text{ ml} \cdot \text{kg}^{-1}$ of local anaesthetic in the caudal space resulted in excessive spread of analgesia in 30% of patients. The authors found more appropriate levels of

analgesia with the use of $0.75\text{--}1\text{ ml}\cdot\text{kg}^{-1}$ of anaesthetic solution.¹⁷ By demonstrating the adequacy of caudal analgesia with $0.5\text{ ml}\cdot\text{kg}^{-1}$ of bupivacaine 0.125% with 1:200,000 epinephrine for penile procedures we have effectively decreased the dose of bupivacaine by at least 33%.

Several mathematical formulae have been used to calculate the volume of local anaesthetic required for caudal blockade.¹⁻⁷ These formulae are based on individual variables, including age, weight, length of the spinal column and number of spinal segments to be blocked. Since these formulae require cumbersome calculations that may be subject to error, none has achieved universal clinical acceptance. However, one such formula for effective sensory blockade is lidocaine $0.056\text{ ml}\cdot\text{kg}^{-1}$ for each segment.⁵ If this formula held for bupivacaine as well as for lidocaine, $0.5\text{ ml}\cdot\text{kg}^{-1}$ of local anaesthetic should anaesthetize nine spinal segments or achieve a sensory level of the second lumbar segment. Since testicular and spermatic cord innervation can be traced up to the tenth thoracic segment, we were concerned that $0.5\text{ ml}\cdot\text{kg}^{-1}$ might be inadequate for inguinal and testicular surgery. Warner *et al.* reported that administration of $0.5\text{ ml}\cdot\text{kg}^{-1}$ of bupivacaine 0.25% with epinephrine achieved longer analgesia for penoscrotal procedures than for inguinal procedures (23.3 hr vs 18 hr respectively in children under five years).¹⁸ In the present study 46% of patients undergoing inguinal procedures in the $0.5\text{ ml}\cdot\text{kg}^{-1}$ group were analgesic during the study period, compared with 58% in the $1\text{ ml}\cdot\text{kg}^{-1}$ group ($P = \text{NS}$). On the basis of these incidences of analgesia, an $\alpha_2 = 0.05$ and $\beta = 0.20$ (power of 80%), we determined that we would require at least 273 patients per group to conclude that the proportion of children undergoing inguinal surgery who are analgesic after $1\text{ ml}\cdot\text{kg}^{-1}$ bupivacaine is greater than the proportion analgesic after $0.5\text{ ml}\cdot\text{kg}^{-1}$. The number of patients included in this study, therefore, is insufficient to establish that our findings regarding inguinal procedures are real (i.e., a type II error may have occurred).

Quantitative assessment of pain relief has proved to be difficult in young children. We elected to use the objective pain scale described by Hannallah *et al.*¹⁰ since its validity was recently verified.¹⁹ Using this pain scoring system, Hannallah *et al.* reported a much lower requirement for supplemental analgesia in patients undergoing orchidopexy after caudal or ilioinguinal nerve blocks than in our patients.¹⁰ However, they used a higher pain score threshold to indicate the need for supplemental analgesia than the pain score threshold used in this study (7 versus 3). Furthermore, their patients were observed for a mean duration of only 219 min (3.6 hr), whereas our patients were observed for at least 12 hr postoperatively. Of the patients who received supplemental analgesics in this

study, most required them more than four hours after surgery.

In addition to providing a greater margin of safety in case of inadvertent intravascular injection, a smaller dose of local anaesthetic administered for caudal blockade permits earlier recovery of motor function and bladder function. Residual motor block in an awake child is unpleasant and delays discharge from the recovery unit. It is our practice to delay discharge from the recovery unit until motor strength in the lower extremities has recovered. In this study discharge from the recovery unit was not delayed because of residual motor blockade. In addition, none of the patients required postoperative catheterization for urinary retention.

In summary, our data demonstrate that caudal blockade with $0.5\text{ ml}\cdot\text{kg}^{-1}$ of bupivacaine 0.125% with 1:200,000 epinephrine is as effective as $1.0\text{ ml}\cdot\text{kg}^{-1}$ of the same concentration with respect to the duration of analgesia, pain scores and narcotic requirement after penoscrotal surgery. Larger volumes ($0.75\text{ ml}\cdot\text{kg}^{-1}$ and $1.0\text{ ml}\cdot\text{kg}^{-1}$) of bupivacaine 0.125% are no more effective than $0.5\text{ ml}\cdot\text{kg}^{-1}$ of the same solution. The effectiveness of $0.5\text{ ml}\cdot\text{kg}^{-1}$ of bupivacaine 0.125% for inguinal surgery, however, remains inconclusive.

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