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Lumbar and Thoracic Epidural Anesthesia for Urologic and Upper Abdominal Surgery in Infants and Children

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Regional anesthesia is often used in infants and children.[1,2] Epidural anesthesia is often performed by the caudal route. The spread and pharmacokinetics of bupivacaine administered caudally have already been studied.[3–5] However, high doses of local anesthetics are necessary to obtain an adequate level of analgesia after caudal administration.[3] Furthermore, caudal anesthesia does not permit reinjection of local anesthetics for prolonged intraoperative or postoperative analgesia. Thus, lumbar or thoracic epidural anesthesia with a catheter, as previously described for postoperative analgesia,[6] seemed to us to be a potentially useful anesthetic technique for upper abdominal surgery. The goal of the present study was to evaluate the feasibility and effectiveness of lumbar and thoracic epidural anesthesia to obtain intraoperative and postoperative analgesia. Also, hemodynamic tolerance, spread, and systemic absorption of bupivacaine were studied. Epidural anesthesia was combined with light general anesthesia in infants and children undergoing urologic and upper abdominal surgery.

METHODS

Twenty infants aged 8.5 ± 16.1 (mean ± SD) months (range 3–36) and weighing 6.5 ± 3.6 kg (range 4–12.5) were studied after approval by the Institutional Investigation Committee and parental consent. They were scheduled to undergo surgery for biliary atresia (n = 9) and urologic procedures (nephrectomy, pyeloplasty) (n = 11). All patients had fasted 6 h before anesthesia and were premedicated with atropine 0.01 mg/kg iv. A cardiotachometer triggered by the ECG provided a continuous record of heart rate. Anesthesia was induced with thiopental 10 mg/kg iv over a 1-min period, and endotracheal intubation was performed after administration of pancuronium bromide 0.1 mg/kg iv. Then, all patients received iv phenoperidine 10 μg/kg (nearly 10% less potent than fentanyl). They were mechanically ventilated with 60% N_2O in oxygen. The nine infants scheduled to undergo Kasai's procedure were given maintenance doses of pancuronium bromide 0.025 mg/kg every 60 min. A 22-gauge radial artery catheter or automated blood pressure cuff allowed continuous monitoring of arterial blood pressure. The epidural block was performed with the child in the lateral decubitus position. An 18-gauge epidural minipack (Portex Division, Wilmington, MA) was used. A median approach at the L2–L3 (n = 11) or T9–T10 (n = 9) interspace was used and correct positioning of the needle was ascertained by the loss of resistance method with an air-filled syringe. Then, a 20-gauge epidural catheter was advanced 1.5 cm into the epidural space. The skin–epidural space distance ranged between 7–14 mm at the thoracic level and between 10–18 mm at the lumbar level. Luer-Lock® adapters with bacteriostatic filters were connected to the free end of the catheter. After an aspiration test, a test dose of 0.5 ml (2.5 mg) of 0.5% bupivacaine HCl with epinephrine 1:200,000 was injected, which was followed by an anesthetic dose of 0.75 ml/kg (3.75 mg/kg) of the same solution. The speed of the injection was 1 ml/min. In the nine patients undergoing the Kasai's operation, a second epidural injection of bupivacaine with epinephrine (2.5 mg/kg) was given after aspiration and a test dose. Surgical skin incision was performed 30 min after the bupivacaine epidural injection. The volume of dextrose in lactated Ringer's solution infused iv before and following epidural anesthesia was 8.5 ± 1 $ml \cdot kg^{-1} \cdot h^{-1}$. Blood loss was minimal in all patients. At the end of surgery, inhalation anesthesia was discontinued, the trachea extubated, and neuromuscular blockade was reversed if clinical signs of prolonged neuromuscular blockade were evident. The patients were taken to the recovery room where they stayed during the first postoperative day. During the first 24 h postoperative, one or two epidural injections of 0.25% bupivacaine with epinephrine (1.25 mg/kg) were given when agitation and pain at the incision site occurred. This injection was always performed after aspiration and a test dose. The following measurements were performed during the study: 1) heart rate and mean arterial pressure at least every 10 min; 2) dissipation of epidural block during surgery estimated by

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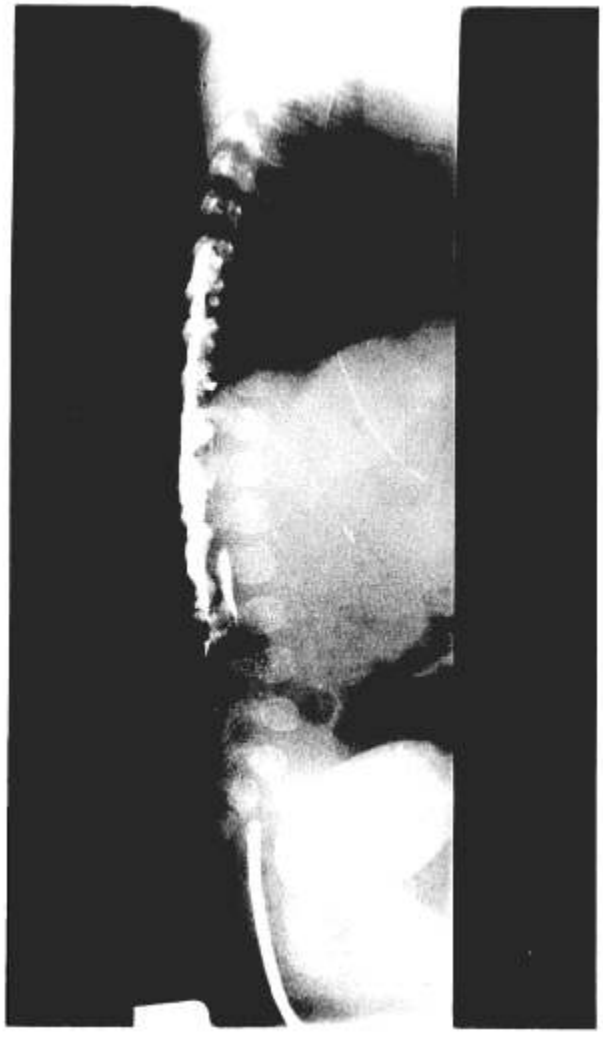

FIG. 1. Example of epidural spread in a 4-month-old infant: opacification of eight segments with 3 ml of iopamidol chloride.

increases in heart rate and mean arterial pressure and after surgery by the appearance of abnormal agitation and pain at incision site; and 3) plasma bupivacaine levels in ten infants (six after thoracic epidural and four after lumbar epidural). Arterial blood samples (2 ml) were drawn 10, 20, 30, 40, 50, and 60 min after initial bupivacaine epidural injection. Plasma was separated by centrifugation at 4° C, stored at −20° C, and assayed in duplicate by high pressure liquid chromatography§; this method measures bupivacaine concentrations between 0.05 and 10 μg/ml with a coefficient of variation of less than 10%. Radiologic epidural spread was measured by injecting a radiopaque solution (iopamidol chloride, Shering Laboratories, Dallas, TX) through the epidural catheter after operation in infants; the volume and speed of injection were identical to those used for the initial dose of bupivacaine (fig. 1).

§ Bishop W, Oppenheim RC, Eyres RL: Analysis of lignocaine and bupivacaine in plasma by high pressure liquid chromotography. Asian J Pharmaceut Sci 2:91–94, 1980.

RESULTS

Neither heart rate nor mean arterial pressure changed in infants receiving lumbar or thoracic epidural anesthesia before and after epidural block as well as after surgical skin incision. The duration of surgical analgesia for the nine longer surgical procedures was 128 ± 12 min (mean values ± SD). Regardless of the number of epidural injections, the duration of postoperative analgesia from the time of the last dose of bupivacaine was 498 ± 94 min. During the postoperative 24 h, 12 infants received one epidural 0.25% bupivacaine with epinephrine injection and eight infants received two injections.

No symptoms of bupivacaine cardiotoxicity were observed after bupivacaine epidural injection. Table I shows bupivacaine plasma levels in ten infants after the initial injection. Maximum bupivacaine plasma levels occurred at 20 min. In one child the maximum plasma level was 2.2 μg/ml; in the other infants this value was always below 1.8 μg/ml.

The mean epidural spread of the injected radiopaque solution was 12 ± 1.5 segments (range 8–16). Spread was always greater cranially than caudally. The upper and lower limits of the radiopaque solution ranged, respectively, from T-1 to T-4 and from T-11 to L-2 for thoracic injection, and T-6 to T-10 and L-2 to L-4 for lumbar injection.

DISCUSSION

Our experience shows that lumbar and thoracic epidural anesthesia with a catheter is feasible in infants weighing between 4–12.5 kg and ranging in age from 3 to 36 months, confirming the previous report of Meigner *et al.*[6] We used a midline approach in contrast to the paramedian approach used by Meigner *et al.*,[6] and found that the 18-gauge Tuohy needle passed easily through the vertebral interspace at lumbar and lower thoracic levels. However, this procedure is probably also possible with smaller needles. We chose to detect the epidural space with a syringe filled with air instead of saline to avoid diluting the bupivacaine. Vascular air embolism has, however, been reported with this technique in parturients,[7] and the use of a saline-filled syringe may be preferred by other clinicians.

Care should then be taken to inject as little saline as possible into the epidural space to avoid undue dilution of the small volume of local anesthetic solution. The skin–epidural space distance we observed was short and similar

TABLE 1. Bupivacaine Plasma Levels following Epidural Injection in Ten Infants (mean ± SD)

	Time after Epidural Injection (min)					
	10	20	30	40	50	60
Bupivacaine plasma levels (μg/ml)	1.14 ± 0.45	1.35 ± 0.51	1.24 ± 0.39	1.11 ± 0.42	1.05 ± 0.42	0.95 ± 0.39

to the values previously reported.¶ Lumbar and thoracic epidural anesthesia carry a potential risk of trauma to the spinal cord. Indeed, the spinal cord in infants may extend lower than the L3–L4 interspace. Therefore, the technique must be performed by well-trained anesthesiologists. We also recommend performing the epidural block at the L3–L4 interspace to decrease the risk of trauma to the spinal cord.

No symptoms of bupivacaine cardiotoxicity were observed in this study. It was not possible to detect central nervous system toxicity because all the infants were under general anesthesia at the moment of epidural bupivacaine injection. In addition, the potential for unrecognized dural or vascular puncture exists, thus aspiration and use of a suitable test dose are important precautions. The use of a test dose with epinephrine is probably efficient to detect an intravascular placement of the catheter. However, the increase in heart rate may be smaller than previously reported in conscious adults[8] because of the tachycardic effects of drugs such as atropine and pancuronium.

Our pharmacokinetic data showed that bupivacaine plasma levels following epidural injection were in the same range and time course as those previously reported after caudal administration.[4,5] The maximum plasma level was well below the value of 4 μg/ml considered to be toxic in adults.[9] This low value, despite the large administered dose, can be explained by the large volume of distribution of bupivacaine in children after caudal injection.[4]

Lumbar and thoracic epidural anesthesia provided effective intraoperative and postoperative analgesia. Indeed, with 60% inspired nitrous oxide and following an initial dose of 10 μg/kg of phenoperidine, surgical skin incision did not induce hemodynamic changes. No additional narcotics were used during surgery, and extubation of the trachea was performed in all the infants without the use of naloxone. After surgery all infants were calm, showed no signs of discomfort, and received no additional opioids. This suggests prolonged and effective postoperative analgesia, similar to that observed after caudal anesthesia.[10] During the first postoperative day, the epidural catheter permits repeat injection of local anesthetics or narcotics[11] for prolonged postoperative analgesia.

We were surprised to find the absence of deleterious cardiovascular effects of epidural block despite the absence of prior iv volume loading and the high thoracic level of the anesthetic. A previous study during caudal anesthesia in infants showed that the cutaneous upper level of analgesia extends further in a cranial direction than the upper limit of contrast material within the epidural space.[12] We can, therefore, presume that the radiologic measurement of the upper level in our study underestimates the clinical upper level. This is also suggested by the excellent analgesia for upper abdominal surgery that we obtained in all of the infants. The infants' hemodynamic tolerance of high thoracic epidural block is similar to that reported after subarachnoid block.[13] At the present time, we cannot explain why infants tolerate partial sympathetic block as well as they do.

Although we did not compare the combination of epidural and general anesthesia with general anesthesia alone, we have demonstrated that epidural anesthesia can be used safely as a supplement to general anesthesia in infants and children, provide effective intraoperative analgesia for urologic and upper abdominal surgery, and allow for prolonged postoperative analgesia.

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Hypokalemia in Trauma Patients

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There is a difference in opinion about whether hyperkalemia or hypokalemia is more common in severe trauma and shock. In traumatic or hemorrhagic shock, intracellular potassium leaks out of cells, resulting in hyperkalemia.[1–4] Smith reports that hypokalemia is more common in severely traumatized patients.[5] A prospective study was conducted to resolve these reported differences and to identify possible causes for changes in serum K concentration following trauma.

MATERIALS AND METHODS

Two hundred and twelve consecutive trauma patients who were transported to the Maryland Institute for Emergency Medicine (MIEM) by helicopter were selected and studied. Estimated time between accident and arrival obtained from police records was 55 ± SD 17 min. Age of the patients studied averaged 31 ± SD 13 yr (ranging from 15 to 83 yr). There were 149 males and 63 females. One hundred ninety-nine patients were automobile accident victims, nine suffered from gunshot wounds, and four suffered from industrial accidents. Each injury to the head, chest, abdomen, or extremities and spine was counted as one body-section injury. On average, injuries were found in 1.8 ± SD 0.81 body sections. Twenty-seven patients were dead on arrival or were moribund and died immediately after admission. Fifty-six of the 212 patients arrived with a systolic arterial blood pressure less than 90 mmHg.

In the 185 patients who were not dead or moribund on arrival, venous blood samples were taken following insertion of a venous catheter and before any treatment or iv fluid infusion therapy was initiated. Sometimes lactated Ringer's solution was infused during transport to the hospital. The venous blood was analyzed for serum electrolytes and blood glucose. Arterial blood was obtained by percutaneous femoral artery puncture at the time of the venous blood sampling and was analyzed for blood gases and lactic acid concentration when enough blood was available. Urine was analyzed for electrolytes if an admission urine sample was obtained. Following the sample taking, the patients were resuscitated with both plasma protein fraction and lactated Ringer's solution. In patients who required blood transfusion, packed red blood cells were administered with an equal volume of plasma protein fraction. For the maintenance of fluid balance, lactated Ringer's solution was used. In patients with serum K concentration less than 3.0 mEq/l, 10 mEq K as a chloride was added to the 1,000 ml iv solution administered. Serum electrolytes were monitored at least every 2 h during resuscitation and surgery. In the 27 patients who were dead on arrival or died shortly after arrival, only serum electrolytes were measured.

Admission serum K concentrations were correlated with admission arterial blood pressure, blood glucose, Pa_{O_2}, Pa_{CO_2}, *p*H, arterial lactic acid level, and urine K concentration with a Pearson product-moment correlation coefficient. The 185 surviving patients were divided into two groups: Group 1 included 56 patients who had an admission systolic arterial blood pressure less than 90 mmHg and Group 2 included 129 patients with an admission systolic pressure greater than 90 mmHg. Serum K concentrations, *p*H, blood, and iv fluid volumes during

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