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Thoracic Epidural Anesthesia *Via* Caudal Route in Infants

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Lumbar and thoracic epidural anesthesia in children has been well described.[1,2] However, this procedure may be technically difficult and hazardous for anatomical reasons in the infant and neonate, even when anesthetized. The spread and pharmacokinetics of caudally administered bupivacaine have been well documented.[3–6] To achieve adequate analgesia for upper abdominal or thoracic surgery *via* this route requires a large volume of local anesthetic agent with potential toxicity, morbidity, and even mortality.[4] We, therefore, studied the feasibility of placement of a thoracic epidural catheter *via* the caudal route.

The study was conducted in three phases. The first phase consisted of a human cadaver study to determine whether a catheter would pass *via* the sacral hiatus to the thoracic epidural space. The second consisted of an animal study to determine whether any trauma was caused by the passage of a catheter along the epidural space for this distance. Finally, a clinical study was performed on a select group of patients requiring biliary tract surgery.

MATERIALS AND METHODS

The study, which was approved by the Ethics Sub-Committee of the Faculty Board, School of Medicine, University of Natal, was carried out in three phases.

Phase 1. Fourteen human cadavers, ages ranging from premature to 11 yr, were studied (table I). The caudal space of the cadavers was entered using a 16-G Medican 1.7 × 40 mm intravenous cannula¶ *via* the sacral hiatus. An 18-G epidural catheter Portex** was then threaded as far as possible into the epidural space through this cannula, or until resistance to its passage was felt. Radio-opaque contrast medium was injected into the catheter once it had been positioned. A radiograph of vertebral column was performed to determine the course of the epidural catheter and the location of its tip.

The epidural space and spinal canal were then dissected to observe the course of the epidural catheter and assess the reasons for any obstruction, if this had occurred during the passage of the catheter.

Phase 2. Piglets possess an epidural space and fatty tissue quite similar to that of human infants. Thus, we studied the efficacy of epidural catheter placement in 12 piglets anesthetized with ketamine and diazepam.

Epidural catheters were introduced into the epidural space through a 16-G Medican intravenous cannula placed through the sacrococcygeal membrane using the technique as described above. The catheter was advanced a predetermined distance as measured along the individual piglet's spine. After 10 min, the anesthetized piglets were sacrificed by exsanguination.

The epidural space was then dissected. Any bleeding into the epidural space was presumed to have occurred prior to exsanguination and to have been caused by the passage of the catheter.

Phase 3. We studied 20 neonates and older infants undergoing biliary tract surgery. In these patients, the exact location of the epidural catheter could be determined by means of a radiograph prior to the introduction of the local anesthetic and the start of the surgery. This control radiograph was performed as a surgical routine for subsequent intraoperative radiographic studies of the biliary tract, and did not, therefore, expose the child to additional radiation. The coagulation profile was normal in all patients studied. General anesthesia was induced with thiopental iv and maintained with 70% nitrous oxide in oxygen. Tracheal intubation was facilitated by the iv administration of succinylcholine, and ventilation was controlled by intermittent positive pressure ventilation.

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TABLE 1. Position of Catheter Tip on Radiograph Following Insertion *Via* the Caudal Hiatus

Number of Case	Age of Cadaver	Catheter Level
1	1 day	C6
2	1 day	T6
3	1 day	C6
4	9 months	T6
5	11 yr	L3
6	7 yr	L5
7	1 month	T3
8	1 day	T2
9	12 days	T5
10	6 days	T9
11	10 days	T8
12	12 days	T5
13	8 yr	L4
14	11 weeks	T6

An epidural catheter was introduced through the sacral hiatus by means of a 16-G Medican cannula as described above in six patients. We subsequently found that the short bevel introducer of the Contiplex® †† cannula facilitated identification of the caudal space. This device was used in the remaining 14 patients.

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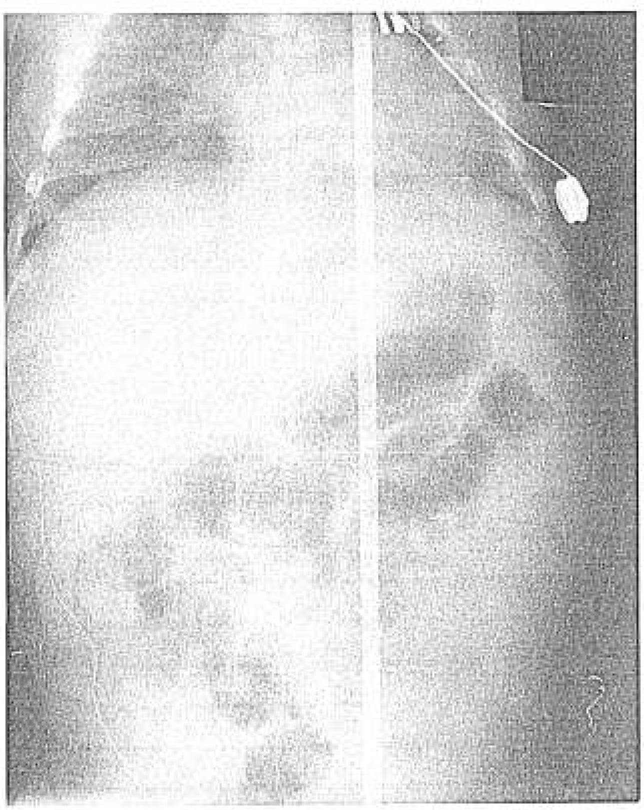

FIG. 1. Clinical study: The path of the catheter in the epidural space is shown. Note the cephalad spread of the contrast medium (horizontal markings are made by the warming blanket).

On penetration of the sacrococcygeal membrane, the needle was removed, leaving the cannula *in situ*. The epidural catheter was introduced through this cannula. An attempt was made to advance the catheter to the level of the eighth thoracic vertebra (T8). The required length was estimated by measuring the distance from the sacral hiatus to T8 prior to insertion. Once *in situ*, a predetermined volume of iopamidol—a water soluble non-irritant radio opaque contrast medium—was injected slowly into the epidural catheter through a millipore bacterial filter to fill the catheter.

The surgical control abdominal radiograph was then taken to determine the exact path of the catheter and location of the catheter tip (fig. 1).

When the position of the catheter was confirmed, bupivacaine 0.5% 0.5 ml/kg was injected through a second bacterial filter. The infants were monitored continuously by means of an ECG, intra-arterial blood pressure, end-tidal CO_2, esophageal temperature probe, and a precordial stethoscope. The response to surgical incision was noted.

The epidural anesthetic was considered successful if there was less than a 5% change in arterial blood pressure or heart rate over baseline in response to surgery.

The epidural catheters were removed intact in the post-anesthetic recovery room (PAR) in all cases prior to their return to the ward.

RESULTS

Phase 1. Table 1 shows the level to which the catheters were introduced in the cadavers. In the 11 infants, under 9 months of age, the catheter could be advanced at least to the thoracic level. In two cases, the catheter passed to the cervical region (fig. 2).

When resistance to the passage of the catheter was felt, we noted at dissection that its passage had been obstructed by a nerve root. It was not possible to overcome this resistance by manipulation of the catheter, such as withdrawal and re-introduction. When the catheter was introduced forcibly against this resistance, the catheter was found at dissection to have coiled up or to have doubled back in the epidural space.

Phase 2. In 11 of the piglets studied, the catheter was introduced without any difficulty to the thoracic region. In one piglet, the catheter was deliberately advanced against a resistance, and, as anticipated, was found at dissection to have doubled back into the lumbar region.

At dissection, there was no evidence of a premortem hemorrhage into the epidural space in any of the piglets.

Phase 3. Twenty infants, 12 male and eight female, ranging in weight from 2.7 to 6.5 kg, who presented for surgery of the biliary system, were anesthetised using this technique (table 2). Their mean age was 11 weeks (range 4 weeks to 5 months). In 19 cases, the epidural catheter was placed within one vertebra of the desired level (fig. 1). On 14 occasions, some slight resistance was felt to the passage of the catheter, and further passage was facilitated by minimal flexion or extension of the infants spine, well within the normal range of movement.

On one occasion, the catheter failed to reach the desired level, despite the flexion/extension maneuver. There was significant resistance to the passage of the catheter, and we elected not to introduce the catheter any further. A radiograph confirmed that the tip of the catheter lay at level T12. In this patient, a successful block was achieved, using a slightly larger volume of bupivacaine.

On one occasion, blood was noted on introduction of the cannula. Following placement, no blood was aspirated from the epidural catheter and, therefore, we felt it probably related to the introduction of the cannula through the sacrococcygeal membrane.

There were no episodes of hypotension, bradycardia, or arrhythmia following the introduction of the local anesthetic agent. At surgical incision, anesthesia was considered successful according to the criteria described above in all patients.

No neurological sequelae were noted during the postoperative stay in hospital or during subsequent visits.

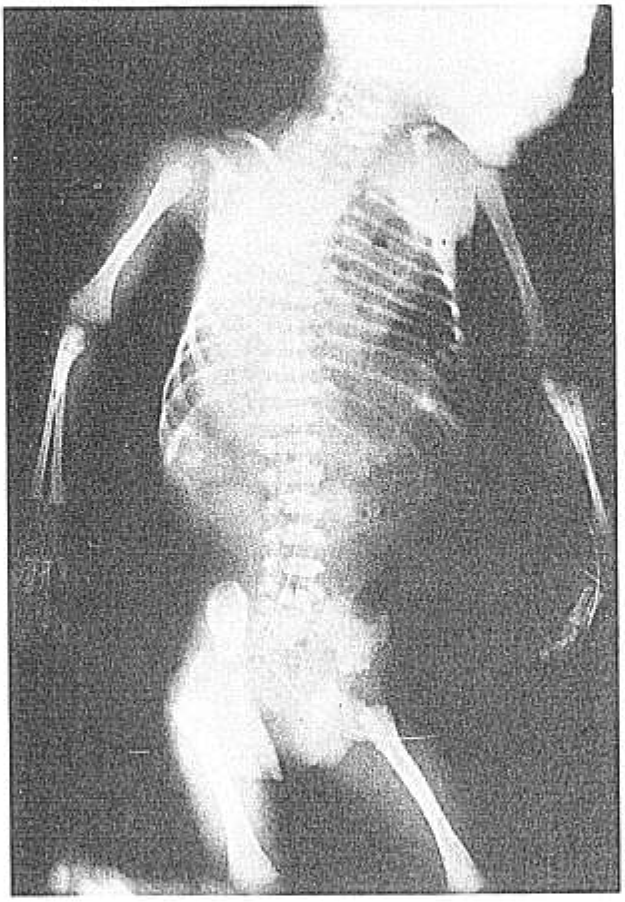

FIG. 2. Cadaver study: The passage of an epidural catheter from the sacral hiatus to the cervical region is clearly demonstrated in this radiograph of a cadaver of an infant.

TABLE 2. Clinical Data of Patients in Phase 3

No.	Age in Weeks	Wt. in kg	Diagnosis	Catheter	Position of Tip Aim T7–T8 Level	Dose in Ml 0.5% Bupivacaine
1	4	4.1	Biliary atresia	M	T8	2
2	8	4.5	Biliary atresia	M	T7	2.5
3	12	5.9	Biliary atresia	M	T9	3
4	16	4.8	Biliary atresia	C	T8	3
5	8	4.5	Biliary atresia	M	T7	2.5
6	12	4.5	Neonatal hepatitis	C	T7	2.5
7	11	4.4	Biliary atresia	C	T8	3.0
8	16	4.3	Biliary atresia	M	T7	2.25
9	10	6.0	Biliary atresia	M	T8	3
10	8	6.5	Choledochal cyst	C	T7	3
11	16	5.6	Biliary atresia	C	T9	3
12	6	2.8	Biliary atresia	C	T9	1.5
13	14	5.0	Biliary atresia	C	T8	2.5
14	12	4.1	Biliary atresia	C	T7	2
15	12	5.7	Biliary atresia	C	T12*	3.5
16	6	2.7	Neonatal hepatitis	C	T8†	1.6
17	22	6.0	Choledochal cyst	C	T8	3.5
18	12	6.1	Biliary atresia	C	T9	3.0
19	16	5.0	Biliary atresia	C	T8	2.5
20	12	4.0	Biliary atresia	C	T8	2.0

M = Medican; C = Contiplex.
* Held up 1.5 cm short of calculated distance.
† Blood in catheter—subsequently cleared.

DISCUSSION

There are several advantages to the use of epidural anesthesia in infants. These include elimination of the use of narcotics and muscle relaxants, both of which may contribute to postoperative respiratory depression. The myocardial depressant effect of the potent inhaled anesthetics is minimized as a lower concentration is required. Emergence is smooth and the need for postoperative analgesics is decreased.

Our experience has shown that an epidural catheter may readily be passed from the caudal to the thoracic epidural space to provide regional anesthesia for upper abdominal surgery in infants weighing 2.7–6.5 kg, ranging in age from 4 weeks to 5 months. We were able to accurately place the catheter at the desired level in all but one patient. In all patients, we were able to accurately predict the site of the catheter tip to within one vertebral space. Although we have shown that placement of the catheter is predictable, we believe that radiographic confirmation of the catheter position should be sought until the anesthesiologist is familiar with the technique.

In animal and human infant cadavers, we found that minor resistance to the passage of the catheter could be overcome by simple flexion or extension of the infants vertebral column. If such resistance is not easily overcome in this manner, no attempt should be made to introduce the catheter further. Such attempts may lead to the catheter curling up or doubling back in the epidural space. To date, we have not been able to demonstrate any evidence of trauma in the small number of patients studied. However, the potential still exists and, therefore, under no circumstances should any force be used to advance the catheter.

The spread of local anesthesia administered caudally has been well documented.[3–6] However, this would expose the infant to potentially toxic doses of local anesthetic if analgesia is required for the upper abdominal or thoracic dermatomes. There is also an unacceptable risk of morbidity and mortality when this technique is used.[4]

By precise placement of an epidural catheter, the dermatomes involved in the surgical procedure may be selectively blocked, minimizing the dose of local anesthetic agent required to provide analgesia. We chose to use weight as a guide to the dosage according to Armitage,[8] as this scheme was considered to be more appropriate for infants under 1 yr of age.

As previous studies have shown that the spread of the local anesthetic in the epidural space is in a cephalad direction,[9,10] it would be appropriate to use a larger volume of local anesthetic agent in those cases where the catheter does not reach the desired level. Figure 1 illustrates the cephalad spread of the contrast medium in one of our patients. The dose used would still be smaller than that required if the local anesthetic agent were to be introduced directly into the caudal space.

A major advantage of this technique is that access to the caudal epidural space is technically easier and less hazardous than to the lumbar or thoracic epidural spaces. Lumbar and thoracic epidurals carry the potential risk of trauma to the spinal cord because of the narrow epidural space in the small infant. It is recommended that these techniques should only be performed by well-trained anesthesiologists.[1,9] It is probably for this reason that these techniques have not attained the same degree of popularity as they have in adults, or as caudal analgesia has in children.

An explanation for the ease with which the catheter can be passed through the epidural space is drawn from the work of Tretjakoff *et al.*[10] They found the epidural fat of the newborn and small infant to have a spongy gelatinous appearance with distinct spaces between individual fat lobules. This was also noted in the cadavers of phase 1 of our study.

Furthermore, an epidural catheter inserted in this manner may also be used for continuous postoperative analgesia using local anesthetic agents[7] or narcotics,[9,11] where high care facilities are available for the close observation of these patients.

We noted the absence of deleterious cardiovascular effects of epidural analgesia despite the high level of blockade and lack of fluid preload. This is in keeping with the findings of other authors following epidural anesthesia in infants[1,2,9] and in infants following subarachnoid block.[12,13]

In summary, we have demonstrated a technically simple alternative route of access to the thoracic and upper lumbar epidural space in the small infant. An epidural catheter can be passed predictably and safely *via* the sacral hiatus, and effective intraoperative analgesia can be provided for infants undergoing upper abdominal and thoracic surgery. This technique also provides the potential for long-term postoperative analgesia in the appropriate circumstances.

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Arterial Blood Pressure and Heart Rate Response to Lighted Stylet or Direct Laryngoscopy for Endotracheal Intubation

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Tracheal intubation is accompanied by varying degrees of sympathetic stimulation, as reflected by increases in heart rate and arterial blood pressure.[1,2] Direct laryngoscopy, as well as insertion of the endotracheal tube, contributes to this effect. Various pharmacologic manipulations[1,3,4] and laryngoscope blades[2,5] have been utilized in attempts to attenuate these hemodynamic changes, but no study has been performed comparing the hemodynamic effects of direct laryngoscopy with an indirect means of tracheal intubation. The present study was carried out to determine if using the lighted stylet (light wand), which does not involve direct laryngoscopy,[6,7] would result in less hemodynamic stimulation when compared to intubation using either straight or curved laryngoscope blades.

MATERIALS AND METHODS

Each patient provided written, informed consent, and the protocol was reviewed and approved by our Human Use Committee of the Department of Clinical Investigation. Fifty-six ASA I patients were assigned to one of three groups: 1) tracheal intubation with a curved laryngoscope blade (No. 3 Macintosh), 2) tracheal intubation with a straight laryngoscope blade (No. 2 Miller), or 3) tracheal intubation with the lighted stylet (Flexi-lum™, Concept Corporation, Clearwater, FL).§ Intubation with the lighted stylet has been previously described.[6,7] Intubations were performed by medical students, interns, residents, and nurse anesthetists. Use of the No. 3 Macintosh and No. 2 Miller blades was determined strictly at random by a computer program. However, the lighted stylet intubations were performed by more experienced (PGY-2 or greater) personnel. In addition to routine monitoring, an arterial catheter was placed in all patients for detection of rapid and transient changes in arterial blood pressure. The arterial trace was continuously recorded on a Siemen's strip chart recorder.

Each patient was premedicated with diazepam 5–10 mg po 1 h prior to surgery. Induction of anesthesia was accomplished by a continuous intravenous infusion of thiopental 1.0 $mg \cdot kg^{-1} \cdot min^{-1}$, which was not termi-

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The opinions contained herein are those of the authors and do not necessarily reflect those of the Department of the Army or the Department of Defense.

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§ As has been discussed, a new lighted stylet (TUBE-STAT™, Concept Corporation, Clearwater, FL), not available at the time of this study, is preferable to the Flexi-lum™ for endotracheal intubation.[8]