Abstract: Thoracic epidural anaesthesia in anaesthetized children requires a meticulous technique and may have an increased success rate when the distance between skin and epidural space is known. The objective of this observational study was to measure the skin to epidural distance (SED) during thoracic epidural puncture in 61 children. The epidural puncture was performed using the loss of resistance technique with saline 0.9%. The distance from the needle tip to the point where the needle emerged from the skin was measured. The postoperative analgesia parameters were also measured. Skin to epidural distance correlated significantly with the age and weight of the children. The equation for the relation between SED (cm) and age was 2.15 + (0.01 × months) and for SED vs weight was 1.95 + (0.045 × kg). Despite considerable variability among individuals, the observed correlation of SED with both age and weight shows that this parameter may be helpful to guide thoracic epidural puncture in anaesthetized children.

Key words: Anaesthetic techniques: regional; epidural; anaesthesia; paediatric; anatomy: epidural space.

Paediatric epidural anaesthesia/analgesia has increased in popularity in the last 20 years, but its success rate and the frequency of complications have not been fully elucidated (1, 2). The smaller size of the vertebral canal and epidural space, and the catheter insertion under general anaesthesia may make epidural cannulation in children more hazardous than in awake adults.

Although newer techniques (ultrasound guidance, stimulation) may be helpful in assisting epidural puncture and catheter insertion, they are not routinely available. The loss of resistance technique still remains the basic technique for recognition of the epidural space. Knowledge of the depth of the epidural space or the skin epidural distance (SED) might increase the success rate and the safety of epidural puncture. However, in children this has only been described for the lumbar epidural space (3, 4).

The main objective of this study was to describe insertion details and to measure the SED during thoracic epidural puncture in anaesthetized children up to 14 years of age. Furthermore, postoperative analgesic efficacy was evaluated.

Patients and methods

Sixty-one patients were included in this prospective observational study for which institutional research committee approval and informed consent from the children and/or parents were obtained. The children were scheduled for major thoracic or abdominal surgery where postoperative thoracic epidural analgesia was selected. Abnormal coagulation and local infection at the epidural puncture site were contra-indications.

Epidural puncture was always performed by an experienced paediatric anaesthesiologist after induction of general volatile anaesthesia with tracheal intubation performed without neuromuscular blocking drugs. All children were monitored with ECG, SpO₂, non-invasive blood pressure and capnography.

The epidural puncture was performed in the right lateral position with the hips flexed. An aseptic technique was used. A paediatric Tuohy needle 20G (for a 24G catheter) was used for children < 10 kg and a 18G needle (for a 20G catheter) for those ≥ 10 kg (Perifix Paed, B Braun, Germany). The needle was introduced 1-2 mm from the midline between two processi spinosi with an angulation of 40–60 degree upward to the long axis of the spine. The intervertebral space of needle insertion
was either one or two segments below the dermatomal level of the intercostal incision (for thoracotomies) or at a low to mid-thoracic level for laparotomies. The loss of resistance technique was performed using saline 0.9%. The needle was advanced with the left index finger and thumb while continuous pressure was exerted on the syringe with the right thumb until loss of resistance was felt. The distance from the needle tip to the point where the needle emerged from the skin after loss of resistance was measured. The epidural catheter (soft Perifix catheter with central opening) was threaded 3 cm cranially in the epidural space. A test dose of 0.25 mg kg⁻¹ bupivacaine with epinephrine 1/200 000 was given followed after 5-10 min by a slow bolus dose up to 1 mg kg⁻¹ bupivacaine. The number of attempts for siting was limited to three. When blood appeared in the needle or syringe further attempts were stopped. Anaesthesia was further maintained with a volatile anaesthetic and rocuronium as non-depolarizing muscle relaxant.

At the end of surgery a continuous epidural infusion of plain bupivacaine was started at 0.4-0.5 mg kg⁻¹ hr⁻¹ for children older than six months and at 0.25 mg kg⁻¹ hr⁻¹ when younger than six months of age. Paracetamol 60-90 mg kg⁻¹ daily was given to all patients in four divided doses. The CHIPPS pain scale was used at frequent intervals in children up to five years of age (5). In older children a numerical analogue pain scale (0-10) was used. When the pain score in either scale was > 3, escape medication was given with an i.v. morphine infusion at 3-20 μg kg⁻¹ hr⁻¹. When children were distressed for reasons other than surgical pain (nasogastric tube, urinary catheter etc.) an infusion of morphine was given, but at a lower dose of 3-5 μg kg⁻¹ hr⁻¹.

The postoperative follow-up of epidural analgesia and adjuvant and escape medication was done according to the hospital’s postoperative children’s pain protocol. This was audited in every case by the hospital acute pain service and recorded into a database.

Data were introduced and analysed in an Excel spreadsheet. Statistical analysis was done using SPSS for Windows. The correlation between SED and weight and age was analysed using the Pearson correlation coefficient. A regression analysis was performed to describe the relation between SED and age or weight. To assess and visualize the effect of the thoracic intervertebral space level on SED, the individual SED’s were recalculated by extrapolation to an age of 24 months based on the linear regression analysis. A P value < 0.05 was considered statistically significant.

### RESULTS

Table 1 summarizes the demographic patient data. The dermatomal level of epidural puncture was a high-thoracic (Th5-6 or above) in 14 children, mid-thoracic (Th6-7 to T8-9) in 40 and low-thoracic (Th9-10 to Th11-12) in seven children.

The epidural needle size was 18-G in 41 children and 20-G in 20 children. The epidural space could be clearly identified with the loss of resistance technique in all children. In 50 children, the epidural space was identified after one puncture attempt. In eight patients, two attempts and in three patients three attempts were necessary. All 20-G catheters were threaded up successfully. In one child a 24-G catheter could not be threaded and in three children threading up the catheter was difficult despite clear loss of resistance.

There were no dural punctures or bloody taps. No signs of intravascular injection were seen after the loading dose of bupivacaine with epinephrine. There were no convulsive events during epidural analgesia and no neurological sequelae or deficits at discharge from the hospital.

The linear relation between SED (cm) and age was:

\[
\text{SED} = 2.15 + (0.01 \times \text{months}).
\]

The formula for SED vs weight was:

\[
\text{SED} = 1.95 + (0.045 \times \text{kg}).
\]

The Pearson correlation coefficient for SED vs age was 0.724 and for SED vs weight was 0.725 (both \( p < 0.01 \)). Figure 1 shows the relation between SED and age in months. There was a wide interindividual variability.

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**Table 1**

Demographic patient data. Data represent numbers or mean (and SD)

| Age (months) | 61.6 (56.2) |
| Gender (n) | |
| male | 34 |
| female | 27 |
| Weight (kg) | 19.7 (14.1) |
| ASA class (n) | |
| I-II | 38 |
| III-IV | 23 |
| Type of surgery | |
| Thoracotomy | |
| Lobectomy | 13 |
| Thoracoplasty | 4 |
| Other | 3 |
| Laparotomy | |
| Tumour resection | 16 |
| Diaphragmatic hernia | 3 |
| Nissen Funduplication | 13 |
| Miscellaneous | 7 |
| Jejunum interposition | 2 |
| Duration of anesthesia (hrs) | 174.3 (94.6) |
Figure 2 shows the relation between SED extrapolated to an age of two years and the level of the intervertebral space. At the lower thoracic intervertebral spaces there was a smaller SED than at the other thoracic intervertebral spaces.

In most patients (n = 37) epidural administration of bupivacaine was continued for 48 hours. In 15 patients, undergoing very painful procedures, epidural analgesia was prolonged for one more day. In one patient a catheter could not be threaded and in eight patients epidural analgesia was stopped prematurely for various reasons: dislocation (n = 1), leakage (n = 1), difficulty in measuring the efficacy of block e.g. analgesia (n = 3), intercurrent septicaemia not catheter-related (n = 1), and morphine administration for mechanical ventilation (n = 2).

Thirty nine patients were discharged to the ward after postoperative recovery room observation. Twenty two patients were electively admitted to ICU postoperatively for either extended monitoring (14 children) or for postoperative mechanical ventilation (eight children).

In 31 children no morphine was required to maintain a pain score < 3/10. In 22 children a morphine dose between 0 and 5 µg.kg⁻¹.hr⁻¹ was given. In eight children an infusion rate between 5 and 20 µg.kg⁻¹.hr⁻¹ was given to facilitate elective (e.g. after jejunum interposition or cardiovascular instability) or secondary mechanical ventilation.

**DISCUSSION**

After major thoracic and abdominal surgery, thoracic epidural anaesthesia reduces postoperative respiratory depression and allows earlier return of...
gastro-intestinal function, and may even reduce
mortality and morbidity (6). The segmental inter-
vertebral approach to the thoracic epidural space
has the advantage of reducing the total dose of local
anaesthetic required for a certain number of der-
matomes to be blocked, thereby improving the
quality of analgesia. This approach, however, may
be associated with greater risk of neurologic dam-
age or dural puncture than thoracic epidural analge-
sia with a catheter inserted via the caudal or lumbar
approach. However, advancing the epidural catheter
from the lumbar intervertebral or the caudal epidur-
al space is frequently unsuccessful (7, 8).

Recently newer techniques such as ultrasound
guidance and stimulation techniques (9, 10) have
been developed for epidural catheter placement.
These are not, however, routinely available and can
only assist in confirming the epidural localisation of
the catheter. The most critical point in the technique
of epidural puncture remains the exact appreciation
of loss of resistance when piercing the ligamentum
flavum. In the present study a good correlation
between SED and age and weight was observed for
the thoracic epidural puncture. However, there was
a rather high interindividual variability. Despite this
limitation, estimation of the SED will be helpful to
guide thoracic epidural puncture and minimize the
potential risks.

Previous studies have measured the SED using
CT scans. When using thoracic epidural midline
insertion a CT-scan derived distance can be calcu-
lated using the perpendicular distance obtained
from preoperative chest CT films and the angle of
the needle insertion (11). This information should
also be used when a preoperative CT-scans of the
thoracic vertebrae is available.

For lumbar epidurals performed in children
using a midline approach in the L3-4 interspace
with the patient in the lateral position, the one
mm.kg⁻¹ body weight rule has been shown to be a
useful guideline for children between six months
and 10 years of age (4). For a 10 kg child this would
give a SED at lumbar level of 1.0 cm. At the tho-
racic level we calculate a distance of 1.95 cm +
(0.045 x 10) = 2.4 cm. The much larger distance at
thoracic level is caused by the longer spinal
processes but also the different angle to the long
axis of the spine with overlap of the spinous
processes. Our study also showed that at the lower
intervertebral spaces the SED is smaller (as for the
lumbar interspaces) than at the other thoracic inter-
spaces.

Measurement of the extent and intensity of
epidural blocks in small children is difficult.

Regular assessment of pain, motor block and respir-
atory parameters remain important. Sensory block
testing was always used in children capable of
responding. However, our primary objective was to
maintain the pain score below 4/10. The number of
children where additional escape medication was
used may seem rather high, but this was mainly due
to morphine being given to allow mechanical venti-
lation. The data in the pain auditing forms also
showed that things other than surgical pain may
cause subjective pain scoring e.g. hunger, bladder
or gastric catheters etc.

In conclusion, a formula was presented for
estimation of the SED using age or weight during
thoracic epidural blocks in anaesthetized children.
Despite considerable variability in SED among
individuals, the observed correlation of SED with
both age and weight shows that this parameter may
be helpful to guide thoracic epidural puncture in
anaesthetized children.

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References

1. Chalkiadis G., The rise and fall of continuous epidural
infusions in children, Paediatric Anaesthesia, 13, 91-3,
2003.
2. Williams D. G., Howard R. F., Epidural analgesia in chil-
dren. A survey of current opinions and practices amongst
UK paediatric anaesthetists, Paediatric Anaesthesia, 13,
3. Hasan M. A., Howard R. F., Lloyd-Thomas A. R., Depth of
4. Rosenberg A. T., Gouws E., Skin-epidural distance in chil-
5. Bütter W., Finke W., Analysis of behavioural and physio-
logical parameters for the assessment of postoperative
analgesic demand in newborns, infants and young chil-
dren : a comprehensive report on seven consecutive
studies, Paediatric Anaesthesia, 10, 303-18, 2000.
anaesthesia : more than just anesthesia/analgesia,
7. Blanco D., Llanazaes J., Rincon R., Ortiz M., Vidal F.,
Thoracic epidural anesthesia via the lumbar approach in
infants and children, Anaesthesiology, 84 (6), 1312-6, 1996.
8. Valaiurucha S., Seefelder C., Houck C. S., Thoracic epidur-
al catheters placed by the caudal route in infants : the
importance of radiographic confirmation, Paediatric
Anaesthesia, 12, 424-8, 2002.
