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Continuous Extrapleural Intercostal Nerve Block for Post Thoracotomy Analgesia in Children

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SUMMARY

The safety and efficacy of continuous extrapleural intercostal nerve block has been well established in adults. This review of our initial paediatric experience suggests a role for this technique in children and discusses risks and benefits relative to other forms of regional analgesia for thoracotomy.

Nine children aged one to twelve years received extrapleural infusions of bupivacaine 0.1-0.2% following lateral thoracotomy for lung resection. An extrapleural catheter was placed by the surgeon prior to thoracotomy closure, and correctly positioned under direct vision external to the parietal pleura alongside the vertebral column. An intra-operative loading dose of bupivacaine, 0.25-0.5% (0.28±0.1 ml/kg, mean±SD) was injected so as to raise a bleb under the parietal pleura which spread longitudinally to bathe several intercostal nerves in the paravertebral gutter. The chest wall was then closed. Infusions of bupivacaine were commenced in the recovery room and continued at a constant rate of 0.21±0.09 ml/kg/h for 72±15 hours. The mean dose of bupivacaine was 284±97 µg/kg/h. Patients also received standard analgesia as an intravenous morphine infusion (10-50 µg/kg/h), or patient-controlled analgesia. Nursing staff were specifically instructed not to alter their usual management of variable rate morphine infusions which are titrated to adequate analgesia.

Morphine requirements in the first 48 postoperative hours remained less than 30 µg/kg/h, oral fluids were well tolerated after 31.2±19.1 hours, nasogastric tubes were removed at 16.7±11.2 hours. Postoperative nausea and vomiting and respiratory depression were not observed in any patient and all were able to comply with physiotherapy. There were no complications of catheter placement or bupivacaine administration.

Our initial experience suggests that this is a safe technique which minimizes complementary opioid administration and provides adequate analgesia for children postthoracotomy for lung resection.

Key Words: ANALGESIA TECHNIQUES: bupivacaine, intercostal, continuous, extrapleural, retropleural, paravertebral, thoracotomy, paediatric

Thoracotomy is a painful procedure which causes marked impairment of pulmonary function. Adequate analgesia after thoracotomy improves compliance with physiotherapy and decreases the risk of atelectasis[1]. In paediatric practice, parenteral opioids are the mainstay of treatment[2] and are associated with respiratory depression, sedation, nausea, vomiting, decreased gut motility and pruritus.

Regional blockade has been advocated by many authors to reduce or negate the need for parenteral opioids after thoracotomy. Techniques described include extradural block[1,3,4] and intercostal nerve block either via injection of multiple intercostal spaces, or by insertion of a catheter to provide continuous blockade of intercostal nerves. These catheters may be placed (i) in the interpleural space between the visceral and parietal pleura[5-8], (ii) alongside the nerve in the subcostal groove as a single[9-12] or multiple[13-15] catheter technique, or (iii) in the extrapleural space outside the parietal pleura[4,16-24]. Evidence suggests that all three of these techniques may have the same sites of spread to multiple levels, both along adjacent intercostal spaces extrapleurally and via the paravertebral space[9,10,15,16,25-29].

A single catheter placed extrapleurally along the paravertebral gutter spreads local anaesthetic both cephalad and caudad to block several intercostal nerves. Posteromedial spread may also block the sympathetic chain and posterior primary rami.

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Extrapleural bupivacaine infusions post thoracotomy in adults, both with[19,21,23] and without[16-18,22] documented paravertebral spread, have been shown to significantly reduce opioid requirements and side-effects, to improve pain scores and to reduce pulmonary complications[16-18,20,22,23].

We report our initial experience with the use of continuous extrapleural intercostal nerve block (CEINB) with bupivacaine for post thoracotomy analgesia in children.

MATERIALS AND METHODS

A protocol was approved by the Patient Care Committee in April 1995 enabling extrapleural bupivacaine infusions to be used routinely for children requiring lateral thoracotomy for lung resection. In the subsequent twelve months, nine patients received continuous extrapleural intercostal nerve block (CEINB) and they are reviewed here.

Informed parental consent was obtained and routine general anaesthesia administered including the use of systemic opioids. The same anaesthetist was involved in all cases. The catheter was placed by the surgeon toward the end of the procedure, the chest wall closed. The patient emerged from anaesthesia, was extubated and transferred to the recovery room.

In the recovery room, routine analgesia was commenced via either nurse-controlled variable rate intravenous morphine infusion (10 to 50 μg/kg/h) or Patient Controlled Analgesia (PCA: background infusion of 10 μg/kg/h with 20 μg/kg bolus and five minute lockout) according to standard hospital protocol. No attempt was made to interfere with routine analgesia as dictated by nurse-controlled infusion or PCA. Patients received high-dependency nursing.

The pain team comprising an anaesthetist, pain fellow and registered nurse reviewed the patients twice daily. The extrapleural catheters remained in situ until removal of chest drains to facilitate patient mobility. The IV morphine infusions were continued for a further 1 to 2 days as required, with subsequent conversion to oral analgesics.

Extrapleural Catheter Placement

Prior to thoracotomy closure, the surgeon placed the extrapleural catheter through a percutaneous 18 gauge Tuohy needle. The entry point was posterior, one intercostal space below the incision interspace, medial to the angle of the rib. The Tuohy needle was passed through skin, external intercostal muscle, and posterior intercostal membrane before its tip entered the extrapleural potential space without penetrating parietal pleura (Figure 1a). The intercostalis intima muscle is not present medial to the angle of the rib.

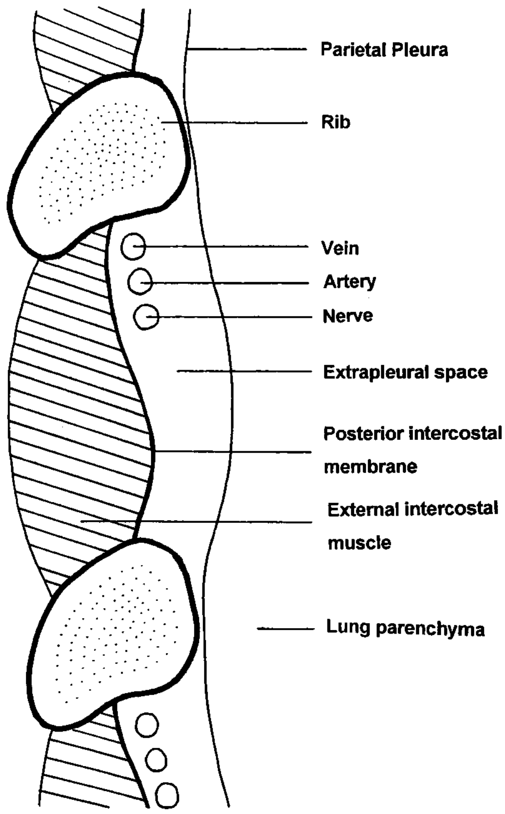

FIGURE 1a: Schematic parasagittal section of an intercostal space posteriorly, medial to the angle of the rib.

A multiholed 20 gauge epidural catheter (Portex® Ltd., Hythe, Kent, England) was inserted 5 to 10 cm into the extrapleural space under direct vision taking care not to perforate the parietal pleura. The catheter was positioned longitudinally, close to the vertebral bodies in the paravertebral gutter, overlying at least three intercostal nerves including one above and below that of the incision interspace. The catheter was sutured to the skin at the exit point, a sterile clear plastic dressing applied and a 0.2 micron epidural filter was flushed and attached. The procedure took less than five minutes to complete.

A loading dose of 0.25-0.5% bupivacaine was injected down the catheter under direct vision of the surgeon raising an extrapleural pocket or "bleb" (Figure 1b). The volume was approximately 0.3 ml/kg, but was individualized such that the extrapleural potential space was seen to fill longitudinally over at least three levels and medially towards the vertebral bodies (Figure 2). A maximum loading dose of 3 mg/kg bupivacaine was used. This

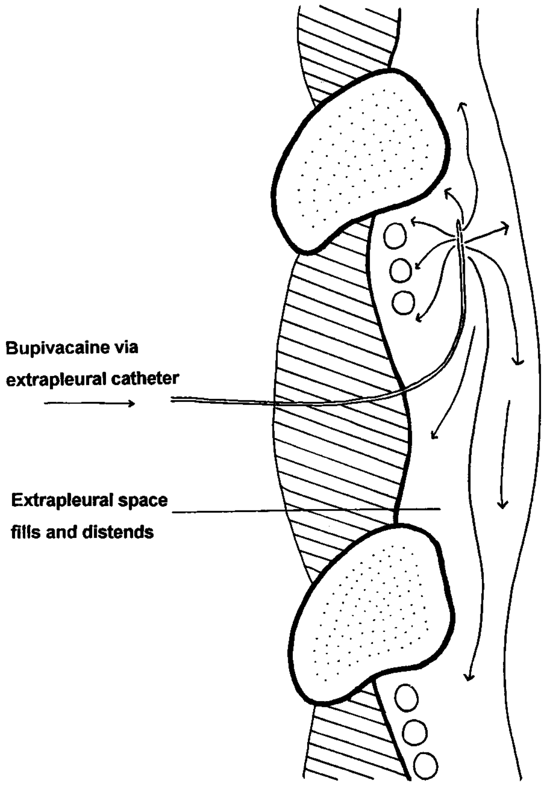

FIGURE 1b: Injection of bupivacaine loading dose; the extrapleural potential space is seen to fill longitudinally over several levels.

correlates with peak bupivacaine levels well below the toxic range[30,31] of 2-4 μg/ml[32].

Bupivacaine 0.1-0.2% infusion was commenced via a computer controlled pump in the recovery room. A volume slightly lower than the required loading volume was infused per hour (approx. 0.2 ml/kg/h), with the maximum infusion rate limited to 400 μg/kg/h[33,34].

All data was collected and analysed by one of the authors (CD). Intraoperative and postoperative administration of morphine and bupivacaine was recorded on an hourly basis. Pain scores (Table 1) and sedation scores (Table 2) were recorded hourly by the nurse caring for the patient. These are standard post-operative scoring systems used in our institution. A visual analog pain score using faces[35] was additionally measured for patients receiving PCA.

The time of removal of nasogastric tube and

TABLE 1
Pain scores

0	Asleep
1	Awake without pain
2	Mild pain
3	Moderate pain
4	Severe pain

TABLE 2
Sedation scores

0	Unrousable
1	Asleep but rousable
2	Drowsy
3	Awake

tolerating oral fluids without nausea or vomiting was recorded. Complications including postoperative nausea and vomiting (PONV), urinary retention, excessive sedation, catheter-related complications and gross symptoms or signs of bupivacaine toxicity were also recorded.

Statistical Analysis

Data are presented as mean values±SD.

RESULTS

Nine consecutive patients requiring thoracotomy for lung resection were included over a twelve month period. Clinical data are tabulated in Table 3.

The same surgeon placed eight of the nine extra-pleural catheters, all under instruction by the same

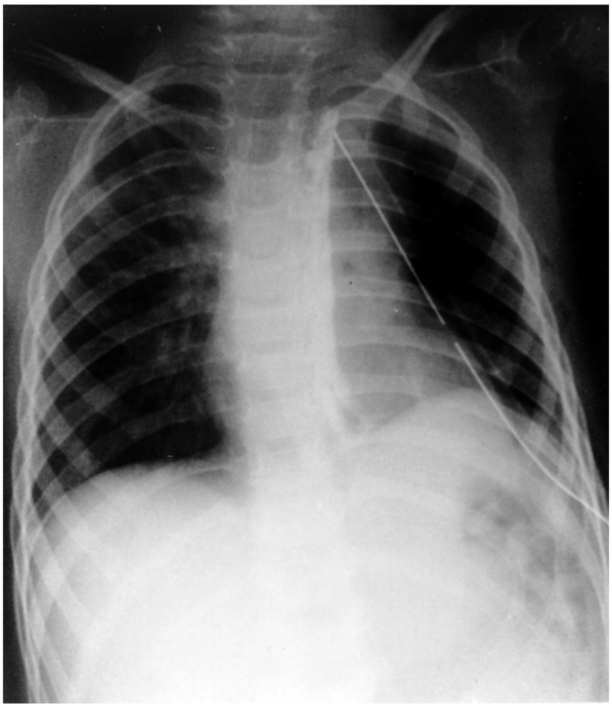

FIGURE 2: Chest X-ray showing extensive spread of contrast over seven intercostal spaces in the left paravertebral region. The extrapleural catheter cannot be seen through the contrast. This three-year-old girl, 14.8 kg, had an extrapleural catheter inserted following left upper lobectomy. Bupivacaine (3 ml 0.375%) was instilled extrapleurally prior to chest closure and followed by 2 ml of contrast media in the recovery room for this X-ray. Infusion of 0.125% bupivacaine was then commenced at 4 ml/hr and continued for 72 hours.

anaesthetist (MC). Operations performed were six lobectomies, one lung biopsy and two wedge resections with insertion of tunneled central line for chemotherapy.

Intraoperative extrapleural bupivacaine loading dose of 0.28±0.1 ml/kg was used. Children less than 20 kg (n=5) required a slightly higher than mean loading volume of 0.31±0.1 ml/kg to spread the minimum three intercostal spaces and a concentration of 0.25% (n=2), 0.375% (n=1), or 0.5% (n=2) was used. Children greater than 20 kg (n=4) required a slightly lower than mean loading volume of 0.24±0.09 ml/kg and bupivacaine 0.25% (n=1) or 0.5% (n=3) was used.

The mean loading dose of bupivacaine was 1.52±0.77 mg/kg.

Bupivacaine infusions of 0.21±0.09 ml/kg/h, at a concentration of 0.1% (n=1), 0.125% (n=7), or 0.2% (n=1), were continued at a constant rate for 72±15 hours. The mean dose of bupivacaine was 284±97 μg/kg/h (max. 410 μg/kg/h).

Mean intraoperative morphine administration was 301±175 μg/kg. All patients received supplementary morphine postoperatively.

Morphine administration in the first 24 hours postoperatively was 697±229 μg/kg/24 hours. This equates to mean morphine requirements of 29 μg/kg/h. Between 24 and 48 hours postoperatively, mean morphine requirements were 618±229 μg/kg/24 hours. This equates to mean morphine requirements of 26 μg/kg/h.

The duration of morphine administration was 92±32 hours.

Pain scores were recorded hourly and specifically studied at 2, 12, 24 and 48 hours postoperatively. Eight of nine patients had adequate postoperative analgesia (scores $\leq$2) at these times. One patient (subject #7) persistently complained of mild to moderate pain (score 2-3) despite extrapleural bupivacaine and relatively large amounts of morphine via PCA.

Sedation scores were recorded hourly and specifically studied at 2, 12, 24 and 48 hours postoperatively. No subject was found to be unrousable (score=0) at any time. The number of patients found to be drowsy (score=2) was considered the most significant observation. Two patients were found to be drowsy, one at 2 hours postoperatively (#4), the other at 24 hours (#3). There were no reports of respiratory depression or medical intervention in these drowsy patients.

Recovery of gastrointestinal motility: Subjects had a rapid progression to tolerance of oral fluids of 31.2±19.1 hours. Nasogastric tubes were removed at 16.7±11.2hours.

PONV, respiratory depression and pruritus did not occur in any patient. Urinary retention requiring catheterization occurred in two patients.

There were no complications due to the presence of the extrapleural catheter or the administration of bupivacaine. All catheters were removed intact after removal of the chest drains.

DISCUSSION

Despite the demonstrated effectiveness and safety of continuous extrapleural intercostal nerve block

TABLE 3
Clinical data

Patient No.	Age	Sex	Weight (kg)	Operation	Analgesia	Bupivacaine Loading Dose Concentration (%)	Bupivacaine Loading Dose Volume (ml)	Bupivacaine Infusion Concentration (%)	Bupivacaine Infusion Rate (ml/h)	Bupivacaine Infusion Duration (Hours)
1	9y 4m	M	30.0	Left upper lobectomy	PCA	0.25	10	0.125	5	68
2	3y 6m	M	14.0	Right upper lobectomy	Infusion	0.5	5	0.1	3	41
3	10y 1m	M	19.5	Left lingular lobectomy	PCA	0.25	4	0.125	4	75
4	9y 3m	M	52.0	Right upper lobectomy	Infusion	0.5	N/R	0.125	5	86
5	12y 2m	M	33.0	Wedge resection right upper lobe	PCA	0.5	5	0.2	5	90
6	5y 5m	F	15.4	Right middle and lower lobectomy	Infusion	0.5	6	0.125	5	62
7	11y 5m	M	66.0	Right thoracotomy for hilar lymph node and lung biopsy	PCA	0.5	15	0.125	8	89
8	1y 10m	M	12.0	Wedge resection right upper lobe	Infusion	0.25	5	0.125	4	69
9	3y 7m	F	14.8	Left upper lobectomy	Infusion	0.375	3	0.125	4	72

(CEINB) in adults[16-18,20, 22,23], there is little experience with this technique in children.

Eng et al[24] reported six children aged 7 to 16 years with CEINB for 120 hours post thoracotomy. Excellent analgesia was attained in all patients, with no requirement for PRN intramuscular opiates or other analgesic drugs while the infusion was in progress. The loading dose of bupivacaine used (0.2 ml/kg of 0.5% bupivacaine) was similar to that used in our study; however, we used an infusion of 0.2 ml/kg/hour of 0.125% bupivacaine rather than 0.5%, reducing the amount of bupivacaine administered by a factor of almost four (284±97 μg/kg/h versus 1 mg/kg/h). This satisfied our criterion that paediatric bupivacaine infusions should not exceed 400 μg/kg/h[33,34].

Vane et al[36] recently described a "retropleural" infusion using a similar technique with a more lateral placement of the extrapleural catheter. Ten neonates undergoing repair of tracheoesophageal fistula or oesophageal atresia were studied, with bupivacaine infusion of 0.125% at 1.5 ml/h (max. 414 μg/kg/h). All babies were extubated promptly postoperatively and none required parenteral opioids. The historical control group (which had IV opioid boluses) was ventilated for an average of 39.3 hours and there were several adverse respiratory incidents.

In both Eng and Vane's studies there were no requirements for supplementary parenteral opioid whilst CEINB was in progress. In contrast, for this study, no attempt was made to interfere with routine postoperative analgesia via nurse-controlled variable-rate morphine infusion or PCA.

Following cessation of the extrapleural bupivacaine infusion, two of our patients did not develop pain until 12 to 24 hours, suggesting a prolonged effect of the bupivacaine pooled within the paravertebral gutter. One patient, a three-year-old child with Downs' syndrome (#2) had both morphine and extrapleural bupivacaine ceased in error at 41 hours postoperatively. This child was pain free and cooperative until 24 hours later when pain became severe despite oral codeine and paracetamol, interfering with physiotherapy and requiring intravenous morphine to be recommenced. The other child, 12 years of age (#5), had extrapleural infusion continued till 90 hours post wedge resection and insertion of central line (for chemotherapy). Twelve hours later this child developed moderate to severe pain necessitating an increase in PCA bolus dose. These observations suggest that bupivacaine may pool extrapleurally, producing intercostal nerve block for up to 24 hours after the infusion is ceased.

Extrapleural Techniques

Several techniques for placement of an extrapleural catheter at thoracotomy have been described[4,16-19]. In the paravertebral gutter, the extrapleural space lies between the parietal pleura and the posterior intercostal membrane and contains the intercostal neurovascular bundle (Figure 1a).

Important features to consider when choosing a technique include (i) the proximity of the catheter to the vertebral column and (ii) the integrity of the parietal pleura in the paravertebral region.

If the catheter is placed medial to the angle of the rib, close to the vertebral column, spread of local anaesthetic solution occurs with relative ease to multiple levels due to reduced adherence of the parietal pleura to the ribs in this region (Figure 1b). If fluid is injected extrapleurally lateral to the angle of the rib, spread within only one intercostal space is more likely[37]. This may explain less effective extrapleural block if the catheter is placed lateral to the angle of the rib due to reduced spread to multiple levels. A reduced chance of blocking the sympathetic chain and the posterior primary rami may also play a role[38].

The integrity of the parietal pleura medial to the angle of the rib is essential to prevent bupivacaine leaking to the interpleural space[16]. Pulmonary lobectomy patients are therefore more suitable to this technique than children having thoracotomy for anterior spinal or closed cardiac surgery, where the pleura may be disrupted in the paravertebral region.

Extrapleural Paravertebral Techniques

Direct catheterization of the paravertebral space at thoracotomy by placing the tip of an extrapleural catheter through the extrapleural fascia has been described in adults[19,23]. There has, however, been some confusion in the nomenclature where this has been described as CEINB[21,23,38]. Karmakar et al[39] recently studied 20 infants with a median age of 5.3 weeks undergoing lateral thoracotomy for ligation of patent ductus arteriosus, repair of coarctation and modified Blalock-Taussig shunt. They described the placement of an extrapleural paravertebral catheter at surgery and commented that the extrapleural fascia was difficult to delineate. Following intraoperative loading dose of 0.25% bupivacaine (1.25 mg/kg), an infusion of 500 μg/kg/h was continued for 24 hours with no opioid supplementation required in 90% of the patients. The remaining 10% failed due to catheter blockage.

The benefits of paravertebral spread are (i) blockade of the intercostal nerve at a site where it is not enclosed by fascial sheaths, (ii) blockade of the sympathetic chain which mediates pain signals from visceral sympathetic afferents, and (iii) blockade of posterior primary rami which mediate pain from the ligaments of costovertebral and costotransverse joints and the posterior spinal muscles[20,38,40].

Continuous intercostal nerve block with an extrapleural catheter has several advantages over other methods of regional analgesia for unilateral thoracotomy such as individual intercostal nerve block, subcostal, interpleural and extradural block. Individual intercostal nerve block of several levels at surgery has a relatively short duration of action and repeated blocks two or three times a day are associated with patient discomfort and a small incidence of pneumothorax[1,41].

Subcostal Catheter Techniques

Placement of single or multiple catheters alongside the nerve in the subcostal groove provides effective analgesia via spread to multiple levels in the extrapleural space. These catheters if inserted percutaneously at the angle of the rib, can be technically difficult to feed medially to ensure multilevel spread, and also involve placing a needle close to the vessels and nerve with the associated risk of intravascular placement and neuropraxia[26]. Placement of the catheter extrapleurally in the paravertebral gutter under direct vision at surgery overcomes these problems and obviates the need for more than one catheter[38].

Interpleural Catheter Techniques

Interpleural analgesia (IPA) using bupivacaine infusions of greater than 750 μg/kg/h is an effective technique in children after lateral thoracotomy for ligation of patent ductus arteriosus, repair of coarctation, excision of thoracic tumour or anterior spinal surgery[5,6,8]. Tobias et al[7] reviewed 14 children with IPA used for a mean of 45 hours post thoracotomy; only five patients required supplemental parenteral opioid. The large doses of bupivacaine required for effective IPA in children, however, have raised concern about bupivacaine toxicity.

McIlvaine et al[5] used high doses of bupivacaine of 1.25 to 2.5 mg/kg/h to attain effective interpleural block in fourteen children. This resulted in potentially toxic levels of bupivacaine of over 4 μg/ml in five patients and over 7 μg/ml in one patient without symptoms or signs of toxicity. McIlvaine[6] also noted that patients who were sat up for longer than one hour experienced pain which was relieved upon returning to the recumbent position; patients with IPA therefore need to remain in a supine or lateral position.

One report by Agarwal et al[42] of a seizure in a three-year-old child with IPA followed the conservative dose of 500 μg/kg/h of bupivacaine for 16 hours. The lung biopsy showed multiple arteriovenous malformations and angiomas which may have enhanced systemic absorption in this child. CEINB and IPA may not be appropriate techniques when there is the potential for markedly increased uptake of local anaesthetics, such as pulmonary angiomas or pleural inflammation.

Extradural Catheter Techniques

The use of thoracic extradural analgesia in children is contentious as it may be technically difficult, symptoms and signs of intravascular placement may be absent[3], and direct trauma to the cord may be undetectable. Catheters inserted at a caudal or lumbar level may be passed to the thoracic region but this is unreliable. Regional anaesthetic techniques using a catheter inserted under vision at thoracotomy which provide adequate analgesia are attractive in terms of lesser risk.

Complications

CEINB, like all regional techniques, has potential complications. Possible local complications include local bleeding, infection, or retained catheter tip. Sympathetic blockade can cause unilateral Horner's syndrome, whilst the phrenic, recurrent laryngeal and vagus nerves could also potentially be blocked. Spread of local anaesthetic to the extradural space is also anatomically possible[43,44].

Systemic bupivacaine toxicity can cause myocardial depression, arrhythmias and seizures. Warning signs include tinnitis, headache, blurred vision, metallic taste and lethargy[2], but children are less likely to report such symptoms and signs[33,42,45]. Accidental intravascular injection is unlikely with CEINB because of the catheter position and the initial dose of bupivacaine being injected under direct vision. Absorption of bupivacaine from the intercostal space, however, is more rapid in children than in adults[30].

Several recent reports of seizures in children receiving infusions of bupivacaine highlight the importance of conservative dosing. These include caudal infusions of 1.67 mg/kg/h in two children[34], and epidural infusion of 1.25 mg/kg/h in another[42]. Recommended maximum doses of 400-500 μg/kg/h are probably safe in children with no other risk factors for seizures[33] such as previous seizures, electrolyte abnormalities (e.g. hyponatremia, hypophosphatemia), high fever[46], or enhanced uptake of local anaesthetic[42]. An adult study of CEINB in twelve patients with 500 μg/kg/h of bupivacaine for 120 hours measured toxic peak levels of 4.9 ± 0.7 μg/ml (mean±SEM) with a wide range of 1.3 to 9.3 μg/ml[47].

Karmakar et al[39] recorded mean maximum serum concentrations of bupivacaine at 2.0 μg/ml at 24 hours in twenty young infants using a paravertebral infusion of bupivacaine 500 μg/kg/h. Bupivacaine levels were showing evidence of accumulation at this time and there was potential for toxic levels to occur if the infusions were continued past the 24 hours. Weston[48] showed safe blood levels with single bolus interpleural bupivacaine 2.0 mg/kg in very low birth weight infants (<1500g) but cautioned about the unpredictability of redosing and the potential for accumulation.

The above evidence justifies the use of conservative doses of bupivacaine of 284 ± 97 μg/kg/h (maximum 410 μg/kg/h) for this study.

Further studies of CEINB and continuous extrapleural paravertebral nerve block in children are required. The technique of tunneling the tip of the extrapleural catheter through to the paravertebral space intraoperatively may provide superior analgesia[24,39]. In particular the adequate assessment of analgesia and the measurement of local anaesthetic pharmacokinetics with these differing techniques in neonates, infants and children need to be studied separately to determine the optimal route, bolus and infusion dosages.

Our initial experience suggests that continuous extrapleural intercostal nerve block with low doses of bupivacaine is a safe technique in children, which minimizes complementary opioid administration and provides adequate analgesia post thoracotomy for lung resection. It has advantages over other forms of regional blockade, especially in terms of ease of insertion, maintenance, and low risk of systemic complications.

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