Brief Review

Lumbar epidural anaesthesia for inguinal hernia repair in low birth weight infants

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In view of the complications of general, spinal, and caudal anaesthesia for inguinal hernia repair in high-risk neonates, an evaluation of lumbar epidural anaesthesia (LEA) was undertaken to assess its technical feasibility, effectiveness and incidence of complications. In 18 consecutive cases, gestational age 26 ± 2.6 wk, birth weight 877 ± 310 g, 16 (89%) had bronchopulmonary dysplasia and 12 (67%) were oxygen-dependent at the time of surgery. Using a standard loss of resistance technique and a 4.0 cm 20 G epidural needle, the epidural space was positively identified on the first attempt in 16 (89%), and on the second attempt in 2 patients (11%). Reflux of 0.9% saline used to identify the epidural space was blood tinged in two cases. Epidural analgesia was achieved in all cases with bupivacaine 0.25% with and without 1:200,000 epinephrine, 0.75 $ml \cdot kg^{-1}$ for the first two cases, and subsequently 1.0 $ml \cdot kg^{-1}$. In 15 patients (83%), good operating conditions were achieved with epidural analgesia alone. Inhalational anaesthesia supplementation was necessary in three cases (17%). In the first two patients, the level of analgesia (T_8) was insufficient to control the response to traction on the hernial sac. In one infant, analgesic to T_4, whose surgery was inadvertently delayed for four hours, inhalation anaesthesia was needed to control restlessness rather than pain. Ten infants were analgesic to T_2, four to T_4, two to T_6 and two to T_8. Intraoperative periodic breathing was seen in seven infants (39%), four with oxyhaemoglobin desaturation to 75%, and two to 85%. All responded to increased FIO_2. No adverse haemodynamic effects were seen. Apnoeic spells in the first 24 hr after surgery occurred in three infants; one of these infants also had apnoeic spells during the previous 24 hr. Otherwise, there were no postoperative complications. We conclude that LEA was technically easy, and provided good operating conditions for most neonates in this study.

Etant donné l'importance des complications de l'anesthésie générale, rachidienne et caudale réalisées pour la cure de hernie inguinale du nouveau-né à haut risque, une évaluation de l'anesthésie épidurale lombaire est entreprise pour en évaluer la faisabilité technique, l'efficacité et la morbidité. Dans 18 cas consécutifs, d'âge conceptionnel de 26 ± 2,6 semaines, pesant à la naissance 877 ± 310 g, dont 16 (89%) souffrent de dysplasie bronchopulmonaire et 12 (67%) survivent sous oxygène au moment de la chirurgie. Avec une technique standard de perte de résistance et une aiguille épidurale 20 G de 4,0 cm, l'espace épidural est repéré au premier essai dans 16 cas (89%) et au deuxième chez deux patients (11%). Le reflux de soluté physiologique 0,9% utilisé pour le repérage revient teinté de sang chez deux patients. Dans tous les cas, l'anesthésie épidurale est réalisée avec de la bupivacaïne 0,25% avec et sans épinéphrine, 0,75 $ml \cdot kg^{-1}$ pour les deux premiers cas et par la suite 1,0 $ml \cdot kg^{-1}$. Chez 15 patients (83%), de bonnes conditions opératoires sont obtenues avec l'épidurale seule. Dans trois cas, on doit supplémenter avec de l'anesthésie inhalatoire (17%). Chez les deux premiers patients, le niveau d'analgésie (T_8) est insuffisant pour abolir la reaction à la traction du sac herniaire. Chez un patient, analgésié à T_4, pour qui la chirurgie doit être retardée pour une heure, l'anesthésie inhalatoire est requise plutôt pour contrôler l'agitation que la douleur. Le niveau analgésié atteint T_2 chez dix enfants, T_4 chez quatre, T_6 chez deux et T_8 chez deux. Une respiration périodique peropératoire survient chez sept patients (39%) dont quatre avec désaturation à 75%, et deux à 85%. Ils réagissent bien à une augmentation de la FIO_2. On ne constate pas de réactions hémodynamiques défavorables. Des périodes d'apnée pendant les 24 hres qui suivent la chirurgie se manifestent chez trois enfants; un de ceux-

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ci avait eu des périodes d'apnée pendant les 24 hres précédentes. On ne constate pas d'autres complications postopératoires. Nous concluons que l'épidurale lombaire est facile techniquement et a produit de bonnes conditions chirurgicales chez la plupart des nouveaux-nés inclus dans l'étude.

With continuing advances in perinatology and neonatal intensive care, more infants survive the immediate perils of extreme prematurity. In these patients there is a high incidence of inguinal hernia, up to 30% in infants less than 1000 g birth weight,[1] for which early surgical correction is required to prevent potentially life-threatening complications.[2] The choice of anaesthesia presents unique anatomical and pathophysiological problems. General anaesthesia is accompanied by a high incidence of complications; further laryngeal damage, aspiration pneumonitis and apnoeic spells.[3-6] Extubation after general anaesthesia in infants with bronchopulmonary dysplasia (BPD) who had been weaned from ventilator dependency and whose tracheas had been extubated previously, can present extreme difficulty. Consequently, regional anaesthesia techniques are advocated. Spinal anaesthesia (SA) is an option[7] but, in our experience, is limited by technical difficulty and uncertain spread, duration and effectiveness.[8] Caudal epidural anaesthesia has been recommended,[9] but is not free of difficulty and complications.[10] Lumbar epidural anaesthesia (LEA) for inguinal hernia repair in infants and children was described in 1954.[11,12] Despite its widespread use in adults, the method has not gained similar acceptance in children and infants. For 18 consecutive inguinal hernia repairs in low birth weight infants we have undertaken an assessment of LEA, to examine its technical feasibility and effectiveness, and the incidence of complications.

Methods

After the hernia was diagnosed, the aim of treatment was to delay surgery until the infant reached 2200 g and was otherwise fit for discharge from hospital. In otherwise stable infants, oxygen dependency alone does not preclude discharge from hospital. To reduce the risk of incarceration and to alleviate parental anxiety, the repair was completed before the infant left the neonatal intensive care nursery.

The LEA was performed with parental consent and approval by the institutional and University Ethics Committees. Contraindications included continued need for respiratory stimulants, coagulopathies, systemic infections, meningitis, hypovolaemia, infection at the puncture side, active intracranial bleeding, intracranial hypertension or cerebrospinal fluid draining catheter, and congenital anomalies of the lower spine. In those infants with previous intracranial bleeding, resorption of clot was demonstrated by serial ultrasound examinations.

Normal oral intake was allowed up to four hours before surgery for infants not maintained on intravenous feeding. A secure intravenous infusion was started before anaesthesia and dextrose 5% in 0.225% saline was administered at a rate of 5.0 $ml \cdot kg^{-1} \cdot hr^{-1}$ by means of an infusion pump. EMLA cream, to facilitate subsequent subcutaneous infiltration with local anaesthetic solution was applied to the region of the $L_{3/4}$ and $L_{4/5}$ interspaces 90 min before surgery, and covered with a non-absorbent dressing. The infant was brought to the previously warmed operating room (25°C) in a warmed transport isolette with ECG monitoring and oxygen administration as necessary.

Anaesthetic technique

Preparations were made for general anaesthesia and resuscitation. Additional monitors included pulse oximeter, automatic electronic sphygmomanometer, precordial stethoscope, and after induction of anaesthesia, rectal temperature. Atropine, 0.02 $mg \cdot kg^{-1}$ *iv*, was administered before induction.

Lumbar epidural anaesthesia was induced with the infant sitting with the back flexed and the head supported and somewhat extended. Landmarks were confirmed. The total dose of 0.25% bupivicaine with or without 1:200,000 epinephrine, 1.0 $ml \cdot kg^{-1}$ (2.5 $mg \cdot kg^{-1}$) was drawn into a plastic Luer slip 3.0 ml syringe. Using aseptic technique and after skin preparation with proviodine, the skin and subcutaneous tissues over the wider of the $L_{3/4}$ or $L_{4/5}$ interspaces was infiltrated with 0.5% lidocaine and pierced in the midline with an 18 G needle. The epidural space was identified by loss of resistance (LOR) using preservative free 0.9% saline under pressure as the indicator as described by Bromage.[13] A 4.0 cm 20-G Tuouhy needle (Preferred Medical Products Inc.) was inserted through the skin puncture to an initial depth of approximately 7.0 mm. The needle is calibrated at 5.0 mm intervals which begin 1.0 cm from the tip (Figure). A 4.0 ml Portex Concord plastic LOR syringe containing about 3.0 ml 0.9% saline was attached. The needle, with the orifice of the Huber tip facing cephalad, was gripped firmly at the junction of hub and shaft between index finger and thumb of one hand and advanced with constant pressure maintained on the plunger of the syringe with the other hand.

The dorsum of the finger gripping the needle was braced against the infant's back so as to provide controlled forward motion and instantaneous braking force immediately the epidural space was entered. The epidural space was identified by loss of resistance at a depth of 1.1 to 1.4 cm, taking care not to inject more than about

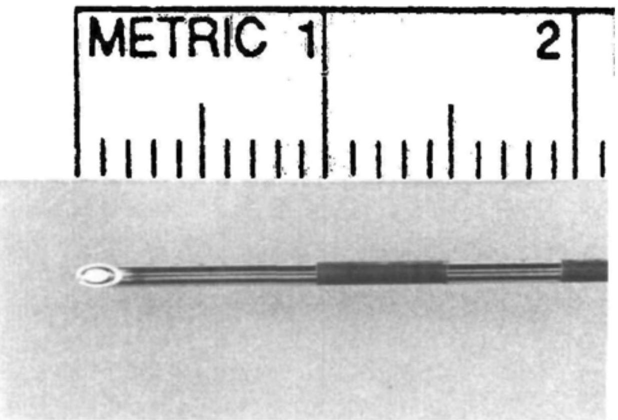

FIGURE Epidural needle 4.0 cm 20 G. Terminal 2.15 cm, showing blunt, rounded Huber tip and 5 mm intervals.

0.5 ml of saline, to minimize dilution of the local anaesthetic. The syringe was detached and the needle hub observed for fluid reflux. An epidural catheter was not inserted.

A test dose of 0.5 ml of local anaesthetic was injected, the stylette replaced, and the infant observed for about four minutes for evidence of subarachnoid block. Absence of flaccid paralysis was tested by estimates of lower limb tone in response to gentle passive movement. The remainder of the calculated dose was injected in approximately 0.5 ml aliquots at 90-sec intervals, with the infant maintained in the sitting position. The stylette was replaced between each injection to prevent reflux and loss of local anaesthetic. The needle was not aspirated at any time. The infant was positioned and prepared for surgery and, if restless, offered a soother containing a cotton ball soaked in 5% dextrose in water. For oxygen-dependent infants, nasal oxygen administration was continued at the rate previously prescribed. Twenty minutes after the last epidural injection, analgesia was confirmed by the absence of response to a towel clip applied to the skin in the surgical field. The sensory level of analgesia was tested at the end of the procedure by pinching the skin.

Postoperative analgesia was provided if necessary with acetaminophen 10–15 $mg \cdot kg^{-1}$ *po*. Postoperative cardiorespiratory monitoring by ECG and the respiratory channel on the ECG monitor was continued until the infant was free of apnoea for 48 hr; otherwise for one week after the most recent apnoeic spell.

Results

The characteristics of the patient population are shown and results summarized in Tables I and II. All infants had been weaned from ventilator care and extubated. Sixteen of 18 infants had BPD (89%), defined as oxygen dependency at 30 days of age, with characteristic chest radiological appearance. Twelve infants (67%) were oxygen-dependent at the time of surgery, receiving low-flow 100% oxygen by nasal cannula, usually 0.05–0.2 $L \cdot min^{-1}$, titrated to produce an SaO_2 of 88–92%. The 18 LEA's were administered by five anaesthetists, both staff anaesthetists and residents. All were familiar with lumbar epidural blockade in the adult, but inexperienced in its use in small infants. In 16 cases, the epidural space was identified on the first attempt. In two cases, the initial LOR was judged to be equivocal, but was positive on the second attempt. In two cases the fluid reflux was blood tinged and although the appearance was not of pure blood, its source was judged to be from a damaged epidural vein. In one infant, epidural puncture was repeated in an adjacent interspace; in the other, after a negative test dose, the fractionated remaining dose was administered without incident.

In all 18 cases, analgesia in the surgical field was confirmed before surgery began by lack of response to a painful stimulus. In 15 cases (83%), surgery was completed with epidural analgesia alone. For the first two

TABLE I Demographic data: $n = 18$ (male). Lumbar epidural anaesthesia for inguinal hernia repair in low birth weight infants

	Mean	*SD*	*Range*
Gestational age (wk)	26	2.6	24–32
Birth weight (g)	877	310	590–1570
Days ventilated	58	27.5	2.5–100
Weight at surgery (g)	2542	361	2150–3330
Postconceptional age at surgery (wk)	40	2.6	36–45
Bronchopulmonary dysplasia	$n = 16$ (89%)		
Oxygen dependent at the time of surgery	$n = 12$ (67%)		

TABLE II Events and complications. Lumbar epidural anaesthesia for inguinal hernia repair in low birth weight infants

Epidural entry	18 (100%)
– First attempt	16 (89%)
– Second attempt	2 (11%)
Successful analgesia	18 (100%)
Level of analgesia:	
– T_2 (dose 1.0 $ml \cdot kg^{-1}$)	10 (56%)
– T_4 (dose 1.0 $ml \cdot kg^{-1}$)	4 (22%)
– T_6 (dose 1.0 $ml \cdot kg^{-1}$)	2 (11%)
– T_8 (dose 0.75 $ml \cdot kg^{-1}$)	2 (11%)
Vascular penetration	2 (11%)
Supplementary inhalation anaesthesia	3 (17%)
Intraoperative period breathing	7 (39%)
– with desaturation: to 85%	2 (11%)
– to 85–75%	4 (22%)
Apnoeic spells in first 24 hr	3 (17%)

procedures in the series, the dose of local anaesthetic solution was 0.75 $ml \cdot kg^{-1}$. In both infants, response to traction on the hernia sac was controlled with brief administration of 0.5–1% halothane in air/oxygen by face mask. At the conclusion of surgery, both were analgesic to T_8. For subsequent cases, the dose was increased to 1.0 $ml \cdot kg^{-1}$. In one case, after surgery was pre-empted for four hours by an acute emergency, inhalational anaesthesia was required to control restlessness rather than pain. This infant was analgesic to T_4. All other infants were either tranquil throughout surgery, or transient restlessness responded to the dextrose/water soother. Ten infants were analgesic to T_2, four to T_4, two to T_6, and two to T_8. Lower limb muscle tone and activity were much reduced, but not abolished. No adverse haemodynamic effects were seen.

Intraoperative periodic breathing, defined as recurring reduction in respiratory activity coinciding with oxyhaemoglobin desaturation, was seen in seven oxygen-dependent infants (39%), two with oxyhaemoglobin desaturation to 85% and four to 75%. All responded to increased FiO_2 and surgery was completed without inhalation anaesthesia supplementation. In the first 24 hr after surgery, three infants had apnoeic spells; one of these had had apnoeic spells during the day before surgery. All responded to stimulation only. Otherwise there were no postoperative complications.

Discussion

The objectives of anaesthesia for inguinal hernia repair in high-risk neonates are to provide analgesia and relaxation without physiological disturbance, avoiding general anaesthesia and systemic sedation. Our experience of spinal anaesthesia suggested that high afferent blockade, to T_4–T_2, was necessary to achieve tranquil operating conditions. In ten cases with high spinal block, although haemodynamic stability was not impaired, we observed transient apnoea in two, and periodic breathing in four. In another study, an increased need for airway management with high spinal blockade was reported.[14] Chest wall motion studies during high SA for inguinal hernia repair in infants born prematurely demonstrated suppression of coordinated intercostal muscle activity.[15]

In 80 consecutive spinal anaesthetics for hernia repair in high-risk neonates with continued practice, our success rate did not improve with continued practice over that previously reported. Inability to perform lumbar puncture (6%), technical difficulty ("bloody tap," 21%), restlessness during surgery requiring supplemental anaesthesia (32%), unpredictable spread and duration of anaesthesia, and adverse respiratory effects with high blockade, led to our abandoning the method. Despite some favourable reports of spinal anaesthesia,[16,17] others have experienced similar difficulties,[18] and caudal epidural anaesthesia for inguinal hernia repair in high-risk neonates is recommended as a more satisfactory alternative.[19,20]

Combined with light general anaesthesia, caudal block (CB) is widely practised in older children for surgery below the umbilicus.[21] In small ex-premature neonates, the method is not free of difficulty. The sacral canal is narrower than in older children, with an increased risk of needle placement outside the epidural space. The dural sac in neonates extends to S_3–S_4, compared with S_2 by two years of age, with increased risk of inadvertent intrathecal injection. Sensory blockade to T_4, considered necessary in conscious neonates to prevent response to peritoneal traction, requires a substantial dose, 3.75 $mg \cdot kg^{-1}$ of bupivacaine.[19] Inadvertent intravascular injection could then cause potentially toxic plasma levels which have been estimated to be 4.0 $\mu g \cdot ml$.[22,23]

In a series of 69 conscious premature and high-risk infants, 14 (22%), required supplementation with inhalational or intravenous sedation, and in five infants (8%), spinal anaesthesia was necessary for completion of surgery.[24] In a series of 1100 paediatric CB's in a teaching hospital,[25] difficult landmarks were found in 11.2%, and the incidence was higher ($P < 0.001$) in patients <10.0 kg. There were 76 bloody taps (6.9%). Eight patients (0.73%) had systemic reactions, defined as brisk onset of tachycardia during or shortly after the CB, all of which responded quickly to hyperventilation with oxygen. Six of these occurred with no previous evidence of blood, all in children weighing <10 kg. Total spinal anaesthesia after CB in an infant has been reported.[26]

Lumbar epidural anaesthesia has theoretical advantages. The landmarks, the iliac crests and the spinous processes of L_3, L_4 and L_5 are easily identified and more constant than the sacral hiatus. Loss of resistance to saline under pressure identifies the epidural space. The blunt rounded bevel of the Huber-tipped Tuohy epidural needle orientated transversely to the longitudinal fibres of the dura may be less likely to pierce the theca than the sharper bevel of the caudal needle. Compared with CB, local anaesthetic solution is injected closer to the nerve roots to be blocked and higher blockade is achieved with a smaller dose. Potential hazards of LEA include inadvertent intrathecal and intravascular injection.

The dimensions of the posterior lumbar epidural space in the infant are unknown. Recent observations from adult cadavers based upon cryomicrotome sections,[27] and using computed tomographic[28,29] and magnetic resonance imaging,[30,31] indicate that the epidural contents are found in circumferentially segmented compartments, rather than in a uniform layer. Posteriorly, an epidural compartment containing fat forms between the middle of one lamina and the cephalad edge of the next lower lamina, roofed

by the inferior portion of the lamina and the ligamenta flava. Large areas of the dura are in direct contact with the spinal canal wall. *In vivo* in infants, due to a relative lack of epidural fat, the posterior interlaminar epidural space may be potential rather than real.

The LOR (liquid) technique originally described by Sicard and Forestier (1921), by Dogliotti (1933), and by Bromage,[13] and the blunt, rounded Huber-tipped Tuohy epidural needle may contribute to accuracy and safety. Advancing the needle with constant pressure applied to the plunger of a saline filled syringe provides an immediate and definite end point when the epidural space is entered. It is postulated that the jet of liquid injected at that moment separates epidural veins and the dura from the tip of the needle.

Compared with SA, our improved success with LEA may have been influenced by anatomical and physiological differences. The target, the rudimentary ligamentum flavum, as part of the wall of the spinal canal, is constant and fixed. The postero-lateral wall of the spinal canal, as a segment of a greater arc than that of the circumference of the theca, offers a larger target. The epidural space may be entered at any point along this arc so that the aim of the needle may be less critical than for spinal anaesthesia.

The dura is a relatively mobile membrane which may be deflected rather than pierced if the aim of the needle is less than perfect. Successful lumbar puncture, indicated by free flow of cerebrospinal fluid (CSF), requires adequate CSF volume and pressure. Both are subject to variations that are not immediately predictable or controllable. Neonatal lumbar puncture requires a high degree of expertise. In the hands of experienced neonatologists, a failure rate of 10% is common. The opportunity for anaesthetists to acquire similar skill is limited. In spinal and thoraco-lumbar epidural anaesthesia, most anaesthetists acquire their training and experience in adult practice. Our experience suggests that proficiency in adult SA is less readily extrapolated to the small infant than is similar competence in LEA.

The quality of epidural blockade is influenced by the dose and concentration of local anaesthetic, and the spread by the volume injected. A dose of 0.25% bupivicaine, 1.0 $ml \cdot kg^{-1}$ (2.5 $mg \cdot kg^{-1}$), was chosen to minimize total dose and motor blockade while achieving an adequate quality and extent of sensory block. In older children, CB with 0.2% and 0.175% bupivacaine is usually combined with general anaesthesia. Separate small boluses were injected to minimize the rate of systemic absorption. Epinephrine was omitted in the last eight patients in the series to avoid increasing the degree of motor blockade and unnecessarily prolonging its duration. With the dose used, systemic absorption from the epidural space is considered to be well below that capable of producing toxic blood levels, estimated to be 4.0 $\mu g \cdot ml$. In pharmacokinetic studies using bupivacaine for caudal anaesthesia, the average peak bupivacaine concentrations following 2.5 $mg \cdot kg^{-1}$ of the plain solution were 1.25 $\mu g \cdot ml$.[32] After 3.75 $mg \cdot kg^{-1}$ (0.75 $ml \cdot kg^{-1}$ of 0.5% bupivacaine with 1:200,000 epinephrine) for thoraco/lumbar epidural anaesthesia in infants and children, peak plasma levels of 1.35 ± 0.51 were measured.[33] In infants, the addition of epinephrine is a questionable marker of inadvertent intravascular injection.[34]

In our hands, lumbar epidural anaesthesia was technically less difficult, and more predictable and effective than previous studies using spinal anaesthesia for inguinal hernia repair in high-risk neonates. Our experience compares favourably with previously published reports of caudal anaesthesia for this procedure. Lumbar epidural anaesthesia has theoretical advantages.

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