Local anesthetics: New insights into risks and benefits
Lirk, Philipp

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: http://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
Failed epidural – causes and management

Based on
Hermanides J, Hollmann MW, Stevens MF, Lirk P
Failed epidural: causes and management
Br J Anaesth 2012; 109: 144-54
Introduction

In contrast to the subjective experience of many anaesthesiologists, failure of epidural anaesthesia and analgesia is a frequent clinical problem (feedback error). Current estimates concerning the incidence of failed epidurals are hampered by lack of a uniform outcome parameter. The definitions given cover a spectrum ranging from insufficient analgesia to catheter dislodgement to any reason for early discontinuation of epidural analgesia (Table 1). In a heterogeneous cohort of 2140 surgical patients, failure rates of 32% for the thoracic, and 27% for the lumbar epidural were described. Of note, active management of insufficient epidural anaesthesia, including a new block, results in an almost complete success rate. In an imaging study investigating failed epidurals, incorrect catheter localization accounted for half of the failures, while the remaining patients experienced suboptimal analgesia through a correctly positioned catheter. A flow chart adapted from Kinsella et al. illustrates in exemplary fashion the problems encountered during epidural anaesthesia using the example of a caesarean section, ultimately resulting in a success rate of just 76% (Figure 1).

The present review summarizes technical factors known to influence block success, and gives an overview of the pharmacologic strategies available to optimise epidural anaesthesia and analgesia. For each section, we performed a comprehensive literature search for full published reports in MEDLINE covering manuscripts until October 2011, with reference lists of retrieved articles searched for additional trials or reports. We ranked meta-analyses and randomized controlled trials highest, with other trials and reports resorted to in case no broad evidence base could be discerned.
Technical factors influencing block success

Anatomical catheter location

Epidural catheters may primarily be placed erroneously, or dislodge during the course of treatment. Collier described transforaminal migration of the catheter tip and asymmetric epidural spread as the most important caveats during epidural analgesia.\(^4\) Primary malposition of epidural catheters has been described, among others, in the paravertebral space, in the pleural cavity, and intravascularly. Even when the epidural space is correctly identified, the catheter will not necessarily follow a straight line when being advanced, but may deviate in different directions. The epidural catheter may exit the epidural space via the intervertebral foramen at levels above or below the insertion site (Figure 2). In obstetric patients, failure of epidural analgesia after initial success was observed in 6.8% of a studied cohort.\(^2\) Furthermore, secondary migration of the catheter after successful initial placement can occur. During normal patient movement, epidural catheters may be displaced by centimetres.\(^5\) Hoshi et al investigated 60 patients undergoing lung surgery with a thoracic epidural, with chest radiographs taken pre- and postoperatively. In 24% of the patients, the catheter had migrated more than one vertebral level. In addition to gross body movements, changes in epidural pressure and cerebrospinal fluid oscillations contribute to displacement of epidural catheters.\(^6\) The epidural space is highly compartmentalized and complex structure,\(^7\) which may influence catheter placement. Moreover, midline fat pedicles may form a barrier to spread of local anaesthetics.\(^7\)

Patient position

Patient positioning potentially affects needle placement by changing the conformation of osseous and soft tissues. In addition to the obvious opening of the posterior interlaminar space by spinal flexion, the position of spinal contents is altered. The position of the spinal cord within the spinal canal is not precisely
predictable using parameters such as sex, weight or height. However, the patient assuming a flexed position with the head down will result in anterior motion of the spinal cord at the thoracic level, while the spinal cord and cauda equina are located more posteriorly at the lumbar level. The spinal cord is flexibly attached within the dural sac, and changes position according to gravity when subjects are positioned supine, or laterally.

The sitting position has been described to result in shorter insertion times and a trend toward higher accuracy at first attempt than the lateral position, but at the cost of more vagal reflexes, and with comparable final success rates. When investigating combined spinal-epidural anaesthesia for caesarean section, no differences were reported concerning insertion times, while another study found more technical difficulties in the lateral compared to the sitting position. Lateral positioning increases the distance from skin to epidural space. Finally, the sitting position leads to epidural venous plexus distension, which may increase risk of vascular puncture, especially in parturients.

**Puncture site**

Numerous studies have shown that anaesthetists tend to be inaccurate when determining the precise dermatomal level for neuraxial puncture. Of note, most studies show that there is a clear tendency to puncture more cranially than intended. Suggested approximate vertebral levels of puncture for various types of surgery are given in Table 2.

**Midline vs Paramedian**

Few studies have examined the effect of median versus paramedian needle placement upon block success. In cadavers, using epiduroscopy, paramedian catheters were observed to cause less epidural tenting, and pass cephalad more reliably than median catheters. In patients, Leeda et al. reported
faster catheter insertion times in the paramedian, and higher incidence of paraesthesia in the median group.\textsuperscript{18} Adequate local infiltration is a prerequisite for patient comfort during paramedian puncture.\textsuperscript{19, 20} Finally, the paramedian approach may be less dependent upon spine flexion.\textsuperscript{20} The risk of vascular puncture during epidural catheter placement was not associated with lumbar median or paramedian technique in parturients,\textsuperscript{19} while another study suggested more paraesthesia and bloody puncture in non-pregnant adults when the median approach was used.\textsuperscript{20}

\textit{Localization of the epidural space}

Inability to correctly insert an epidural catheter in the first place or the number of attempts to catheter placement is not reported in most studies, while differences are likely to exist between the thoracic vs. lumbar approach. For example, Rigg and coworkers were completely unable to localize the thoracic epidural space in 13/447 (2.9\%) attempts.\textsuperscript{21}

Placement of the epidural catheter in the correct position necessitates tools to identify the epidural space. There is considerable variation in the methods used to confirm epidural needle position.\textsuperscript{22} Loss of Resistance (LoR) using saline has become the most widely used method, while LoR to air and the hanging drop technique are less widely used.\textsuperscript{\textit{e.g.}}\textsuperscript{22} A meta-analysis by Schier and colleagues in 2009 included 5 RCTs comparing LoR to saline versus air: four in the obstetric population and one in a general patient population, summarizing a total of 4422 patients. No significant difference in any outcome was found, except an absolute 1.5\% reduction in postdural puncture headache when using saline vs. air.\textsuperscript{23} In the meantime, a clinical trial comparing combined spinal-epidural punctures using air vs. saline found no difference in success rate or adverse events.\textsuperscript{24} A recent retrospective study of 929 obstetric epidurals found that when using air for LoR, significantly more attempts were needed as
compared to using saline, with comparable final success rates. Subgroup analyses showed that the use of the “preferred technique” (defined as the technique used by a practitioner >70% of the time) resulted in significantly fewer attempts, a lower incidence of paresthesia, and fewer unintentional dural punctures, irrespective of whether saline or air was used for LoR.

The hanging drop technique depends on negative pressure within the epidural space. Recent experimental evidence suggests that negative pressure is suboptimal in reliably detecting the epidural space, and if at all, the hanging drop technique is prudent only in the sitting position. Of note, identification of the epidural space was reported 2 mm deeper for the hanging drop as compared to LoR, possibly indicating increased risk of dural perforation.

Finally, whatever technique is used, it is of importance to realise that the ligamentum flavum is not continuous in all patients, and the presence of midline gaps may make the loss of resistance to needle advancement and injection of air/saline less perceptible when the median approach is used.

A number of technical aids for epidural anaesthesia have been described, none of them exhibiting sufficient accuracy and practicability to as yet justify the increased effort and cost of their routine use in adults. Ultrasound may serve as an educational tool and enhance the learning curve for epidural anaesthesia, and pre-assessment of lumbar epidural space depth has been shown to correlate well with actual puncture depth in obese parturients. In children, ultrasound allows for identification of neuraxial structures, particularly in neonates. Below an age of 3 months only the vertebral bodies are ossified, enabling detailed visualization of spinal structures. At age 3 months or older, the vertebral column further ossifies, leading to decreased visibility. At approximately age 7 years, visibility of the neuraxial structures, especially the thoracic segments, is significantly reduced and comparable with that of young adults. Despite apparently obvious advantages of ultrasound-guided epidural
Failed epidural – causes and management

anaesthesia in children, only one randomized controlled trial has been conducted to date. Willschke et al. compared ultrasound to LOR to identify the epidural space. Use of ultrasound led to less bony contact, a shorter time to block success, and decreased supplemental opioid requirements. Recently, visualization of epidural spread of local anaesthetic has been used to predict optimal individual epidural dose. e.g.33

**Catheter insertion and fixation**

The catheter should be inserted at least 4 cm into the epidural space, and a recent study reported a higher success rate when slightly more than 5 cm were achieved. Tunnelling the epidural catheter for 5 cm in a cohort of 82 patients was associated with less motion of the catheter, but the percentage of catheters maintaining original position was not statistically different. In more than 200 patients undergoing either thoracic or lumbar epidural anaesthesia, tunnelling led to significantly decreased catheter migration, with a modest clinical net result of 83% of functioning catheters after 3 days, as compared to 67% without tunnelling. Suturing of the epidural catheter was similarly associated with less migration, but at the cost of increased inflammation at the puncture site. Whereas erythema at the puncture site was not associated with bacterial colonization in small-scale studies, one larger study described a positive correlation. In a retrospective observational study involving more than 500 children, tunnelling a caudal epidural catheter reduced risk of bacterial colonization to levels comparable to untunneled lumbar catheters. These results may be related to the fact that tunnelling places the catheter entry point above the diaper in babies and toddlers and may not be easily transferred to an adolescent population undergoing lumbar or thoracic epidural anaesthesia. It seems prudent, however, to consider tunnelling caudal epidural catheters in babies and toddlers. In lumbar and epidural catheters, the advantages are less straightforward and the
necessity to prevent dislodgement (often dependent on type of surgery) needs to be weighed against the increased incidence of erythema at the puncture site, potentially linked to increased risk of bacterial colonization. Catheter fixation devices are available which may significantly reduce migration percentage and reduce rates of analgesic failure.\textsuperscript{40} Unfortunately there are no studies comparing modern dressing devices with tunnelling techniques with respect to migration, analgesic failure, or infection.

\textit{Test dose}

The optimal way to pharmacologically determine position of the epidural catheter has been debated. When administering a test dose, the two main objectives are to detect intrathecal and intravascular catheter placement. The optimal strategy to detect intrathecal catheter placement was long considered to be lidocaine coupled with epinephrine. Specific regimens to detect intravascular catheter position have been advocated for non-pregnant adult patients (fixed epinephrine test dose), parturients (fentanyl test dose), and children (weight-adjusted epinephrine test dose).\textsuperscript{41} It should be kept in mind that a non-significant increase in heart rate (<15\%) does not guarantee correct position. Furthermore, patients sensitive to intravascular epinephrine (parturients, patients with cardiac or vascular disease) may experience undesired effects in case the test dose is “positive”. However, this risk is most likely outweighed by the deleterious effects of local anaesthetic intoxication should intravascular placement not be detected. Test doses consisting of lidocaine (to detect intrathecal placement) and epinephrine (to detect intravascular placement) are recommended in patients without contraindications to epinephrine.
Failed epidural – causes and management

Material

Problems with the material itself may be responsible for epidural failure. The orifice of the catheter can be in the lateral or anterior epidural space, thereby leaking the local anaesthetic preferably to one side and producing an unilateral block.\(^{42}\) In general, multi-orifice catheters are considered superior to single-orifice catheters.\(^{4,43}\) Manufacturer’s errors may occur, such as faulty markings on the epidural catheter. This can lead to erroneous depth of catheter placement.\(^{44}\) Debridement in the catheter or disconnection may similarly cause epidural failure.\(^4\) One important preventable cause for obstruction of the epidural infusion system is air lock in the bacterial filter. Depending on the type, as little as 0.3 to 0.7 ml of air is sufficient to cause obstruction.\(^{45}\)

Knotting of the catheter inside or outside the body can cause obstruction. Only 13% of lumbar catheters inserted in a group of 45 men were advanced more than 4 cm without coiling, with coiling occurring at a mean insertion depth of 2.8 cm.\(^{46}\) The frequency of knotting catheters is estimated to be 1:20,000-30,000 epidurals.\(^{47}\) Based on 18 case reports, Brichant et al. concluded that 87% of the knots occurred less than 3 cm from the tip of the catheter and that 28% of the knots were associated with a loop in the catheter.\(^{47}\) Removal of a presumably knotted catheter can be attempted after sensitivity has returned to monitor for neurological symptoms during catheter removal. When radicular symptoms or pain occur during removal of a catheter, this should be immediately stopped.\(^4\) It has been suggested that removal is easiest if position at insertion and removal are similar.\(^4\) Surgical removal of a broken catheter is not obligatory if the patient remains asymptomatic.\(^{47}\)
Pharmacologic optimisation of epidural anaesthesia

Local anaesthetic dose versus volume

The influence of dose, concentration and volume upon spread of epidural anaesthesia and analgesia has been subject of considerable research, and different constellations of volume and concentration have been assessed. In general, the main determinant of epidural action is the local anaesthetic dose, with volume playing a minor role. Thus, quality of epidural analgesia depends on total local anaesthetic dose rather than volume or concentration, either in conventional or patient-controlled epidural analgesia. Although there seems to be a tendency towards more extended sensory block and lower blood pressures with lower concentrations at higher volume \(^{48,49}\) and one study even found a higher rate of PONV,\(^{50}\) most studies did not detect such increased side effects \(^{51-56}\)

The situation may be different when local anaesthetic solutions are applied as bolus. There is evidence supporting the role of volume in spread of anaesthesia. For example, the number of dermatomes blocked during labour analgesia was higher in a high-volume bupivacaine group than a low-volume group when the same dose was administered\(^{57}\). But again, the evidence is equivocal. Sakura and coworkers found that the spread of lumbar epidural anaesthesia for gynaecological surgery was similar whether 20 ml 1% lidocaine, or 10 ml 2% lidocaine were used. However, the intensity of block was higher in the lido 2% group.\(^{58}\) If the difference between injected volumes differs by more than 200\% for the same concentration, the block will spread further in the high-volume group.\(^{59}\) For bolus application there is evidence that reducing dose increases probability of differential blockade. In healthy volunteers, dose-dependency of differential blockade was demonstrated at 0.075 and 0.125\% bupivacaine.\(^{60}\) Higher bupivacaine concentrations caused motor block. It should further be kept in mind that differential blockade is a complex phenomenon, in
Failed epidural – causes and management

part caused by differential conduction block of spinal nerves and roots, and in part by differential central somatosensory integration. Dose is the primary determinant of epidural anaesthesia, with volume and concentration playing a subordinate role during continuous or patient-controlled epidural anaesthesia (PCEA) application. The effect of volume is more pronounced during bolus application.

Motor block may be more extensive when performing lumbar epidural anaesthesia because of the spatial proximity of motor fibers. This was recently confirmed in audit form. In labour, low-dose epidural analgesia may be associated with less operative vaginal deliveries. The use of smaller doses in higher volumes has therefore been advocated for obstetric analgesia.

Choice of local anaesthetic

The three main long-acting local anaesthetics for epidural anaesthesia and analgesia are bupivacaine, levobupivacaine, and ropivacaine. The prospect of improved differential blockade, and concerns regarding cardiac safety have driven the increased use of the newer L-stereoisomers. The equipotency of these three drugs has been the subject of many clinical studies. For example, equal concentrations and dosing of bupivacaine and ropivacaine (0.125%, with fentanyl 2mcg/ml) lead to equal efficacy concerning analgesia, but significantly less motor block in the ropivacaine group. However, comparison of equal doses of, e.g., bupivacaine and ropivacaine is difficult as the difference in potency is approximately 40-50%. This has profound consequences because to interpret differential toxicity, this difference in potency needs to be taken into account. If one translates potency difference to the toxic threshold of local anaesthetic causing convulsions in animal models, near equipotency of bupivacaine and ropivacaine concerning toxicity becomes apparent. The likelihood of successful resuscitation after local anaesthetic intoxication has been described as lower
when bupivacaine is the causative agent based upon receptor binding.\textsuperscript{66} However, the therapy advocated to support resuscitation of patients intoxicated with local anaesthetics, intralipid, may be more beneficial in bupivacaine- than in ropivacaine-induced toxicity owing to the lipophilic properties of bupivacaine.\textsuperscript{67} There is no evidence to refute bupivacaine in favour of the newer stereoisomers when used for epidural anaesthesia or analgesia in adults. Based upon pharmacologic data, switching local anaesthetics is not likely to improve epidural anaesthesia.

\textit{Addition of opiates}

The addition of small doses of opiate allows for dose reduction of local anaesthetics while improving quality of analgesia. The vast majority of studies support the use of a combination of local anaesthetic and opioid over either drug alone.\textsuperscript{68} In a 1998 meta-analysis, Curatolo et al. showed that epidural fentanyl was a beneficial adjuvant to local anaesthetics administered for surgical analgesia, improving pain therapy with a low incidence of nausea, and rare occurrence of pruritus.\textsuperscript{69} The addition of opiates allows for smaller concentrations of local anaesthetic, thereby possibly reducing motor block postoperatively, or during labour.\textsuperscript{70} In fact, it has been stated that the entire concept of low-dose local anaesthetics for analgesia is feasible only when opioids are used as adjunct therapeutics.\textsuperscript{71} Moreover, recent data suggest that epidural opioids can enhance the quality of suppression of the surgical stress response.\textsuperscript{72}

Profound differences exist between hydrophilic opioids (such as morphine) and lipophilic opioids (such as fentanyl and sufentanil). Microdialysis studies demonstrate that epidural morphine has a longer residence time in the epidural space, and results in higher CSF concentrations as compared to sufentanil and fentanyl.\textsuperscript{73} This long residence time results in a spinal mechanism
of action, and consequently, clinical studies show a substantial dose reduction in morphine when used epidurally instead of intravenously. Corresponding evidence for lipophilic opioids such as fentanyl and sufentanil, however, is more conflicting. While some studies show a clear benefit of adding epidural fentanyl to bupivacaine, others suggest that effects of epidural fentanyl are primarily mediated by supraspinal mechanisms after systemic absorption. In a recent study undertaken in healthy volunteers, differences were observed between continuous and bolus infusion. While continuous infusion resulted in non-segmental analgesia (indicating supraspinal action), bolus injection resulted in segmental analgesia (indicating significant spinal contribution). Therefore, the elicitation of a spinal analgesic mechanism may depend on sufficient concentrations of fentanyl in the epidural space to allow for diffusion into the CSF, i.e., estimated above 10 mcg/ml, which exceeds current postoperative analgesia regimens.

Finally, some potential disadvantages of epidural opioid administration should be discussed. First, the safety of opioids in obstetric analgesia has been subject of discussion. Potential disadvantages of epidural opioid application include possible interference with breast-feeding, but a recent randomized controlled trial found no effect of epidural fentanyl on breastfeeding initiation and duration. Second, biphasic respiratory depression may occur when hydrophilic opioids are given epidurally. With hydrophilic opioids such as morphine, the first peak corresponds to absorption from the epidural space into the systemic circulation and occurs 30-90 minutes after injection, while a second depression occurs 6-18 hours later as morphine spreads towards the brainstem. In lipophilic opioids, there is only an early depression due to absorption and rostral spread.
Chapter 2.3

Addition of epinephrine

The addition of adrenaline to epidural solutions causes two desired effects. First, vasoconstriction causes delayed absorption of local anaesthetic into the systemic circulation, with higher effect-site and lower plasma concentrations. Second, adrenaline has specific antinociceptive properties predominantly mediated via alpha-2 adrenoreceptors. Effects of epinephrine with regards to local anaesthetics and opioids are supra-additive. For example, the MLAC of bupivacaine is reduced by 29% in labouring parturients. Adding epinephrine to a low-dose thoracic epidural infusion of ropivacaine and fentanyl improved pain relief and reduced nausea.

Vasoconstriction plays a key role in the supra-additive effect of adrenaline during epidural analgesia. Amide-type local anaesthetics are not metabolized in the epidural space, liver, such that the main determinant for their concentration there is absorption into the systemic circulation and subsequent hepatic metabolism. This absorption is biphasic, with an initial fast peak reflecting the fluid phase and later a slower second peak corresponding to resorption from the lipid compartment at the site of injection. Addition of epinephrine to local anaesthetic solutions slows down the first phase of systemic absorption. The net clinical effect is a more profound block, or sufficient block already at lower LA dose. The same mechanism seems to be valid for opioids.

Further, epidural epinephrine has a specific alpha-2-mediated antinociceptive effect causing decreased presynaptic transmitter release and postsynaptic hyperpolarization within the substantia gelatinosa of the spinal cord dorsal horn. Therefore, the full effect is only observed when the epidural catheter is positioned within the vicinity of the spinal cord, i.e. above L1. Lumbar catheters necessitate higher concentrations of local anaesthetic and opioid, and here, adding epinephrine may increase the possibility of motor block. Studies suggest a concentration of 1.5-2 µg/ml as effective.
Finally, some potential risks of adding epinephrine should briefly be discussed. Potential side effects have been described in obstetrics, the main concern that adrenaline-containing solutions potentially cause longer labor, and decreased uterine blood flow. At doses usually used clinically, spinal cord ischemia seems to be no clinically significant problem.

Bolus versus continuous dosing

The advent of PCEA has profoundly changed the administration of postoperative pain treatment. In labour analgesia, a meta-analysis by van der Vyver et al. demonstrated that patients undergoing obstetric PCEA needed less co-analgesic interventions, while requiring less local anaesthetic, and potentially having a decreased likelihood of motor block, albeit without a difference in maternal satisfaction and no effect upon mode of delivery. Using pain scores and cumulative local anaesthetic dose as outcome parameters, conflicting evidence has been put forward to prove or refute background infusions. It is important to keep in mind that PCEA requirement are determined by the site of surgery, and surgery for malignant disease, as well as patient weight and age seem to be the most important predictors. The addition of a continuous infusion to PCEA during labour resulted in reduced total dose of local anaesthetic while providing effective analgesia. A reduction in local anaesthetic dose was found only in demand-only PCEA, but not in the group with background infusion by Vallejo, who found similar outcomes in all groups. Recently, Lim and colleagues showed that demand-only PCEA did result in less LA administered, but also in more breakthrough pain, higher pain scores, and lower maternal satisfaction during labour. More refined techniques such as programmed intermittent epidural bolus (PIEB) combined with PCEA have shown potential for even more accurate analgesia.
Conclusion

Failure of epidural anaesthesia and analgesia occurs in up to 30% in clinical practice. Some technical factors can help to increase primary and secondary success rate. Epidural catheters may be erroneously placed, or may migrate secondarily after initial correct placement due to body movement and oscillations in cerebrospinal fluid. Moreover, catheters may deviate from the midline during insertion. The optimal depth of insertion in adults is approximately 5 cm. The most widely used method with the least side effects for localizing the epidural space is loss of resistance to saline. None of the additional technical tools available has sufficient accuracy and predictability to justify routine use, with the exception of a growing evidence-base for ultrasound in obese patients and infants. The optimal test dose should combine lidocaine (to detect intrathecal placement) and epinephrine (to detect intravascular placement) in the absence of contraindications to epinephrine. In the case of catheter knotting, direct retrieval of the catheter should be attempted once anaesthesia has worn off, while surgical intervention is rarely indicated. The choice of long-acting local anaesthetic seems to be less important clinically. Dose is the primary determinant of continuous epidural anaesthesia, with volume and concentration playing a subordinate role. Addition of opiates may substantially increase the effectiveness of epidural analgesia. Epinephrine strengthens analgesia by delaying resorption of local anaesthetic from the epidural space, and by direct antinociceptive action at the spinal cord. The method most supported by literature for postoperative analgesia is patient controlled epidural analgesia with background infusion.

References


5 Hamilton CL, Riley ET, Cohen SE. Changes in the position of epidural catheters associated with patient movement. *Anesthesiology* 1997; 86: 778-84; discussion 29A

6 Eide PK, Sorteberg W. Simultaneous measurements of intracranial pressure parameters in the epidural space and in brain parenchyma in patients with hydrocephalus. *J Neurosurg* 2010; 113: 1317-25

7 Hogan QH. Epidural anatomy: new observations. *Can J Anaesth* 1998; 45: R40-8


12 Coppejans HC, Hendrickx E, Goossens J, Vercauteren MP. The sitting versus right lateral position during combined spinal-epidural anesthesia for cesarean delivery: block characteristics and severity of hypotension. *Anesth Analg* 2006; **102**: 243-7


19 Griffin RM, Scott RP. Forum. A comparison between the midline and paramedian approaches to the extradural space. *Anaesthesia* 1984; **39**: 584-6

20 Podder S, Kumar N, Yaddanapudi LN, Chari P. Paramedian lumbar epidural catheter insertion with patients in the sitting position is equally successful in the flexed and un- flexed spine. *Anesth Analg* 2004; **99**: 1829-32

22 Wantman A, Hancox N, Howell PR. Techniques for identifying the epidural space: a survey of practice amongst anaesthetists in the UK. *Anaesthesia* 2006; **61**: 370-5


26 Moon JY, Lee PB, Nahm FS, Kim YC, Choi JB. Cervical epidural pressure measurement: comparison in the prone and sitting positions. *Anesthesiology* 2010; **113**: 666-71


30 Balki M, Lee Y, Halpern S, Carvalho JC. Ultrasound imaging of the lumbar spine in the transverse plane: the correlation between estimated and actual depth to the epidural space in obese parturients. *Anesth Analg* 2009; **108**: 1876-81


33 Lundblad M, Lonnqvist PA, Eksborg S, Marhofer P. Segmental distribution of high-volume caudal anesthesia in neonates, infants, and toddlers as assessed by ultrasonography. *Paediatr Anaesth* 2011; **21**: 121-7


35 Bougher RJ, Corbett AR, Ramage DT. The effect of tunnelling on epidural catheter migration. *Anaesthesia* 1996; **51**: 191-4


38 Tripathi M, Pandey M. Epidural catheter fixation: subcutaneous tunnelling with a loop to prevent displacement. *Anaesthesia* 2000; **55**: 1113-6

39 Bubeck J, Boos K, Krause H, Thies KC. Subcutaneous tunneling of caudal catheters reduces the rate of bacterial colonization to that of lumbar epidural catheters. *Anesth Analg* 2004; **99**: 689-93, table of contents

40 Clark MX, O'Hare K, Gorringe J, Oh T. The effect of the Lockit epidural catheter clamp on epidural migration: a controlled trial. *Anaesthesia* 2001; **56**: 865-70
Failed epidural – causes and management

45 Lin CC. Air-locked epidural filter. Anesthesiology 2003; 99: 515
Chapter 2.3

52 Dernedde M, Stadler M, Taviaux N, Boogaerts JG. Postoperative patient-controlled thoracic epidural analgesia: importance of dose compared to volume or concentration. *Anaesth Intensive Care* 2008; **36**: 814-21


54 Senard M, Joris JL, Ledoux D, Toussaint PJ, Lahaye-Goffart B, Lamy ML. A comparison of 0.1% and 0.2% ropivacaine and bupivacaine combined with morphine for postoperative patient-controlled epidural analgesia after major abdominal surgery. *Anesth Analg* 2002; **95**: 444-9, table of contents


Failed epidural – causes and management


64 Meister GC, D’Angelo R, Owen M, Nelson KE, Gaver R. A comparison of epidural analgesia with 0.125% ropivacaine with fentanyl versus 0.125% bupivacaine with fentanyl during labor. *Anesth Analg* 2000; 90: 632-7


77 George MJ. The site of action of epidurally administered opioids and its relevance to postoperative pain management. *Anaesthesia* 2006; **61**: 659-64

Epidural analgesia and breastfeeding: a randomised controlled trial of epidural techniques with and without fentanyl and a non-epidural comparison group. *Anaesthesia* 2010; **65**:145-53

Carvalho B. Respiratory depression after neuraxial opioids in the obstetric setting. *Anesth Analg* 2008; **107**:956-61

Polley LS, Columb MO, Naughton NN, Wagner DS, van de Ven CJ. Effect of epidural epinephrine on the minimum local analgesic concentration of epidural bupivacaine in labor. *Anesthesiology* 2002; **96**:1123-8


Thomas JM, Schug SA. Recent advances in the pharmacokinetics of local anaesthetics. Long-acting amide enantiomers and continuous infusions. *Clin Pharmacokinet* 1999; **36**:67-83


Niemi G, Breivik H. The minimally effective concentration of adrenaline in a low-concentration thoracic epidural analgesic infusion of bupivacaine, fentanyl

88 Soetens FM, Soetens MA, Vercauteren MP. Levobupivacaine-sufentanil with or without epinephrine during epidural labor analgesia. *Anesth Analg* 2006; **103**: 182-6, table of contents


101 Sitsen E, van Poorten F, van Alphen W, Rose L, Dahan A, Stienstra R. Postoperative epidural analgesia after total knee arthroplasty with sufentanil 1 microg/ml combined with ropivacaine 0.2%, ropivacaine 0.125%, or levobupivacaine 0.125%; a randomized, double-blind comparison. *Reg Anesth Pain Med* 2007; 32: 475-80
Table 1 – Definitions and rates of failed epidural anaesthesia or analgesia

<table>
<thead>
<tr>
<th>Type of surgery</th>
<th>Definition</th>
<th>Failure rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eappen et al. IJOA 1998</td>
<td>Any reason for intervention</td>
<td>550/4240 (13.1%)</td>
</tr>
<tr>
<td>Obstetric Lumbar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ready et al. RAPM 1999</td>
<td>Technical defects</td>
<td>N=2140</td>
</tr>
<tr>
<td>General surgery Thoracic /</td>
<td>/ Insufficient block</td>
<td>(32%) lumbar (27%)</td>
</tr>
<tr>
<td>Lumbar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>McCleod et al. Anaesthesia 2001</td>
<td>Technical defects</td>
<td>83/640 (13.0%)</td>
</tr>
<tr>
<td>Major abdominal surgery</td>
<td>/ Insufficient block</td>
<td></td>
</tr>
<tr>
<td>Thoracic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rigg et al. Lancet 2002</td>
<td>Failed insertion / Removed early</td>
<td>203/431 (47.1%)</td>
</tr>
<tr>
<td>Gastrointestinal surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thoracic / Lumbar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neal et al. RAPM 2003</td>
<td>Catheter dislodgement</td>
<td>8/46 (14.2%)</td>
</tr>
<tr>
<td>Esophagectomy Thoracic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pan et al. IJOA 2004</td>
<td>Inadequate analgesia, spinal tap</td>
<td>1099/7849 (14%)</td>
</tr>
<tr>
<td>Obstetric Lumbar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdominal oncology Thoracic</td>
<td>Failed block, premature removal of catheter</td>
<td>31/125 (24.8%)</td>
</tr>
<tr>
<td>Pratt et al. J GI Surg 2008</td>
<td>Failed block, premature catheter removal</td>
<td>49/158 (31.0%)</td>
</tr>
</tbody>
</table>
Failed epidural – causes and management

Kinsella et al. 99
Aneesthesia, 2008
C-section
Lumbar
Inadequate anesthesia
302/1286 (23.5%)

Königsrainer 34
Anaesthesia 2009
Major surgery
Thoracic / Lumbar
Insufficient analgesia, motor block, catheter dislodgement
124/300 (41.4%)

Table 2 - Landmarks for epidural anesthesia and analgesia

<table>
<thead>
<tr>
<th>Desired dermatome level of neuraxial block</th>
<th>Anatomic landmark</th>
<th>Optimal insertion point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of surgery</td>
<td>Upper dermatomal block level</td>
<td></td>
</tr>
<tr>
<td>Esophagus, lung</td>
<td>T1</td>
<td>Below clavicle</td>
</tr>
<tr>
<td>Upper abdomen</td>
<td>T1</td>
<td>Below clavicle</td>
</tr>
<tr>
<td>Lower abdomen</td>
<td>T6</td>
<td>Distal sternum</td>
</tr>
<tr>
<td>Cesarean delivery</td>
<td>T4</td>
<td>Nipples</td>
</tr>
<tr>
<td>Lower extremity</td>
<td>L1-2</td>
<td>Inguinal crease</td>
</tr>
</tbody>
</table>