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REVIEW ARTICLES

# Failed epidural: causes and management

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## Editor's key points

- Inadequate anaesthesia or analgesia with an epidural may be common.
- There are technical (equipment, anatomy) and pharmacological (drugs, doses) causes.
- The use of adjuvants appears to increase the success rate.
- Postoperatively, the use of patient-controlled epidural anaesthesia with background infusion appears most effective.

**Summary.** Failed epidural anaesthesia or analgesia is more frequent than generally recognized. We review the factors known to influence the success rate of epidural anaesthesia. Reasons for an inadequate epidural block include incorrect primary placement, secondary migration of a catheter after correct placement, and suboptimal dosing of local anaesthetic drugs. For catheter placement, the loss of resistance using saline has become the most widely used method. Patient positioning, the use of a midline or paramedian approach, and the method used for catheter fixation can all influence the success rate. When using equipotent doses, the difference in clinical effect between bupivacaine and the newer isoforms levobupivacaine and ropivacaine appears minimal. With continuous infusion, dose is the primary determinant of epidural anaesthesia quality, with volume and concentration playing a lesser role. Addition of adjuvants, especially opioids and epinephrine, may substantially increase the success rate of epidural analgesia. Adjuvant opioids may have a spinal or supraspinal action. The use of patient-controlled epidural analgesia with background infusion appears to be the best method for postoperative analgesia.

**Keywords:** epidural, analgesic techniques; extradural, anaesthetics local

In contrast to the subjective experience of many anaesthetists, failure of epidural anaesthesia and analgesia is a frequent clinical problem. Current estimates of the incidence of failed epidurals are hampered by the lack of a uniform outcome measure. 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 thoracic and 27% for lumbar epidural were described.[1] Of note, active management of inadequate epidural anaesthesia, including a new block, results in an almost complete success rate.[2] In an imaging study of failed epidurals, incorrect catheter placement accounted for half of the failures, while the remaining patients experienced suboptimal analgesia through a correctly positioned catheter.[3] A flow chart illustrates the problems encountered during epidural anaesthesia using the example of a Caesarean section, ultimately resulting in a success rate of just 76% (Fig. 1).

This review summarizes technical factors known to influence block success, and gives an overview of the pharmacological strategies available to optimize epidural anaesthesia and analgesia. For each section, we performed a comprehensive literature search for full published reports in MEDLINE covering manuscripts up to October 2011, with reference lists of retrieved articles searched for additional trials or reports. We ranked meta-analyses and randomized controlled trials (RCTs) 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 incorrectly, or become dislodged during the course of treatment. Transforaminal migration of the catheter tip and asymmetric spread have been described during epidural analgesia.[4] Primary misplacement of epidural catheters in the paravertebral space, in the pleural cavity, and intravascularly has been described. Even when the epidural space is correctly identified, the catheter will not necessarily follow a straight line when being advanced. The epidural catheter may leave the epidural space through an intervertebral foramen at levels above or below the insertion site (Fig. 2). In a group of obstetric patients, failure of epidural analgesia after initial success was observed in 6.8%.[2] Secondary migration of the catheter after successful initial placement can occur. During normal patient movement, epidural catheters may be displaced by centimetres.[5] In 60 patients undergoing lung surgery with a thoracic epidural, with chest radiographs taken before and after operation, the catheter had migrated more than one vertebral level in 24%. In addition to body

**Table 1** Definitions and rates of failed epidural anaesthesia or analgesia. *Pre-intervention group in an intervention study

| | Type of surgery | Failure definition | Failure rate | Thoracic/lumbar |
|---|---|---|---|---|
| Eappen and colleagues[97] | Parturients receiving epidural analgesia or anaesthesia for delivery | Any reason requiring catheter replacement after the catheter was secured to the back with adhesive tape, a greater than three dermatomal segment discrepancy between analgesic level as assessed by temperature (ice) sensation in a patient complaining of pain after the initial bolus of epidural bupivacaine | 550/4240 (13.1%) | Lumbar |
| Ready[1] | All surgical patients | Any condition during the course of treatment that requires epidural catheter replacement or the addition of another major treatment modality such as i.v. patient-controlled analgesia | *n*=2140; thoracic (32%); lumbar (27%) | Thoracic:lumbar ?:? |
| McLeod and colleagues[98] | Major oesophageal, gastric, small and large bowel surgery, and aortic aneurysm repair | Apparent inability to deliver local anaesthetic/opioid solution to the epidural space due to occlusion, dislodgement, or leakage, or poor spread within the epidural space resulting in patchy or unilateral block | 83/640 (13.0%) | Thoracic |
| Rigg and colleagues[22] | Major abdominal operations or oesophagectomy | Could not be inserted, removed before leaving operating theatre, removed before 72 h | 203/431 (47.1%) | Thoracic:lumbar ?:? |
| Neal[90] | Oesophagectomy | Catheter dislodgement | 8/46 (14.2%) | Thoracic |
| Pan and colleagues[2] | Obstetric neuraxial analgesia and anaesthesia | Epidural or CSE procedures resulting in inadequate analgesia or no sensory block after adequate dosing at any time after initial placement, inadvertent dural puncture with the epidural needle or catheter, i.v. epidural catheter, or any technique requiring replacement or alternative management | 1099/7849 (14%) | Lumbar |
| Motamed and colleagues[3] | Major elective abdominal surgery for cancer | Interruption of epidural analgesia before 48 h for any reason. A VAS score that exceeded 30 mm at rest and persisted for 45 min after a rescue 5 ml epidural 0.125% bupivacaine injection and 1 g paracetamol i.v. were administered | 31/125 (24.8%) | Thoracic |
| Pratt and colleagues[99] | Pancreatoduodenectomy | Aborted before anticipated (fourth postoperative day) because of haemodynamic compromise, inadequate analgesia, or both | 49/158 (31.0%) | Thoracic |
| Kinsella[100] | Anaesthesia for Caesarean section | Loss of cold sensation, using ethyl chloride spray, from T4 (the nipples) down to S5 (the buttocks), and also anaesthesia (no feeling) to a 19 G needle inserted at several points along the line of surgical incision at T12 | 302/1286 (23.5%) | Thoracic:lumbar ?:? |
| Konigsrainer and colleagues[35] | Thoraco-abdominal surgery, upper abdominal surgery, colorectal surgery, and other | Motor weakness, catheter dislodgement, insufficient analgesia | 124/300* (41.4%) | Thoracic:lumbar 241:59 |

movements, changes in epidural pressure and cerebrospinal fluid (CSF) oscillations can contribute to the displacement of epidural catheters.[6] The epidural space is a compartmentalized and complex structure,[7] which may influence catheter placement. Midline fat pedicles may form a barrier to the spread of local anaesthetics.[7]

## Patient position

Patient positioning potentially affects needle placement by changing the relationship 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 measures such as sex, weight, or height. The patient assuming a flexed position with the head down will result in the anterior movement of the spinal cord at the thoracic level, while the spinal cord and cauda equina will be more posterior at the lumbar level.[8] The spinal cord is flexibly attached within the dural sac, and changes position according to gravity when subjects are positioned supine, or laterally.[9]

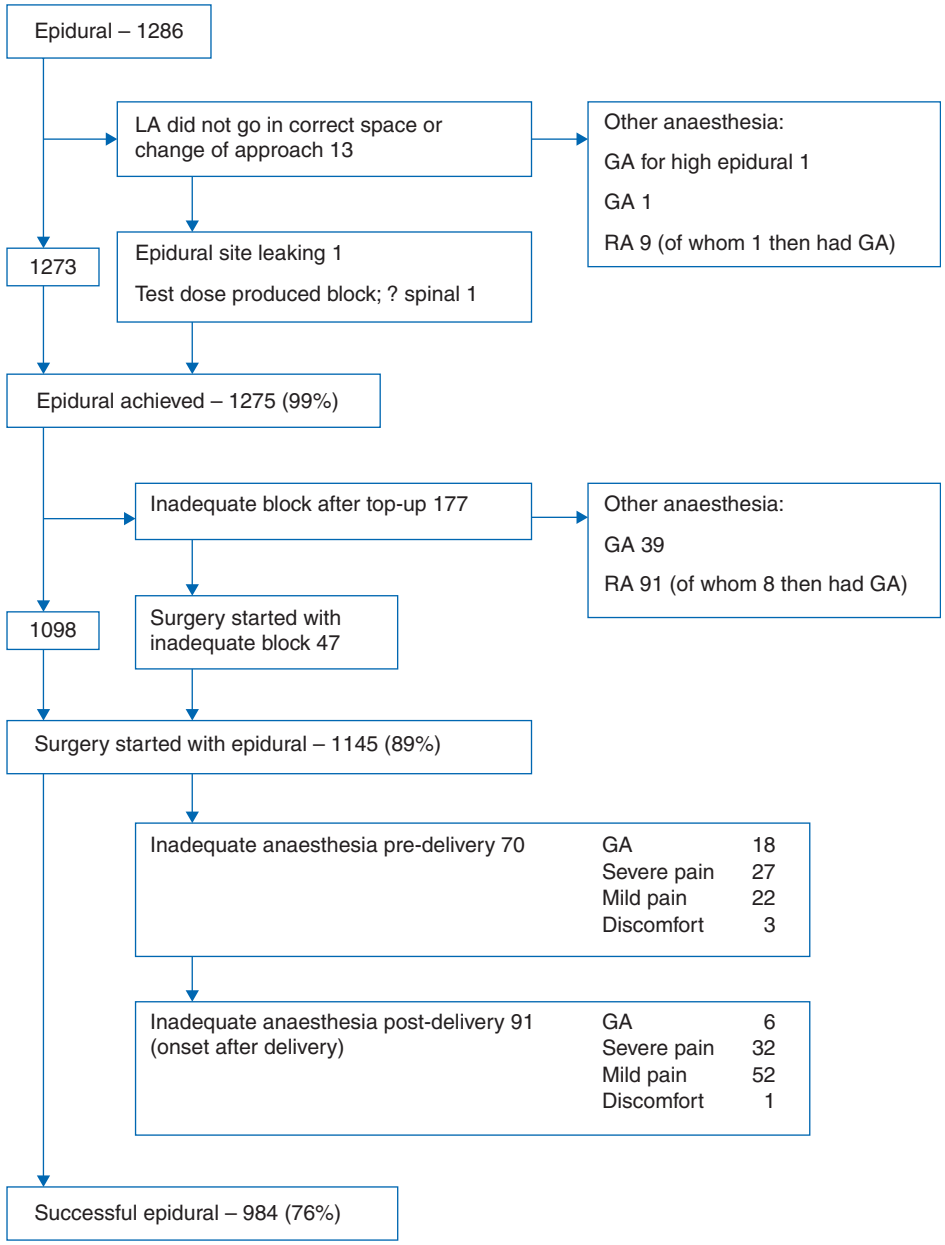


**Fig 1** Regional anaesthesia failure in 5080 Caesarean sections; adapted with permission from Kinsella.[100]

The sitting position has been described to result in shorter insertion times and a trend towards higher accuracy at the first attempt than the lateral position, but at the cost of more vagal reflexes, and with comparable final success rates.[10] In combined spinal–epidural anaesthesia for Caesarean section, no differences were reported for insertion times,[11] while another study found more technical difficulties in the lateral compared with the sitting position.[12] Lateral positioning increases the distance from the skin to the epidural space.[13] The sitting position leads to epidural venous plexus distension,[14] which may theoretically increase the risk of vascular puncture, especially in parturients.[15]

## Puncture site

It is known that anaesthetists tend to be inaccurate when determining the precise dermatomal level for neuraxial puncture.[16] Of note, most studies show that there is a tendency for the site to be more cranial than intended. Suitable block levels and anatomical landmarks for various types of surgery are suggested in Table 2.

## Midline vs paramedian

There have been few studies comparing the midline and paramedian approach on block success. In cadavers, using

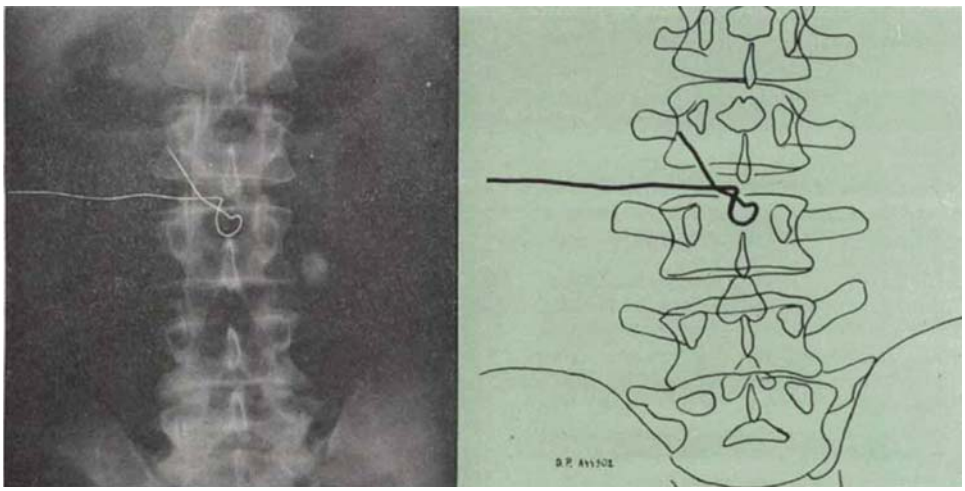

**Fig 2** Epidural catheter exhibiting through the transforaminal passage; reproduced from Hehre and colleagues with permission.[17]

**Table 2** Landmarks for epidural anaesthesia and analgesia

| Desired dermatome level of neuraxial block | | | |
|---|---|---|---|
| **Type of surgery** | **Upper dermatomal block level** | **Anatomical landmark** | **Optimal insertion point** |
| Oesophagus, lung | T1 | Below clavicle | T6–7 |
| Upper abdomen | T1 | Below clavicle | T9–10 |
| Lower abdomen | T6 | Distal sternum | T9–10 |
| Caesarean delivery | T4 | Nipples | L4–5 |
| Lower limb | L1-2 | Inguinal crease | L4–5 |

epiduroscopy, paramedian catheters were observed to cause less epidural tenting, and pass cephalad more reliably than midline catheters.[18] In patients, faster catheter insertion times were reported in the paramedian, and higher incidence of paraesthesia in the midline group.[19] Adequate local infiltration is a prerequisite for patient comfort during paramedian puncture.[20 21] The paramedian approach may be less dependent upon spine flexion.[21] The risk of vascular puncture during epidural catheter placement was not associated with lumbar midline or paramedian technique in parturients,[20] while another study suggested more paraesthesia and bloody puncture in non-pregnant adults when the midline approach was used.[21]

## Localization of the epidural space

Inability to correctly insert an epidural catheter at the first attempt and the number of attempts required is not reported in most studies, while differences are likely to exist between the thoracic and lumbar levels, for example, one study reported inability to localize the thoracic epidural space in 13 out of 447 (2.9%) attempts.[22]

Correct placement obviously requires correct identification of the epidural space. A variety of methods are used to confirm epidural needle position.[23] The 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.[23] A meta-analysis in 2009 included five RCTs comparing LoR with saline *vs* air: four in the obstetric population and one in a general patient population, with a total of 4422 patients. No significant difference in any outcome was found, other than a 1.5% reduction in post-dural puncture headache when using saline.[24] A study comparing combined spinal–epidural punctures using air or saline found no difference in the success rate or adverse events.[25] A recent retrospective study of 929 obstetric epidurals found that when using air for LoR, significantly more attempts were needed compared with using saline, with comparable final success rates.[26] Subgroup analyses showed that the use of the 'preferred technique' (i.e. the technique used by a practitioner >70% of the time) resulted in significantly fewer attempts, a lower incidence of paraesthesia, and fewer dural punctures, irrespective of whether saline or air was used for LoR.[26]

The hanging drop technique depends on negative pressure within the epidural space. Recent experimental evidence suggests that negative pressure is poor at reliably detecting the epidural space, and if at all, the hanging drop technique is useful only in the sitting position.[27] Of note, identification of the epidural space was reported at 2 mm deeper for the hanging drop when compared with LoR, possibly indicating increased risk of dural perforation.[28] Whichever technique is used, it is important to realize that the ligamentum flavum is not continuous in all patients, and the presence

of midline gaps may make the LoR to needle advancement and injection of air/saline less perceptible when the midline approach is used.[29]

A number of technical aids for epidural anaesthesia have been described, but none of them have sufficient accuracy and practicability to justify the increased effort and cost of their routine use in adults. Ultrasound is a useful educational tool and can enhance the learning curve for epidural anaesthesia.[30] Ultrasound pre-assessment of lumbar epidural space depth has been shown to correlate well with actual puncture depth in obese parturients.[31] In children, ultrasound allows for the 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. After 3 months, ossification of the vertebral column leads to decreased visibility. By the age of 7 yr, visibility of the neuraxial structures, especially the thoracic segments, is significantly reduced and comparable with that of young adults.[32] Despite apparently obvious advantages of ultrasound-guided epidural anaesthesia in children, only one RCT has been conducted, and it found that the use of ultrasound led to less bony contact, a shorter time to block success, and decreased supplemental opioid requirements.[33] Recently, visualization of epidural spread of local anaesthetic has been used to predict optimal individual epidural dose.[34]

## Catheter insertion and fixation

The catheter should be inserted at least 4 cm into the epidural space,[5] and a recent study reported a higher success rate with more than 5 cm.[35] 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.[36] 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, when compared with 67% without tunnelling.[37] Suturing of the epidural catheter was similarly associated with less migration, but at the cost of increased inflammation at the puncture site.[38] Whereas erythema at the puncture site was not associated with bacterial colonization in small-scale studies,[39] one larger study described a positive correlation.[40] In a retrospective observational study of >500 children, tunnelling a caudal epidural catheter reduced the risk of bacterial colonization to levels comparable with untunnelled lumbar catheters.[40] 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. For lumbar and epidural catheters, the advantages are less obvious and the need to prevent dislodgement must 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.[41] Unfortunately, there are no studies comparing modern dressing devices with tunnelling techniques with respect to migration, analgesic failure, or infection.

## Test dose

The best pharmacological way to determine correct placement of an epidural catheter is unclear. A test dose is given with the two main objectives of detecting intrathecal or intravascular catheter placement. The optimal strategy to detect intrathecal catheter placement was long considered to be lidocaine 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).[42] It is of note 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 undesirable side-effects if the test is positive. However, this risk is most likely outweighed by the systemic toxic effects of local anaesthetic should intravascular placement not be detected. A test dose of lidocaine (to detect intrathecal placement) and epinephrine (to detect intravascular placement) is recommended in patients without contraindications to epinephrine.

## Equipment

Equipment problems may be responsible for epidural failure. The orifice of the catheter can lie laterally or anteriorly in the epidural space putting the local anaesthetic more to one side and producing an unilateral block.[43] In general, multi-orifice catheters are considered better than single-orifice catheters.[44] Occasionally, manufacturing errors may occur, such as faulty markings on the epidural catheter, which can lead to wrong depth of placement.[45] Debris in the catheter or disconnection may similarly cause epidural failure.[4] One important preventable cause for obstruction of the epidural infusion system is an air lock, of as little as 0.3–0.7 ml of air, in the bacterial filter.[46]

Knotting of the catheter internally or externally can cause obstruction. Only 13% of lumbar catheters inserted in a group of 45 men were advanced more than 4 cm without coiling, and coiling occurred at a mean insertion depth of 2.8 cm.[47] Based on 18 case reports, the frequency of knotted catheters is estimated to be 1:2000–30 000 epidurals with 87% of the knots occurring <3 cm from the tip of the catheter and 28% of the knots were associated with a loop in the catheter.[48] Removal of a presumed knotted catheter can be attempted after sensation 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

**Table 3** Comparison of various epidural doses and volumes

| Study | Comparison | *n* | Pain | Other effects and side-effects |
|---|---|---|---|---|
| Laveaux and colleagues[101] | Bupivacaine 0.5%+4 μg ml$^{-1}$ fentanyl *vs* 0.125%+1 μg ml$^{-1}$ | 15/15 | No difference | No difference in requirement of rescue medication, respiratory depression |
| Snijdelaar and colleagues[57] | Bupivacaine 0.75%+4 μg ml$^{-1}$ sufentanil *vs* 0.125%+0.7 μg ml$^{-1}$ | 30/30 | No difference | No difference in arterial pressure, PONV, sedation, respiratory depression. Significantly more rescue boli needed by bupivacaine 0.75% group |
| Liu and colleagues[56] | Ropivacaine 0.2%+4 μg ml$^{-1}$ fentanyl *vs* 0.1%+2 μg ml$^{-1}$ *vs* 0.05%+1 μg ml$^{-1}$ | 10/10/10 | No difference | No difference in PONV, pruritus, sedation, hypotension. Motor block and dosage of ropivacaine increased in the ropivacaine 0.1%+2 μg ml$^{-1}$ fentanyl group. Epidural solutions were applied via PCEA |
| Kampe and colleagues[51] | Ropivacaine 0.1% *vs* 0.2% (+1 μg ml$^{-1}$ sufentanil) | 11/11 | No difference | No difference in requirement of rescue medication, sensory block, motor block, patient satisfaction. More PONV in 0.1% group |
| Senard and colleagues[55] | Bupivacaine 0.1% *vs* 0.2%; ropivacaine 0.1% *vs* 0.2% (+0.1 mg h$^{-1}$ morphine) | 15/15; 15/15 | No difference | No difference in sensory block, motor block, PONV, patient satisfaction. Significant reduction in required dose of local anaesthetics in low-concentration groups. Local anaesthetics were applied via PCEA, the epidural morphine via independent constant infusion |
| Dernedde and colleagues[50] | Levobupivacaine 0.15% *vs* 0.5% | 27/27 | No difference | No difference in requirement of rescue medication, sensory block, PONV, patient satisfaction. More motor block and lower arterial pressure in the 0.15% group |
| Dernedde and colleagues[49] | Levobupivacaine 0.15% *vs* 0.5% *vs* 0.75% | 26/33/31 | No difference | No difference in requirement of rescue analgesics, patient satisfaction, motor block. Sensory block two segments higher and arterial pressure lower in 0.15% group |
| Dernedde and colleagues[54] | Levobupivacaine 0.15% *vs* 0.5% | 21/20 | No difference | No difference in requirement of rescue medication, sensory block, motor block, PONV, patient satisfaction. Marginally ($P = 0.052$) lower arterial pressure in 0.5% group |
| Sitsen and colleagues[102] | Ropivacaine 0.125% *vs* 0.2% (+1 μg ml$^{-1}$ sufentanil) | 21/21 | No difference | No difference in patient satisfaction, motor blockade |
| Dernedde and colleagues[53] | Levobupivacaine 0.15% *vs* 0.5% | 30/30 | No difference | No difference in requirement of rescue medication, sensory block, motor block, arterial pressure, heart rate, PONV, patient satisfaction. Levobupivacaine was applied via PCEA |
| Danelli and colleagues[52] | Levobupivacaine 0.75% *vs* 0.125% | 33/32 | No difference | No difference in motor block, haemodynamic stability |

stopped.[4] It has been suggested that removal is easiest if the patient is in the same position as at insertion.[4] Surgical removal of a broken catheter is not compulsory if the patient remains asymptomatic.[48]

## Pharmacological optimization of epidural anaesthesia

### Local anaesthetic dose vs volume

The influence of dose, concentration, and volume on the spread of epidural anaesthesia and analgesia has undergone considerable research, and many different volumes and concentrations have been assessed. In general, the main determinant of epidural action is the local anaesthetic dose, with volume playing a more minor role (Table 3). Thus, the quality of epidural analgesia depends on total local anaesthetic dose rather than volume or concentration, either in conventional or patient-controlled epidural analgesia. There is a trend towards more extended sensory block and lower arterial pressure with lower concentrations at higher volume.[49 50] Similarly, one study found a higher rate of postoperative nausea and vomiting (PONV),[51] but most studies did not find increased side-effects.[52–57] 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. There is evidence supporting the role of volume in the 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 total dose was given.[58] However, the evidence is equivocal. The spread of lumbar epidural anaesthesia for gynaecological surgery was similar with 20 ml lidocaine 1% or 10 ml lidocaine 2% was used, but the intensity of block was higher in the 2% group.[59] If the difference in volume injected is >200% for the same concentration, the block will spread further in the high-volume group.[60] For bolus dosing, there is evidence that reducing the dose increases the probability of differential block. In healthy volunteers, dose-dependency of differential block was demonstrated with bupivacaine 0.075 and 0.125%.[61] Higher bupivacaine concentrations

caused motor block. Differential block is complex and is caused partly by differential conduction block of spinal nerves and roots, and partly by differential central somatosensory integration.[62]

Motor block may be more extensive when performing lumbar epidural anaesthesia because of the spatial proximity of motor fibres.[35] In labour, low-dose epidural analgesia may be associated with fewer operative vaginal deliveries.[63] The use of a smaller dose in a higher volume has therefore been advocated for obstetric analgesia.[64]

## Choice of local anaesthetic

The three main long-acting local anaesthetics for epidural anaesthesia and analgesia are bupivacaine, levobupivacaine, and ropivacaine. Supposedly better differential block and cardiac safety have increased the 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 2 $\mu$g ml$^{-1}$) have equal analgesic efficacy, but significantly less motor block in the ropivacaine group.[65] However, comparison of equal doses of, for example, bupivacaine and ropivacaine, is difficult as the difference in potency is ~40–50%.[66] In assessing differential toxicity, this difference in potency needs to be taken into account. The toxic threshold of local anaesthetic causing convulsions in animal models[66] approaches equipotency with bupivacaine and ropivacaine if this potency difference is included. The likelihood of successful resuscitation after local anaesthetic toxicity is lower with bupivacaine because of prolonged receptor binding.[67] However, lipid rescue may be more effective for bupivacaine than ropivacaine toxicity due to the lipophilic properties of bupivacaine.[68] There is little evidence to refute the use of bupivacaine for epidural anaesthesia or analgesia in adults. From the pharmacological data, changing agents is not likely to improve epidural anaesthesia.

## Addition of opioids

The addition of small doses of opioid allows for the reduction in the local anaesthetic dose while improving the quality of analgesia. The majority of studies support the use of a combination of local anaesthetic and opioid over either drug alone.[69] A meta-analysis from 1998 showed that epidural fentanyl was a beneficial adjuvant to local anaesthetics for surgical analgesia, improving pain therapy and with a low incidence of nausea and pruritus.[70] The addition of opioids allows for lower concentrations of local anaesthetic, potentially reducing motor block after operation or during labour.[71] It has been suggested that the concept of low-dose local anaesthetics for analgesia is feasible only when adjunct opioids are used.[72] Recent data suggest that epidural opioids can enhance the suppression of the surgical stress response.[73]

There are marked differences in clinical effect between hydrophilic opioids, such as morphine, and lipophilic opioids, such as fentanyl and sufentanil. Microdialysis studies show that epidural morphine has a longer residence time in the epidural space, and results in higher CSF concentrations compared with sufentanil or fentanyl.[74] This longer residence time results in a spinal mechanism of action, and consequently, a substantial reduction in morphine dose required epidurally compared with i.v.[75] The evidence for lipophilic opioids such as fentanyl and sufentanil, however, is conflicting. While some studies show a clear benefit of adding epidural fentanyl to bupivacaine,[76] others suggest that effects of epidural fentanyl are primarily mediated by supraspinal mechanisms after systemic absorption.[77] A recent study in healthy volunteers found differences between continuous and bolus infusion. While continuous infusion resulted in non-segmental analgesia, indicating a supraspinal action, bolus injection resulted in segmental analgesia which indicates a significant spinal contribution.[76] Therefore, a spinal analgesic mechanism may depend on sufficient concentrations of fentanyl in the epidural space to allow diffusion into the CSF. This has been estimated to be >10 $\mu$g ml$^{-1}$, which is greater than most current postoperative analgesia regimens.[78]

There are some potential disadvantages of epidural opioid administration. First, the safety of opioids in obstetric analgesia has been questioned and include possible interference with breastfeeding.[79] However, a recent RCT found no effect of epidural fentanyl on breastfeeding initiation or duration.[80] Secondly, 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 min after injection, while the second occurs 6–18 h later as morphine spreads towards the brainstem. With lipophilic opioids, there is only early depression due to absorption and rostral spread.[81]

## Addition of epinephrine

The addition of epinephrine to epidural solutions has two useful effects. First, vasoconstriction causes delayed absorption of local anaesthetic into the systemic circulation, with higher effect-site and lower plasma concentrations. Secondly, epinephrine has specific antinociceptive properties predominantly mediated via $\alpha$-2 adrenoreceptors. The effects of epinephrine on local anaesthetics and opioids are additive. For example, the minimum local anaesthetic concentration (MLAC) of bupivacaine is reduced by 29% in labouring parturients.[82] Adding epinephrine to a low-dose thoracic epidural infusion of ropivacaine and fentanyl improved pain relief and reduced nausea.[83]

Vasoconstriction plays a key role in the effect of epinephrine on epidural analgesia. Amide-type local anaesthetics are not metabolized in the epidural space and the main determinant for their concentration 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.[84] The addition of

epinephrine to local anaesthetic solutions slows the first phase.[85] The net clinical effect is a more profound block, or a lower dose requirement. The same mechanism seems to apply to opioids.[86]

Epidural epinephrine has a specific α-2-mediated antinociceptive effect causing decreased presynaptic transmitter release and postsynaptic hyperpolarization within the substantia gelatinosa of the spinal cord dorsal horn.[87] Therefore, the full effect is only observed when the epidural catheter is positioned close to the spinal cord, that is, above L1. Lumbar catheters require higher concentrations of local anaesthetic and opioid, and here, adding epinephrine may increase the risk of motor block.[87] Studies suggest a concentration of 1.5–2 μg $ml^{-1}$.[88]

Some potential risks of adding epinephrine include causing longer labour, and decreased uterine blood flow.[89] At doses used clinically, spinal cord ischaemia seems not to be a clinically significant problem.[90]

### Bolus vs continuous dosing

The use of PCEA has profoundly changed postoperative pain management. In labour analgesia, a meta-analysis demonstrated that obstetric patients using PCEA needed less co-analgesic interventions, less local anaesthetic, and decreased likelihood of motor block. However, there was no difference in maternal satisfaction or mode of delivery.[91] There is conflicting evidence on the benefit of background infusions when pain scores and cumulative local anaesthetic dose are used as a measure of outcome. PCEA requirements are determined by the site of surgery, surgery for malignant disease, and also patient weight and age.[92] The addition of a continuous infusion to PCEA during labour resulted in reduced total dose of local anaesthetic while providing effective analgesia.[93] A reduction in local anaesthetic dose was found only in demand-only PCEA, but not with background infusion by Vallejo and colleagues,[94] despite similar outcomes. Demand-only PCEA resulted in lower local anaesthetic requirement, but also in more breakthrough pain, higher pain scores, and lower maternal satisfaction during labour.[95] More refined techniques such as programmed intermittent epidural bolus combined with PCEA have shown potential.[96]

## Conclusion

In conclusion, failure of epidural anaesthesia and analgesia occurs in up to 30% in clinical practice. Some technical factors can help to increase the primary and secondary success rate. Epidural catheters may be incorrectly placed, or may migrate after initial correct placement due to body movement and oscillations in CSF. Catheters may deviate from the midline during insertion. The optimal depth of insertion in adults is ~5 cm. The most widely used method with the least side-effects for localizing the epidural space is LoR to saline. None of the additional technical tools available has sufficient accuracy and predictability to justify routine use, but there is a growing evidence-base for ultrasound in obese patients and infants. The optimal test dose should combine lidocaine and epinephrine, to detect intrathecal and intravascular placement, respectively. The choice of long-acting local anaesthetic agent 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 opioids may substantially increase the effectiveness of epidural analgesia. Epinephrine augments analgesia by delaying resorption of local anaesthetic from the epidural space, and by direct antinociceptive action at the spinal cord. The use of patient-controlled epidural analgesia with background infusion appears to be the best method for postoperative analgesia.

## Declaration of interest

None declared.

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