

## REVIEW ARTICLE

# Combined spinal–epidural techniques

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### Summary

The combined spinal–epidural technique has been used increasingly over the last decade. Combined spinal–epidural may achieve rapid onset, profound regional blockade with the facility to modify or prolong the block. A variety of techniques and devices have been proposed. The technique cannot be considered simply as an isolated spinal block followed by an isolated epidural block as combining the techniques may alter each block. This review concentrates on technical and procedural aspects of combined spinal–epidural. Needle-through-needle, separate-needle and combined-needle techniques are described and modifications discussed. Failure rates and causes are reviewed. The problems of performing a spinal block before epidural blockade (potential for unrecognised placement of an epidural catheter, inability to detect paraesthesia during epidural placement, difficulty in testing the epidural, delay in positioning the patient) are described and evaluated. Problems of performing spinal block after epidural blockade (risk of catheter or spinal needle damage) are considered. Mechanisms of modification of spinal blockade by subsequent epidural drug administration are discussed. The review considers choice of technique, needle type, patient positioning and paramedian vs. midline approach. Finally, complications associated with combined spinal–epidural are reviewed.

**Keywords** *Anaesthesia, regional; combined spinal–epidural.*

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The combined spinal–epidural technique (CSE) involves intentional subarachnoid blockade and epidural catheter placement during the same procedure. CSE allows a rapid onset of neuraxial blockade, which can subsequently be prolonged or modified. Ideally it combines the best features of spinal blockade (rapid onset, profound blockade, low drug dosage) and epidural blockade (titratable levels, ability to prolong indefinitely) and avoids their respective disadvantages (spinal: single-shot nature, unpredictable level of blockade; epidural: missed segments, incomplete motor block, poor sacral spread, local anaesthetic toxicity). However, it is a more complicated technique than either block alone and produces a multicompartiment block. This introduces the potential for new complications and the modification of existing complications. CSE cannot be considered as simply a spinal block followed by an epidural block. A variety of techniques, equipment and regimens have been described. New complications and reasons for technical failure are encountered. Epidural injection may

modify the spinal block and epidural drugs may not behave as they would without prior dural puncture.

### Review aims and method

This review examines the current literature on technical aspects of the CSE technique and factors that distinguish it from either spinal or epidural blockade. The review does not consider different drug regimens or address the role of the technique as analgesia during labour. Owing to the limited number of randomised controlled trials and other high-quality research, the review is descriptive. Articles were found by *Medline* search through the years 1975–1999 using the search words ‘spinal’ or ‘subarachnoid’ and ‘epidural’ or ‘extradural’. Reference lists in these publications were searched. The major anaesthetic journals were hand searched. This search identified 58 articles, 41 abstracts, 117 letters, 40 case reports, eight reviews and three editorials. Much of the technical information is contained in letters to journal editors. The lack of strong evidence

was illustrated in the recently published American Society of Anesthesiologists' Practice Guidelines for Obstetrical Anesthesia [1]. Despite widespread use, the task force was unable to confirm whether CSE is beneficial to mother or fetus for labour or for Caesarean section, because of insufficient evidence.

### Origin

Intentional drug injection outside and within the subarachnoid space was first described by a surgeon, Soresi, in 1937 [2]. Using a single needle he injected local anaesthetic into the epidural space before advancing and performing a subarachnoid block. Ceralaru, in Romania, first reported the technique using two lumbar interspaces in 1979 [3]. In the same year Brownridge suggested the technique for obstetric anaesthesia [4] and reported its use 2 years later [5]. The needle-through-needle technique was described independently by Coates and Mumtaz in the same issue of the same journal in 1982 [6, 7]. This technique was first used in obstetric practice by Carrie in 1984 [8].

### Applications of CSE techniques

CSE was first described in the modern era for urological surgery [3]. More recently it has become an established technique for analgesia in labour [9, 10] and anaesthesia for Caesarean section [11]. Obstetric anaesthesia and analgesia have generated most reports of the technique. It is regarded by some as the optimum regional technique for non-obstetric surgery [12] and has been used for orthopaedic [12], trauma [13], general [14], vascular [15] and gynaecological surgery [16]. It has also been used for paediatric anaesthesia [17]. CSE is the technique of choice for determining minimum intrathecal drug doses [18] and for assessing the interaction between intrathecal and epidural drugs [14, 19, 20].

### Epidemiology

There are few data on use of the technique prior to this decade. In 1992, Rawal surveyed hospitals in 17 European countries [21]. CSE use varied between countries, representing 0.2% (Ireland) to 60% (Holland) of major regional blockade. Most use was for major orthopaedic and lower abdominal surgery. Also in 1992, in the same 17 European countries, CSE was used for Caesarean section by 8% of respondents [22]. In 1993, in Sweden, two-thirds of departments used CSE and up to a third of lower limb arthroplasty surgery was performed using CSE anaesthesia [23]. In 1997, 28% of Canadian anaesthetists reported using CSE for labour analgesia [24]. It has been estimated that use of the CSE increased 10-fold between 1992 and 1997 [25].

## Techniques of needle insertion and variations

Several CSE techniques are described, probably in part because no single technique is entirely satisfactory. Techniques have been varied and modified in order to increase success and avoid potential or actual complications. The complications associated with each technique are discussed fully below.

### Single pass

Soresi described performing epidural injection and then advancing the same needle into the subarachnoid space [2]. Sprotte described a similar technique in which a needle was placed in the epidural space and remained there while blockade developed [26]. If blockade was inadequate, the needle was advanced and subarachnoid injection performed. No catheters were used and it is difficult to imagine what advantages these techniques have over pure subarachnoid blockade.

### Needle-through-needle

The epidural space is identified as if performing an epidural block. A spinal needle is then passed through the epidural needle and beyond its tip, until the dura is punctured. Subarachnoid drug is administered and, after removing the spinal needle, an epidural catheter is placed. Needle-through-needle CSE requires that subarachnoid blockade is initiated before epidural catheter placement. The technique may be performed with a normal epidural needle and a long spinal needle. A large number of commercial kits are available, designed specifically for needle-through-needle CSE. It is the most widely reported CSE technique in the literature and is likely to be the most frequently used. Potential problems with needle-through-needle CSE include: failure of the spinal component, inadvertent insertion of the catheter into the subarachnoid space and damage to either of the needles through friction between them.

### 'Backeyes'

Several commercial CSE kits include an epidural needle with a small hole in the greater curvature of the tip [27]. This 'backeye' ensures that the dural puncture site is displaced from the epidural catheter and, by allowing the spinal needle to follow a straight route, reduces the likelihood of friction between the two needles at the Huber point. Successful exit via the backeye varies between 50% [28] and 100% [27]. Several techniques improve backeye location: bending the spinal needle so that concavity of its curve is on the side of the backeye increases success [28–30]; a second, larger, spinal needle may be used as a guide within the epidural needle, through which the fine spinal needle is passed [31]; finally the Espocan® needle (B Braun Medical, Melsungen AG, Melsungen Germany) includes

a plastic sleeve to guide the spinal needle to the backeye and eliminate needle-to-needle contact [32]. Comparing epidural needles with and without a backeye, Joshi, using a 26 G Quincke spinal needle, found similar performance, but that dural puncture was more easily felt using a backeye [33]. In contrast, Paech was unable to feel dural puncture with a 26 or 27 G pencil-point spinal needle in 24% of cases using a backeye compared with 6% without [34].

#### *Spinal needle stabilisation*

During needle-through-needle CSE, the epidural needle acts as spinal needle introducer as far as the epidural space. The spinal needle passes through few tissue planes and is poorly anchored. The needles used may be long and narrow requiring relatively large forces for fluid injection. Both factors contribute to displacement during injection, which may lead to the failure of the technique. Tunstall suggested a drop of fluid on a spinal needle to mark the position relative to the introducer when performing subarachnoid block but this could be applied equally to CSE [35]. Nickalls & Dennison used an artery clip to anchor the spinal needle at the point of dural puncture [36]. Johnson used small bore extension tubing [37] to mimic Winnie's immobile needle approach and minimise movement [38]. Some commercial kits include spinal needles with Luer locks or other devices to allow fixation to the epidural needle [39] but this necessitates that the spinal needle extends a fixed distance beyond the tip of the epidural needle. This risks failure if the extension is too short [33] or nerve damage if too long [25, 40]. Ratchet devices that allow stabilisation and variable, measured extension beyond the epidural needle tip have been evaluated, with low failure rates [40, 41].

#### *Identification of dural puncture*

Because of the long thin needles used, dural puncture may be difficult to feel during needle-through-needle CSE. Kopacz & Bainton used a 'hanging drop' in the epidural needle to identify dural puncture, relying on the 'negative pressure' generated in the epidural space as the spinal needle indents the dura [42].

#### *Epidural catheter insertion before subarachnoid injection*

Conventional needle-through-needle CSE necessitates epidural catheter insertion after subarachnoid block, which could cause neural damage since warning signs, such as paraesthesia, are lost. To avoid this Simsa suggested inserting a 29 G spinal needle into a 16 G Tuohy needle, fixing it, then without removing it, inserting an 18 G epidural catheter through the same needle [41]. Wilhelm & Standl placed a 22 G epidural catheter via a 18 G Tuohy needle before placing a 25 G spinal needle through the Tuohy needle and out of a backhole [13]. Both techniques

allow an epidural test dose to be given before subarachnoid injection but are technically complicated.

#### **Separate needles**

With this technique, subarachnoid injection and epidural catheter placement are performed through different needles. The two components of the blockade may be carried out in either order.

#### *Separate interspaces*

Brownridge's first report of CSE in obstetric anaesthesia described epidural catheter placement at L<sub>1-2</sub> followed by subarachnoid block at L<sub>3-4</sub> [5]. This allowed the epidural catheter to be placed and tested before subarachnoid block was initiated, which is not possible with needle-through-needle CSE. However, there is a theoretical risk that the spinal needle may strike the epidural catheter during placement, damaging the needle or catheter [43, 44]. Neither complication has been reported, but may be avoided by combining a thoracic epidural and lumbar spinal [45] or by separating the two procedures by a greater distance than the length of catheter left in the epidural space [46]. Peutrell & Hughes used separate-needle CSE for hernia repair in ex-premature babies [17]. Lumbar subarachnoid injection with a 25 G needle was followed by placing a caudal epidural 23 G catheter.

#### *Single interspace techniques*

Using two interspaces implies two separate local anaesthetic injections and this can be avoided by using a single interspace. Turner & Reifenberg reported the 'single space double-barrel technique' [47]. An epidural needle is sited followed by a spinal needle introducer at the same interspace. The epidural catheter is then inserted and spinal needle insertion follows. This was criticised as being 'inherently unsafe' [48] because the spinal needle was introduced after the epidural catheter. The original report of 90 cases described one catheter being damaged by an introducer needle.

Cook recently proposed a technique to avoid many of the practical problems of CSE [49]. A spinal needle is placed as low as possible in the selected interspace and the CSF identified. The spinal needle stylet is replaced and an epidural needle is placed cephalad in the same interspace. The epidural catheter is then placed. The spinal needle stylet is removed and subarachnoid blockade performed. The technique allows placement of the epidural catheter before subarachnoid injection but does not require placing the spinal needle with an epidural catheter *in situ*. The technique has not yet been evaluated critically.

#### **Combined needle**

Eldor & Chaiminsky described a combined spinal epidural needle made by joining a spinal needle along the length of

a Tuohy needle, including bending around the tip [50]. Similar double-barrel, parallel needles were developed by Torrieri & Aldrete in the early 1980s [51] and reported in 1988 [52]. Similar needles were reported in 1990 by Bleck [53] and by Coombs [54]. These were designed to avoid friction between spinal and epidural needle and to ensure dural puncture was separated from epidural catheter placement. Eldor *et al.* subsequently described a straight-barrelled 20 G spinal needle brazen to an 18 G Tuohy needle. The 20 G spinal needle acted as a conduit for a 28–32 G spinal needle. There were two failures in the first 13 cases reported [55, 56].

These needles allow subarachnoid blockade and epidural catheter placement to be carried out in either order. Fine, long spinal needles are required to pass through the spinal conduit. There are no published rigorous evaluations of these needles or comparisons with other techniques and they are not in widespread use.

### Dual catheter technique

An epidural catheter and a subarachnoid catheter are placed. Both separate-needle and modified needle-through-needle techniques have been described. The technique allows epidural catheter placement before subarachnoid block and allows incremental subarachnoid anaesthesia. Intrathecal placement of the planned epidural catheter and catheter entanglement are potential problems. The problems of continuous spinal anaesthesia, such as cauda equina syndrome, are also introduced [57]. With two catheters, accidental subarachnoid injection of drug intended for epidural injection is probably the most dangerous aspect. Dahl *et al.* studied 14 patients with a thoracic epidural catheter and an 18 G lumbar intrathecal catheter undergoing abdominal surgery [58]. The intrathecal catheter was removed at the end of surgery and the epidural catheter used for postoperative analgesia. The technique allowed near perfect analgesia without systemic opioids, and there were no failures. Vercauteren *et al.* used a modified needle-through-needle technique to introduce a 20 G epidural catheter and a 27 G intrathecal catheter through a 16 G epidural needle and 22 G spinal needle in 12 high-risk patients [15]. The technique failed in one of 12 patients studied and in one patient both catheters were inserted intrathecally. Dual catheter techniques are rarely used.

### Comparisons between techniques

#### Low dose ('sequential CSE') vs. full dose CSE techniques

Rawal and co-workers advocated a two-stage CSE whereby an intentionally small subarachnoid dose is administered accepting that a low block may occur. This is then 'topped-up' with epidural drugs 15–20 min later [11, 59]. Others

report similar techniques [60–62]. Epidural top-ups act rapidly after CSE and allow prompt elevation of block level when it is too low [63]. This 'sequential CSE' technique allows neuraxial blockade to be restricted to the lowest level needed and minimises sympathetic blockade [11, 64]. This makes the technique theoretically suitable for patients with cardiac disease or at risk of hypotension [65]. The technique has also been used to study the minimum dose of intrathecal local anaesthetic suitable for ambulatory anaesthesia [18] and Caesarean section [64]. The disadvantage of the technique is that adequate blockade takes longer to produce than with full doses making it unsuitable for urgent surgery [65]. Surprisingly, Thorén *et al.*, comparing sequential CSE with spinal anaesthesia for Caesarean section found that sequential CSE was associated with more hypotensive episodes [65]. One explanation is the delay in positioning that occurs when CSE is used. Most anaesthetists report using 'full-dose' techniques for routine CSE [23] but it is a useful technique for high-risk patients.

#### CSE vs. epidural or spinal blockade

Neither epidural nor subarachnoid blockade completely abolish neural transmission in 'blocked' regions. Dirkes *et al.* used a dual catheter technique to study electrical sensory thresholds with epidural, subarachnoid or CSE blocks, and found that CSE raised sensory thresholds more than spinal or epidural block alone [14]. CSE can therefore produce a physiologically denser block than either technique alone. A similar dual catheter technique with intense local anaesthetic blockade considerably diminished the stress response to major surgery [58]. Whether there is any outcome benefit to this increased blockade is unproven.

Epidural or spinal anaesthesia for Caesarean section is inadequate in up to 4% of cases [66]. It is suggested that CSE might reduce the risk of conversion of regional to general anaesthesia to 0.16% [67]. Rawal *et al.* compared sequential CSE with epidural anaesthesia for Caesarean section [11]. The CSE technique provided better analgesia and muscle relaxation with less hypotension and was associated with lower maternal and fetal blood levels of bupivacaine, reflecting the smaller doses used. Mission *et al.* compared CSE with either spinal or epidural anaesthesia and found CSE to be the optimal technique [68]. CSE was as fast to perform as epidural anaesthesia and associated with less hypotension and less drug usage. Spinal anaesthesia was as rapid as CSE. Davies *et al.* compared CSE with 'optimal epidural anaesthesia' (alkalinised local anaesthetic with opioid) [69]. CSE provided more rapid blockade, similar haemodynamic conditions and equal neonatal outcome. Maternal satisfaction was high in both groups but the CSE group was associated with less pain at delivery, lower anxiety and greater satisfaction peri-operatively.

Norris *et al.*, studying over 1000 patients receiving CSE or epidural analgesia in labour, found a lower accidental dural puncture rate but a higher failure rate in the CSE group [70]. Ramasamy *et al.* retrospectively examined records of 456 CSE and 296 epidurals for labour and also found a lower incidence of accidental dural puncture in the CSE group [71]. Holmström *et al.* compared CSE for orthopaedic surgery with spinal or epidural techniques [12]. Operative conditions were better under CSE than under epidural anaesthesia and the ability to prolong the block led the authors to conclude CSE combined the advantages of both techniques alone.

### CSE vs. continuous spinal anaesthesia (CSA)

Wilhelm & Standl randomly allocated 60 patients with lower limb trauma to receive CSE or CSA via a micro-catheter [13]. CSE took longer (8 vs. 13 min), required more dural punctures per patient and was associated with more technical problems (47 vs. 13%) than CSA. The authors concluded that CSE had no advantages over CSA. The needle-through-needle CSE technique chosen involved epidural catheter placement and test dose administration before spinal needle insertion. This is an unusual, complicated technique and may have increased time taken and difficulty. Most of the complications of CSE were minor such as 'bloody tap'.

### Needle-through-needle vs. separate-needle techniques

There are little data on the relative use of needle-through-needle and separate-needle CSE. In 1993, in Sweden, Holmström *et al.* found that 64% of departments preferred separate-needle CSE, 22 of 27 respondents performing subarachnoid blockade after epidural catheter placement [23]. However separate-needle CSE was used more in smaller units and the authors suggest that the numbers of needle-through-needle and separate-needle CSEs were approximately equal.

Lyons *et al.* compared needle-through-needle and separate-needle CSE in a randomised study of 100 patients undergoing Caesarean section [72]. Separate-needle CSE had a lower spinal failure rate (4 vs. 16%), was associated with less hypotension and took no longer than needle-through-needle CSE. The separate-needle group had higher blocks. A larger number in the separate-needle group did not favour the technique compared with previous epidural analgesia, but this was not statistically significant. This lack of satisfaction was attributed to performing two injections for separate-needle and only one for needle-through-needle CSE. The high failure rate of needle-through-needle CSE in this study has been criticised as being unrepresentative [73, 74].

Casati *et al.* studied 120 nonobstetric patients randomly

allocated to needle-through-needle or separate-needle CSE performed in the sitting position [75]. The needle-through-needle technique was quicker to perform with no significant differences between the resultant blocks. Failure of spinal anaesthesia (5%) and hypotension (23%) was higher in the needle-through-needle group than in the separate-needle group (1.6% and 13%), although these differences were not significant. Patient acceptance was significantly greater in the needle-through-needle group (85% rating the procedure as good vs. 64%). The authors concluded that the needle-through-needle technique is faster, better tolerated and no more difficult.

Rawal *et al.*, reviewing separate-needle and needle-through-needle CSE techniques, concluded that needle-through-needle CSE can 'be expected to cause considerably less discomfort, trauma and morbidity, including backache, epidural venous puncture, haematoma, infection and technical difficulties' [66]. This view was criticised for lacking any evidence base [76]. The specialised equipment for needle-through-needle CSE is estimated to cost  $\approx$  40% more than a standard epidural set and 27 G pencil-point needle needed for separate-needle CSE [77].

### Problems and complications of CSE techniques

Complications may be specific to needle-through-needle or separate-needle techniques or may be considered according to whether the spinal or epidural component is performed first.

#### Failure of the spinal component of needle-through-needle CSE

In early reports of needle-through-needle CSE, failure of spinal anaesthesia occurred in 10–25% of cases [8, 10, 12, 18, 33, 39, 72, 77]. More recent reports using a variety of needle combinations detail failure in  $\approx$  5% [25, 73, 75, 78, 79]. Failure rates below 2% are possible [40], and Westbrook *et al.* reported one failure in 150 patients using a 26 G spinal needle [80]. The largest audit available, of 6700 patients in labour, recorded spinal failure in 4.9% and failure of spinal and epidural in 0.42% (F. Plaat & R. E. Collis, pers. commun.).

There are many reasons that may explain failure of the needle-through-needle technique:

**1** Too short a spinal needle will not extend far enough beyond the tip of the epidural needle to reach the dura [8]. Work during deliberate dural puncture with a Tuohy needle found that the epidural–dural distance varied between 5 and 25 mm, was  $>$  15 mm in 30% and  $>$  20 mm in 9% [81]. Clinical studies during needle-through-needle CSE report an epidural–dural distance between 3 and 17 mm [36, 41] with 16% requiring  $<$  5 mm extension [40], 15%  $>$  10 mm [33] and 3%  $>$  13 mm [40]. The problem is increased if

needles designed to exit a backeye take the longer route though the Huber tip [31, 33]. Early needle designs allowed projection of as little as 7 mm [31, 82] but most current needle designs extend 12–15 mm.

**2** Excessively long needles pose problems of handling and depth of placement. During needle-through-needle CSE, the spinal needle is only anchored by the dura and needle movement is difficult to prevent. Long fine needles have high internal resistance leading to delay in reflux of CSF [70, 83], difficulty in stabilisation during injection [62, 74] and increasing the risk of loss of drug during injection [39, 62, 73]. A long spinal needle may enter the subarachnoid space then pass through it and out through the anterior dura [62, 82]. Anterior dural puncture may also occur if a blunt spinal needle causes apposition of posterior and anterior dura, the needle passing through the dural sac without encountering CSF [84].

**3** Deviation from the midline will lengthen the epidural–dural distance and a Huber tip may exacerbate this [31, 85–87]. The dural sac is triangular in the lumbar region with the apex pointing posteriorly [88, 89]. Small degrees of lateral deflection allow the spinal needle to pass by.

**4** Saline, used to identify the epidural space, may enter the spinal needle and be misinterpreted as CSF [42]. Some use air for identifying the epidural space for this reason [90]. Vigfússon & Jóhannesdóttir compared the quality of blockade after epidural location using air or saline in 110 CSE procedures [91]. More failures occurred in the saline group but the differences were not statistically significant.

**5** Very fine pencil-point needles (28 G and smaller) may lack the rigidity and sharpness to puncture the dura [18]. Brighthouse & Wilkins reported five occasions of difficulty in puncturing the dura with a 25 G Whitacre needle [92].

**6** Lack of appreciation of dural puncture (poor feel) is common with needle-through-needle CSE. Paech & Evans, using an epidural needle with a backeye and a 26 G pencil-point spinal needle, did not feel dural puncture in 24% of cases [34] and Hoffmann *et al.*, using a similar needle, in 26% of cases [40]. Blockade was still successful in 98%. Lack of feel during dural puncture with needle-through-needle CSE leads some to prefer to perform the two familiar techniques separately; the separate-needle technique.

### Failure of the epidural in CSE

Epidural failure rate in CSE has been studied less than spinal failure but is unlikely to differ much from failure for epidural techniques alone [77; F. Plaat & R. E. Collis, pers. commun.]. The reports that do exist are conflicting. Two reports from the same authors found 18–22% failure of epidural analgesia for postoperative analgesia after CSE compared with 6–8% after epidural alone [93, 94]. The techniques were not randomised or blinded and this finding needs corroboration. In contrast, Eappen *et al.*, in a

retrospective chart review of 4000 cases, found that the likelihood of an obstetric epidural needing resiting was reduced if it was part of a CSE technique rather than an epidural alone [95].

### Problems due to performing epidural after spinal blockade

Theoretical problems include subarachnoid placement of the epidural catheter, difficulty delivering or interpreting an epidural test dose, failure to detect warning paraesthesia or delay during epidural placement. These problems are inherent to needle-through-needle CSE and can also occur when separate-needle CSE involves epidural blockade after subarachnoid block.

#### *Accidental subarachnoid placement of intended epidural catheter*

An epidural catheter may enter the subarachnoid space during CSE by passing through the known hole made by the spinal needle or through an unrecognised hole made by the epidural needle. The problem is particularly important during CSE as prior interpretation of an epidural test dose is often difficult. Separate-needle CSE where the epidural catheter is placed first [47, 49] or distant from dural puncture can avoid this problem but needle-through-needle CSE cannot. ‘Backholes’ and combined needles also aim to ensure that the epidural catheter reaches the dura at a point away from the dural puncture.

Subarachnoid placement is certainly uncommon but there are several reports in which it has happened or been suspected [66, 96–99]. Because of the multicompartiment block produced by CSE it is not possible from the reports to be sure whether the catheters entered the subarachnoid space after unrecognised dural puncture with the Tuohy needle, through the spinal needle hole or migrated later [100].

Needle-through-needle CSE via a Tuohy needle theoretically increases the risks of subarachnoid catheter placement as the Huber tip directs the catheter towards the hole made by the spinal needle. Rotation of the Tuohy needle through 180° after spinal placement has been advocated to redirect the epidural catheter away from the dural hole [6, 59, 98, 101–103]. However epiduroscopy shows that Tuohy needles routinely tent the dura after insertion [104] and rotation increases the ease of dural puncture [81], the necessary force reducing as the extent of rotation increases [105]. Of the authors recommending rotation, one had an accidental subarachnoid catheter rate of 4% [98] and another reported that a dural puncture rate of 3% without rotation increased to 17% when needle rotation was introduced [103]. In the suspected cases, above, rotation was practised in two [99, 106]. Rotation of the epidural needle within the epidural space cannot be recommended.

*In vitro* testing suggests that it is possible to force an 18 G

catheter through the dural hole made by a 22 G spinal needle but not through those made by 26 G needles [11]. To examine this, Holmström *et al.* performed epiduroscopy on 15 fresh cadavers, making dural holes with 25 or 26 G cutting spinal needles and 18 G Tuohy needles [104]. Size 17 and 19 G epidural catheters were then directed at the holes. Neither catheter entered single holes made by the spinal needles, nine of 20 catheters (45%) entered holes made by the Tuohy needle and, when five dural punctures were made with the spinal needle, a catheter passed through the dura in one of 20 attempts (5%). This suggests the risk of subarachnoid catheter placement (or migration) through a dural puncture made by fine spinal needle is small but can occur after accidental dural puncture with a Tuohy needle. In another epiduroscopy study, Holst *et al.* were unable to pass an 18 G epidural catheter into single dural holes made by a 27 G Quincke needle [107]. In spite of these results, Ramasamy *et al.* reported a 1.1% incidence of suspected intrathecal catheter migration following CSE, compared with 0.3% after conventional epidural [71]. Rawal *et al.* reported > 26 000 cases of CSE without any recognised intrathecal catheter insertion or migration [66].

It is important to realise that any epidural catheter may migrate into the subarachnoid space, whether placed as part of a CSE or not. During CSE, subarachnoid placement of an intended epidural catheter at the time of insertion is probably more frequent than migration and, if small spinal needles are used, this is likely to be due to unnoticed dural damage with the epidural needle [66]. This risk increases if the epidural needle is rotated. Aspiration tests and modified test doses should be used in an attempt to detect misplacement particularly before the catheter is used for the first time. A high index of suspicion is necessary.

#### *Epidural catheter migration through the dura*

This is rare and probably no more common than after routine epidural placement. Large studies have not reported this complication [10, 70]. However it is one explanation of a number of cases of unexpectedly profound block. In one case, severe respiratory depression and dense motor block with hypotension developed after catheter injection of a second dose of diamorphine and bupivacaine [108]. Previous injection had been uneventful. The authors suggest catheter migration through the arachnoid mater from an unrecognised subdural position. Other cases may have occurred but have been interpreted as cases of abnormal drug passage between epidural and subarachnoid space (see below).

#### *Epidural test doses and aspiration tests*

When subarachnoid block is established before placing an epidural catheter, a conventional epidural 'test dose'

cannot be interpreted and may be potentially dangerous by extending subarachnoid block [109–111]. Some consider CSE techniques intrinsically unsafe for this reason [112], while others believe a test dose unnecessary if dilute solutions are used [10]. A test dose can be delayed until subarachnoid block is regressing but this interrupts analgesia and correct interpretation remains difficult if residual block persists [85, 109, 111, 113, 114]. Logically, a test dose should be given by someone who can treat a high block, usually an anaesthetist, which in obstetrics increases the workload [10, 113, 115]. The problem cannot be avoided using needle-through-needle CSE but may be if separate-needle CSE is used and the epidural catheter is placed before subarachnoid block [47, 49] or if a modified needle-through-needle technique as described above is used [41].

Collis *et al.* used a high-volume low-concentration epidural test dose/loading dose (fentanyl 30 µg and bupivacaine 15 mg in 15 ml) in 300 cases of CSE for obstetric analgesia without problems [10]. Foss & D'Angelo used lignocaine 45 mg and epinephrine 15 µg in 3 ml following subarachnoid analgesia in 12 volunteers [116]. Injected intrathecally, but not epidurally, this dose produced objective and subjective changes in blockade without adverse effects. It requires further evaluation in different patient groups.

Problems with test doses may lead to greater reliance on negative aspiration tests to confirm epidural catheter placement [66]. However, when performing needle-through-needle CSE, fluid has been noted at the hub of the epidural needle [29, 33, 70, 117] or within the epidural catheter [97, 118]. Haridas found fluid in the epidural needle in 20%, in the catheter in 80% and could aspirate this fluid in 18% after CSE in the sitting position [119]. The fluid was confirmed as CSF in all cases but none of the catheters was placed in the subarachnoid space.

It is axiomatic, therefore, that all boluses injected into an epidural catheter after CSE should be of such a nature that unintentional subarachnoid administration will not be dangerous and neural blockade must be monitored rigorously after boluses. Each bolus should be regarded as a test dose [120, 121].

#### *Paraesthesia during epidural catheter placement*

There is concern that placing an epidural catheter after initiating subarachnoid blockade may prevent warning paraesthesiae and therefore raise the risk of neurological complications [122]. This has parallels with performing regional blockade in the anaesthetised patient [43], and is inherent in needle-through-needle CSE. During separate-needle CSE (if subarachnoid injection is performed first) both the epidural needle and catheter may be placed after the subarachnoid block.

A retrospective audit compared the incidence of paraesthesia during epidural catheter insertion between needle-through-needle CSE and epidural [43]. Both techniques (3000 epidurals and almost 300 CSEs) were associated with 30–32% paraesthesia without clinical sequelae. The authors point out this was low-dose ‘analgesic CSE’ for labour and results may not be applicable for ‘anaesthetic CSE’ such as for Caesarean section. Casati *et al.* reported no difference in the incidence of paraesthesia during catheter insertion in 120 patients undergoing needle-through-needle or separate-needle CSE (10% vs. 11.6%) [75]. Turner & Reifenberg (‘single space double-barrel technique’) [47] and Wilhelm & Standl (modified needle-through-needle technique with the epidural catheter placed before the spinal needle) [13] reported 13% and 17% paraesthesia, respectively. There were no long-term sequelae in these reports.

#### *Delay in completing epidural catheter placement*

When subarachnoid block is initiated before placing and securing the epidural catheter there is inevitably some delay in attending to the developing neural blockade [39, 110, 123]. The delay is usually brief and of no consequence, providing it is anticipated [124]. However, it may alter the final characteristics of the block [125, 126]. Holmström *et al.* found a higher level of blockade when comparing spinal and CSE in the sitting position using plain bupivacaine [12]. They attributed this finding to the extra time the CSE group sat in this position, ‘three to four minutes longer to allow introduction of the epidural catheter’.

Unexpected delay may occur due to blood entering the catheter, difficulty in advancing the catheter or paraesthesia during advancement. No warning of these problems is likely during epidural needle placement but each may require either further attempts at catheter placement or abandoning the epidural component of CSE. Efforts to place the catheter may need epidural needle rotation or resiting at a different interspace. Delay between subarachnoid injection and completing the CSE will then be considerable. This exposes the patient to the problems of the developing subarachnoid blockade while the anaesthetist’s attention is on the procedure [124] and risks cardiovascular destabilisation or block failure.

Parturients undergoing Caesarean section are at particular risk as onset of subarachnoid blockade is swift and hypotension occurs rapidly [127]. Hyperbaric local anaesthetic solutions are frequently used and any delay in positioning the patient can lead to unilateral or saddle block depending on the patient’s position [45, 73, 128]. Roberts & Brighthouse reported a case where a ‘bloody tap’ with the epidural catheter led to delay and unilateral blockade and necessitated general anaesthesia [79].

The frequency of delay leading to poor block has not been reported but was alluded to in one of the first reports of needle-through-needle CSE [7] and occurred in two of the first 40 obstetric cases using the technique [8]. Proposed solutions include inserting the epidural catheter before the subarachnoid block [79], using isobaric, rather than hyperbaric, local anaesthetics [7] or rolling the patient onto the other side and then performing the epidural block separately [110]. The alternative is to abandon or delay the epidural [66, 126]. This may lead to inadequate operative blockade, early return of sensation during a prolonged procedure, poor postoperative analgesia and poor patient satisfaction. Delay is particularly important if a ‘sequential’ CSE is used [11, 59]: the intentionally small intrathecal dose may prove entirely inadequate.

The potential for cardiovascular instability during delay has led some authors to recommend that CSE should only be performed in the lateral position [43, 126]. However, even if large doses of drug are used, prolonged lateral positioning may lead to inadequate block [129, 130].

Delays can be prevented by inserting the epidural catheter before administering subarachnoid drugs, which requires a separate-needle technique.

#### **Other problems specific to needle-through-needle CSE**

##### *Friction, needle damage and metallic particles*

The possibility of spinal needle damage during contact with the epidural needle has been suggested [123, 131, 132]. Eldor argues that friction between spinal and epidural needle generates metallic fragments which are then introduced into the subarachnoid space [133, 134]. Eldor & Brodsky propose this as a cause of aseptic meningitis following CSE [135]. These claims originate from the observation of notches seen at the tip of a Tuohy needle after needle-through-needle CSE and have been used to support the use of double-barrelled needles designed by Eldor [136].

Several authors have examined this question. Carrie, referring to the use of Quincke needles, reported that if the spinal needle bevel is perpendicular to the Tuohy needle bevel (i.e. appropriately orientated for atraumatic dural puncture and cephalad positioning of the epidural catheter), contact between needles is minimal [137]. He also reported manufacturers’ investigations that failed to find increased epidural needle markings or spinal needle damage. Herman *et al.* undertook microscopy and photomicrography and found no additional metal shards when a 24 G Sprotte needle was passed through a variety of epidural needles [138]. A small dent in the tip of the Huber point was confirmed but was due to malleability rather than loss of metal mass. No spinal needle damage



was observed. Of note is that application of magnets to new, unused epidural needles consistently revealed metal flakes which were not removed by manufacturers' washing process or saline flushing. Atomic absorption spectroscopy techniques showed no excess of metal after up to five passes of a 29 G Quincke needle through an 18 G Tuohy needle [107]. Even after repeated, intentional rough handling and inappropriate alignment of needle bevels there were no additional metal particles or Tuohy needle damage. Finally, Hargreaves used energy-dispersive X-ray analysis and scanning electron microscopy to examine fluid flushed through epidural needles after CSE and found no additional metal whether using Quincke or pencil-point needles [139].

If metal flakes do enter the body it is unlikely that significant reaction will occur. Eldor's claims of inflammation and oedema from release of metallic ions by acidic local anaesthetics [134] are based on data from before the introduction of medical grade stainless steel [140]. Nickel is the usual source of allergy and, although medical grade stainless steel contains 8–10% nickel, it is tightly bound in the alloy, 'hypoallergenic' and does not elicit a hypersensitivity response even when implanted in nickel-sensitive patients [141].

To summarise, the needle-through-needle technique is unlikely to cause the introduction of metal shards into the patient and even were this to occur the consequences would be negligible. Should there be concerns in specific patients the Espocan needle (described above) or separate-needle CSE prevent any needle-needle contact.

### Problems when performing the spinal block after epidural placement

This requires a separate-needle technique and has the advantage of allowing the epidural catheter to be placed and tested before spinal blockade.

#### *Damage to epidural catheter or spinal needle*

Introducing a spinal needle with an epidural catheter in place could allow the spinal needle to strike the epidural catheter leading to spinal needle damage [123] or catheter fracture [43]. The technique has been described as inherently unsafe [48].

Roberts & Brighthouse reported that it is not possible *in vitro* to perforate an epidural catheter with a 24 G Sprotte or 25 G Whitacre needle [79]. Cutting point needles have not been studied. Turner & Reifenberg reported catheter damage by an introducer needle during separate-needle CSE [47]. To date there is no report of catheter damage by a spinal needle during CSE.

Spinal needle tips are easily damaged by contact with bone [142] and striking an epidural catheter might cause similar problems [43]. Fine pencil-point needles with large

side ports are the most susceptible. However, Westbrook & Carrie estimated that the force (applied laterally) needed to bend a 25 G Whitacre needle tip is 42 times the force needed for this needle to penetrate the dura [143]. The complication has not been reported.

Needle-catheter contact can be eliminated if the length of catheter in the epidural space is less than the distance between epidural and spinal punctures. Most separate-needle techniques site the spinal needle one space below the epidural puncture. This would avoid needle-catheter contact if epidural catheters all travelled cephalad, but up to 60% of midline lumbar and thoracic catheters curl up or turn caudad [144, 145]. Cephalad positioning is improved by using the paramedian approach [146]. The separate-needle technique described by Cook claims to avoid problems of needle-catheter contact [49].

### CSE procedure

The results of any central neuraxial block may be altered by patient positioning, the approach to the spine, the needle(s) used and the baricity of drug used. These factors have particular relevance for CSE but several factors may interact.

#### Patient position and drug baricity

Positioning patients for CSE is controversial with studies reporting conflicting results. Caesarean section, which often requires a rapid onset of high block while minimising hypotension, is particularly problematic.

Norris *et al.* reported significantly more first-time success with CSE in the sitting position [70]. Identification of the midline is easier, CSF pressure is higher [70, 82] and CSF flow is faster [34]. All might reduce failure, particularly for needle-through-needle CSE with long fine needles. Studying spinal anaesthesia, Inglis *et al.* found that the block was quicker to perform in the sitting position than in the lateral position [147]. Using hyperbaric bupivacaine, final block levels were the same in either group but those in the lateral position needed more ephedrine. Patel *et al.*, using 10 mg of hyperbaric bupivacaine 0.5% and CSE for Caesarean section, found lower blockade, slower spread and less hypotension in the sitting than the lateral position [124]. Epidural top-ups were needed by 39% of sitting patients to achieve adequate block. Conversely, Yun *et al.* used 12 mg of hyperbaric bupivacaine 0.75% with fentanyl 10 µg and found no difference in speed of onset or final block height whether the sitting or lateral position was used [126]. The sitting group were more hypotensive and needed more ephedrine, despite excluding patients if they remained sitting for more than 3 min for epidural catheter insertion.

Kestin argued that subarachnoid injection for Caesarean

section should only be performed in the lateral position because of the risk of saddle block with hyperbaric anaesthetic solutions [43]. If a lateral position is used, Russell has shown that right lateral leads to fewer inadequate blocks than left [130]. CSF pressure increases considerably in the lateral position if flexed beyond 90° [148] so it may be useful to increase flexion during dural puncture while adopting lesser degrees of flexion while siting the epidural needle.

The 'Oxford position' is a left lateral position with minimal Trendelenburg [80]. The shoulders are supported on a 3-litre infusion bag and the head on three pillows to curve the thoracic and cervical spine laterally. The aim is to promote cephalad spread into the lower thoracic spine but prevent extension beyond the upper thoracic segments. The authors claim a very low risk of high block and hypotension even when 2.8 ml of bupivacaine 0.5% is used in parturients.

Regarding baricity, 'isobaric' plain bupivacaine and combinations with opioids are hypobaric at body temperature [8, 149]. Vercauteren *et al.* studied CSE in the lateral position for Caesarean section and compared hyperbaric and plain bupivacaine 6.6 mg with sufentanil 3.3 µg [150]. Mean block height was the same in both groups but the plain group had greater variability resulting in more blocks that were too high or too low. This group also experienced more nausea, hypotension and required more ephedrine. In contrast, Frigon *et al.* compared hyperbaric and plain bupivacaine 9.75 mg in the sitting position [151]. The authors found a faster onset with the plain solution and a lesser requirement for epidural top-ups before surgery.

Patient position and drug baricity interact and good technique requires that both are considered together so that positioning can be used to manipulate blockade rather than lead to its failure. The procedure can be performed more quickly sitting, but delays will lead to inadequate block particularly if hyperbaric solutions are used. The consequences of this will depend in part on whether a sequential or full-dose technique is used. The advantage of hyperbaric solutions is greater predictability of block [152] with less likelihood of high block and associated hypotension and nausea. Advantages of 'isobaric' solutions are that spread is less posture dependent [150] and, if hypotension occurs, head-down tilt may be used to increase venous return without causing cephalad extension [150]. Differential sensory/motor blockade may also be improved [62]. Neither position nor baricity is 'right': different choices are necessary in different clinical situations.

#### **Which approach: paramedian or midline?**

Using needle-through-needle CSE, both spinal and epidural use the same approach. Westbrook *et al.* reported no

difference in success or complications whether the midline or paramedian approach was used, although numbers were small [80]. For separate-needle CSE, midline and paramedian approaches can be used for each component as required.

The midline approach reduces spinal failure during CSE as the epidural–dural distance is least here [146]. The risk of 'missing' the triangular-shaped dural sac is minimised [40] but technique is critical as deviation from the midline may still lead to failure.

For epidural placement, the paramedian approach has several advantages. It reduces accidental dural puncture [104, 146] and the oblique approach to dural fibres may lessen the incidence of postdural puncture headache [80]. It also increases the likelihood of cephalad catheter placement [146]. One of the reasons for the reduced risk of accidental dural puncture is that the epidural–dural distance is ≈ 6 mm more than in the midline [146]; needle-through-needle CSE via the paramedian approach may therefore require even longer spinal needles.

#### **Which needle?**

Needles used for CSE depend on the technique chosen. For separate-needle CSE, the choice is as for spinal anaesthesia. For needle-through-needle CSE, long needles are needed. Using combined needles, a very fine and long needle (28 G or smaller) is needed to pass through the double-barrelled spinal needle channel.

Needle choice depends on factors such as the likelihood of failure and incidence of postdural puncture headache. Unfortunately those needles likely to reduce postdural puncture headache often increase failure. Other considerations include risk of subarachnoid placement or migration of the epidural catheter, drug flux through the dural hole and introduction of tissue into the subarachnoid space.

#### *Which size?*

As for spinal block in general, during CSE small needles are used to reduce the risk of postdural puncture headache. Below a certain size no advantage accrues and handling is difficult. Needle-through-needle CSE requires needles ≈ 30% longer than conventional spinal needles, which increases the problems of handling, delays in CSF reflux [153, 154], resistance to injection [34, 155] and obstruction [39, 155]. The smallest needle evaluated for CSE is 30 G [39], with which Lesser *et al.* reported a 24% failure rate and 11% incidence of mild headache. Simsa used a 29 G Quincke-point needle and achieved a remarkable 2% failure and 1% postdural puncture headache rate [41]. The equipment included a fixation device to minimise needle movement during the procedure.

The risk of subarachnoid placement or migration of epidural catheters through the dural hole made by the

spinal needle is virtually eliminated if needles smaller than 24 G are used [104].

#### *Which design?*

Equivalent size pencil-point needles cause less CSF leakage [156, 157] and less postdural puncture headache than Quincke needles [158, 159]. The sharp leading edge of Quincke-point needles may cause concern during needle-through-needle CSE as it can pass through dura with minimal force such that dural puncture may not be felt [156], it enters neural tissue more readily [160] and it carries more skin and tissue debris than a pencil-point needle [160, 161]. Conversely pencil-point needles are relatively blunt, may not pierce the skin without an introducer [162] and, when using long fine needles, dural puncture may be difficult [18, 156] or impossible [92]. Successful dural puncture is frequently noted by a 'click', providing a good end-point for needle-through-needle CSE [80, 153]. During needle-through-needle CSE, the spinal needle tip position may be unclear and a pencil-point needle orifice might straddle the dura leading to block failure [80, 82]: some insert the needle 1–2 mm beyond dural puncture to avoid this problem [126, 162]. However, the dural click is probably due to considerable recoil of indented dura making this unnecessary [163]. Pencil-point needles are considered by some to be inappropriate for CSE specifically because they need to project further into the subarachnoid space than Quincke needles, increasing the risk of neural damage [47, 164]. There is no evidence to support this. Lastly, spinal needles deviate during insertion: long, fine, laterally orientated Quincke-tip needles deviating most [84, 165]. During needle-through-needle CSE, the epidural needle eliminates this deviation as the spinal needle is introduced close to the dura. The Huber tip induces deviation itself.

Uncles & Westbrook suggested that a fine pencil-point needle should be the needle of choice for CSE but, if there is difficulty with dural puncture, this should be changed to a Quincke-tipped needle [166]. Pencil-point needles are used in most reports.

#### *Which length beyond the epidural tip?*

Needles that are too short will not reach the dura during needle-through-needle CSE [8]. If too long they increase paraesthesia [25] and may pass through the dural sac and into the anterior epidural space [89]. Needles that project up to 10 or 13 mm beyond the epidural needle tip will reach the dura in 85% and 97% of cases, respectively [33, 40]. Suggested optimum lengths range from 12 mm [166], 12–15 mm [18] to 'at least 17 mm' [126]. This last recommendation appears excessive and might risk neural damage. Rawal suggests that pencil-point needles should protrude 1–2 mm more than Quincke-tipped needles

[121]. A compromise is a needle that extends 11–13 mm beyond the epidural needle tip, which will be too short in < 5% of cases and may be substituted for a longer needle only if CSF is not seen.

#### *Which needle orientation?*

Needle orientation does not affect postdural puncture headache rate if a pencil-point needle is used as the needle separates dural fibres. Orienting the bevel of a Quincke-tip needle laterally reduces postdural puncture headache even for needles as fine as 27 G [167, 168].

Rosenberg recently reviewed the subject of needle choice and argues that a 26- or 27 G pencil-point needle used with a stylet and introducer is optimum [76]. With smaller needles, technical difficulties outweigh any reduction in postdural puncture headache. Use of an introducer eases insertion, reduces contamination and reduces deviation of fine needles. During needle-through-needle CSE, the epidural needle is the 'perfect introducer'. There may be an argument for using slightly larger needles; Westbrook reported little decrease in CSF leak between 25- and 27 G Whitacre needles [156] and Urmey reported 25% failure with needle-through-needle CSE using a 27 G needle [18]. Lyons *et al.* reported a 16% failure rate with needle-through-needle CSE using a 26 G, but few others have performed so poorly [72]. Randalls *et al.* had a 4% failure rate with a 27 G pencil-point needle [78]. Paech & Evans reported 80% perfect procedures, 2% failure and 2% mild postdural puncture headache with 26 and 27 G Whitacre needles [34] and Hoffmann *et al.* achieved 2% failure with a 27 G pencil-point needle [40]. Westbrook *et al.* used a 26 G Whitacre needle with 90% perfect procedures, 0.7% failure and 2% significant postdural puncture headache [80]. Experienced practitioners using 26 to 27 G needles appear able to achieve failure rates below 5% with acceptably low rates of postdural puncture headache.

### **Incidence of postdural puncture headache**

The cause of postdural puncture headache remains unproven, but CSF leak greater than the rate of production leads to a fall in CSF volume. Subsequent traction on the meninges and cerebral vasodilation may cause headache. Post-partum women may be at particular risk because of reduced CSF volumes and reduced CSF production during diuresis.

In 1981 it was noted that, after accidental dural puncture, successful epidural analgesia led to reduced headache incidence [169]. Early reports of the CSE technique showed a very low incidence of postdural puncture headache [5, 11, 62]. Dennison and Kumar each recorded two cases of mild postdural puncture headache in 400 and 300

cases, respectively [62, 170]. Remarkably, Brownridge reported no postdural puncture headache in >1000 cases of Caesarean section under separate-needle CSE [123]. Proposed reasons for the low incidence of postdural puncture headache include the use of epidural injections [80, 171], or infusions [33] minimizing CSF leak, the use of spinal opioids [123], use of appropriately fine pencil-point needles [80], oblique spinal needle dural puncture due to deflection by the Tuohy needle [113] and good technique reducing accidental dural punctures [33, 70]. During needle-through-needle CSE, the epidural needle acts as the optimum introducer [172] and may reduce multiple dural punctures [66, 170].

Compared with an epidural alone, CSE probably increases postdural puncture headache and this is important in labour analgesia when CSE may be used instead of epidural analgesia. Norris *et al.* found no greater incidence of postdural puncture headache in parturients receiving CSE rather than epidural analgesia [70] but, as the CSE group had a lower incidence of accidental dural puncture, this suggests that some headaches were due the spinal component of CSE. Collis *et al.* reported a postdural puncture headache rate of 2.3% in 300 parturients receiving needle-through-needle CSE for labour using a 27 G pencil-point needle [10]. This led some to choose to avoid CSE in labour [173]. McLoughlin reported that, of the seven cases of postdural puncture headache in Collis *et al.*'s paper, three had accidental dural puncture with a Tuohy needle and two had more than one intentional subarachnoid block [174]. The residual postdural puncture headache rate was therefore 1.3%. Plaat and Collis continued the audit to over 6700 patients and found postural headache in 0.82%, accidental dural puncture in 0.45% and the need for blood patch in 0.42%. They estimated an excess postdural puncture headache rate (above that associated with an epidural alone) of 3 in 1000 (F. Plaat & R. E. Collis, pers. commun.).

If there is a particular need to avoid postdural puncture headache, use of a fine pencil-point needle is indicated. The oblique paramedian approach may reduce the rate further [80, 175]. Should postdural puncture headache occur after CSE with the epidural catheter still in place headache may be treated with fluid [6, 7, 176], blood [11] or drugs via the catheter [11].

### **CSE as a multicompartiment block: effects of prior dural puncture on epidurally administered drugs**

#### **Drug flux**

CSE involves intentional dural puncture followed by epidural drug administration. This introduces the possibility of drug flux from the epidural to the subarachnoid space which may alter the characteristics of the block.

In 1958, Sykes reported total spinal blockade when epidural local anaesthetic was administered above the site of an accidental dural puncture [177]. Migration of drug through the perforated dura was advanced as the cause in this and subsequent similar reports [169]. After one such case, radiopaque dye injected into the epidural space was seen to enter the subarachnoid space [178]. Sykes referred to Dawkins data on 187 cases in which an epidural catheter was placed after accidental dural puncture. When the catheter was placed at the same vertebral level, accidental total spinal occurred in 19%; when placed at a different level this reduced to 2.3%. These differences are notable as needle-through-needle CSE involves intentionally siting the epidural catheter at the same level as recent dural puncture.

In the above cases, the dural puncture was accidental and made with a large epidural needle. Spinal needles used for CSE are likely to be small and noncutting but epidural drug administration may be very close to the site of dural puncture. Does this make a difference? In a cadaver study, Holst *et al.* were unable to see any epidural dye entering the subarachnoid space when 15 ml was injected after dural puncture with a 29 G Quincke needle [179]. However, Collier reported that radiopaque dye was seen to enter the subarachnoid space in one of three patients when injected into an epidural catheter within 1 h of needle-through-needle CSE [180]. Repeating the study in 15 patients 3 h after needle-through-needle CSE (26 G pencil point spinal needle), no subarachnoid dye was seen [181]. The authors estimated volumes as small as 0.5–1 ml would have been detected.

The absence of macroscopic transfer of dye through a dural hole does not rule out clinically relevant drug flux. An early report commented on surprisingly extensive spread of conventional epidural top-ups following CSE [11]. Myint *et al.* reported cardiorespiratory arrest following a Caesarean section under needle-through-needle CSE using a 24 G Sprotte needle. The possibility of opioid transfer from the epidural space to the subarachnoid via the dural hole was proposed as a cause [111] although others interpreted the case as one of catheter misplacement or migration [114, 180, 182]. Eldor *et al.* reported a similar case of respiratory depression 6 h after epidural morphine 3.5 mg, given as part of needle-through-needle CSE [183]. Ramasamy *et al.* compared patients with epidural or CSE for labour who then needed Caesarean section; more women with CSE required unexpectedly small epidural top-ups [71]. Others have noted that, during needle-through-needle CSE, CSF may enter the epidural needle after removal of the spinal needle, and have argued that this suggests a patent dural hole exists through which drugs might flow in the opposite direction [29, 33, 70, 117].

Subarachnoid pressure [184] is normally regarded as greater than epidural pressure by 5–15 cmH<sub>2</sub>O [176, 185].

This pressure gradient is an obstacle to drug flux into the subarachnoid space. However epidural pressure rises transiently, but dramatically, after drug administration [184, 186]. Although similar rises in subarachnoid pressure occur there is a brief period during which epidural pressure may exceed subarachnoid pressure [187]. This produces conditions that would allow drug flux into the subarachnoid space. Bickford Smith suggested that flux may be reduced by efforts to elevate the CSF pressure such as sitting the patient up and by slow epidural injection [112]. In support of this, Okada *et al.* reported that opioid effect is increased if epidural buprenorphine is given by bolus rather than infusion after CSE [187].

Bernards *et al.* showed that drug flux across monkey meninges *in vitro* is altered by dural puncture [188]. Drug flux increases with the size of needle used and is determined more by hole size than by the physicochemical properties of the drug. The clinical importance of drug transfer depends in part on how well the drug crosses intact meninges. Transfer of lignocaine across the intact dura is similar to transfer after puncture with a 27 G Whitacre needle. In contrast, morphine has very low transfer across the intact dura but similar quantities as lignocaine transfer after dural puncture. So dural puncture has little effect on lignocaine flux but dramatically increases morphine transfer (and that of other drugs with low dural penetrance). The investigators emphasise that flux of drug across the dural hole may be increased if small volumes are injected into the epidural space. The combination of a large spinal needle and a low volume, high concentration epidural injection of a drug with poor dural permeability placed close to the dural hole is therefore most dangerous.

The clinical importance of this was confirmed by Swenson *et al.* who investigated anaesthetised sheep having an epidural catheter placed followed by dural puncture one space cephalad (not typical of CSE technique) [189]. One hour later, morphine was administered epidurally. Brainstem concentrations of morphine at 6 h were increased by dural puncture and by increasing needle size. Compared with no dural puncture, a 25 G Whitacre and 18 G Tuohy needle produced morphine concentrations eight and 20 times higher, respectively.

Leighton *et al.* reported that dermatomal block with epidural local anaesthetic is increased if performed 100 min after intrathecal injection of opioid (via a 27 G Whitacre or 24 G Sprotte needle) [190]. Transfer of local anaesthetic via the dural puncture may be the mechanism but a pharmacodynamic potentiation of local anaesthetic by residual intrathecal opioid could not be ruled out. Suzuki *et al.* found that dural puncture *per se* (without drug injection) altered the dermatomal distribution of subsequent epidural blockade [16]. The extent of caudal block was increased with no change in the cephalad

spread. The authors suggest that this could be used to enhance sacral spread when using epidural blockade.

The conclusion is that epidural drugs should be administered with particular care following CSE. Some drug will transfer through the dural puncture site; the clinical importance of this will depend on both the spinal needle used, the drug, its volume and concentration. The most marked clinical effects are likely when dural puncture with a large spinal needle is followed by administration of a high concentration drug of low dural penetrance near to the dural puncture site. The possibility of a similar clinical effect arising from unrecognised accidental dural puncture with the epidural needle and (rarely) epidural catheter misplacement or migration [66, 108] should not be forgotten. Infusions of low concentrations of local anaesthetic (or combinations of drugs) are therefore safer than high concentration boluses [121].

### Epidural top-up and extension of subarachnoid blockade

Rawal noted early in the development of the CSE technique that standard epidural top-ups produced rapid and extensive augmentation of spinal blockade [11]. Other investigators also reported this [45]. Several explanations have been postulated for this observation and include:

- 1 continued spread of the drug originally injected into the subarachnoid space;
- 2 leakage of epidural drug via the hole in the dura into the subarachnoid space (drug flux, discussed above);
- 3 cephalad displacement of CSF and subarachnoid drug due to dural compression by epidural fluid (volume effect);
- 4 epidural pressure changes (becoming atmospheric) altering spread of subarachnoid drug [170];
- 5 epidural blockade unmasking subclinical spinal blockade above the clinical level of blockade.

Several reports support the importance of the volume effect. Blumgart *et al.* studied parturients undergoing needle-through-needle CSE with a 26 G spinal needle in the sitting position [63]. Injection of 10 ml epidural saline 5 min after subarachnoid injection of hyperbaric bupivacaine increased cephalad spread of the block as much as 10 ml bupivacaine 0.5%. They suggested that the mechanism was compression of the dural sac by epidural injection forcing CSF and 'unfixed' drug cephalad. Takiguchi *et al.* performed a similar study using hyperbaric local anaesthetic, lateral positioning and separate-needle CSE in nonpregnant patients [191]. Epidural saline 10 ml injected 5–10 min after subarachnoid block raised the analgesic level by several dermatomes compared with control. Myelography in two volunteers showed that 5 ml of epidural saline narrowed the subarachnoid space to 40% of its original diameter and raised the dye level by one vertebra. A further 5 ml narrowed the subarachnoid space to 25%

and, after 20 ml, dye rose a further vertebral level. Fukushima *et al.* used CT myelography and found that dural sac compression lasted more than 30 min after epidural injection [87]. Park *et al.* reported a case in which a large bolus of epidural saline after prolonged epidural anaesthesia without evidence of dural puncture produced signs suggestive of total spinal and this was attributed to a volume effect [192].

Stienstra *et al.* used needle-through-needle CSE with a 27 G Whitacre needle in nonpregnant patients to compare 10 ml epidural boluses of saline or bupivacaine with control (no bolus) after subarachnoid blockade with plain bupivacaine had reached its peak (13 min) [193]. The effect of saline in augmenting blockade was confirmed but epidural bupivacaine extended the blockade more than saline. The authors concluded that blockade extension is due to two processes: a rapid volume effect followed by a slower pharmacological effect. Suzuki *et al.* found dural puncture with a fine needle without drug injection enhanced caudal spread of blockade with no change in cephalad spread [16], which suggests the pharmacological effect of epidural injection is largely due to action in the epidural space rather than from drug flux through the dural puncture site.

In contrast, Pedraza *et al.* found block extension due to a combination of compression and drug flux. They studied subarachnoid puncture and simultaneous epidural lignocaine (group 1) and subarachnoid bupivacaine with delayed epidural lignocaine (group 2) [194]. Each study group had a control group, epidural alone and spinal alone, respectively. In each active group spread of blockade was faster and higher than in control groups suggesting that both drug flux (group 1) and compression (group 2) contribute.

Mardirosoff *et al.* studied orthopaedic patients undergoing needle-through-needle CSE with a 27 G Whitacre needle and hyperbaric bupivacaine 0.5% [195]. Patients remained sitting for 5 min after injection. In previous studies, relatively low subarachnoid blocks were extended, in this the initial block reached the T<sub>7</sub> dermatome. Epidural saline 10 ml was injected 5 or 20 min after subarachnoid injection. Block extension, greater than in a control group, occurred in the 5 min group only. This suggests a volume effect lasting < 20 min. In the same study, 10 ml epidural saline was compared with 10 ml bupivacaine 0.2%, both at 7 min after subarachnoid injection. Neither group showed spread greater or faster than a control group. In contrast to Stienstra *et al.*, who demonstrated a volume effect at 13 min, here it lasted < 7 min and a weak solution of local anaesthetic caused no extension. The authors suggest that hyperbaric local anaesthetic is less susceptible to a volume effect, particularly if the patient remains sitting for 5 min. The lack of detectable extension

with local anaesthetic was attributed to the relatively high and dense preceding subarachnoid block.

Finally, using lignocaine for the initial subarachnoid block, epidural injection of saline during block regression was found to be ineffective at extending or delaying regression of the block [196]. Epidural saline hastened regression of sensory anaesthesia compared with control. The investigators suggest that epidural saline compresses the subarachnoid space and reduces residual free local anaesthetic via bulk CSF movement or increased vascular clearance. Epidural lignocaine produced dermatomal motor blockade but did not alter regression of sensory anaesthesia. This suggests that, once spinal blockade is regressing, epidural injection produces a *de novo* epidural block rather than enhancing spinal blockade.

These studies lead to the conclusion that subarachnoid block extension after CSE can be produced by epidural injection of saline while the block is developing. The effect is principally brought about by dural compression and is likely to effect hypobaric solutions and low blocks most. Once blockade is established, the results are inconsistent. Injection of local anaesthetic solutions have a greater effect than saline alone and both drug flux into the subarachnoid space and effects in the epidural space contribute. If epidural injection is delayed until the subarachnoid block is regressing, extension does not occur and regression may be enhanced.

### Safety aspects

Concerns have been raised about the safety of CSE. Several aspects have been discussed above. Additional concerns include the risk of infection and neural damage.

### Life-threatening complications

#### Death

The most recent Confidential Enquiry into Maternal Deaths in the United Kingdom reported only one death directly attributable to anaesthesia and this followed CSE [197]. Spinal anaesthetic was provided with 2.25 ml bupivacaine heavy (concentration not specified but likely to be 0.5%). Epidural alfentanil 125 µg, clonidine 150 µg and 15 ml bupivacaine 0.375% were administered soon after. The patient developed a high block, respiratory difficulty and hypotension. Despite intensive treatment, cardiac arrest occurred and she could not be resuscitated. The authors of the report describe the dose of spinal anaesthetic as excessive and regarded the epidural as unnecessary. Resuscitation was not conventional and care was considered substandard. Certainly doses of drugs used in the epidural space were excessive in the context of CSE. Inappropriate catheter placement or drug flux cannot be ruled out from the report.

### Cardiac arrest

Hawthorne & Lyons reported a case of cardiac arrest complicating separate-needle CSE for elective Caesarean section [198]. Lignocaine 2% 4 ml via an epidural catheter was administered 5 min before an intrathecal dose of hyperbaric bupivacaine 15 mg and diamorphine 200 µg. Profound hypotension and a T<sub>2</sub> block was followed by cardiovascular collapse. Resuscitation was successful and peripartum cardiomyopathy was diagnosed postoperatively. The role of the CSE technique in precipitating the collapse is unclear. Of note is that a relatively large dose of local anaesthetic was used and a high block ensued. Such high doses are not needed using CSE for elective surgery as the epidural allows augmentation of inadequate spinal blockade.

### Infection

#### Meningitis

Spinal anaesthesia is associated with a very low incidence of meningitis. Two historical studies, each of more than 10 000 patients, did not report any cases of meningitis [199, 200]. Several instances of meningitis following CSE have been reported [201–205] and Stallard & Barry reported meningitis when spinal anaesthesia was used 6 h after epidural analgesia but not as a CSE technique [206]. All cases were investigated promptly and treatment led to complete recovery without sequelae.

Five of the six cases occurred after CSE in labour. Collis reported three cases in the first 3000 cases of CSE for labour in one department but none in the subsequent 3700 (F. Plaat & R. E. Collis, pers. commun.). Meningitis may occur after spinal [207, 208] or epidural block in labour [209, 210] but it is rare. The majority of cases of meningitis following regional anaesthesia occur only after intentional or accidental dural puncture [201, 211]. CSE involves intentional dural puncture. Bacterial meningitis after labour may occur without spinal instrumentation but this is estimated at < 1 in 8000 births [212]. In the reported cases, there were no apparent lapses in aseptic technique. Skin commensals were putative causative agents in four of the six cases and no organism was found in two. However, it is not clear that meningitis occurred through 'introduction' of infection and haematogenous spread may have been the cause. In three cases, instrumentation of the spine occurred more than once to establish satisfactory analgesia; this was also a feature in a cases of meningitis occurring after isolated obstetric spinal [207, 208]. The subject is controversial and the aetiology of meningitis following CSE has been questioned [213]. Harding *et al.* reported two cases and considered that one was due to introduction of infection during epidural blood patch and the other was aseptic meningitis due to contamination with antiseptic solution [201].

Several aspects of CSE for labour may increase the risk of infection over either epidural or spinal block. CSE differs from spinal anaesthesia in several aspects including the percutaneous insertion of a foreign body close to the site of a dural puncture. The possibility of introducing infection at a site closer to neural tissue than when performing epidural block must not be over-looked and the use of CSE in labour has been questioned by several authors for this reason [211, 212, 215]. Regional block for obstetric analgesia is often performed outside the theatre environment and asepsis may be more difficult to achieve in a distressed patient. Skin preparation with antiseptics does not render the skin sterile [207] and large needles carry both skin and detergent at their tips [160, 161]. Bacteraemia is known to occur during vaginal delivery in up to 10% of parturients [216, 217], while > 25% of epidural catheters used for labour may be contaminated with bacteria [218]. Unlike epidural block, CSE allows this contamination close to a dural hole. Needle-through-needle CSE might be thought to be safer than separate-needle CSE as there is no contact between spinal needle and skin. This has not been demonstrated and skin contact can be avoided with separate-needle CSE if a spinal needle introducer is used. The reported cases of meningitis all followed needle-through-needle CSE but this is probably the most common technique used. Whether small spinal needles reduce the likelihood of epidural infection spreading to the subarachnoid space is speculative.

It is clear that scrupulous aseptic precautions should be taken whenever performing CSE. Precautions should include thorough hand washing, skin preparation with multiple coats of an alcohol-based antiseptic [207] and a gown, hat and face mask should be worn [219]. Regarding the epidural component, repeated handling of the catheter may be avoided by using a continuous infusion or closed system (e.g. patient-controlled epidural analgesia pump) rather than intermittent top-ups [220]. When headache follows CSE it should not be assumed to be due to dural puncture; meningitis should be considered and there should be a low threshold for initiating investigations to exclude it [205].

#### Epidural abscess

There are two reports of epidural abscess complicating CSE [221, 222]. It seems unlikely that epidural abscess should be more likely after CSE than epidural techniques. In one case, the patient had early surgical evacuation and the authors considered this mandatory because of the theoretical increased risk of intrathecal spread through the dural puncture site [221]. The other case was managed conservatively with almost complete neurological recovery [220].

*Aseptic meningitis*

This is a self-limiting noninfective syndrome, occurring within 24 h of dural puncture [220]. There is mild fever, headache, nuchal rigidity and photophobia. CSF is turbid with raised white blood cell count (mostly lymphocytes), low-normal glucose, raised protein and no organisms found on Gram stain or growth. Although the condition is self-limiting it is difficult to distinguish from infective or partly treated infective causes so most individuals receive antibiotics. Failure to exclude bacterial infection may lead to serious morbidity or death. Antibiotic treatment is usually instituted for 48 h while no bacterial growth is confirmed, followed by further observation off antibiotics [223].

In the past, aseptic meningitis was reported to occur in up to 1 in 400 cases [222] but this reduced dramatically in the 1960s [223]. Proposed causes include introduction of cores of tissue, drugs such as heavy amethocaine [224], contamination of equipment with detergent [201, 223] and, more recently, metal fragments after CSE [135]. This latter cause has not been substantiated. Presumed aseptic meningitis has been reported on one occasion after CSE [201]. The patient received antibiotics and made a full recovery.

**Neurological damage**

In Plaat and Collis's audit of CSE in 6700 obstetric cases, neurological damage occurred in 0.25%. All cases were minor and transient (F. Plaat & R.E. Collis, pers. commun.).

*Spinal needle paraesthesia and neurological damage*

Needle-through-needle CSE requires spinal needle insertion when the 'feel' of tissue planes has been bypassed by the epidural needle. Needles are necessarily long, dural puncture may not be felt and needle stabilisation is difficult. These factors could lead to an increase in the incidence of spinal needle paraesthesia.

Casati *et al.* reported 8–10% spinal needle paraesthesia whether needle-through-needle or separate-needle CSE was used [75]. In a prospective evaluation using a slowly advanced lockable spinal-epidural device, Hoffmann *et al.* reported paraesthesia in four of 151 patients (2.6%) [40]. This compares with a report of 6% in over 4000 subarachnoid anaesthetics [225]. However, Herbstman *et al.* found paraesthesia rates between 16 and 29% when comparing four different needles of 119–124 mm length for needle-through-needle CSE [25]. Longer needles, particularly where the length of extension beyond the epidural needle tip was longer than 12 mm, caused more paraesthesia during insertion, but there were no sequelae.

Long-term sequelae occur more frequently if paraesthesia occurs during needle insertion [225]. In one case, paraesthesia during needle-through-needle CSE and a 'dry

tap' was followed by persistent neurological defect [226]. It is possible that the sensation of dural puncture felt in this report was due to the spinal needle entering neural tissue. Turner & Reifenberg reported 26% paraesthesia during spinal needle insertion with one case of persistent dysaesthesia using a separate-needle technique (epidural placement before spinal needle) [47].

*Haematoma*

One case of subdural haematoma has been reported after needle-through-needle CSE in a patient with mild thrombocytopenia (platelet count  $119 \times 10^9 l^{-1}$ ) [227]. The technique was complicated by the appearance of blood at the epidural needle hub and a bolus and infusion of heparin were subsequently administered. The patient was managed conservatively and recovered fully. There is no obvious reason to suspect spinal haematoma to be more common following needle-through-needle CSE than after other central nerve blockade but during separate-needle CSE the spinal canal is entered twice. To date there are no reports of haematoma following separate-needle CSE.

*Unexplained neurological damage*

Several cases of unexplained neurological defect following CSE have been reported [226, 228, 229]. Neurological complications after regional techniques are infrequent and causal association may be difficult to prove. Because of the small numbers involved it is too early to prove or refute whether CSE is associated with a greater risk of neurological sequelae than other techniques.

Cauda equina syndrome followed uneventful needle-through-needle CSE in one case [228] where subarachnoid block with bupivacaine 0.5% was followed by epidural infusion of bupivacaine 0.25%  $8 \text{ ml.h}^{-1}$  for 42 h. The cause was unclear. Whether the presence of a dural hole increases the risk of neural damage when such large doses of local anaesthetics are used can only be speculative. Paech reported a similar but milder case of sacral nerve damage [229]. Uneventful needle-through-needle CSE was followed by natal cleft hypoaesthesia lasting for 7 months. In this case, epidural infusion consisted of patient-controlled pethidine for 72 h.

It is difficult to draw firm conclusions from such cases. However, it is important to realise that the epidural component of CSE is modified by the prior dural puncture. It should be assumed that small amounts of epidurally administered drugs will enter the subarachnoid space and solutions with preservatives or other agents considered unsafe for intrathecal administration should not be used. In addition, it is possible that spread of drug to the sacral region may be increased [16]. High doses of local anaesthetic should probably be avoided.



## Conclusion

Combined spinal–epidural techniques provide an opportunity to utilise the major advantages of spinal and epidural anaesthesia. However, the combined technique also introduces the potential side-effects of each technique. Compared with spinal anaesthesia there is an increased risk of failure of the spinal component and compared with epidural anaesthesia, CSE risks the potential for postdural puncture headache and makes conventional epidural test doses impractical. CSE produces a multicompartiment block such that behaviour of the spinal block may be modified by subsequent epidural injections and epidural drugs may transfer into the CSF. These features may be used to advantage but may cause complications if not anticipated. Intentional breaching of the dura allows the possibility of meningitis from poor aseptic technique. CSE has been incorporated into the armamentarium of regional anaesthetic techniques; it may be the optimum regional technique for a variety of analgesic and operative situations but should be used only after adequate training by experienced practitioners.

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