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Editorial

Epidural endeavour and the pressure principle

''*Nothing endures but change*''
Heraclitus (540–480 BC)

Anaesthetic dogma dictates that the epidural space is a potential rather than actual cavity, compressed to subatmospheric (negative) pressures in vivo. As such, it is relatively straightforward to define its margins but much more challenging to describe the physical characteristics of its lumen. Historically, clinicians have exploited the transitional interface between margin and lumen to identify the site of the epidural space for therapeutic intervention by direct drug administration or catheter placement. Despite significant advances in the fidelity of regional techniques as a whole, confirmation of access to the epidural space remains an indirect or *inferred* phenomenon. This sets it apart from other practical procedures such as spinal anaesthesia or central venepuncture which have visible end-points to confirm success.

Before considering methods available to access this potential space, we need to distinguish between techniques that facilitate *identification* of the epidural space and those which aid *confirmation* of catheter placement. The distinction is not merely sophistry. The former is a matter of the translation of sensory data, tactile, auditory, visual or otherwise, to accurately demarcate the transition from one body cavity to another. The latter may be regarded as an aid to safety and efficacy, with a reduced risk of intrathecal and intravascular injection plus an enhanced success of analgesia without failure, patchy or segmental block.

In 1933, Dogliotti described a technique for identification of the epidural space using fluid as a medium, which relied upon the different tissue densities encountered as a needle is passed through the thick, fibrous ligamentum flavum into the epidural space beyond [1]. The elegance of this 'loss of resistance' (LOR) technique accounts for how little it has changed in the intervening years. After enduring many modifications, no other technique has yet to challenge its pre-eminence.

Despite its unassailable position, 'loss of resistance' could be considered a scientific misnomer. The point at which the needle tip breaches the deep surface of the ligament and free flow of fluid into the epidural space occurs represents a transition from potential space to actual. The 'resistance' of this subatmospheric potentiality is more correctly termed a capacitance, despite the fact that the LOR point can be identified without hesitation.

The technique with which we are so familiar may be more accurately described as a 'drop of pressure' technique. Mathematical analysis of epidural space location by pressure transduction of the fluid column within an epidural syringe-needle system has demonstrated pressure increases as the needle passes through skin, fat and muscle to a maximum of 689 ± 124 cm water as the needle penetrates the ligament [2]. On entering the epidural space, an exponential decrease in pressure is observed to an end-residual level of 22 cm water. It is this exponential decay in pressure, with a time constant of approximately 2 s, which is transposed to the characteristic tactile sensation of 'loss of resistance'. These pressure changes are important, as they form the physical basis of potential epidural techniques of the near future.

The optimum medium for loss of resistance has long been the subject of considerable debate. The principal choice remains between loss of resistance to saline (LORS), air (LORA), local anaesthetic and a combination thereof. There now appears to be something of a rapprochement in the literature and the spectre of grudging consensus is looming from the fog of controversy. At risk of fanning the fires once more, there is now a balance of evidence that favours saline as the LOR medium of choice [3–5].

Even with the most meticulous technique by experienced operators, complications of epidural insertion occur with greater frequency in LORA. There is a greater incidence of both inadvertent dural puncture and failure to thread an epidural catheter [6]. This is presumably related to reduced proprioceptive feedback from a compressible fluid, such as air, resulting in inferior fidelity for identifying that all-important pressure drop. Similarly, introduction of even a small volume of air into the epidural space carries with it an increased risk of 'missed segment' in comparison with liquid techniques [7, 8]. More serious complications of LORA derive from gas injection into a cavity other than the epidural space. Pneumocephalus [9, 10], venous air embolism [11] and subcutaneous emphysema [12] have all been described. There is also a suggestion that volumes of air greater than 2–3 ml may predispose to spinal nerve root or cord compression [13, 14] and the development of postepidural paraesthesia [15].

LORS is not without its own detractors. The use of saline has been reported to slow the onset and reduce the quality of epidural analgesia [16, 17], presumably as a result of dilution of subsequent analgesics. Utilising local anaesthetic as a loss of resistance medium, with immediate injection of an analgesic agent as soon as the epidural space is entered, is an alternative to offset this effect. However, the technique has not gained favour in routine UK practice as a result of justifiable safety concerns and a paucity of evidence that the onset of pain relief is significantly improved. There are strong advocates of techniques utilising a combination of saline and air, such as the 'membrane in a syringe', which allows for identification of the pressure drop with saline whilst avoiding air injection into the epidural space [18]. Bi-digital pressure on either

side of an advancing needle also appears to enhance tactile information and reduce the incidence of 'false' LOR [19]. Whilst innovative, these modifications have yet to prove themselves sufficiently superior to LORS to challenge its supremacy.

Currently, it is reasonable to propose that the optimum balance of risk and benefit in epidural space identification is represented by the LORS technique. Whilst this may not be enough for longstanding air users to alter their personal practice, it is arguable that the evidence is now compelling enough for the teaching of LORA to a new generation of practitioners to be abandoned in favour of saline. Like most areas in medicine where the difference in outcomes is subtle and the dogma engrained, this tenet will not be universally acceptable. However, it is arguable that gas-pushing should be set adrift!

There are effective alternatives to the loss of resistance that exploit the negative pressure characteristics of the epidural space. The 'hanging drop' technique, described a year before loss of resistance, relies upon the aspiration of a small volume of fluid from the hub of a needle as pressure between atmosphere and epidural space equalises on access [20]. Advocates of this method cite fine control of the epidural needle tip, without a syringe attached during advancement, as a major advantage. Whilst there are few data for direct comparison, there would appear still to be a potential for significant air aspiration interfering with subsequent block. There is also evidence that LOR techniques are intrinsically less likely to result in dural puncture [21]. Modifications of the hanging drop technique include the 'drip and tube method', wherein entry to the epidural space is marked by the commencement of fluid ingress from a microdrip infusion set connected to the advancing epidural needle. This modification obviates the effects of air aspiration and has proved safe and effective in 'single-shot' epidural analgesia for infants and children [22, 23].

Recognition of the limitations of LOR as the only indicator of successful epidural access, has led to the investigation of adjunctive technologies to assist or enhance sensory feedback. Continuous monitoring of a pressure waveform within a fluid-filled epidural needle system can provide operator feedback, either with visual waveform analysis or acoustic enhancement. For confirmation of epidural access, both seem promising technologies [24, 25]. The benefits of such techniques would appear to be better needle control, objective pressure end points and an avoidance of 'false loss of resistance' resulting in incorrect catheter placement. Ultrasonography is rapidly becoming accepted as an invaluable tool in peripheral nerve blockade. Although yet to make the same impact in epidural practice, it does have strong proponents. Grau and colleagues have championed its use both in indirect estimation of 'depth of space' before epidural analgesia and in 'real time', allowing needle manipulation and confirmation of access [26]. Their results suggest that ultrasound guidance both reduces technical failure rate and enhances analgesic efficacy once placement has been achieved [27].

I have deliberately distinguished between techniques devised to access the epidural space and those utilised to confirm that a catheter subsequently inserted does indeed reside in the epidural space. It is to the latter that we must now turn. If we are to assume that the pressure at the proximal end of a catheter accurately reflects epidural space pressure, then the assumption can be exploited to confirm placement. A 'falling meniscus' within the catheter, as atmospheric pressure forces fluid into the space, is reassuring as it implies a dynamic balance within the system that would be absent were the catheter to be misplaced into an area of fixed pressure, such as in subcutaneous fat. A consideration of the relative merits of 'negative' aspiration of blood or cerebrospinal fluid and test-dosing is beyond the purview of this account. It is catheter pressure, transduced or observed, on which I wish to concentrate.

Epidural space pressure is dependent upon and altered by intra-abdominal pressure, which itself demonstrates physiological pulsatility, as it responds to central venous pressure. It follows therefore that a pressure observed in the epidural catheter should be subject to changes which are similar in direction and proportion to venous pressure. This postulate has been neatly exploited in the context of obstetric epidural analgesia by an original article in this issue of *Anaesthesia*, and its veracity seemingly confirmed. Chilvers, Geoghegan, Moore and Shah are to be congratulated, not only on the elegance of their study, but also on the fact that it was conducted at catheter *removal*, an innovative solution to the problems of consent in labour and a neat way to confirm that the epidurals under consideration were indeed effective. What they have demonstrated is that, when correctly placed, brief compression of the jugular vein will produce a visible rise in meniscus height of fluid within an epidural catheter.

There is support for utilising catheter pressure in the non-obstetric epidural setting. Localisation of thoracic epidural catheters has been investigated by transduction of the epidural pressure waveform [28]. The presence of positive, pulsatile pressure waveform deflections, in synchrony with cardiac contractions, implies correct catheter placement. In another study, transduction of lumbar and thoracic catheter waveforms compared well with formal nerve stimulation, via the epidural catheter, for detection of correct catheter placement [29]. However, whilst there were no false positive events recorded (no catheters identified as correctly placed that were not), both techniques demonstrated a significant number of false negatives, with only a moderate sensitivity of 80%. This suggests that the absence of a pulsatile waveform alone is not adequate to infer misplacement and that it should be combined with other testing modalities, including clinical response to analgesia before a decision to re-site or abandon an epidural is made. It is notable that, when both techniques were combined, the overall sensitivity increased to 97%.

What is not clear from the small number of investigations published is whether there is a difference between thoracic and lumbar epidurals in waveform transmission or if the performance

of a Valsalva manoeuvre by a conscious subject, with a voluntary increase in abdominal pressure by forced expiration against a closed glottis, can add sensitivity to the accuracy of placement confirmation. A prospective study with endpoints including an objective measurement of the quality of analgesia or the requirement for re-insertion would go some way towards endorsing the validity of the introduction of this test as a routine. Despite potential limitations, the attraction of this test remains that it is safe, simple, inexpensive and utilises equipment readily available in any operating theatre.

Obstetric epidural analgesia has previously been singled out as an almost unique medical intervention [30]. An invasive procedure, which carries with it a small but finite chance of a serious potential side-effect or complication, is undertaken to provide a humanitarian service for the relief of suffering during what is essentially a normal physiological process. Any simple, non-invasive bedside test which has the potential to enhance the safety and efficacy of this process must be applauded if it can protect patients from harm and anaesthetists from misadventure.

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Editorial

New maintenance fluid guidelines for children: is 0.9% sodium chloride with 5% glucose a good choice?

'In the past eight years, three children have needlessly died in our hospitals. The reason they died is not complicated. It was the administration of this fluid (0.18% saline with 4% glucose) which caused the deaths…'

This is neither the conclusion of a medical investigation, nor is it the finding of a coroner. The words were those of a journalist, broadcast as fact in an uncompromising television documentary on Ulster Television [1]. It featured three cases of fatal hyponatraemic encephalopathy in children who had been prescribed hyponatraemic maintenance fluids, and further alleged cover-up of deficient practice.

Such was the strength of public feeling in the region that a government enquiry which had begun (itself prompted by the television documentary) was halted to permit police scrutiny. In fact at least one additional case was added to the remit of the enquiry and there have been referrals to the General Medical Council.

The administration of hyponatraemic intravenous fluids compounding conditions which themselves cause hyponatraemia has been shown to result in serious mortality and morbidity [2, 3]. The scale of the problem is difficult to quantify but, unless the Northern Ireland experience is totally unrepresentative of practice throughout the United Kingdom, it is already clear that loss of life may have reached high into double figures.

Similarly, a tendency towards hyponatraemia in a number of conditions is now very well established. About half of all patients with severe neurological or respiratory sepsis can be expected to be biochemically hyponatraemic at presentation [4–6]. One study found that 10% of otherwise healthy children presenting to the emergency department with normal serum sodium went on to develop hyponatraemia during their admission, in part due to the administration of dilute intravenous fluids [7].

As recently as 2004, up to 60% of anaesthetists who responded to an APA (Association of Paediatric Anaesthetists) survey stated that they routinely prescribed dilute solutions such as 0.18% saline with glucose for peri-operative children [8], a population known to be susceptible to antidiuretic hormone (ADH) secretion and hyponatraemia.

The National Patient Safety Agency (NPSA) recently finished a prolonged consultation and plans imminently to make recommendations for the administration of intravenous fluids to children. This is both appropriate and timely. Much of its guidance, for example compulsory review and electrolyte sampling, is sensible and is to be welcomed. It is in relation to maintenance fluids that the anticipated advice might be considered controversial. After all, as an authoritative body, its recommendations could have the effect of mass medication, so it is important that such advice is correct and subjected to the most rigorous monitoring and review.

With this in mind, the inclusion of a little used maintenance fluid (0.9% saline with 5% glucose) presents something of a puzzle. This choice has been made not because it is definitely the most appropriate preparation, but rather because it is the only licensed, glucose-containing fluid which is unlikely to worsen hyponatraemia.

In 2006, Northern Ireland's Chief Medical Officer's multidisciplinary working group similarly felt poorly placed to recommend an unlicensed product when it suggested the same preparation, although it further urged the province's Department of Health to seek to license and make available more appropriate preparations [9]. Just such a preparation, Polionique B66, has been in use for many years in France.

Polionique B66, a lactated Ringer's solution with 1% glucose, gained widespread acceptance following a number of deaths from hyponatraemic encephalopathy in the 1980s. The change was apparently instigated by French paediatric anaesthetists and happened without government intervention. Experience with this product is now well into its second decade and it appears to be entirely safe [10]. Although unlicensed in the UK, at least one UK provider has signaled its willingness to produce a similar product if requested so to do, and one district general hospital is planning to use it.

Considering the issue of a default solution, there are a number of import-