British Journal of Anaesthesia **96** (**3**): 292–302 (2006)
doi:10.1093/bja/ael006 Advance Access publication January 23, 2006

BJA

REVIEW ARTICLE

Epidural abscesses

S. Grewal[1]*, G. Hocking[1] and J. A. W. Wildsmith[2]

[1]*Nuffield Department of Anaesthesia, John Radcliffe Hospital, Oxford, UK.*
[2]*University Department of Anaesthesia, Ninewells Hospital and Medical School, Dundee, Scotland, UK*
**Corresponding author: Nuffield Department of Anaesthesia, The John Radcliffe Hospital, Headley Way, Headington, Oxford OX3 9DU, UK. E-mail: sarah.grewal@tiscali.co.uk*

Until recently epidural abscess was considered a rare, almost theoretical, complication of central nerve block, but anecdotal reports suggest that this is no longer the case. Thus a review of the risk factors, pathogenesis, clinical features and outcome of this condition is appropriate, the primary aim being to make recommendations on best anaesthetic practice to minimize the risk of this serious complication. A search of EMBASE©, PUBMED© and MEDLINE© databases from 1966 to September 2004 was performed using several strategies, supplemented by reference list screening. Spontaneous epidural abscess is rare, accounting for 0.2–1.2 cases per 10 000 hospital admissions per year. Estimates of the incidence after central nerve block vary from 1:1000 to 1:100 000. Risk factors (compromised immunity, spinal column disruption, source of infection) are present in the majority of patients, whether the condition is spontaneous or associated with central nerve block. Presentation is vague, fever and back pain usually preceding neurological deficit. Diagnosis requires a high index of suspicion and modern imaging techniques. Treatment involves early surgical drainage to prevent permanent deficit and high dose parenteral antibiotics chosen with bacteriological advice. Primary prevention depends on proper use of full aseptic precautions. Epidural abscess can be a catastrophic consequence of central nerve block. Early diagnosis will minimize permanent damage, but primary prevention should be the aim. There is a need for a large survey to indicate the true incidence to better inform the risk–benefit ratio for central nerve block.

Br J Anaesth 2006; **96**: 292–302

Keywords: anaesthetic techniques, epidural; anaesthetic techniques, regional; complications, abscess; complications, infections; complications, neurological

Epidural abscess is a rare medical emergency, accounting for 0.2–1.2 cases per 10 000 hospital admissions per year,[47 60] which, if left untreated, results in catastrophic and irreversible neurological damage. Until recently its association with central neuraxial block was so unusual that the incidence was impossible to quantify, and a single case merited a published report. However, the appearance of several small series of cases in the last few years suggests that it is no longer as rare a complication.[95 138 144] This manuscript reviews epidural abscess to identify risk factors in anaesthetic practice and to make proposals to minimize the risk.

Methods

The literature in this review was obtained from a computer search of the EMBASE©, PUBMED© and MEDLINE© databases from 1966 through to September 2004. A number of different search strategies were used without language restriction. Search terms included 'epidural', 'spinal', 'infection', 'abscess', 'complication', 'asepsis' and 'aseptic technique'. Additional reports were identified from reference list screening and review articles. Further articles were also identified from the microbiology literature and cross-referenced with articles on central venous catheter infections. Microbiological advice was obtained and the evidence discussed.

Abstracts were screened for relevance and full articles obtained. Authors were not contacted for additional information.

General considerations

Risk factors

In a major meta-analysis of reports encompassing 915 patients, Reihsaus and colleagues[104] noted predisposing

risk factors in 854. The degree of risk associated with each is unclear, but the main ones are:

(i) *Compromised immunity*: diabetes mellitus, steroid or other immunosuppressive therapy, malignancy, pregnancy, HIV infection, alcoholism and cirrhosis.[108 135]
(ii) *Disruption of the spinal column*: degenerative disease and disruption by trauma, surgery or instrumentation, including discography, chemonucleosis and central neuraxial block, the latter also providing a direct portal for organisms. Even temporally distant blunt trauma is a risk factor.[29]
(iii) *Source of infection*: respiratory, urinary and minor soft tissue infections may all act as primary sources of haematogenous spread; i.v. drug abusers are constantly at risk, as are patients with indwelling vascular catheters.

Of the disease processes, diabetes mellitus is the most important, with studies reporting it as a factor in 18–54% of cases.[29 47 104] The second most common factor in many studies is a history of i.v. drug abuse (7–40%),[91 132] although these figures reflect the study populations of poor, urban communities in the USA.[47 58] Remote infection has been described in up to 44% of cases,[104] with minor skin or soft tissue infections being encountered in 7–44%.[58 80] Spread is usually haematogenous, but it may be contiguous from psoas, paraspinal or retropharyngeal abscesses. Ten per cent of cases in the review were preceded by trauma, which may have disrupted anatomical barriers or created a portal for the direct entry of bacteria. A haematoma provides ideal conditions for bacterial growth, whatever the route of entry. The presence of a number of factors obviously increases the risk. For example, in the postpartum period there is altered immunity, with a large raw area open to contamination by skin or faecal flora after delivery, and the epidural space may have been cannulated.[61]

Pathogenesis of spinal cord damage

The exact mechanism by which an epidural abscess causes spinal cord damage is unclear. Cord compression can be demonstrated radiologically, but the damage is often out of proportion to the degree of compression.[82] Tetraplegia with a completely patent subarachnoid space and complete obliteration of the subarachnoid space without neurological deficit have both been described.[17] Even if the subarachnoid space is unobstructed, recovery after surgery is often prolonged, in contrast to the faster and more complete response to decompression of a tumour. Thus, ischaemia, due to thrombosis of leptomeningeal vessels or compression of spinal arteries, may be involved,[131] with compression and infarction possibly being relevant at different times in the evolution of the injury.

Presentation

The early signs and symptoms may be vague, the 'classic' triad of back pain, fever and variable neurological deficit occurred in only 13% of patients by the time of diagnosis, and contributed to diagnostic delay in 75%.[14 29 30] Fever usually appears first, and is followed by back pain, whereas neurological deficit occurs late. There may be a history of neck stiffness with cervical lesions,[29] and children may complain of abdominal pain or feeling generally 'unwell'.[14 36] The presence of any of the risk factors should raise the suspicion of an abscess. It is important to remember that most epidural infections present from primary care and to clinicians in other hospital specialties. As a speciality, we need to ensure that the awareness of this condition is increased throughout the medical profession as a whole.

Clinical examination

Fever, meningism and pain on palpation or percussion of the back may be noted. Neurological features (variable weakness, sensory loss and diminished or absent reflexes) develop progressively, although neonates and preverbal children often present with advanced neurological deficit, having been only non-specifically 'unwell'.[35 127]

Investigations

Blood tests

Laboratory investigations are helpful, but not diagnostic. Leukocytosis was present in only 68% of cases in one series,[29] whereas the erythrocyte sedimentation rate was consistently elevated, even in patients without neurological deficit,[30 126] and was above 30 mm h^{-1} in a series of patients without fever or leukocytosis.[142] In adults, especially those with systemic infection, there may be thrombocytopaenia, whereas children often have thrombocytosis.[6 126] Blood cultures may grow the infecting organism, especially in those with haematogenous spread and in i.v. drug abusers.[71 90]

Lumbar puncture

This may yield useful information from analysis of CSF or aspirated pus, but not consistently so.[54 143] Given that lumbar puncture in this situation is not without significant risks, such as spread of infection to the subarachnoid space[43 48 103 104 117 124] and an estimated 14% risk of spinal coning,[47] radiological investigation would seem more appropriate in contemporary practice.

Imaging

Plain radiographs provide useful information in no more than 20% of cases,[101] and although myelography will demonstrate the presence of a space occupying lesion reliably, it is an invasive procedure with potentially serious complications (see lumbar puncture above). CT has long been considered the investigation of choice and is only now being replaced by MRI. It is non-invasive, produces reliably high-resolution axial tomograms of the spine, and can detect both encroachment of the spinal canal and air in epidural pus.[63] However, it does not always reliably delineate the spinal cord, epidural space or contained lesions because it is insufficiently sensitive to different soft tissue densities,[27]

particularly in the cervical region where bone artefact may obscure the canal. Intrathecal injection of water soluble contrast media may aid soft tissue identification, and CT may also be used to guide percutaneous drainage as an alternative to surgical decompression.[73] MRI is as effective as myelography in diagnosing epidural abscess (91% *vs* 92%),[47] although it is superior in the emergency situation because the spinal cord can be examined in all planes without moving a patient with neurological injury. MRI can also detect spinal and paraspinal infections, and is now the recommended screening procedure in spinal infection, myelography with high-resolution CT being used as a supplementary study in the few patients with non-diagnostic images.[96]

Microbiology

Micro-organisms may reach the epidural space during instrumentation, along catheter tracks, in injected solutions, and by local or haematogenous spread. Most infections are bacterial (Table 1), but mycobacterial, fungal and parasitic abscesses also occur. The spectrum of infection depends on the population being studied. In the 'developed' world the organisms most frequently encountered are *Staphylococcus aureus* (57–93% of cases), Streptococci (18%) and a variety of Gram-negative bacilli (13%).[8 58 80 81 88 112] There are isolated Japanese reports of tuberculous abscesses in immunocompromised patients,[40 123 128] but this infection occurs more widely in less well developed countries.[54] Epidural abscesses involving unusual (*Prevotella oris*, *Listeria myocytogenes*, *Candida albicans*, and *Mycobacterium avium intracellulare*)[33 38 57 71 110] or even 'exotic' organisms such as Guinea worm appear to be on the increase.[59] Some argue that this is because of the greater prevalence of immune compromise secondary to HIV/AIDS or chemotherapy, but others suggest that it is due to changes in bacterial flora in the age of antibiotic therapy.[104]

Differential diagnosis

The correct diagnosis may be suspected in only 40% of patients at the time of presentation,[30 111] because many pathologies more common than epidural abscess present with back pain, fever and spinal tenderness. The possibilities include other infections in and around the spinal column (particularly tuberculosis[2]), degenerative disease of the disc or vertebra, primary or secondary tumour, vascular and neurological disease. Although headache is more usual, meningitis can also present with backache. Epidural abscess has mimicked other causes of back pain, presenting as sciatica secondary to disc herniation, but with minimal features of infection,[56 66] and as transverse myelitis in an HIV positive patient.[99] The clear message from the literature is that a high index of suspicion is essential.

Management

Most authorities conclude that early surgical decompression and prolonged (6–12 weeks—see below) antibiotic therapy (i.v., followed by oral) are the mainstays of treatment,[74 81 107 143] although some acknowledge that there is a place for conservative management with antibiotics alone in carefully selected patients.[58]

Table 1 Infective agents in 830 patients with epidural abscess. Simplified and adapted from Reihsaus and colleagues[104]

Gram-positive cocci—*Staphylococcus aureus*/*epidermidis*/*mitis*/sp., coagulase-negative staphylococci	621
Other Gram-positive bacteria—*Streptococcus pneumoniae*/*viridans*/*pyogenes*/*milleri*/sp., *Enterococcus* sp.	58
Facultatively anaerobic, Gram-negative rods—*Escherichia coli*, *Proteus mirabilis*/sp., *Enterobacter* sp., *Salmonella* sp., *Klebsiella* sp., *Citrobacter*, *Serratia*, *Haemophilus*	38
Anaerobic gram-negative rods—*Bacteroides* sp.	5
Aerobic gram-negative rods—*Pseudomonas aeruginosa*+sp.	15
Mycobacteria	9
Mixed bacterial	27
Fungi—*Aspergillus fumigatus*+sp., *Sporotrichium schenkii*, *Torulopsis glabrata*	13
Parasites—*Dracunculus*, *Echinococcus*	3
Assorted other—*Neisseria*, *Acinetobacter*, *Brucella* sp., *Clostridium*, *Actinomyces*, *Propionibacterium*, *Nocardia*	12

Surgery

Details of surgical technique are beyond the scope of this review, but a few points may be made. The commonest procedure is a posterior laminectomy, although the anterior approach may give better access to some abscesses. The key aim is to use suction–irrigation to remove pus, debride granulation tissue and drain all affected areas.

For dorsal abscesses well delineated by imaging, percutaneous drainage is possible, and may be the treatment of choice for multi-compartmental abscesses involving the epidural space, and for paraspinal compartments where laying open is impracticable.[24] Percutaneous drainage has been used mostly in very small children to avoid the long-term complications of spinal surgery,[35] but has been reported in adults.[24 50 66]

Antibiotics

As in any bacterial infection, definitive therapy should be guided by culture and sensitivity studies, but pending their results, and working in close consultation with a bacteriologist, the following principles apply. The drug(s) used must have bactericidal activity against *S. aureus*, low toxicity to permit prolonged treatment, and the capability to penetrate bone effectively.[105 129] A combination of synergistic agents is appropriate until definitive bacteriology results are available. For probable Staphylococcal infection some recommend high dose, semi-synthetic penicillin, substituting a first-generation cephalosporin if possible in patients allergic to penicillin. Second generation cephalosporins also have reasonable anti-staphylococcal activity. Pseudomonal infections will require beta-lactam agents, or monobactams in those allergic to that group. Synergistic doses of aminoglycoside are often also given.[115] The alternative is to start with a third generation cephalosporin and a penicillin with anti-staphylococcal activity, with or without metronidazole,

while awaiting the results of culture.[34 134] In patients likely to be carrying methicillin resistant *S. aureus*, clindamycin or vancomycin should be part of the empirical regimen.[36 37 79]

Antibiotics have been given for up to 12 weeks, but 4–6 weeks is more usual. Intravenous treatment for 3–4 weeks is recommended for primary epidural infection, extended to 6–8 weeks if there is associated vertebral osteomyelitis.[134] Oral treatment is usually continued for up to 6 weeks, but some consider this unnecessary.[29 32] Efficacy of antimicrobial therapy and duration of treatment required can be established by monitoring reduction in ESR, CRP, pain, improvement in function and resolution of radiographic abnormalities. It may be appropriate to stop parenteral antibiotics after 4 weeks if the abscesses are drained, the patient is improving clinically and the ESR has decreased by half.[115]

Non-surgical management

It might be assumed that every patient with an epidural abscess should undergo surgery, but 11% of those identified in a major review did not,[70 104] and another report identified 38 such individuals in case series and reports published between 1970 and 1990.[140] The reasons for medical management were wide: minor neurological signs with the patient already established on antibiotics; poor surgical candidate due to an underlying medical condition; an abscess so extensive that surgery would destabilize the spine; and irreversible paraplegia; one patient refused surgery. The neurological deficit was unchanged or improved in all these patients except two, who died from sepsis syndrome, suggesting that the results of medical and surgical treatment are equivalent. However, medical management may have failed in many patients subsequently treated surgically,[58] a conclusion supported by the observation that 19% of patients treated medically suffered a neurological deterioration while on appropriate antibiotics.[70] Specific criteria have been proposed for the antibiotics used when patients are managed medically.[70]

Some series have noted that tuberculous epidural abscess responds well to non-operative treatment, with good return of function even when the neurological deficit was present for weeks or months.[68 69] Operative treatment is only recommended when medical therapy has failed to produce resolution of symptoms after several weeks and, even then, it may not improve the radiological appearance because of dense scar formation.[19 92] Overall, an epidural abscess due to tuberculosis infection has a better prognosis than one caused by other organisms.[2]

Corticosteroid therapy

Corticosteroids, particularly dexamethasone, are an integral part of the treatment of many central nervous system disorders, such as tumours and abscesses, primarily to reduce pressure, but they are used rarely in epidural abscess. An assertion that steroid administration is associated with worse outcome may be partly to blame, but this may simply reflect the tendency to give steroids to more extensively affected patients.[27 29] Basically, there is insufficient evidence on which to base the use of steroids in epidural abscess, and the low incidence of the condition means that such evidence is unlikely to be obtained.

Outcome

The mortality of epidural abscess has decreased significantly as diagnosis and treatment have improved. A mortality of 81% was reported in 1926,[26] but this decreased from 34 to 16% between 1954 and 1980.[104] Some recent surveys have figures below 10%,[2 30 42 52 125] but larger studies of non-tuberculous patients suggest that the true figure remains between 13 and 16%.[58] Death may be due to overwhelming sepsis or secondary to prolonged immobility. As mortality has decreased, the proportion of patients surviving with lesser neurological deficits or making a full recovery has increased.[104] However, virtually every paper on the subject repeats the same message: 'delay in diagnosis and treatment still occur in a relatively high proportion of cases and are likely to prejudice outcome'.[81] Many complications can occur, with the neurological features depending on the site and severity of the abscess, thoracic lesions tending to produce more severe long-term disability than lumbar ones.[137] Complications of surgery include damage to both the spinal column and its contents.[125]

Prognostic factors

Khanna and colleagues[58] followed up 41 patients for an average of 21 months, and identified three factors that were significantly and independently associated with poor outcome; patient age, degree of thecal sac compression and duration of symptoms. With every decade increase in age, the likelihood of poor outcome doubled, presumably due to declining health and, possibly, reduced 'plasticity' of the spinal cord.

Duration of symptoms has long been recognized as influencing outcome,[46] absence of paralysis, or its presence for <36 h, being associated with better survival and return of function. Others have confirmed both these findings.[8 29 143]

A low platelet count may be associated with worse outcome, but may be acting simply as a surrogate marker for the severity of sepsis. The presence of pus as opposed to granulation tissue is also associated with a better outcome because this reflects acute rather than chronic disease.[58]

Anaesthesia and epidural abscess

Epidural abscess may, rarely, occur in association with anaesthesia, usually after central nerve block, although there are reports which demonstrate that instrumentation of the vertebral canal may not necessarily be responsible.[15 18] Central nerve block is most often performed in two distinct types of patient; the young, and usually fit, parturient with minimal risk factors for epidural abscess, and the elderly patient, often with multiple co-morbidities, requiring

Table 2 Risk of epidural abscess for various clinical groups. Some of the data collection methods are flawed and some denominators are not known. Figures in brackets represent extrapolated data

	Population		
	Mixed	**Obstetric**	**Surgical**
Aromaa and colleagues[4]	2/170 000		
Auroy and colleagues[7]	0/30 000		
Dahlgren and Tornebrandt[25]	0/9200		
Kane[53]	0/50 000		
Kindler and colleagues[61]	2/13 000	1/2000	Nil (<1/9000)
Phillips and colleagues[95]	1/2500	Nil (<1/5000)	1/800
Rygnestad and colleagues[113]			2/2000
Scott and Hibberd[120]		1/505 000	
Wang and colleagues[136]	1/1930	Nil	

major surgery and, thus, with significant risk factors. It might be expected that the incidence would reflect the apparent level of risk, but there is much variation (Table 2).

Phillips and colleagues[95] reported three epidural abscesses occurring in surgical patients over a short time period. They calculated an incidence of 1 in 800, using the number of non-obstetric epidurals performed over 5 years. If the 5000 obstetric epidurals performed during the same period, and in which there were no abscesses, were included, the incidence reduced to 1 in 2500. However, it may be more accurate to conclude a risk of <1 in 5000 for obstetric epidurals. Subsequent correspondence included two reports from other UK hospitals claiming incidences of 1 in 1000 and 1 in 600 'surgical' epidurals respectively, with the rider that the risk might be as high as 1 in 100–200 in some patients.[41 44] A Danish paper based on all the epidurals performed in that country in 1 year gave an incidence of 1 in 1930,[136] and a Swiss review of 13 000 epidurals, of which about 4000 were in obstetric patients, identified two abscesses, both of them in obstetric patients, giving an incidence of 1 in 2000 for that group.[60] At the other extreme, a 3 yr prospective study from Sweden reported no abscesses in nearly 18 000 patients receiving central blocks, over half of which were epidural,[25] although the risk increased to 1 in 923 if an epidural catheter was placed in a patient with other significant risk factors for neurological deficit. In a retrospective survey of complications associated with obstetric epidurals in the UK only one epidural abscess was reported in 505 000 patients.[120]

Estimating the true incidence of a rare complication from such disparate reports is not easy, but there is some suggestion that it might be of the order of 1 in 1000 in surgical, and 1 in 2000 in obstetric, patients. However, some of the reports have been triggered by a small local 'series' of cases, possibly overestimating the incidence as larger series are associated with lower figures. Equally, not all cases may be published, so that the incidence is underestimated, although Reihsaus and colleagues[104] noted that only 3.9% of all epidural abscesses were associated with anaesthetic interventions. They derived an epidural related incidence of 1 in 100 000 but it is difficult to judge how accurate that figure is. Only prospective collection of numerator (number of abscesses) and denominator (number of central blocks) data will provide the true figure.

Clinical features

The history is, as with the 'spontaneous' lesion, typically vague with fever, backache and leukocytosis occurring 4 or more days after instrumentation. There may be evidence of superficial infection at the needle/catheter insertion site, and neurological deficit may or may not be present.[60 118] The differential diagnoses, investigation and management are as described above.

Microbiology

The spectrum of organisms infecting epidural catheters is similar to those causing spontaneous abscesses. Of 26 cases associated with epidural catheter identified by Reihsaus and colleagues[104] the organisms were *S. aureus* (18), *Staphylococcus epidermidis* (4), *Pseudomonas aeruginosa* (2), coagulase-negative Staphylococci (1) and *Pyocyaneus* (1). In 9 patients who had received a single shot epidural or spinal anaesthetic, the organisms were *S. aureus* (8) and *Pseudomonas* (1).

Outcome

Comparative figures suggest that the outcome may be worse after epidural abscess associated with anaesthesia. Complete recovery occurred in 38%, compared with 43% in spontaneous cases, and severe neurological deficit in 27%, compared with 15%. One possible explanation is that the frequency of back pain and fever in postoperative and obstetric patients leads to dismissal of early features as inconsequential.[104] Symptoms may also begin only after discharge from hospital, or a superficial infection may be treated with antibiotics so allowing progression of the underlying abscess.[95 100] These factors delay diagnosis and treatment, and can consequently lead to a worse outcome.

Risk factors

The risk factors for an epidural abscess related to anaesthesia are as for the sporadic lesion, but some specific aspects merit emphasis.

(i) *Compromised immunity*: many of the factors mentioned above are seen regularly in the surgical patient. Bromage has drawn attention to the risks of corticosteroids, particularly when injected epidurally in chronic pain states.[15]

(ii) *Disruption of the spinal column*: all peri-vertebral injections breach the considerable protection which nature provides for the vertebral canal and its contents. Poor technique can lead to damage through a number of mechanisms, and the techniques should never be approached lightly. Difficulty in insertion may be associated with a breakdown in aseptic technique, and has

been shown to be associated with an increase in the incidence of central venous line infection.[23]

There is no directly parallel study relating to central block. No bacteria were cultured from 38 epidural needles used in patients in whom an average of three attempts were made over 20 min.[91] However, one pass of even a fine needle will create some bleeding, and this is bound to be greater when multiple passes are made with larger needles and a catheter is inserted, or perhaps when the patient has been given antithrombotic agents. The resulting haematoma will then provide an ideal culture medium, no matter how the organism reaches it. This hypothesis is supported by case reports where infection was thought to have occurred in a haematoma after difficult insertion.[9 55] It follows that all instrumentation should be performed as gently as possible.

(iii) *Duration of catheterization*: studies quoting a low incidence of epidural infection often relate to catheterization for 2 days or less,[102 119] but longer duration has been associated with an incidence of infection of 4.3%, a figure approaching that for intravascular devices.[49 89] If increases in infection rates with time do approach those for intravascular devices it may be appropriate to extrapolate from data on pulmonary artery catheters where a greater risk of colonization exists after 5 days.[106] Further, intraventricular devices do not become infected before day 3, with 85% of infections occurring after day 5,[86] lending some support to the widespread practice of removing an epidural catheter by day 4. Figures for intraventricular devices may not be directly relevant, but there can be few indications for such an extended period of epidural block, and re-assessment of the risk/benefit ratio would certainly be wise after 4 days, if not sooner. It has been suggested that the administration set and filter should be changed after 3 days and that the anaesthetist who placed the catheter must take full part in any decision to leave it for longer.[41]

(iv) *Source of infection*: just because an abscess follows a block does not mean that the organism was introduced by the anaesthetist, but the need for an aseptic technique would seem self-evident. However, there has been some dispute regarding the details of that technique. To assess what is necessary, bacteriological studies of potential sources of infection need to be reviewed, and supported with further evidence drawn from studies of central line insertion.

Asepsis and bacteriological risk

Studies have shown that both equipment and solutions can become contaminated. After a single insertion using an aseptic technique of operating room clothing, hat, skin preparation with 10% povidone iodine, sterile gloves and a drape, around 18% of spinal and epidural needles collected immediately were contaminated with skin commensal organisms,[98] as were 5% of syringes of epidural infusate.[51] There were no cultures grown from the corresponding catheter tips, and contamination does not equate with infection, but such studies indicate that an avenue for infection is present. Different aspects of aseptic technique have been studied.

Basic precautions

There is good evidence that the risk of central venous catheter infection is reduced by the use of maximal sterile precautions, that is mask, cap, sterile gloves, gown and large drape, compared with only sterile gloves and a small drape.[97 114] The incidence of both catheter infection and catheter related septicaemia was lower in the maximal precaution group, and the infective complications occurred later, implying that they were less likely to be related to failure of aseptic technique. The need to wear a surgical facemask during a central nerve block is often questioned, primarily on the basis of evidence that masks do not decrease the rate of surgical wound infection.[130] However, masks have been shown to reduce bacterial contamination of the area in front of the operator's face.[83 94] Can 'not wearing a mask' be justified now that identical organisms have been grown from an epidural abscess and a nasal swab from an anaesthetist who did not wear a mask?[20 87] Basic precautions as described above are not new, and are in accordance with the AAGBI Guidelines for Infection Control in Anaesthesia.[5]

Skin disinfection

Although skin colonization is not related to the occurrence of venous catheter related septicaemia, catheter sepsis, which is arguably more relevant to the epidural situation, is predicted by it.[75] Thus, skin disinfection is essential, but an effective agent must be used. A range of studies has shown the superiority of chlorhexidine over other common agents at killing bacteria and reducing the incidence of subsequent infection in a range of clinical settings,[21 23] including epidural block.[62] The specific preparation is important because alcohol solutions are more effective than aqueous ones, chlorhexidine (0.5%) in ethanol (80%) being fully bactericidal in 15 s. Skin biopsies taken 10 min after skin preparation for laminectomy suggest alcohol solutions are more effective at penetrating lipid barriers in hair follicles and the stratum corneum.[116] Other agents require longer to reduce bacterial counts and while any preparation should be allowed sufficient time to work the arguments for chlorhexidine are significant. Solutions from multiuse bottles of one of the alternatives, povidone iodine, may even become contaminated with bacteria, and be less effective than that from new ones, suggesting that single-use containers should be used.[11]

Catheter dressings

The dressing around an epidural catheter must serve several functions, the most important of which is to minimize the

risk of premature displacement. Transparent, adhesive dressings have become popular because they allow inspection of the entry point without disturbing it and risking accidental displacement. Such inspection confirms that the catheter has not moved and that there is no local inflammation, but many of these dressings are impermeable so that the underlying skin becomes moist and an ideal medium for bacterial growth. However, a porous dressing may allow bacteria easier access to the site.[95] A study, in 1989, found that a dry gauze dressing produced lower rates of insertion site colonization, local infection and systemic infection than a transparent one, although it may not have been made with the semi-permeable material available today.[23] However, a more recent study, using a semi-permeable dressing, did not find any practical difference in the first week.[72]

The main rationale for using transparent dressings is inspection without disturbance,[95] but does this reduce the risk of epidural abscess? Visible inflammation, even without purulence, is associated with significant bacterial colonization and should, it has been recommended, prompt catheter removal.[78] Although the absence of inflammation does not mean that there is no bacterial colonization, nor even deep infection, such colonization rarely leads to significant epidural infection. Catheter colonization rates as high as 35% were not associated with any deep infections,[28,64] but the number of patients studied was tiny in relation to the incidence of epidural abscess, although a number of other studies confirm the finding.[65] Each change of dressing of a pulmonary artery catheter doubles the risk of colonization,[84] and colonization has a 13% risk of invasive infection,[106] figures which, if they apply to epidurals, support the use of clear dressings which do not need changing at inspection.

One way of reducing skin colonization is to place antiseptic around the puncture site. Iodine based powders (which tend to reduce dressing adhesion) and chlorhexidine impregnated discs significantly reduce epidural skin entry point colonization,[78,122] but whether this reduces the risk of infection is unknown. Chlorhexidine discs reduced neonatal central line colonization, but did not influence catheter related infection compared with skin cleaning with povidone iodine.[39] Venous catheter related blood stream infections have been reduced by chlorhexidine–silver sulphadiazine impregnated lines, but this innovation cannot be extended to epidural catheters because chlorhexidine is neurotoxic.[76]

Infusion systems

Epidural infusate has been the source of infection although it is thought to be the least important because many solutions have a degree of antibacterial activity.[55] It seems sensible to use large volume reservoirs of epidural infusate prepared by the pharmacy or a reputable supplier instead of repeatedly changing syringes, which may be sub-optimally prepared on the ward,[77] and so minimize the breaking of a closed infusion system.[16]

A common concern is what to do if the epidural infusion system becomes disconnected somewhere between the bacterial filter and the patient. An interesting laboratory study using deliberately contaminated catheters suggested that reconnection is safe within 8 h provided that the fluid inside the catheter is static (or the meniscus has moved <12.5 cm) and does not move when lifted above the level of the patient. The outside must be soaked in 10% povidone iodine solution, or similar, for 3 min and allowed to dry thoroughly before up to 20 cm is cut from the end with a sterile instrument. If these conditions are not met, the catheter must be removed.[67]

Antibiotic prophylaxis

Two studies have examined the effect of antibiotic prophylaxis in long-term (many weeks) epidural catheterization, one finding a reduction in catheter infection,[3] and the other not.[31] Another study, performed in surgical patients with epidural catheters in place for 2–3 days, found that catheter colonization with skin flora was not associated with invasive infection, and occurred irrespective of the administration of antibiotics for surgical prophylaxis.[65] The authors concluded that it is inappropriate to use prophylactic antibiotics purely for epidural insertion, a conclusion supported also by guidelines on their use for central venous lines.[139]

Overview and recommendations

The risk of epidural abscess after central nerve block is unknown, and even begs the question of whether there is any risk at all, but the occurrence of such a catastrophic lesion within days or weeks of instrumentation of the vertebral canal will raise the suspicion that the two are related. Thus the risk–benefit analysis governing the decision to use major block techniques should at least reflect the possibility that there is an association, but the problem for the clinician is that neither risk nor benefit is quantified. Many benefits are claimed for regional anaesthesia, but even a major meta-analysis has been unable to confirm these definitively except for the effect on postoperative pain.[109] After very major surgery, high quality pain relief may be enough in itself, especially if it minimizes the need for intensive care facilities,[45,85] but the level of risk of all the major complications is unknown, and only a very major survey will provide the answers. This puts the onus on the clinician who believes that a regional technique may be beneficial to be able to justify its use, and then perform and manage the block in a way which minimizes the risk of infection and, should the worst happen, results in the earliest possible diagnosis and treatment.

Minimizing risk

First, patient assessment must identify factors which might predispose the patient to developing an epidural abscess. Such a risk factor may not contra-indicate a block, but it should ensure a greater level of awareness among all the staff responsible for the patient's care.

Second, although definitive proof is lacking, there is strong circumstantial evidence that maximal sterile

precautions (clean area with long sleeved sterile surgical gown, large drapes, sterile gloves, theatre cap, a face-mask,[97 114 139] and assistants who are trained to support this technique so that its safety is not prejudiced[12 13]), as recommended for central venous lines, must be adopted. Anaesthetists should wash and disinfect their hands according to local guidelines, prepare the patient's back with 0.5% chlorhexidine in at least 70% alcohol, and give the solution sufficient time to dry completely before the skin is punctured. All the above recommendations are in line with the AAGBI Guidelines for Infection Control in Anaesthesia,[5] which are likely to be quoted in the event of an adverse outcome.

The needle (and catheter if used) should be inserted as atraumatically as possible to minimize the risk of haematoma formation. Ideally, the acute pain team should review the patient daily and ensure compliance with local guidelines on catheter inspection/dressing and other aspects of management.

Early diagnosis

The major complications of central nerve block are potentially catastrophic and, thankfully, rare, but this contrast makes for difficulty when deciding upon the appropriate level of information to provide to both our patients and the staff responsible for their immediate supervision. With a continuous epidural, the major concerns are (in likely temporal sequence) migration to the subarachnoid space, vertebral canal haematoma and epidural abscess. A common factor is deteriorating spinal cord function: extensive numbness, loss of control of bladder or bowel, and lower limb paralysis. Often, these features are ascribed simply to the effects of the block, even when they redevelop hours or days after they have regressed, but the least malign implication is that the block is excessive, which itself can cause morbidity.[141] All staff, nursing and surgical, must recognize that lower limb paralysis is, at best, unwanted and mandates immediate re-referral. This policy requires:

(i) Regular assessment of lower limb motor power in every patient receiving continuous epidural block.

(ii) Epidural catheter placement at the lumbar level only if clinically necessary. This is so in labour and for lower limb surgery, but abdominal wounds are innervated from the thoracic level and the epidural should be placed close to the central dermatome of those innervating the wound to optimize analgesia and minimize lower limb weakness.[45]

(iii) A solution unlikely to produce paralysis, particularly when the lumbar level has to be used. Analgesia with minimal lower limb weakness is obtained in labour and the same should be possible after surgery.[1 93] Ropivacaine produces less motor block than bupivacaine,[121] opioids allow reductions in local anaesthetic concentration,[10] particularly with patient controlled epidural analgesia,[133] and other additives have similar effects.[22]

(iv) Because epidural abscess can present after discharge from hospital, consideration should be given to discharging patients with an information sheet noting the possible symptoms and signs of epidural abscess, and with advice to seek medical help if they persist or progress. Such a scheme has been tried in Oxford recently. The information sheet would be for the patient's benefit, but would also prompt the clinician to consider the diagnosis. With the development of N3 (a combination of broadband connections and network services linking all NHS organizations), and the electronic patient record, it should be possible to highlight the significance of unexpected fever or back pain in a patient who has had an epidural recently. Together, these changes could hopefully increase awareness of epidural abscess, and hence reduce the chances of late diagnosis with poorer outcome.

References

1 Abrahams M, Higgins P, Whyte P, Breen P, Muttu S, Gardiner J. Intact proprioception and control of labour pain during epidural analgesia. *Acta Anaesthesiol Scand* 1999; **43**: 46–50

2 Akalan N, Ozgen T. Infection as a cause of spinal cord compression: a review of 36 spinal epidural abscess cases. *Acta Neurochir (Wien)* 2000; **142**: 17–23

3 Aldrete JA, Williams SK. Infections from extended epidural catheterization in ambulatory patients. *Reg Anesth Pain Med* 1998; **23**: 491–5

4 Aromaa U, Lahdensuu M, Cozanitis DA. Severe complications associated with epidural and spinal anaesthesias in Finland 1987–1993. A study based on patient insurance claims. *Acta Anaesthesiol Scand* 1997; **41**: 445–52

5 Association of Anaesthetists of Great Britain and Ireland. *Infection Control in Anaesthesia,* 2002

6 Auletta JJ, John CC. Spinal epidural abscesses in children: a 15-year experience and review of the literature. *Clin Infect Dis* 2001; **32**: 9–16

7 Auroy Y, Narchi P, Messiah A, Litt L, Rouvier B, Samii K. Serious complications related to regional anesthesia: results of a prospective survey in France. *Anesthesiology* 1997; **87**: 479–86

8 Baker AS, OJemann RG, Swartz MN, Richardson EP Jr. Spinal epidural abscess. *N Engl J Med* 1975; **293**: 463–8

9 Beaudoin MG, Klein L. Epidural abscess following multiple spinal anaesthetics. *Anaesth Intensive Care* 1984; **12**: 163–4

10 Berti M, Casati A, Fanelli G, *et al.* 0.2% Ropivacaine with or without fentanyl for patient-controlled epidural analgesia after major abdominal surgery: a double-blind study. *J Clin Anesth* 2000; **12**: 292–7

11 Birnbach DJ, Stein DJ, Murray O, Thys DM, Sordillo EM. Povidone iodine and skin disinfection before initiation of epidural anesthesia. *Anesthesiology* 1998; **88**: 668–72

12 Bowler IC. Appropriate precautions for insertion of epidural catheters. *J Hosp Infect* 1996; **33**: 302–4

13 Breivik H. Safe perioperative spinal and epidural analgesia: importance of drug combinations, segmental site of injection, training and monitoring. *Acta Anaesthesiol Scand* 1995; **39**: 869–71

14 Bremer AA, Darouiche RO. Spinal epidural abscess presenting as intra-abdominal pathology: a case report and literature review. *J Emerg Med* 2004; **26**: 51–6

15 Bromage PR. Spinal extradural abscess: pursuit of vigilance. *Br J Anaesth* 1993; **70**: 471–3

16 Brooks K, Pasero C, Hubbard L, Coghlan RH. The risk of infection associated with epidural analgesia. *Infect Control Hosp Epidemiol* 1995; **16**: 725–8

17 Browder J, Meyers R. Pyogenic infections of the spinal epidural space: a consideration of the anatomic and physiologic pathology. *Surgery* 1941; **10**: 296–308

18 Burgess CM, Wolverson AS, Dale MT. Cervical epidural abscess: a rare complication of intravenous cannulation. *Anaesthesia* 2005; **60**: 605–8

19 Buyukbebeci O, Karakurum G, Gulec A, Erbagci A. Tuberculous osteomyelitis of the lumbosacral region: a spinal epidural abscess with presacral extension. *Arch Orthop Trauma Surg* 2004; **124**: 346–8

20 Catchpole CR, Symonds JM, O'Dell C. Epidural catheter insertion and operating theatre standards. *J Hosp Infect* 1996; **32**: 79–81

21 Chaiyakunapruk N, Veenstra DL, Lipsky BA, Saint S. Chlorhexidine compared with povidone-iodine solution for vascular catheter-site care: a meta-analysis. *Ann Intern Med* 2002; **136**: 792–801

22 Cohen S, Lowenwirt I, Pantuck CB, Amar D, Pantuck EJ. Bupivacaine 0.01% and/or epinephrine 0.5 μg/ml improve epidural fentanyl analgesia after cesarean section. *Anesthesiology* 1998; **89**: 1354–61

23 Conly JM, Grieves K, Peters B. A prospective, randomized study comparing transparent and dry gauze dressings for central venous catheters. *J Infect Dis* 1989; **159**: 310–19

24 Cwikiel W. Percutaneous drainage of abscess in psoas compartment and epidural space. Case report and review of the literature. *Acta Radiol* 1991; **32**: 159–61

25 Dahlgren N, Tornebrandt K. Neurological complications after anaesthesia. A follow-up of 18 000 spinal and epidural anaesthetics performed over three years. *Acta Anaesthesiol Scand* 1995; **39**: 872–80

26 Dandy WE. Abscesses and tumours in the spinal epidural space. *Arch Surg* 1926; **13**: 477–94

27 Danner RL, Hartman BJ. Update on spinal epidural abscess: 35 cases and review of the literature. *Rev Infect Dis* 1987; **9**: 265–74

28 Darchy B, Forceville X, Bavoux E, Soriot F, Domart Y. Clinical and bacteriologic survey of epidural analgesia in patients in the intensive care unit. *Anesthesiology* 1996; **85**: 988–98

29 Darouiche RO, Hamill RJ, Greenberg SB, Weathers SW, Musher DM. Bacterial spinal epidural abscess. Review of 43 cases and literature survey. *Medicine (Baltimore)* 1992; **71**: 369–85

30 Davis DP, Wold RM, Patel RJ, *et al*. The clinical presentation and impact of diagnostic delays on emergency department patients with spinal epidural abscess. *J Emerg Med* 2004; **26**: 285–91

31 De Jong PC, Kansen PJ. A comparison of epidural catheters with or without subcutaneous injection ports for treatment of cancer pain. *Anesth Analg* 1994; **78**: 94–100

32 Del Curling O, Gower DJ, McWhorter JM. Changing concepts in spinal epidural abscess: a report of 29 cases. *Neurosurgery* 1990; **27**: 185–92

33 Derkinderen P, Bruneel F, Bouchaud O, Regnier B. Spondylodiscitis and epidural abscess due to *Candida albicans*. *Eur Spine J* 2000; **9**: 72–4

34 Ericsson M, Algers G, Schliamser SE. Spinal epidural abscesses in adults: review and report of iatrogenic cases. *Scand J Infect Dis* 1990; **22**: 249–57

35 Fischer EG, Greene CS, Winston KR. Spinal epidural abscess in children. *Neurosurgery* 1981; **9**: 257–60

36 Flikweert ER, Postema RR, Briel JW, Lequin MH, Hazebroek FW. Spinal epidural abscess presenting with abdominal pain. *Eur J Pediatr Surg* 2002; **12**: 141–3

37 Frank AL, Marcinak JF, Mangat PD, *et al*. Clindamycin treatment of methicillin-resistant *Staphylococcus aureus* infections in children. *Pediatr Infect Dis J* 2002; **21**: 530–4

38 Frat JP, Godet C, Grollier G, Blanc JL, Robert R. Cervical spinal epidural abscess and meningitis due to *Prevotella oris* and *Peptostreptococcus micros* after retropharyngeal surgery. *Intensive Care Med* 2004; **30**: 1695

39 Garland JS, Alex CP, Mueller CD, *et al*. A randomized trial comparing povidone-iodine to a chlorhexidine gluconate-impregnated dressing for prevention of central venous catheter infections in neonates. *Pediatrics* 2001; **107**: 1431–6

40 Gettler JF, el-Sadr W. Cranial epidural abscess due to *Mycobacterium tuberculosis* in a patient infected with the human immunodeficiency virus. *Clin Infect Dis* 1993; **17**: 289–90

41 Gosavi C, Bland D, Poddar R, Horst C. Epidural abscess complicating insertion of epidural catheters. *Br J Anaesth* 2004; **92**: 294–5

42 Grieve JP, Ashwood N, O'Neill KS, Moore AJ. A retrospective study of surgical and conservative treatment for spinal extradural abscess. *Eur Spine J* 2000; **9**: 67–71

43 Hagiwara N, Hata J, Takaba H, Saku Y. Late onset of spinal epidural abscess after spinal epidural catheterization. *No To Shinkei* 2003; **55**: 633–6

44 Hearn M. Epidural abscess complicating insertion of epidural catheters. *Br J Anaesth* 2003; **90**: 706–7

45 Heller AR, Litz RJ, Djonlagic I, *et al*. Combined anesthesia with epidural catheter. A retrospective analysis of the perioperative course in patients ungoing radical prostatectomy. *Anaesthesist* 2000; **49**: 949–59

46 Heusner AP. Nontuberculous spinal epidural infections. *N Engl J Med* 1948; **239**: 845–54

47 Hlavin ML, Kaminski HJ, Ross JS, Ganz E. Spinal epidural abscess: a ten-year perspective. *Neurosurgery* 1990; **27**: 177–84

48 Hollis PH, Malis LI, Zappulla RA. Neurological deterioration after lumbar puncture below complete spinal subarachnoid block. *J Neurosurg* 1986; **64**: 253–6

49 Holt HM, Andersen SS, Andersen O, Gahrn-Hansen B, Siboni K. Infections following epidural catheterization. *J Hosp Infect* 1995; **30**: 253–60

50 Hori K, Kano T, Fukushige T, Sano T. Successful treatment of epidural abscess with a percutaneously introduced 4-French catheter for drainage. *Anesth Analg* 1997; **84**: 1384–6

51 James FM, George RH, Naiem H, White GJ. Bacteriologic aspects of epidural analgesia. *Anesth Analg* 1976; **55**: 187–90

52 Joshi SM, Hatfield RH, Martin J, Taylor W. Spinal epidural abscess: a diagnostic challenge. *Br J Neurosurg* 2003; **17**: 160–3

53 Kane RE. Neurologic deficits following epidural or spinal anesthesia. *Anesth Analg* 1981; **60**: 150–61

54 Kaufman DM, Kaplan JG, Litman N. Infectious agents in spinal epidural abscesses. *Neurology* 1980; **30**: 844–50

55 Kee WD, Jones MR, Thomas P, Worth RJ. Extradural abscess complicating extradural anaesthesia for caesarean section. *Br J Anaesth* 1992; **69**: 647–52

56 Keon-Cohen BT. Epidural abscess simulating disc hernia. *J Bone Joint Surg Br* 1968; **50**: 128–30

57 Khan KM, Pao W, Kendler J. Epidural abscess and vertebral osteomyelitis caused by *Listeria monocytogenes*: case report and literature review. *Scand J Infect Dis* 2001; **33**: 714–16

58 Khanna RK, Malik GM, Rock JP, Rosenblum ML. Spinal epidural abscess: evaluation of factors influencing outcome. *Neurosurgery* 1996; **39**: 958–64

59 Khwaja MS, Dossetor JF, Lawrie JH. Extradural guinea-worm abscess. Report of two cases. *J Neurosurg* 1975; **43**: 627–30

60 Kindler C, Seeberger M, Siegemund M, Schneider M. Extradural abscess complicating lumbar extradural anaesthesia and analgesia in an obstetric patient. *Acta Anaesthesiol Scand* 1996; **40**: 858–61

61 Kindler CH, Seeberger MD, Staender SE. Epidural abscess complicating epidural anesthesia and analgesia. An analysis of the literature. *Acta Anaesthesiol Scand* 1998; **42**: 614–20

62 Kinirons B, Mimoz O, Lafendi L, Naas T, Meunier J, Nordmann P. Chlorhexidine versus povidone iodine in preventing colonization of continuous epidural catheters in children: a randomized, controlled trial. *Anesthesiology* 2001; **94**: 239–44

63 Kirzner H, Oh YK, Lee SH. Intraspinal air: a CT finding of epidural abscess. *Am J Roentgenol* 1988; **151**: 1217–18

64 Kost-Byerly S, Tobin JR, Greenberg RS, Billett C, Zahurak M, Yaster M. Bacterial colonization and infection rate of continuous epidural catheters in children. *Anesth Analg* 1998; **86**: 712–16

65 Kostopanagiotou G, Kyroudi S, Panidis D, *et al*. Epidural catheter colonization is not associated with infection. *Surg Infect (Larchmt)* 2002; **3**: 359–65

66 Kotilainen E, Sonninen P, Kotilainen P. Spinal epidural abscess: an unusual cause of sciatica. *Eur Spine J* 1996; **5**: 201–3

67 Langevin PB, Gravenstein N, Langevin SO, Gulig PA. Epidural catheter reconnection. Safe and unsafe practice. *Anesthesiology* 1996; **85**: 883–8

68 Latronico N, Tansini A, Gualandi GF, *et al*. Successful non-operative treatment of tuberculous spinal epidural abscess with cord compression: the role of magnetic resonance imaging. *Eur Neurol* 1993; **33**: 177–80

69 Lee BB, Kee WD, Griffith JF. Vertebral osteomyelitis and psoas abscess occurring after obstetric epidural anesthesia. *Reg Anesth Pain Med* 2002; **27**: 220–4

70 Leys D, Lesoin F, Viaud C, *et al*. Decreased morbidity from acute bacterial spinal epidural abscesses using computed tomography and nonsurgical treatment in selected patients. *Ann Neurol* 1985; **17**: 350–5

71 Liang JD, Fang CT, Chen YC, Chang SC, Luh KT. *Candida albicans* spinal epidural abscess secondary to prosthetic valve endocarditis. *Diagn Microbiol Infect Dis* 2001; **40**: 121–3

72 Little K, Palmer D. Central line exit sites: which dressing? *Nurs Stand* 1998; **12**: 42–4

73 Lyu RK, Chen CJ, Tang LM, Chen ST. Spinal epidural abscess successfully treated with percutaneous, computed tomography-guided, needle aspiration and parenteral antibiotic therapy: case report and review of the literature. *Neurosurgery* 2002; **51**: 509–12

74 Mackenzie AR, Laing RB, Smith CC, Kaar GF, Smith FW. Spinal epidural abscess: the importance of early diagnosis and treatment. *J Neurol Neurosurg Psychiatr* 1998; **65**: 209–12

75 Maki DG, Weise CE, Sarafin HW. A semiquantitative culture method for identifying intravenous-catheter-related infection. *N Engl J Med* 1977; **296**: 1305–9

76 Maki DG, Stolz SM, Wheeler S, Mermel LA. Prevention of central venous catheter-related bloodstream infection by use of an antiseptic-impregnated catheter: a randomized, controlled trial. *Ann Intern Med* 1997; **127**: 257–66

77 Mann E. Epidural analgesia: have we got it right? *Nurs Times* 1998; **94**: 52–4

78 Mann TJ, Orlikowski CE, Gurrin LC, Keil AD. The effect of the biopatch, a chlorhexidine impregnated dressing, on bacterial colonization of epidural catheter exit sites. *Anaesth Intensive Care* 2001; **29**: 600–3

79 Marcinak JF, Frank AL. Treatment of community-acquired methicillin-resistant *Staphylococcus aureus* in children. *Curr Opin Infect Dis* 2003; **16**: 265–9

80 Maslen DR, Jones SR, Crislip MA, Bracis R, Dworkin RJ, Flemming JE. Spinal epidural abscess. Optimizing patient care. *Arch Intern Med* 1993; **153**: 1713–21

81 McGee-Collett M, Johnston IH. Spinal epidural abscess: presentation and treatment. A report of 21 cases. *Med J Aust* 1991; **155**: 14–17

82 McLaurin RL. Spinal suppuration. *Clin Neurosurg* 1966; **14**: 314–36

83 McLure HA, Talboys CA, Yentis SM, Azadian BS. Surgical face masks and downward dispersal of bacteria. *Anaesthesia* 1998; **53**: 624–6

84 Morin AM, Kerwat KM, Klotz M, *et al*. Risk factors for bacterial catheter colonization in regional anaesthesia. *BMC Anesthesiol* 2005; **5**: 1

85 Mutirangura P, Stonebridge PA, Clason AE, *et al*. Ten-year review of non-ruptured aortic aneurysms. *Br J Surg* 1989; **76**: 1251–4

86 Narayan RK, Kishore PR, Becker DP, *et al*. Intracranial pressure: to monitor or not to monitor? A review of our experience with severe head injury. *J Neurosurg* 1982; **56**: 650–9

87 North JB, Brophy BP. Epidural abscess: a hazard of spinal epidural anaesthesia. *Aust N Z J Surg* 1979; **49**: 484–5

88 Nussbaum ES, Rigamonti D, Standiford H, Numaguchi Y, Wolf AL, Robinson WL. Spinal epidural abscess: a report of 40 cases and review. *Surg Neurol* 1992; **38**: 225–31

89 Nystrom B, Larsen SO, Dankert J, *et al*. Bacteraemia in surgical patients with intravenous devices: a European multicentre incidence study. The European Working Party on Control of Hospital Infections. *J Hosp Infect* 1983; **4**: 338–49

90 Obrador GT, Levenson DJ. Spinal epidural abscess in hemodialysis patients: report of three cases and review of the literature. *Am J Kidney Dis* 1996; **27**: 75–83

91 Orlikowski C, Majedi PM, Keil AD. Bacterial contamination of epidural needles after multiple skin passes. *Br J Anaesth* 2002; **89**: 922–4

92 Pareyson D, Savoiardo M, D'Incerti L, Sghirlanzoni A. Spinal epidural abscess complicating tuberculous spondylitis. *Ital J Neurol Sci* 1995; **16**: 321–5

93 Parry MG, Fernando R, Bawa GP, Poulton BB. Dorsal column function after epidural and spinal blockade: implications for the safety of walking following low-dose regional analgesia for labour. *Anaesthesia* 1998; **53**: 382–7

94 Philips BJ, Fergusson S, Armstrong P, Anderson FM, Wildsmith JA. Surgical face masks are effective in reducing bacterial contamination caused by dispersal from the upper airway. *Br J Anaesth* 1992; **69**: 407–8

95 Phillips JM, Stedeford JC, Hartsilver E, Roberts C. Epidural abscess complicating insertion of epidural catheters. *Br J Anaesth* 2002; **89**: 778–82

96 Post MJ, Quencer RM, Montalvo BM, Katz BH, Eismont FJ, Green BA. Spinal infection: evaluation with MR imaging and intraoperative US. *Radiology* 1988; **169**: 765–71

97 Raad II, Hohn DC, Gilbreath BJ, *et al*. Prevention of central venous catheter-related infections by using maximal sterile barrier precautions during insertion. *Infect Control Hosp Epidemiol* 1994; **15**: 231–8

98 Raedler C, Lass-Florl C, Puhringer F, Kolbitsch C, Lingnau W, Benzer A. Bacterial contamination of needles used for spinal and epidural anaesthesia. *Br J Anaesth* 1999; **83**: 657–8

99 Rao U, Prasad S, Rajvanshi P, Gupta B. Spinal epidural abscess in HIV positive patient masquerading as transverse myelitis. *J Assoc Physicians India* 1999; **47**: 248

100 Rathmell JP, Garahan MB, Alsofrom GF. Epidural abscess following epidural analgesia. *Reg Anesth Pain Med* 2000; **25**: 79–82

101 Ravicovitch MA, Spallone A. Spinal epidural abscesses. Surgical and parasurgical management. *Eur Neurol* 1982; **21**: 347–57

102 Ready LB, Loper KA, Nessly M, Wild L. Postoperative epidural morphine is safe on surgical wards. *Anesthesiology* 1991; **75**: 452–6

103 Redekop GJ, Del Maestro RF. Diagnosis and management of spinal epidural abscess. *Can J Neurol Sci* 1992; **19**: 180–7

104 Reihsaus E, Waldbaur H, Seeling W. Spinal epidural abscess: a meta-analysis of 915 patients. *Neurosurg Rev* 2000; **23**: 175–204

105 Reller LB. The serum bactericidal test. *Rev Infect Dis* 1986; **8**: 803–8

106 Rello J, Coll P, Net A, Prats G. Infection of pulmonary artery catheters. Epidemiologic characteristics and multivariate analysis of risk factors. *Chest* 1993; **103**: 132–6

107 Rigamonti D, Liem L, Sampath P, *et al*. Spinal epidural abscess: contemporary trends in etiology, evaluation, and management. *Surg Neurol* 1999; **52**: 189–96

108 Rigamonti D, Liem L, Wolf AL, *et al*. Epidural abscess in the cervical spine. *Mt Sinai J Med* 1994; **61**: 357–62

109 Rodgers A, Walker N, Schug S, *et al*. Reduction of postoperative mortality and morbidity with epidural or spinal anaesthesia: results from overview of randomised trials. *Br Med J* 2000; **321**: 1493

110 Rotstein AH, Stuckey SL. *Mycobacterium avium* complex spinal epidural abscess in an HIV patient. *Australas Radiol* 1999; **43**: 554–7

111 Royakkers AA, Willigers H, van der Ven AJ, Wilmink J, Durieux M, van Kleef M. Catheter-related epidural abscesses—don't wait for neurological deficits. *Acta Anaesthesiol Scand* 2002; **46**: 611–15

112 Russell NA, Vaughan R, Morley TP. Spinal epidural infection. *Can J Neurol Sci* 1979; **6**: 325–8

113 Rygnestad T, Borchgrevink PC, Eide E. Postoperative epidural infusion of morphine and bupivacaine is safe on surgical wards. Organisation of the treatment, effects and side-effects in 2000 consecutive patients. *Acta Anaesthesiol Scand* 1997; **41**: 868–76

114 Safdar N, Kluger DM, Maki DG. A review of risk factors for catheter-related bloodstream infection caused by percutaneously inserted, noncuffed central venous catheters: implications for preventive strategies. *Medicine (Baltimore)* 2002; **81**: 466–79

115 Sapico FL. Microbiology and antimicrobial therapy of spinal infections. *Orthop Clin North Am* 1996; **27**: 9–13

116 Sato S, Sakuragi T, Dan K. Human skin flora as a potential source of epidural abscess. *Anesthesiology* 1996; **85**: 1276–82

117 Schadel A, Bottcher HD, Haverkamp U, Wagner W, Schmilowski GM. Computed tomographic diagnosis of epidural abscess, subdural empyema, meningitis and brain abscess. *Laryngol Rhinol Otol (Stuttg)* 1983; **62**: 164–7

118 Schroter J, Wa DD, Hoffmann V, Bach A, Motsch J. Epidural abscess after combined spinal-epidural block. *Can J Anaesth* 1997; **44**: 300–4

119 Schug SA, Torrie JJ. Safety assessment of postoperative pain management by an acute pain service. *Pain* 1993; **55**: 387–91

120 Scott DB, Hibbard BM. Serious non-fatal complications associated with extradural block in obstetric practice. *Br J Anaesth* 1990; **64**: 537–41

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

122 Shapiro JM, Bond EL, Garman JK. Use of a chlorhexidine dressing to reduce microbial colonization of epidural catheters. *Anesthesiology* 1990; **73**: 625–31

123 Shope TR, Garrett AL, Waecker NJ. Mycobacterium bovis spinal epidural abscess in a 6-year-old boy with leukemia. *Pediatrics* 1994; **93**: 835–7

124 Smith AS, Blaser SI. Infectious and inflammatory processes of the spine. *Radiol Clin North Am* 1991; **29**: 809–27

125 Sorensen P. Spinal epidural abscesses: conservative treatment for selected subgroups of patients. *Br J Neurosurg* 2003; **17**: 513–18

126 Tang HJ, Lin HJ, Liu YC, Li CM. Spinal epidural abscess—experience with 46 patients and evaluation of prognostic factors. *J Infect* 2002; **45**: 76–81

127 Tang K, Xenos C, Sgouros S. Spontaneous spinal epidural abscess in a neonate with a review of the literature. *Childs Nerv Syst* 2001; **17**: 629–31

128 Terada Y, Matsunobe S, Kou T, *et al*. A case of miliary tuberculosis and chest wall cold tuberculous abscess with contents draining into the epidural space. *Nihon Kyobu Shikkan Gakkai Zasshi* 1992; **30**: 500–2

129 Tetzlaff TR, Howard JB, McCraken GH, Calderon E, Larrondo J. Antibiotic concentrations in pus and bone of children with osteomyelitis. *J Pediatr* 1978; **92**: 135–40

130 Tunevall TG. Postoperative wound infections and surgical face masks: a controlled study. *World J Surg* 1992; **15**: 383–7

131 Van de Warrenburg BP, Wesseling P, Leyten QH, Boerman RH. Myelopathy due to spinal epidural abscess without cord compression: a diagnostic pitfall. *Clin Neuropathol* 2004; **23**: 102–6

132 Van Winter JT, Nielsen SN, Ogburn PL. Epidural abscess associated with intravenous drug abuse in a pregnant patient. *Mayo Clin Proc* 1991; **66**: 1036–9

133 Vandermeulen EP, Van AH, Vertommen JD. Labor pain relief using bupivacaine and sufentanil: patient controlled epidural analgesia versus intermittent injections. *Eur J Obstet Gynecol Reprod Biol* 1995; **59**: S47–54

134 Verner EF, Musher DM. Spinal epidural abscess. *Med Clin North Am* 1985; **69**: 375–84

135 Wagner DK, Varkey B, Sheth NK, DaMert GJ. Epidural abscess, vertebral destruction, and paraplegia caused by extending infection from an aspergilloma. *Am J Med* 1985; **78**: 518–22

136 Wang LP, Hauerberg J, Schmidt JF. Incidence of spinal epidural abscess after epidural analgesia: a national 1-year survey. *Anesthesiology* 1999; **91**: 1928–36

137 Wang LP, Hauerberg J, Schmidt JF. Long-term outcome after neurosurgically treated spinal epidural abscess following epidural analgesia. *Acta Anaesthesiol Scand* 2001; **45**: 233–9

138 Wang LP, Hauerberg J, Schmidt JF. Epidural abscess after epidural catheterization. Frequency and case reports. *Ugeskr Laeger* 2000; **162**: 5640–1

139 Ward V, Wilson J, Taylor L, Cookson B, Glynn A (eds). *Preventing Hospital-Acquired Infection: Clinical Guidelines*. Public Health Laboratory Service, 1997

140 Wheeler D, Keiser P, Rigamonti D, Keay S. Medical management of spinal epidural abscesses: case report and review. *Clin Infect Dis* 1992; **15**: 22–7

141 Wildsmith JA. Postoperative pressure sores after epidural anaesthesia. Informed nursing care is needed. *Br Med J* 2001; **322**: 733

142 Wong D, Raymond NJ. Spinal epidural abscess. *N Z Med J* 1998; **111**: 345–7

143 Yang SY. Spinal epidural abscess. *N Z Med J* 1982; **95**: 302–4

144 Yin KS, Wang C, Lucero Y. Myelopathy secondary to spinal epidural abscess: case reports and a review. *J Spinal Cord Med* 1998; **21**: 348–54