Review Article

Spinal anaesthesia in obstetrics

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Spinal anaesthesia has been used since the 1800s but, due to a number of complications, the popularity of this technique has waxed and waned. In the 1950s, it was the most widely used method of anaesthesia and analgesia in obstetrics but it fell out of fashion with the arrival of the epidural technique which allowed a continuous method of delivering analgesia with relatively few complications. Hypotension and the high incidence of postdural puncture headaches were two reasons for the decline in the popularity of spinal anaesthesia in the young, otherwise healthy pregnant population. With the development of newer needles and bevel designs and methods whereby the incidence of hypotension can be minimized, spinal anaesthesia is making a reappearance in obstetrical anaesthesia spheres. The purpose of this article is to review the history, effects, technique, indications, contraindications and complications of this method of anaesthesia as it applies to the obstetrical patient.

A cause de certaines complications, la rachianesthésie qui avait été déjà utilisée depuis la fin du siècle dernier, a connu des bonds et des chutes de popularité. Dans les années 1950, elle était la forme d'analgésie et d'anesthésie la répandue en obstétrique. Elle a cessé d'être à la mode avec l'arrivée de l'épidurale qui permettait d'administrer l'anesthésie en mode continu avec un minimum de complications. L'hypotension et l'incidence élevée de céphalée post-rachidienne ont constitué les deux raisons du déclin de la rachianesthésie pour le bénéfice d'une population de femmes jeunes et biens portantes. Avec le développement de nouvelles aiguilles et de nouveaux modèles de pointes, et de méthodes qui minimisent l'incidence de l'hypotension, la rachianesthésie effectue un retour en anesthésie

Key words

ANAESTHESIA: obstetrics;

ANAESTHETIC TECHNIQUES: spinal;

COMPLICATIONS: hypotension, headache.

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obstétricale. L'objectif de cet article est de rappeler l'histoire, les effets, les techniques, les indications, les contraindications et les complications de cette technique anesthésique appliquée à l'obstétrique.

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The use of spinal anaesthesia for surgical procedures dates back to 1885 but it wasn't until the 1940s when Adriani and associates established safe, standardized techniques that this method of analgesia became popular in obstetrics.^{1,2} By the mid-1950s, over half a million subarachnoid blocks had been performed in pregnant patients in the United States.² The major physiological concerns about this technique centre around the hypotension associated with the block and its potential maternal and fetal effects.² With increasing understanding of the physiological changes in pregnancy and the technological advances that have occurred, more precise determination of the effects of spinal anaesthesia in the parturient have become possible. Prophylactic measures such as prehydration, positioning and vasopressors have all been used to minimize hypotension with this technique.

Another bothersome problem with the subarachnoid approach is the high incidence of postdural puncture headache which is more common in the young, female population. Smaller gauge needles, non-cutting tips and newer bevel designs have now decreased the incidence of postdural puncture headache to an acceptable level.³

Advantages of spinal anaesthesia include the speed of onset of the drug when given into the subarachnoid space and the generally reliable nature of the block. The presence of cerebrospinal fluid (CSF) as a definitive endpoint allows for a more certain outcome than with epidural anaesthesia.³ Therefore, this technique may be used in situations where epidural anaesthesia has been attempted and failed or when there is some degree of urgency to administer an anaesthetic to facilitate delivery.³ The extremely small dose of local anaesthetic used nearly eliminates the possibility of a systemic toxic reaction and will not cross the placenta to any appreciable degree.

The role of spinal anaesthesia in obstetrics has returned as a viable alternative for Caesarean section and in combination with epidural anaesthesia may have a role to play in the management of labour.

This review article gives an overview of the maternal and fetal effects of spinal anaesthesia as well as the actual technical considerations. These include the administration of vasopressors, prophylactic prehydration, needle and drug options and a discussion of specific techniques such as the combined spinal-epidural and continuous spinal technique. Indications, contraindications and complications are also discussed.

History

Dr. James Corning, a New York surgeon, is often quoted as being the first person to perform a spinal anaesthetic. This took place in 1885.¹ Although most techniques relating to the approach to the subarachnoid space had been described by the early 1900s, their application to

the obstetrical population was somewhat delayed. However, there are sporadic reports of obstetrical anaesthesia delivered by the subarachnoid route for Caesarean section in Canada as early as 1901.³ Further investigation into the approach to the neuraxis led to the development of epidural blockade which is very much a product of the 20th century.⁴ The sacral approach to the epidural space was used for vaginal delivery in 1909 and the lumbar approach was popularized in the 1930s. Massey Dawkins performed the first epidural in Britain in 1942.⁴

For years after the first applications of spinal anaesthesia in obstetrics by Kreis, Doloris and Malartic in 1900, this method of analgesia was condemned by obstetric authorities and therefore had very little clinical application.² The high degree of complications, poor results and the lack of understanding of the interaction between the physiological changes occurring in pregnancy with the changes associated with spinal anaesthesia were cited as the reasons for concern.² In the 1940s, when Adriani and his associates introduced a standardized technique, the safety of spinal anaesthesia in obstetrics was appreciated and by the late 1950s, over half a million subarachnoid blocks were being done for obstetrical patients in the United States.²

Spinal anaesthesia reached its peak in obstetrical anaesthesia and analgesia in the 1950s when it was the most frequently used anaesthetic technique for vaginal delivery and Caesarean section.⁵ Its advantages revolved around its simplicity of administration, its reliability of action and its minimal side effects.⁵ The danger of aspiration and fetal/neonatal depression associated with general anaesthesia were avoided. Improved technical developments in the administration of local anaesthesia by the epidural route and the development of longer acting local anaesthetic agents led to a decline in popularity of spinal anaesthesia in the latter half of the 1960s. Associated complications, including hypotension and postdural puncture headaches, as well as the inability to provide continuous analgesia without a fear of neurological damage paved the way for the rapid advancement of the epidural technique of analgesia. However, spinal anaesthesia in obstetrics has some obvious advantages over the epidural route, and with the development of small gauge needles and newer bevel designs, this method has recently enjoyed a resurgence in popularity in the obstetrical anaesthesia world.

Maternal and fetal effects of spinal anaesthesia

Maternal effects

The most frequent important physiological effect of spinal anaesthesia is the hypotension that results from the block. The decrease in arterial pressure is more severe and can

occur much more rapidly than in her non-pregnant counterpart. The associated hypotension results from a decrease in peripheral resistance and peripheral venous pooling resulting in decreased venous return, cardiac output and arterial blood pressure. In the parturient, the gravid uterus plays a critical role in the compression of the inferior vena cava, pelvic veins and the aorta and its branches.² Howard, Goodson and Mengert first described the "supine hypotensive syndrome."⁶ A compensatory mechanism exists that can offset the hypotension in the parturient. This occurs by a reflex increase in neurogenic vasoconstrictor tone which increases total peripheral resistance, forcing blood back to the right side of the heart and stabilizes cardiac output and blood pressure.² With spinal anaesthesia, this compensatory mechanism is impaired. The position of the patient once the block has been established may have an effect on the degree of hypotension that develops. A decrease in blood pressure to <100 mmHg systolic or by >30 mmHg from preanaesthetic values, is as high as 80%.⁷ Ueland *et al.* performed haemodynamic studies on 12 patients who received spinal anaesthesia and demonstrated an average reduction in blood pressure from 124/72 to 67/38 mmHg with the patient in the supine position 5–10 min after the block had been given.⁸ The cardiac output decreased 34%, stroke volume 44%, and heart rate increased 17%. If the patient's position were changed from supine to lateral, the cardiac output and stroke volume increased and the heart rate decreased. Arterial blood pressure also improved.⁸

The incidence of hypotension with spinal anaesthesia is less in labouring than in non-labouring patients.⁷ This may result from the autotransfusion of the vascular system with approximately 300 ml of blood that occurs with each uterine contraction. Other physiological effects of spinal anaesthesia include nausea and vomiting. Although the mechanism is unclear, it may be a secondary effect relating to the maternal hypotension which in turn causes decreased cerebral blood flow.⁷ Correction of the hypotension usually improves these symptoms.

As technology has advanced, the ability to determine more accurately both the maternal and fetal effects of spinal anaesthesia has become possible. Cardiac output may be calculated from Doppler ultrasound measurement of ascending aortic blood flow velocity combined with cross-sectional echocardiography of the aortic orifice area.⁹

In 1992, Robson *et al.* compared the haemodynamic changes in parturients receiving either spinal or epidural anaesthesia using Doppler ultrasound and an echocardiographic method of determining cardiac output.⁹ In the spinal group, 15 of 16 patients developed hypotension to <80 mmHg and in two of these, the hypoten-

sion lasted for more than five minutes. All patients sustained a decrease in stroke volume and a decrease in cardiac output was observed in 12 of 16 patients. The haemodynamic changes associated with spinal anaesthesia were more profound than those associated with epidural anaesthesia. In 1993, in a similar study, incremental doses of local anaesthetic through an indwelling spinal catheter were found to be associated with greater haemodynamic stability than a single bolus injection of local anaesthetic.¹⁰ However, reports of neurological injury associated with the use of spinal catheters limited their use.

Fetal effects

Spinal anaesthesia *per se* has no direct fetal effects since the amount of local anaesthetic used is too small to reach the fetal circulation.² However, a decrease in maternal blood pressure and cardiac output may have deleterious effects. A decrease in uteroplacental blood flow and intervillous perfusion may alter transfer of oxygen, carbon dioxide and nutrients to the fetus. Stenger *et al.* found that neonates born of mothers who had uncorrected hypotension secondary to spinal anaesthesia had an increased oxygen capacity, reduced oxygen content and saturation and an increase in oxygen utilization.²

The changes in carbon dioxide tension resulted in a lower pH in infants in the uncorrected hypotensive group than in the corrected group. These findings were subsequently confirmed by Shnider.¹¹ Further studies indicated that persistent maternal hypotension could have effects on the fetal heart rate pattern often manifested by late decelerations.²

Despite acid-base disturbances which were seen in infants whose mothers had sustained hypotension secondary to spinal anaesthesia, Apgar scores were not lower than neonates with normal acid-base variables. During the late 1970s and early 1980s, more sophisticated assessments of neonatal neurological and behavioural function were developed. These included the Bayley Scale, The Brazelton Neonatal Behavioral Assessment Scale (NBAS), the Graham-Rosenblith behavioral examination, the Prechtl-Beintema neurologic examination, the Scanlon Early Neonatal Neurobehavioral Scale (ENNS) and the Amiel-Tison/Barrier/Shnider Neurological and Adaptive Capacity Score (NACS).¹² The most commonly used neurobehavioral test used to assess the effect of anaesthetics in the first 48 hr of life was the Scanlon ENNS. In a paper published in 1978 by Hodgkinson *et al.* fetal neurobehavioral function was assessed using the Scanlon ENNS. One group of mothers received general anaesthesia for Caesarean section and the other group received spinal anaesthesia. Spinal anaesthesia was associated with better neurobehavioral assessment as evidenced by higher ENNS scores.¹³ Corke, Datta and Ostheimer in 1982 pro-

spectively examined acid-base values and performed neonatal neurobehavioral studies in babies born to mothers who had received spinal anaesthesia for Caesarean section. Although the babies born to mothers who had sustained hypotension were more acidotic than controls, no neurobehavioral abnormalities were noted at 4 and 24 hr of life. They concluded that a brief period of hypotension (<2 min) was not deleterious to the neonate.¹⁴

Robson *et al.* demonstrated increases in the umbilical artery pulsatility index in mothers receiving spinal anaesthesia.⁹ These changes correlated with a lower umbilical artery pH although no neonate was depressed at birth. Changes in umbilical artery Doppler velocity waveforms are thought to reflect changes in resistance in the fetal umbilical placental vascular bed. Increases in the pulsatility index, reflecting increases in umbilical vascular resistance are felt to be secondary to a decrease in uteroplacental blood flow. These changes occur due to a decrease in maternal cardiac output.⁹

Further studies demonstrated that neonates born to mothers who had received spinal anaesthesia for Caesarean section were more acidemic than neonates whose mothers had received epidural anaesthesia.¹⁵ Valli *et al.* compared fetal blood flow velocities in patients undergoing Caesarean section with either epidural, spinal or a combined anaesthetic technique (spinal/epidural).¹⁶ Blood pressure was maintained >90 mmHg by an infusion of etilefrine (a combined alpha and beta₁ agonist). There was an increase in the uterine artery pulsatility index (PI) only in the spinal group after the onset of T₇ analgesia which was probably secondary to an increase in uterine arterial resistance. No acid-base disturbances or Apgar score differences were noted between groups.¹⁶

Technique

Preload

Prehydration with 1,000 ml of lactated Ringer's solution infused rapidly in 15–30 min before the induction of spinal anaesthesia to avoid hypotension was reported by Wollman and Marx.¹⁷ When the prehydration was combined with left uterine displacement there were no cases of hypotension.

Clark *et al.* in 1976 challenged the value of volume expansion in the prevention of hypotension.⁷ Without preventative measures, the incidence of hypotension has been reported as high as 82%.⁷ Patients who received prophylactic fluid loading and lateral displacement did have a decreased incidence of hypotension (53%) but it did not abolish the problem altogether.

Due to the fact that this combination of preloading and left uterine displacement did not prevent the hypotension, investigators considered that higher volumes of

preload might be needed. It was also considered that the relatively short half-life of crystalloid solutions might be a problem and that perhaps the use of colloid should be considered.¹⁸ Mathru *et al.* studied 87 patients. Forty-six received 15 ml · kg⁻¹ albumin 5% in Ringer's lactate with dextrose 5% (D5RL) over 15–20 min before spinal anaesthesia.¹⁹ Forty-one patients received the same volume of D5RL without albumin. There was a zero incidence of hypotension in the albumin-treated group and better clinical and biochemical scores in the neonates.

Rout *et al.* demonstrated that rapid infusion of crystalloid over ten minutes did not affect the incidence of hypotension in parturients receiving spinal anaesthesia for Caesarean section and caused an increase in central venous pressure.²⁰ Rout also compared no preload with 20 ml · kg⁻¹ crystalloid solution over 15–20 min before spinal anaesthesia in 140 patients undergoing elective Caesarean section.²¹ Hypotension was defined as a systolic pressure of <100 mmHg, or a decrease in systolic pressure to <80% of baseline. Hypotension occurred in 55% of the preloaded patients and in 71% of the unpreloaded patients. This represented a difference in incidence of 16% and again confirmed his previous finding that preloading does not eliminate the hypotension associated with spinal anaesthesia. He went further to say that, in a situation where an emergency Caesarean section was needed, spinal anaesthesia should not be denied because there is inadequate time to preload the patient with intravenous fluids properly.²¹ These comments received support from other obstetrical anaesthetists including Birnbach and Datta although they pointed out that although preloading did not eliminate the hypotension, it did decrease the incidence and therefore should not be abandoned on that basis.²² Bassell and Marx, in response to this study by Rout, commented that, in the emergency situation, spinal anaesthesia indeed does play a role and that rapid administration of fluid is possible by the use of large bore cannulae and pressure pumps. They cautioned against the avoidance of preloading patients and commented as well on the potential salutary effects of volume on uteroplacental blood flow.²³

The effect of the application of elasticated Esmarch bandages in the prevention of hypotension was examined in a study which compared three groups of patients receiving spinal anaesthesia for Caesarean section. The first group had their legs elevated to 30° on pillows, the second group had Esmarch bandages applied in conjunction with leg elevation and the third group had neither manoeuvre employed.²⁴ All patients received a crystalloid preload of 20 ml · kg⁻¹ over 20 min and every patient had left lateral tilt ensured. The incidence of hypotension in the control group was 53%, in the leg elevation alone group, 39% and 18% in the group who had their legs wrapped.

The conclusion was that this relatively simple procedure should be used more often to avoid the hypotension associated with spinal anaesthesia in the parturient presenting for elective Caesarean section.²⁴

Vasopressors

For many years, ephedrine has been the vasopressor of choice in obstetrical anaesthesia. The reason revolves around its combined alpha- and beta-mimetic effect. With its use, cardiac output, heart rate, systolic and diastolic blood pressure all increase. Splanchnic and renal blood flow decrease but coronary, cerebral and muscle blood flow increase.²⁵

Gutsche *et al.* in 1976 compared preload alone or preload in combination with prophylactic ephedrine in healthy patients having a Caesarean section with spinal anaesthesia.²⁶ They found that the administration of prophylactic ephedrine decreased the incidence of hypotension as well as of nausea and vomiting. There were no adverse maternal or neonatal effects. Rolbin *et al.* in 1982 reported a larger, randomized study of prophylactic *im* ephedrine for Caesarean section in patients receiving epidural anaesthesia. The incidence of hypotension was less in the ephedrine group but in 66% of this group, persistent hypertension was observed.²⁷

Intramuscular injections of ephedrine before central neural blockade may have unpredictable absorption and effect.²⁵ As found in Rolbin's study, hypertension may be a problem with prophylactic ephedrine and if this drug is combined with oxytocics, severe hypertension may occur. This would be a serious consideration in the patient with pre-eclampsia.²⁶ Therefore, it seems prudent to await the onset of hypotension and treat it immediately with fluid and vasopressors. The addition of vasopressor therapy may be used in the form of an infusion which can be titrated to effect or may be used as a bolus. Comparison of the dosages required for treatment of hypotension related to spinal anaesthesia for Caesarean section by the bolus method or the infusion method was done by Kang *et al.* They showed no differences in dose requirement between the two groups but a higher incidence of nausea and vomiting in the bolus group. (36% vs 5%).²⁸

The use of ephedrine as a vasopressor for the obstetrical population was evaluated in the early 1970s by Ralston. He showed that in hypotensive pregnant ewes, ephedrine restored maternal blood pressure and uterine blood flow without harm to the fetus.²⁹ This suggested that ephedrine used prophylactically could have beneficial effects. The concern about its potential for causing hypertension, however, was a disadvantage. Despite studies in normotensive gravid ewes that have shown that ephedrine increases uterine blood flow even in the presence of a 50% increase in maternal systolic blood pressure, the associated prob-

lems with the mother's blood pressure cannot be ignored.^{29,30} Other investigators have shown ephedrine to be effective in partially restoring uterine blood flow and in improving the acid-base status of fetal lambs of ewes who became hypotensive from spinal anaesthesia.^{11,31}

Other vasopressor therapy has been considered in the obstetrical population. Etilefrine is used in Europe and compares favourably with ephedrine. Methoxamine, an alpha agonist, has been used to treat hypotension but early work suggested that it may cause a decrease in uteroplacental perfusion and was best avoided.²⁹ Phenylephrine, whose alpha effects are the same as those of methoxamine has also been avoided in the past due to potential undesirable effects in the mother and fetus.² When compared with ephedrine, phenylephrine given prophylactically to Caesarean section patients given epidural anaesthesia was found to be effective.³² Concern about its potential vasoconstrictive action on the uteroplacental circulation has prompted further studies. Moran *et al.* compared ephedrine and phenylephrine given to mothers having Caesarean section delivery with spinal anaesthesia.³³ Maternal venous, umbilical artery and umbilical vein blood gases were measured. Neonatal Apgar and ENNS were assessed. Ephedrine (10 mg bolus) or phenylephrine (80 µg bolus) was given if the maternal blood pressure decreased by 5 mmHg or greater from baseline maternal systolic blood pressure. Incremental boluses were added to maintain maternal systolic blood pressure above 100 mmHg. The added boluses were 5–10 mg ephedrine or 40–80 µg phenylephrine. They demonstrated lower umbilical artery pH, higher PCO₂ and base deficits in the ephedrine group although all values were within normal limits. There were no other differences between groups. Apgar scores, ENNS and maternal nausea and vomiting were not different. The average total dose for ephedrine was 41 ± 4 mg and 335 ± 31 µg for phenylephrine. There was a difference in maternal heart rate with a mean increase in heart rate of 13 bpm in the ephedrine group and a mean decrease in heart rate of 26 bpm in the phenylephrine group. The authors commented that in some maternal conditions such as mitral stenosis or in patients receiving tocolytic therapy, phenylephrine may have an advantage over ephedrine in the treatment of hypotension.³³

Severe hypertension associated with the use of phenylephrine has been reported in two patients who received a massive overdose of the drug. The first received a 750 µg bolus and developed bradycardia, ventricular ectopics and a blood pressure of 250/140 mmHg and the second received 250 µg as a bolus. Her blood pressure increased to 183/91 mmHg and was associated with fetal bradycardia. It was stressed at this time that phenylephrine must be administered as small boluses in the range of 20–100

μg . As well, if ephedrine has been found to be ineffective in the treatment of the hypotension, phenylephrine 20–40 μg may be safely added to achieve the desired effect. From the comments of these authors, phenylephrine was found to be very reliable in its ability to restore maternal blood pressure when compared to ephedrine.³⁴

It has been thought for many years that phenylephrine had the potential, as a pure alpha agonist, to decrease uteroplacental perfusion. In the previous studies, no adverse effects were noted in the neonatal outcome of mothers treated with phenylephrine. The hormone atrial natriuretic peptide (ANP) is produced by the fetus in response to a number of stimuli including the administration of sympathomimetics such as ephedrine.³⁵ It was hypothesized that ephedrine crosses the placenta and causes an increase in fetal heart rate via beta receptor stimulation and induces fetal ANP release. It was decided to compare the effects of ephedrine and phenylephrine on the fetal ANP levels. Patients receiving spinal anaesthesia for Caesarean section were randomly assigned to receive either ephedrine (5 $\text{mg} \cdot \text{ml}^{-1}$) or phenylephrine (40 $\mu\text{g} \cdot \text{ml}^{-1}$). One to two ml were given to maintain systolic blood pressure >100 mmHg. The results of this study indicated that the effects of ephedrine and phenylephrine on the regulatory mechanism involving the ANP concentrations were the same and that the release of ANP was not solely mediated by beta receptors. No adverse effects were noted in the neonates whose mothers had received phenylephrine.³⁵

Choice of needle

The second problem with spinal anaesthesia in obstetrics has been the unacceptably high incidence of postdural puncture headache (PDPH). Although the mechanism of the headache is not completely understood, it is felt that the leak of cerebrospinal fluid through the puncture site and the resultant traction of intracerebral contents is a reasonable aetiology. As well, cerebral vasodilatation occurs and may contribute. The reduced production of cerebrospinal fluid in the period of puerperal diuresis may increase the incidence of this side effect in the parturient.³⁶

Hart and Whitacre suggested that a needle that would "separate" the dural fibres rather than one that "cuts or tears" might reduce leakage by allowing closer apposition of the dural fibres on withdrawal of the needle.³⁷ At this point, they designed the Whitacre needle with its opening proximal to the tip. Small diameter needles, parallel insertion of the needle with relation to the dural fibres, hyperextension of the head at the time of puncture and flexion of the head when supine and the use of "pencil point" needles have all been suggested for decreasing the incidence of headache.³⁸

FIGURE The commonly used spinal needle tips.

Postdural puncture headache associated with spinal anaesthesia in obstetrics has become the third most frequent reason for claims against obstetric anesthesiologists in the United States according to closed claim studies.³⁹ The median payment was \$5,000.00 with a range from \$1,000.00 to \$20,000.00.

The following figure depicts the various types of spinal needles which are available and their unique needle and bevel design (Figure). The Quincke needle has a cutting tip. The Sprotte needle is a modification of the Whitacre needle, which is a pencil point design with a larger side port.

A summary of studies comparing different bevel designs and needle gauges is illustrated in the following table (Table I). The incidence of PDPH was found to be lower in all studies with the use of pencil point needles (Whit-

TABLE I Incidence of postdural puncture headaches: needle comparison

Reference	Needle type		Sample Size		Headache (%)	
	A	B	A	B	A	B
Cesarini ³⁸	24S	25Q	55	55	0	14.5
Mayer ⁴⁰	24S	27Q	151	147	0.7	3.4
Shutt ⁴¹	22W	26Q	93	48	1.1	10.4
	25W					
Campbell ⁴²	25W	24S	150	150	0.7	4.0
Sears ⁴³	24S	22S	186	189	1.61	1.59

W = Whitacre needle; Q = Quincke needle; S = Sprotte needle.

acre or Sprotte) than with needles with a cutting tip (Quincke).

Choice of drug

Local anaesthetic requirements decrease in the pregnant patient with spinal local anaesthetic dosages being 30% less than in the non-pregnant state.⁴⁴ This decrease in local anaesthetic requirement begins early in the first trimester. Hormonal changes that alter neuronal responsiveness, especially progesterone and an increased neuronal sensitivity from biochemical changes appear to be responsible.⁴⁵⁻⁴⁷ As the pregnancy advances, a decrease in the volume of the epidural and subarachnoid space secondary to engorgement of the epidural veins also affects local anaesthetic requirements.

The choice of local anaesthetic for spinal anaesthesia will depend on the desired duration of action. Tables II and III illustrate choices of drugs, dosages and duration of action for spinal anaesthesia for both vaginal delivery and Caesarean section (Tables II and III). Adjunctive agents may be added including epinephrine 0.2 mg and for the Caesarean section dosages we add 10 µg fentanyl and 0.25 mg of preservative-free morphine.

In most cases, anaesthetists administer spinal local anaesthetic agents as hyperbaric solutions although isobaric lidocaine 2%, 2.5-3 ml has resulted in reliable anaesthesia for Caesarean section.⁴⁸ Studies have suggested that the interaction between gravity and baricity is the primary determinant of spread of the hyperbaric solutions in the CSF.⁴⁹ In the supine position, after the administration of a subarachnoid block, hyperbaric local anaesthetic pools in the thoracolumbar vertebral column which slopes 8-12 degrees cephalad.⁵⁰ The lowest part of the thoracic spine represents a level of T₅-T₆. This may then account for the improved anaesthetic reliability of hyperbaric solutions.⁵¹

Attempts to prolong the duration and intensity of the block with subarchnoid local anaesthetics have included the addition of epinephrine to the solution. Epinephrine

will prolong the duration of tetracaine spinal anaesthesia by 30-50% but there is some controversy as to whether epinephrine prolongs the duration of spinal anaesthesia with lidocaine or bupivacaine.⁵²⁻⁵⁴ If epinephrine is added to the local anaesthetic solution, the recommended dosage is 0.2 mg.

Many different opioids have been used as adjunctive agents with local anaesthetic in the subarachnoid space. The addition of fentanyl 10 µg to patients receiving 5% lidocaine with dextrose (50-70 mg) and epinephrine 200 µg for elective Caesarean section has been shown to have a beneficial effect on the quality of anaesthesia.⁵⁵ The addition of 0.2 mg of subarachnoid morphine to patients receiving hyperbaric bupivacaine 0.75% for Caesarean section was shown by Abouleish to provide excellent post-operative analgesia with an acceptable incidence of side effects.⁵⁶ The addition of 10 µg sufentanil to hyperbaric bupivacaine 0.75% spinal anaesthetic for Caesarean section improved the duration of effective analgesia. Measurements were made by noting the use of intraoperative opioid requirements and the time until the need for post-operative analgesics.⁵⁷

Age, height, weight and body mass index have been suggested variables with relation to the requirements for drugs in the subarachnoid space.⁵⁰ Height, however, has been felt to be one of the most important variables in determining drug dosages. Norris examined the relationship between height and sensory spread of analgesia in patients receiving spinal anaesthesia for Caesarean section with 12-15 mg of hyperbaric bupivacaine.⁵⁰ He noted no difference in the spread of analgesia in patients with a range of height from 147-174 cm. Vertebral column length was also noted and was not found to be predictive of the spread of sensory analgesia. This contrasts with the findings of Hartwell.⁵⁸ Vertebral column length was measured from C₇ to the level of the iliac crest and to the sacral hiatus and was found to correlate with the level of sensory analgesia. Despite the suggestions that height does not influence the level of block associated with spinal anaesthesia, it is still the method by which most anaesthetists calculate the dosage of drug to be given. Until such time as further studies elucidate other ways of determining drug dosages, height of the patient will remain an important factor.

The intrathecal administration of opioids alone have been used in the obstetrical population for both pain relief in labour as well as for delivery. The advantages of these drugs include the lack of sympathetic blockade and its resultant hypotension. As well, the selective sensory blockade that is obtained with some opioids and the lack of motor blockade allows these patients to ambulate during labour and delivery and post partum. Morphine, meperidine, fentanyl, butorphanol and nalbuphine have

TABLE II Local anaesthetics and dosages for subarachnoid block for vaginal delivery

Local anaesthetic*	Dosage per patients height			Onset of Action (min)	Duration of action (min)
	5 feet (152 cm)	5 feet, 6 inches (168 cm)	6 feet, 0 inches (183 cm)		
5% lidocaine in 7.5% dextrose (premixed)	35 mg (0.7 ml)	40 mg (0.8 ml)	45–56 mg (0.9 ml)	1–3	45–60
1% tetracaine + equal volume of 10% dextrose	5 mg (0.5 ml) + 0.5 ml	6 mg (0.6 ml) + 0.6 ml	7 mg (0.7 ml) + 0.7 ml	3–5	90–120
Total volume	1.0 ml	1.2 ml	1.4 ml		
1% tetracaine + equal volume of 10% procaine	4 mg (0.4 ml) + 40 mg (0.4 ml)	5 mg (0.5 ml) + 50 mg (0.5 ml)	6 mg (0.6 ml) + 60 mg (0.6 ml)	2–4	90–120
Total volume	0.8 ml	1.0 ml	1.2 ml	2–4	90–120
0.75% bupivacaine in 8.25% dextrose	5 mg (0.7 ml)	7.5 mg (1.0 ml)	10 mg (1.3 ml)		

*All preparations listed are hyperbaric.

TABLE III Local anaesthetics and dosages for subarachnoid block for caesarean delivery

Local anaesthetic*	Dosage per patient's height					Onset of action (min)	Duration of action (min)
	5 feet (152 cm)	5 feet, 3 inches (160 cm)	5 feet, 6 inches (168 cm)	5 feet, 9 inches (175 cm)	6 feet 0 inches (183 cm)		
5% lidocaine in 7.5% dextrose (premixed)	60 mg (1.2 ml)	65 mg (1.3 ml)	70 mg (1.2 ml)	75 mg (1.5 ml)	80 mg (1.6 ml)	1–3	45–60
1% tetracaine + equal volume of 10% dextrose	7 mg (0.7 ml) + 0.7 ml	8 mg (0.8 ml) + 0.8 ml	9 mg (0.9 ml) + 0.9 ml	10 mg (1.0 ml) + 1.0 ml	11 mg (1.1 ml) + 1.1 ml	3–5	90–120
Total volume	1.4 ml	1.6 ml	1.8 ml	2.0 ml	2.2 ml		
1% tetracaine + equal volume of 10% procaine	6 mg (0.6 ml) + 60 mg (0.6 ml)	7 mg (0.7 ml) + 70 mg (0.7 ml)	8 mg (0.8 ml) + 80 mg (0.8 ml)	9 mg (0.9 ml) + 90 mg (0.9 ml)	10 mg (1.0 ml) + 100 mg (1.0 ml)	2–4	90–120
Total volume	1.2 ml	1.4 ml	1.6 ml	1.8 ml	2.0 ml		
0.75% bupivacaine in 8.25% dextrose	7.5 mg (1.0 ml)	10 mg (1.3 ml)	12 mg (1.6 ml)	14 mg (1.9 ml)	15 mg (2.0 ml)	2–4	90–120
0.5% bupivacaine glucose-free tetracaine	12.5 (2.5 ml)	–	15 mg (3.0 ml)	–	17.5 mg (3.5 ml)	2–8	75–120

All preparations listed are hyperbaric except tetracaine.

all been evaluated. Intraspinal beta-endorphins may produce profound and prolonged analgesia but are not presently approved for investigation in this country.⁵⁹ Variable results have been found with intrathecal opioids for labour and delivery and the side effects associated with them have somewhat limited their use.^{60–64} Pruritus, with incidences as high as 80%, nausea and vomiting, urinary retention (40–60%) and respiratory depression have caused concern with their use in the subarachnoid space.

The position of the patient when the spinal is performed has been demonstrated to affect the spread of hyperbaric local anaesthetic solution.⁶⁵ Higher blocks are

therefore anticipated if the block is performed in the lateral rather than in the sitting position.⁶⁵

Nausea prophylaxis

Since nausea and vomiting are relatively common side effects associated with spinal anaesthesia and its resultant hypotension, attempts have been made to decrease the incidence. Lussos *et al.* studied the antiemetic efficacy and safety of prophylactic metoclopramide for patients undergoing Caesarean section with spinal anaesthesia.⁶⁶ Forty-two patients were randomly assigned to receive either 10 mg metoclopramide *iv* or placebo before induction

of spinal anaesthesia. Neonatal acid-base status and ENNS were assessed. Lussos found a lower incidence of nausea and vomiting both before and after delivery in the group who received metoclopramide (14% vs 81% overall).

Metoclopramide is used as an anti-emetic due to its antagonism of the central dopaminergic receptors in the chemoreceptor trigger zone.⁶⁶ It also causes peripheral cholinergic potentiation accounting for its gastrokinetic properties. It has been avoided in obstetrics in the past due to its potential fetal effects as well as reports of extrapyramidal symptoms and acute dystonic reactions.⁶⁶ Chestnut has shown a three-fold decrease in the incidence of postdelivery intraoperative nausea in patients receiving $0.15 \text{ mg} \cdot \text{kg}^{-1}$ metoclopramide *iv*. These patients had epidural anaesthesia for their Caesarean delivery.⁶⁷ Since nausea and vomiting can be very disturbing to the obstetrical patient especially while supine during a Caesarean section, the decrease in incidence of this complication with the use of metoclopramide may be useful.

Specific techniques

CONTINUOUS SPINAL ANAESTHESIA

The limitation of single subarachnoid bolus doses of local anaesthetic was recognized in the early 1900s and Lemmon, in 1940, first described a method of giving continuous spinal anaesthesia.⁶⁸ Due to the advantages of subarachnoid administered local anaesthetic agents and opioids, refinements of the technique of continuous spinal anaesthesia were attempted. Hurley in 1987 reported on their use of a 32-gauge, 36-inch polyimide catheter inserted into the subarachnoid space through a 26-gauge needle.⁶⁹ This technique was used in the labouring patient and a variety of local anaesthetics were given through the catheter with good results.

Continuous spinal anaesthesia has many potential advantages over epidural anaesthesia in the obstetrical population. Much less local anaesthetic is required (10–15 times less than epidural doses) thereby markedly reducing the chance of a systemic toxic reaction. As well, CSF provides a definite end-point for identification and increases the chance of a successful block. A rapid onset of sensory analgesia can be obtained which may be of crucial importance in an emergency situation and subarachnoid opioids will provide long-lasting postoperative analgesia. Disadvantages centre around the potential difficulty of siting the catheter, a potential increase in the incidence of postdural puncture headache with large-diameter catheters and the potential complications of infection, nerve trauma and haemorrhage.⁶⁸

Although it has long been recognized that spinal anaes-

thesia could have potential neurological side effects, concern about this problem seemed to be more an issue with the development of the continuous spinal catheters. Rigler *et al.* described four cases of cauda equina syndrome that occurred in association with continuous spinal anaesthesia.⁷⁰ Rigler raised the possibility that high concentrations of hypertonic local anaesthetic solutions may cause a direct toxic reaction on the nerves exposed. Over the years, other neurological abnormalities have been described with the use of a continuous spinal catheter including adhesive arachnoiditis.^{71,72} Again, the concern about exposing the neural tissue to prolonged and repeated doses of high concentration, hypertonic local anaesthetic solutions was expressed. These issues were addressed again when the problems associated with 2-chloroprocaine were identified in the 1980s.^{73,74}

Complications associated with the continuous spinal technique of anaesthesia including potential neurotoxicity and the higher incidence of method failure cause many people to question the need for this technique.⁷⁵ Concerns about the safety of the use of the technique including the microcatheters and their association with the cauda equina syndrome caused the FDA in the United States to withdraw the manufacturer's marketing approval for intrathecal catheters smaller than 27-gauge.⁷⁵ The continuous spinal technique of anaesthesia may still have a place in modern anaesthesia in very specific areas, but at present its role in obstetrical anaesthesia seems to be questionable.

COMBINED SPINAL/EPIDURAL ANAESTHESIA (CSE)

The possibility of combining the advantages of both the epidural and spinal techniques of anaesthesia and analgesia was first described by Brownridge in 1981.⁷⁶ This method would allow the reliability of the spinal block, combined with the flexibility of the epidural block.⁷⁷ Thoren compared the combined spinal/epidural technique with a spinal block for Caesarean section. The combined spinal/epidural block (CSE) was done with the needle-through-needle" technique. An 18-gauge Tuohy needle is placed in the epidural space and through it a 26-gauge Quincke spinal needle is introduced. Local anaesthetic is given through the Quincke needle which is then removed. With the bevel of the Tuohy needle facing in the cephalad direction from the outset, an epidural catheter is then threaded into the epidural space. Bupivacaine, 1.5 ml of 0.5% hyperbaric solution, was given to the CSE group and was compared to 2.5 ml of the same solution given to the spinal group. The time of onset of block was shorter in the spinal group and the block was higher. All patients in the CSE group required extension of their blocks with epidural bupivacaine. Surgical anaesthesia was good to excellent in both groups

and there were no differences in Apgar scores, acid-base status or ENNS.⁷⁷

Preliminary evaluations of smaller gauge spinal needles were not optimistic due to the high failure rate associated with them.⁷⁸ The fact that the spinal needle was introduced through a Tuohy epidural needle may have been responsible for the high failure rate. Lyons *et al.* suggested, therefore, that perhaps separate spaces should be used for a combined spinal/epidural technique.⁷⁹ He studied 100 women scheduled for elective Caesarean section. Group I received a CSE technique with a 30-gauge spinal needle introduced through a Tuohy needle as previously described. In Group II two spaces were used, one for the siting of the epidural catheter and the second for the placement of the spinal needle. The needle-through-needle technique failed to provide adequate surgical anaesthesia in 16% of patients whereas the "double-space" technique failed in only 4% of patients. The authors therefore advocated the use of separate spaces when using the CSE technique.

Westbrook went on to evaluate the use of a combined spinal/epidural needle set which used a 26-gauge pencil point needle introduced through a 16-gauge Tuohy needle.⁸⁰ One hundred and fifty patients were studied and the failure rate of the technique (0.67%) was much lower than previously reported. There was a 1.3% incidence of PDPH which required blood patch. This method of anaesthesia was felt to be valuable for patients undergoing Caesarean section.

With the development of the CSE technique, its applications to the labouring patient need to be considered. Since we know that subanalgesic doses of opioids potentiate local anaesthetic agents, it seems logical that this method may have a role in the pregnant patient who either cannot tolerate or does not wish a sympathetic or sensory block. Opioids could be administered spinally and provide varying degrees of analgesia depending on the drug chosen. This could be administered in the early stages of labour and would allow the parturient to ambulate without fear of a sensory or sympathetic block. Later, as labour progresses, the epidural catheter could then be used for the administration of local anaesthetics or the combination of local anaesthetic and opioids. Anaesthesia for both vaginal and Caesarean deliveries could be achieved through the indwelling catheter. Abouleish divided labouring patients into three groups.⁶³ He compared intrathecal morphine 0.2 mg, 10 ml of bupivacaine 0.125% and a combination of epidural bupivacaine and intrathecal morphine. He found that in the intrathecal morphine and epidural bupivacaine groups, analgesia was felt to be inadequate for labour, but the combination of the two provided excellent analgesia. It was also noted that bupivacaine dose requirements were

decreased by the use of subarachnoid morphine. As mentioned previously, this combined technique may have certain advantages over our present technique of anaesthesia for labouring patients and requires further evaluation.

Summary

Although individual variations exist, the following is a guide for the administration of a spinal anaesthetic to a patient presenting for an elective Caesarean section.

- 1 Premedicate the patient with 30 ml of a non-particulate antacid. If the patient has recently eaten, ranitidine 150 mg and/or metoclopramide 10 mg *iv* may be given.
- 2 Insert a large-bore intravenous cannula, preferably a 16-gauge and prehydrate the patient with 1500–2000 ml of a balanced salt solution immediately before giving the spinal anaesthetic.
- 3 Apply monitors. These should include an ECG, a non-invasive blood pressure monitor and a pulse oximeter.
- 4 Ensure that all equipment is prepared should general anaesthesia be required.
- 5 Ensure that drugs for the administration of a general anaesthetic as well as resuscitative drugs are diluted and ready for immediate use.
- 6 Place the patient in either the lateral decubitus or sitting position and ensure that she is maximally flexed for ease of insertion of the needle.
- 7 After preparing the skin with an antiseptic solution, identify either the L₂₋₃ or L₃₋₄ interspace.
- 8 Inject local anaesthetic into the skin and subcutaneous tissue.
- 9 A 25- or 26-gauge of the non-cutting type is recommended. This can be inserted through an 18-gauge introducer needle. The spinal needle is advanced until loss of resistance is felt and removal of the stylet reveals the presence of clear colourless free-flowing CSF.
- 10 After CSF has been identified, local anaesthetic is injected. Table III summarizes the drugs which can be used. Commonly, hyperbaric bupivacaine 0.75% is used in a dose/volume which is individualized for the patient's height. Fentanyl 10 µg and morphine 0.25 mg may be added to the solution for postoperative analgesia.
- 11 The patient should then be turned to the supine position and a wedge placed under her right hip. If the blood pressure cannot be maintained, it may be necessary to place the wedge under the left hip.
- 12 Oxygen should be administered by face mask.
- 13 Blood pressure should be monitored every minute for the first 15 min and ephedrine 5–10 mg *iv* given at the first sign of a decrease in blood pressure.

Indications

The advantages of spinal anaesthesia are several. The first is that it is easily administered. The appearance of CSF serves as a clear end-point and, therefore, presumably will increase the reliability of the block.^{81,82} The action of the local anaesthetics administered into the subarachnoid space is rapid and predictable.⁸³ A very considerable advantage is that the dose of local anaesthetic is extremely small and, therefore, the chance of a systemic reaction is almost negligible. Some of the other advantages of spinal anaesthesia, such as the ability of the mother to be awake for the birth of her child and improve bonding, do not differ from those of epidural anaesthesia. Also, if general anaesthesia is not the best option for the mother and baby, either epidural or spinal anaesthesia can be considered.

Specific indications for spinal anaesthesia versus epidural anaesthesia have been suggested. In situations where large doses of local anaesthetic need to be avoided, spinal anaesthesia would be a better alternative.⁸³ As well, spinal anaesthesia may have a role in the patient who requires urgent Caesarean section. Recognizing the potential complications of general anaesthesia in the parturient, including the inability to intubate the trachea and the potential for aspiration of gastric contents, spinal anaesthesia may serve as a viable alternative. One would assume, due to the simplicity of the technique of spinal anaesthesia and the rapid onset of drug action, that this method of anaesthesia could be useful in an emergency situation.^{44,84} The onset of action of the local anaesthetics depends on the drug used but can be as soon as one minute of administration.⁴⁴ Maximum cephalad spread appears to occur within ten minutes of the administration of the drug.⁴⁴ Marx *et al.* evaluated Apgar and fetal acid-base status in 126 parturients who underwent Caesarean section for fetal distress.⁸⁵ General anaesthesia was administered to 71 and the remainder had a regional technique, 33 spinal and 22 extension of an epidural block. One minute Apgar scores were better in the regional anaesthesia group. Marx concluded that subarachnoid anaesthesia was a reasonable method of anaesthesia for Caesarean section for fetal distress in patients who do not have an epidural already in place. Criticism of this study centred around the lack of discussion or reporting on the time from the diagnosis of fetal distress to surgical incision. It appears that further investigation into the potential advantage of spinal anaesthesia in this situation is warranted.

The presence of CSF as an end-point for the identification of the subarachnoid space offers an increased chance of a reliable block in comparison with the epidural technique. Epidural anaesthesia may also be "patchy." The presence of midline bands and structures

causing compartmentalization of local anaesthesia in the epidural space have been reported by a number of authors.^{86,87} With spinal anaesthesia, patchiness is extremely unusual although subarachnoid septa do exist.⁸⁸

The administration of opioids by the subarachnoid route may have some advantages in the high-risk obstetrical patient in labour. These include patients in whom the cardiovascular and neuromuscular effects of regional anaesthesia are undesirable. Patients with cardiac disease such as aortic stenosis, Eisenmenger's syndrome, coarctation of the aorta or pulmonary hypertension can receive analgesia in labour with spinal opioids.⁸⁹ Spinal anaesthesia may be more easily administered than epidural anaesthesia to the morbidly obese parturient. The use of spinal opioids in the morbidly obese must be accompanied by the recognition that these patients are at higher risk for respiratory depression and hypoxaemia.⁵⁶ However, the use of local anaesthesia administered by a "saddle block" may be more easily performed than epidural anaesthesia for delivery.

Spinal opioids may be used in the patient who is suffering from pregnancy-induced hypertension provided that there are no contraindications to spinal anaesthesia.⁸⁹ The lack of sympathetic block is an advantage in this situation as well as the analgesia which positively influences uteroplacental blood flow by abolishing hyperventilation.

Many specific indications have been considered for the use of spinal anaesthesia in obstetrics. Kestin has suggested that in the situation where either epidural anaesthesia has failed or the maximum amount of local anaesthetic has been administered, spinal anaesthesia is an option.⁹⁰ Malan reported a patient with a known difficult airway who presented for urgent Caesarean section. She was managed with a continuous spinal anaesthetic and the author advocated this technique for the management of the obstetric patient with a difficult airway.⁹¹ Further reports questioned the safety of these two previous statements, and Mets *et al.* reported on a patient who received a subarachnoid anaesthetic after an inadequate epidural block.⁹² She subsequently developed apnoea and ascending paralysis requiring tracheal intubation. High spinal anaesthesia following epidural anaesthesia has been described by two other authors and Mets felt there could be some common mechanism for the development of this complication. Previous epidural administration of local anaesthetic may collapse the subarachnoid space below the termination of the cord allowing a given volume of subarachnoid anaesthetic to spread more extensively.⁹² No matter what the mechanism, it is prudent to be prepared for this outcome when considering giving a spinal anaesthetic following an inadequate epidural block or in a patient with a suspected or known difficult airway.

In patients with altered vertebral anatomy, epidural anaesthesia may be technically difficult to perform and may be associated with a higher degree of complications. Spinal anaesthesia may be indicated in these patients, specifically for Caesarean section where a general anaesthetic might otherwise be given. Spinal anaesthesia has been successfully administered to a patient with spina bifida who wished to remain awake for her Caesarean section.⁹³ The paucity of reports in the literature describing regional anaesthesia for Caesarean delivery in these patients probably stems from the fact that general anaesthesia has been used extensively in this situation. Nonetheless, in patients with spina bifida, spinal anaesthesia may be considered.

Scoliosis is common in the parturient and may or may not have been corrected by Harrington rod instrumentation. Many reports on regional anaesthesia following spinal surgery have reinforced the fact that regional anaesthesia, usually epidural, is safe but not always successful or easily performed.^{94,95} The use of spinal anaesthesia in these patients may not only be more easily performed but also associated with a more reliable block.^{96,97}

Contraindications

Table IV summarizes the absolute and relative contraindications to spinal anaesthesia. The administration of regional anaesthesia to the patient with pregnancy-induced hypertension has undergone much re-thinking over the years. Epidural anaesthesia is now recognized as offering considerable advantages to the parturient by abolishing the pain of labour and its negative effects on uteroplacental blood flow and neonatal acid-base status.⁹⁸ The question of using spinal local anaesthesia in this condition, however, has not been investigated. Concern about the hypotension and the prophylactic or therapeutic use of vasopressors in a patient whose response to vasopressors is abnormal has most likely limited the study of spinal anaesthesia in the pre-eclamptic patient.⁹⁸

Patients with obstructive cardiac lesions such as aortic stenosis, mitral stenosis, pulmonary hypertension, and coarctation of the aorta who would not easily tolerate any rapid change in preload or afterload may not be suitable candidates for spinal anaesthesia with local anaesthetics. Patients with a right-to-left cardiac shunt may increase their shunt with the decrease in systemic vascular resistance associated with spinal anaesthesia.

Patients suffering from multiple sclerosis may have post partum exacerbation of their disease. The association of regional anaesthesia and post partum neuropathy may be difficult to distinguish from the inherent disease process. Therefore the use of spinal anaesthesia must be carefully considered.⁹⁹ Rolbin *et al.* cautioned that regional

TABLE IV Contraindications to spinal anaesthesia

Absolute

- 1 Patient refusal
- 2 Known hypersensitivity to the drug
- 3 Inability to communicate with patient
- 4 Lack of resuscitative equipment or drugs
- 5 No intravenous access
- 6 Ignorance of technique
- 7 Severe uncorrected hypovolaemia
- 8 Hypotension or shock
- 9 Coagulopathy
- 10 Local cutaneous infection at site of puncture
- 11 Increased intracranial pressure

Relative

- 1 Obstructive cardiac lesions or right to left shunts
- 2 Active central nervous system disease
- 3 Primary herpes
- 4 Pregnancy-induced hypertension
- 5 Myasthenia gravis

anaesthesia may aggravate respiratory impairment in patients suffering from myasthenia gravis.¹⁰⁰

Controversy exists regarding the use of regional anaesthesia in the presence of active herpes. Viraemia is present with the first outbreak of the lesions. There is a 10% incidence of meningitis associated with this disease and for this reason the risk of an alternative method of anaesthesia must be weighed against the theoretical risk of introducing the virus into the central nervous system.¹⁰¹

A great deal of controversy exists over the coagulation variables which are acceptable before administering a regional anaesthetic. Paraplegia caused by a spinal haematoma is a very rare but disastrous complication of a regional anaesthetic technique. Although epidural anaesthesia seems to be inherently more traumatic than spinal anaesthesia, the number of case reports of haematomas is similar.¹⁰² In the majority of cases where a haematoma was reported, a bleeding diathesis was present.¹⁰²

Rolbin *et al.* reported on the outcome of over 80,000 epidural anaesthetics which had been performed at Mount Sinai Hospital over a 30-yr period.¹⁰³ There were no epidural haematomas despite their postulation that up to 5000 obstetrical patients would have had a platelet count of less than $150,000 \text{ cell} \cdot \text{L}^{-1}$. This suggested that in the absence of bleeding disorders, epidural or spinal insertion virtually never causes symptomatic spinal haematoma.

The abnormalities of platelet count, function and aggregation in patients with pre-eclampsia have long been recognized.¹⁰² However, what is less well understood is the level and function of the platelet count that would preclude the use of regional anaesthesia. Many arbitrary cut-offs have been suggested and the ability to study this

problem would be statistically and ethically difficult. Although controversies exist, the following is one recommendation for the use of regional anaesthesia in the pre-eclamptic patient. If the platelet count is $>100,000$ and the D-dimer is normal, then one could proceed with a regional technique.¹⁰² If the platelet count or D-dimer is abnormal, a bleeding time is performed. If this is normal, a regional technique can be considered.¹⁰²

Complications

Lidocaine 5%

There have been a number of reports recently about the potential neurotoxicity associated with hyperbaric lidocaine 5%.¹⁰⁴⁻¹¹⁰ Transient neurological deficits involving bilateral radicular leg pain implicated lidocaine 5% as a potential etiological agent in this neurotoxicity.¹⁰⁴⁻¹¹⁰ The cauda equina syndrome has been reported in a number of patients following the use of hyperbaric lidocaine 5% in continuous spinal anaesthesia.^{70,107} Injection of hyperbaric lidocaine 5% into models of the spinal canal can result in maldistribution and potentially toxic concentrations of local anaesthetic in dependent regions within the CSF.¹¹¹⁻¹¹³ It seems prudent, therefore, in light of the neurological complications that have been reported with lidocaine 5%, to administer the lowest concentration of drug to achieve the desired result.¹¹⁰ Anaesthetists should be aware of these neurological events and keep them in mind when contemplating the use of subarachnoid hyperbaric lidocaine 5%.

Postdural puncture headache

DIFFERENTIAL DIAGNOSIS

The classical spinal headache has a number of specific qualities. It is typically fronto-occipital and may radiate to the neck and shoulders. It is aggravated in the sitting or standing position and improves in the supine position. There may be accompanying symptoms including, photophobia, nausea, vomiting, tinnitus, deafness and other visual disturbances. Occasionally, an abducens nerve palsy may be present.¹¹⁴ The headache usually appears within 48 hr of the dural puncture and has a variable duration.^{3,114}

Although it is natural to suspect postdural headache in a parturient who has either received a spinal anaesthetic or an unintentional dural tap during an attempted epidural, it is not uncommon for women to experience headaches in the first week postpartum. Stein *et al.* reported that the incidence of headache not related to anaesthesia was 39%.¹¹⁵ The differential diagnosis of post partum headache includes (i) psychogenic, (ii) meningitis, (iii) sinus headache, (iv) tension headache, (v) cerebral

haemorrhage, (vi) cerebral infarction, (vii) hypertensive crisis (pre-eclampsia), (viii) migraine, (ix) metabolic (electrolyte imbalance, hypoglycaemia).³

PREVENTION

Halpern *et al.* published a metaanalysis of randomized trials involving the use of different needles for spinal anaesthesia.¹¹⁶ His findings revealed that non-cutting needles produced less headache than cutting needles and that smaller needles produced less headache than larger needles of the same type. It was noted that very small-gauge cutting needles were more difficult to use and might therefore have a higher failure rate. His suggestion was that a small noncutting needle should be used for patients at high risk for the development of postdural puncture headache.

TREATMENT

A number of treatments have been suggested for the patient with a postdural puncture headache. She should be reassured that treatment is available and the aetiology of the headache elucidated. Classically, patients who have had lumbar punctures have been encouraged to maintain the supine position for 24 hr. This is only a temporizing measure since, on adopting the upright position, the patient will usually develop the headache. Once the headache has developed, the supine position will improve the symptoms but will not usually abolish them.¹¹⁷ Tight abdominal binders have been used but are uncomfortable and have fallen out of fashion.¹¹⁴ Additional hydration which has been a time-honoured measure in the treatment of postdural puncture headache was felt to be effective by restoring CSF volume. There has been no conclusive evidence, however, to confirm the effectiveness of this therapy.^{114,117} A number of drugs have been suggested such as vasopressin, antihistamines, steroids and alcohol but without proved effect.¹¹⁴ Oral analgesics may decrease the symptoms. Caffeine has been a popular treatment with the thought that its cerebral vasoconstrictive properties will offset the cerebral vasodilatation which is felt to contribute to the headache.¹¹⁴ Caffeine can be given in doses of 300 mg *po* in the morning.³

The definitive treatment of the spinal headache is the epidural blood patch (EBP). It is a highly effective technique: 89% of patients receiving relief of symptoms following the first injection and a further 8% after the second injection.¹¹⁸ The amount of blood which should be used for the patch has been widely debated. It appears that 12-20 ml should be injected and the injection stopped if the patient complains of back or leg pain.¹¹⁴ If the first blood patch is unsuccessful, it may be repeated.

Long-term complications of an EBP are rare. Backache, transient leg and neck pain and occasional nerve

root irritation have been reported.¹¹⁴ Serious neurological sequelae have usually been associated with complicating factors.¹¹⁴ Fever and signs of an infection preclude the use of an EBP.

Prophylactic EBP have been suggested in the prevention of a postdural puncture headache but studies have been conflicting. Various factors need to be taken into consideration. The epidural catheter interferes with the normal coagulation process and may therefore affect the ability of blood injected through it to clot once *in situ*.¹¹⁷ The potential for infection may be higher through an epidural catheter which has been in place for many hours.¹¹⁴ However, Colonna-Romano did a randomized prospective trial of immediate EBP through an indwelling epidural catheter and found this to be effective.¹¹⁹ Other methods of treating spinal headaches include a Dextran patch (20–30 ml Dextran 40 given epidurally), epidural saline and in extremely rare situations, surgery.^{114,117}

Backache

Backache is a very common complaint during pregnancy and the incidence has been reported as high as 49%.¹²⁰ MacArthur *et al.* have suggested that long-term backache after delivery was associated with epidural anaesthesia.¹²¹ As this study was complicated by "recall bias," Breen *et al.* investigated the association between epidural anaesthesia and back pain in 1,042 patients.¹²² They concluded that predisposing factors for post partum back pain included a history of back pain, younger age, greater weight, and shorter stature. Epidural anaesthesia did not appear to be associated with back pain one to two months after delivery.

Other neurological complications

Spinal anaesthesia may be complicated by aseptic meningitis, adhesive arachnoiditis or the cauda equina syndrome. The cauda equina syndrome can be recognized by the development of urinary and faecal incontinence, sensory loss in the perineal area and some degree of motor weakness which begins after the regression of the block.¹²³ Aseptic meningitis is characterized by high fever, headache, nuchal rigidity and photophobia.¹²⁴ The prognosis is good with full neurological recovery being the rule.¹²⁵ It is important to differentiate between aseptic and septic meningitis since treatment will differ. The aetiology of aseptic meningitis appears to be related to chemical irritation of the subarachnoid space usually from detergent-contaminated equipment.^{124,125} Septic meningitis may be bacterial or viral in origin. Bacterial meningitis can occur if sterile technique is breached and can be a very serious disease. Diagnosis is made by history, as seen with aseptic meningitis as well as CSF identification of the causative

organism which is found in 80% or more of patients with this disease process.¹²⁶ Although rare, bacterial meningitis can occur in the absence of a break in aseptic technique.¹²⁶ Viral meningitis may potentially occur in patients who have primary herpes simplex virus. Although epidural anaesthesia has been used without problems in these patients, the safety of spinal anaesthesia is not known.¹²⁶

Adhesive arachnoiditis results in a gradual progressive weakness and sensory loss in the lower extremities which begins several weeks or months after spinal anaesthesia. The cause is not completely understood but may be related to chemical contaminants, vasoconstrictors or organization of clots.¹²⁷ It may progress to complete paraplegia and even death.¹²³

Cranial nerve lesions may occur although usually in association with postdural puncture headaches.¹²⁷ Involvement of the oculomotor, trochlear, abducens, facial and vestibulocochlear nerves has been reported with incidences between 2 and 8%.¹²⁷

Spinal cord ischaemia is another potential, serious complication relating to spinal anaesthesia. Aetiological factors which may contribute to it include prolonged hypotension, the use of epinephrine, incorrect positioning or compression. There is usually motor paralysis with or without sensory loss.¹²³

The incidence of direct neurological damage from spinal needles is extremely rare.¹²⁷ Severe lancinating pain while performing the block should alert the operator that the spinal roots are being irritated and requires removal of either the needle or catheter should this occur.

If a major neurological complication occurs, it is necessary to act quickly to prevent long-term sequelae. The precise location of the neurological lesion should be determined and a differential diagnosis and plan for treatment developed. The assistance of a neurological colleague is warranted.

Cardiovascular

HEART BLOCK

Bradycardia associated with spinal anaesthesia is felt to be secondary to the blockade of preganglionic cardiac accelerator fibres which arise from the first through the fifth thoracic dermatomes.¹²⁷ As well, decreases in right atrial pressure secondary to a decrease in venous return may contribute to the development of bradycardia. Treatment with fluids, repositioning (especially if left uterine displacement is not optimum), vagolytics and alpha-agonists have been advocated.^{127,128} A Wenckebach type of heart block has been reported following Caesarean section with spinal anaesthesia and persisted for a few hours postoperatively.¹²⁸

ELECTROCARDIOGRAPHIC CHANGES

Abnormalities in the ST-T segment in patients undergoing Caesarean section with either an epidural or spinal anaesthetic have been reported.^{129,130} Holter monitoring and transthoracic 2-D echocardiography were used to record ST segment changes during Caesarean section in 170 patients. Depression of the ST segments occurred in 38% of patients with epidural anaesthesia and in 14% of patients with spinal anaesthesia. No abnormalities in wall motion were noted on echocardiography and no creatine kinase changes were noted in any of these patients. Tachycardia was associated with ST segment changes in 10% of time epochs.

Eisenach *et al.* estimated cardiac sympathetic tone by spectral analysis of heart rate variability in 15 patients undergoing Caesarean section with spinal anaesthesia.¹³¹ One-third of patients developed ST depression and the cause of this finding was felt to be due to diminished cardiac sympathetic tone and unrelated to myocardial ischaemia.

High block

A higher block than expected can occur with spinal anaesthesia in patients who have had unsuccessful attempts at epidural anaesthesia.¹³² This may be due to leakage of local anaesthetic through the dural puncture hole, if local anaesthetic had been administered into the epidural space, or a physical effect of the volume of fluid in the epidural space which displaces the CSF. Also, CSF may leak out of the dural puncture hole leading to a lower volume of CSF in the subarachnoid space and the decrease in CSF volume leads to a higher block than expected.¹³³ Caution is advised in any situation where a spinal is performed after fluid, either saline or local anaesthetic, has been given into the epidural space.¹³²

Other

NAUSEA

Incidences of nausea relating to spinal anaesthesia range from 14–45%.¹³⁴ Nausea has been associated with hypotension and treatment of the hypotension often results in the disappearance of the nausea.⁷ Peritoneal traction and exteriorization of the uterus may also cause nausea and may be related to a lower concentration of local anaesthetic in the higher dermatomes which receive pain impulses from the peritoneum. This may occur despite an adequate dermatomal level of anaesthesia.¹³⁴ Metoclopramide may decrease the incidence of this complication.⁶⁶

Conclusion

Spinal anaesthesia has enjoyed a recent re-birth into the

practice of obstetrical anaesthesia. With the ability to examine the cardiovascular effects of local anaesthetics given by the subarachnoid route, the safety of this technique in the parturient will be established. Echocardiography and Doppler velocimetry have already been used to assess the physiological outcome of a sympathetic block with spinal anaesthesia.

The advantages to the technique include its reliability, speed of onset and small drug dosage. Whether or not this technique has major advantages over the epidural approach will require further investigation. The incidence of postdural puncture headaches has been reduced to <1% and is no longer a disadvantage of the technique. Interesting ideas about the combination of spinal and epidural analgesia and anaesthesia for labour may prove to be another development in this decade. The use of a small dose of subarachnoid opioid with an indwelling epidural catheter for use later in labour would allow the parturient to ambulate for a longer period of time without discomfort and may increase patient satisfaction. Once anaesthesia is required, local anaesthetics could be delivered through the already indwelling epidural catheter.

The potential airway disasters that can occur with general anaesthesia in the parturient have resulted in the examination of alternative methods of anaesthesia in the urgent/emergency situation. Spinal anaesthesia, due to its rapid onset of action, may have a part to play although further studies will need to be done to support its use.

Epidural anaesthesia has been used for many years in the obstetrical population but it appears that spinal anaesthesia will begin to play a major role in the future of obstetrical analgesia and anaesthesia.

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References

- 1 Vandam LD. On the origins of intrathecal anesthesia. *Int Anesthesiol Clin* 1989; 27: 2–7.
- 2 Berges PU. Regional anesthesia for obstetrics. *Clin Anesth* 1969; 2: 141–66.
- 3 Carter J, Macarthur A. Spinal anaesthesia for Caesarean section. *Contemporary Anaesthesia* 1994; 4: 11–5.
- 4 Wildsmith JAW. The history and development of local anaesthesia. In: Wildsmith JAW, Armitage EN (Eds.). *Principles and Practice of Regional Anaesthesia*, 2nd ed. Edinburgh: Churchill Livingstone, 1993: 1–7.
- 5 Akamatsu TJ. Advances in obstetric anesthesiology during the period 1960–1970. *Clin Anesth* 1969; 3: 221–51.
- 6 Howard BK, Goodson JH, Mengert WF. Supine hypoten-

- sive syndrome in late pregnancy. *Obstet Gynecol* 1953; 1: 371-7.
- 7 Clark RB, Thompson DS, Thompson CH. Prevention of spinal hypotension associated with Cesarean section. *Anesthesiology* 1976; 45: 670-4.
 - 8 Ueland K, Gills RE, Hansen JM. Maternal cardiovascular dynamics I. cesarean section under subarachnoid block anesthesia. *Am J Obstet Gynecol* 1968; 100: 42-54.
 - 9 Robson SC, Boys RJ, Rodeck C, Morgan B. Maternal and fetal haemodynamic effects of spinal and extradural anaesthesia for elective Caesarean section. *Br J Anaesth* 1992; 68: 54-9.
 - 10 Robson SC, Samsoon G, Boys RJ, Rodeck C, Morgan B. Incremental spinal anaesthesia for elective Caesarean section: maternal and fetal haemodynamic effects. *Br J Anaesth* 1993; 70: 634-8.
 - 11 Shnider SM, DeLorimier AA, Holl JW, Chapler FK, Morishima HO. Vasopressors in obstetrics I: correction of fetal acidosis with ephedrine during spinal hypotension. *Am J Obstet Gynecol* 1968; 102: 911.
 - 12 Dailey PA, Baysinger CL, Levinson G, Shnider SM. Neurobehavioral testing of the newborn infant. *Clin Perinatol* 1982; 9: 191-214.
 - 13 Hodgkinson R, Bhatt M, Kim SS, Grewal G, Marx GF. Neonatal neurobehavioural tests following cesarean section under general and spinal anesthesia. *Am J Obstet Gynecol* 1978; 132: 670-4.
 - 14 Corke BC, Datta S, Ostheimer GW, Weiss JB, Alper MH. Spinal anaesthesia for Caesarean section. *Anaesthesia* 1982; 37: 658-62.
 - 15 Ratcliffe FM, Evans JM. Neonatal wellbeing after elective caesarean delivery with general, spinal, and epidural anaesthesia. *Eur J Anaesthesiol* 1993; 10: 175-81.
 - 16 Valli J, Pirhonen J, Aantaa R, Erkkola R, Kanto J. The effects of regional anaesthesia for Caesarean section on maternal and fetal blood flow velocities measured by doppler ultrasound. *Acta Anaesthesiol Scand* 1994; 38: 165-9.
 - 17 Wollman SB, Marx GF. Acute hydration for prevention of hypotension of spinal anesthesia in parturients. *Anesthesiology* 1968; 29: 374-80.
 - 18 Rout CC, Rocke DA. Prevention of hypotension following spinal anesthesia for cesarean section. *Int Anesthesiol Clin* 1994; 32: 117-35.
 - 19 Mathru M, Rao TLK, Kartha RK, Shanmugham M, Jacobs HK. Intravenous albumin administration for prevention of spinal hypotension during cesarean section. *Anesth Analg* 1980; 59: 655-8.
 - 20 Rout CC, Akoojee SS, Rocke DA, Gouws E. Rapid administration of crystalloid preload does not decrease the incidence of hypotension after spinal anaesthesia for elective Caesarean section. *Br J Anaesth* 1992; 68: 394-7.
 - 21 Rout CC, Rocke DA, Levin J, Gouws E, Reddy D. A re-evaluation of the role of crystalloid preload in the prevention of hypotension associated with spinal anesthesia for elective cesarean section. *Anesthesiology* 1993; 79: 262-9.
 - 22 Birnbach DJ, Datta S. Intravenous fluid preload in the prevention of spinal block-induced hypotension in parturients: I (Letter). *Anesthesiology* 1994; 80: 701.
 - 23 Bassell GM, Marx GF. Intravenous fluid preload in the prevention of spinal block-induced hypotension in parturients: II (Letter). *Anesthesiology* 1994; 80: 702.
 - 24 Rout CC, Rocke DA, Gouws E. Leg elevation and wrapping in the prevention of hypotension following spinal anaesthesia for elective Caesarean section. *Anaesthesia* 1993; 48: 304-8.
 - 25 McCrae AF, Wildsmith JAW. Prevention and treatment of hypotension during central neural block. *Br J Anaesth* 1993; 70: 672-80.
 - 26 Gutsche BB. Prophylactic ephedrine preceding spinal analgesia for cesarean section. *Anesthesiology* 1976; 45: 462-5.
 - 27 Rolbin SH, Cole AFD, Hew EM, Pollard A, Virgint S. Prophylactic intramuscular ephedrine before epidural anaesthesia for Caesarean section: efficacy and actions on the fetus and newborn. *Can Anaesth Soc J* 1982; 29: 148-53.
 - 28 Kang YG, Abouleish E, Caritis S. Prophylactic intravenous ephedrine infusion during spinal anesthesia for cesarean section. *Anesth Analg* 1982; 61: 839-42.
 - 29 Ralston DH, Shnider SM, De Lorimier AA. Effects of equipotent ephedrine, metaraminol, mephenteramine and methoxamine on uterine blood flow in the pregnant ewe. *Anesthesiology* 1974; 40: 354-70.
 - 30 Casady GN, Moore DC, Bridenbaugh LD. Post-partum hypertension after the use of vasoconstrictor oxytocic drugs. *JAMA* 1960; 172: 1011-5.
 - 31 James FM III, Greiss FC Jr, Kemp RA. An evaluation of vasopressor therapy for maternal hypotension during spinal anesthesia. *Anesthesiology* 1970; 33: 25-34.
 - 32 Ramanathan S, Grant GJ. Vasopressor therapy for hypotension due to epidural anesthesia for cesarean section. *Acta Anaesthesiol Scand* 1988; 32: 559-65.
 - 33 Moran DH, Perillo M, LaPorta RF, Bader AM, Datta S. Phenylephrine in the prevention of hypotension following spinal anesthesia for cesarean delivery. *J Clin Anesth* 1991; 3: 301-5.
 - 34 Taylor JC, Tunstall ME. Dosage of phenylephrine in spinal anaesthesia for Caesarean section (Letter). *Anaesthesia* 1991; 46: 314-5.
 - 35 Pierce ET, Carr DB, Datta S. Effects of ephedrine and phenylephrine on maternal and fetal atrial natriuretic peptide levels during elective cesarean section. *Acta Anaesthesiol Scand* 1994; 38: 48-51.
 - 36 Thomas TA, Noble HA. A re-evaluation of the Whitacre spinal needle in obstetric anaesthesia - a pilot study (Letter). *Anaesthesia* 1990; 45: 489.
 - 37 Hart JR, Whitacre RJ. Pencil-point needle in prevention of postspinal headache. *JAMA* 1951; 147: 657-8.

- 38 Cesarini M, Torrielli R, Lahave F, Mene JM, Cabirol C. Sprotte needle for intrathecal anaesthesia for Caesarean section: incidence of postdural puncture headache. *Anaesthesia* 1990; 45: 656-8.
- 39 Chadwick HS, Posner K, Caplan RA, Ward RJ, Cheney FW. A comparison of obstetric and nonobstetric anaesthesia malpractice claims. *Anesthesiology* 1991; 74: 242-9.
- 40 Maver DC, Quance D, Weeks SK. Headache after spinal anaesthesia for caesarean section: a comparison of the 27-gauge Quincke and 24-gauge Sprotte needles. *Anesth Analg* 1992; 75: 377-80.
- 41 Shutt LE, Valentine SJ, Wee MYK, Page RJ, Prosser A, Thomas TA. Spinal anaesthesia for Caesarean section: comparison of 22-gauge and 25-gauge Whitacre needles with 26-gauge Quincke needles. *Br J Anaesth* 1992; 69: 589-94.
- 42 Campbell DC, Douglas MJ, Pavy TJG, Merrick P, Flanagan ML, McMorland GH. Comparison of the 25-gauge Whitacre with the 24-gauge Sprotte spinal needle for elective Caesarean section: cost implications. *Can J Anaesth* 1993; 40: 1131-5.
- 43 Sears DH, Leeman MI, Jassy LJ, O'Donnell LA, Allen SG, Reisner LS. The frequency of postdural puncture headache in obstetric patients: a prospective study comparing the 24-gauge versus the 22-gauge Sprotte needle. *J Clin Anesth* 1994; 6: 42-6.
- 44 Hunt CO. Spinal anaesthesia for obstetrics. *Int Anesthesiol Clin* 1989; 27: 26-30.
- 45 Datta S, Hurley RJ, Naulty JS, et al. Plasma and cerebrospinal fluid progesterone concentrations in pregnant and nonpregnant women. *Anesth Analg* 1986; 65: 950-4.
- 46 Flanagan HL, Datta S, Lambert DH, Gissen AJ, Covino BG. Effect of pregnancy on bupivacaine-induced conduction blockade in the isolated rabbit vagus nerve. *Anesth Analg* 1987; 66: 123-6.
- 47 Datta S, Lambert DH, Gregus J, Gissen AJ, Covino BG. Differential sensitivities of mammalian nerve fibers during pregnancy. *Anesth Analg* 1983; 62: 1070-2.
- 48 Kumar A, Bala I, Bhukal I, Singh H. Spinal anaesthesia with lidocaine 2% for Caesarean section. *Can J Anaesth* 1992; 39: 915-9.
- 49 Denson DD, Bridenbaugh PO, Turner PA, Phero JC. Comparison of neural blockade and pharmacokinetics after subarachnoid lidocaine in the Rhesus monkey. II: effects of volume, osmolality and baricity. *Anesth Analg* 1983; 62: 995-1001.
- 50 Norris MC. Patient variables and the subarachnoid spread of hyperbaric bupivacaine in the term parturient. *Anesthesiology* 1990; 72: 478-82.
- 51 Möller IW, Fernandes A, Edström HH. Subarachnoid anaesthesia with 0.5% bupivacaine: effects of density. *Br J Anaesth* 1984; 56: 1191-94.
- 52 Moore DC, Chadwick HS, Ready LB. Epinephrine prolongs lidocaine spinal: pain in the operative site the most accurate method of determining local anesthetic duration. *Anesthesiology* 1987; 67: 416-8.
- 53 Abouleish EI. Epinephrine improves the quality of spinal hyperbaric bupivacaine for caesarean section. *Anesth Analg* 1987; 66: 395-400.
- 54 Spivey DL. Epinephrine does not prolong lidocaine spinal anaesthesia in term parturients. *Anesth Analg* 1985; 64: 468-70.
- 55 Connelly NR, Dunn SM, Ingold V, Villa EA. The use of fentanyl added to morphine-lidocaine-epinephrine spinal solution in patients undergoing caesarean section. *Anesth Analg* 1994; 78: 918-20.
- 56 Abouleish E, Rawal N, Rashad MN. The addition of 0.2 mg subarachnoid morphine to hyperbaric bupivacaine for caesarean delivery: a prospective study of 856 cases. *Reg Anesth* 1991; 16: 137-40.
- 57 Courtney MA, Bader AM, Hartwell B, Hauch M, Grennan MJ, Datta S. Perioperative analgesia with subarachnoid sufentanil administration. *Reg Anesth* 1992; 17: 274-8.
- 58 Hartwell BL, Aglio LS, Hauch MA, Datta S. Vertebral column length and spread of hyperbaric subarachnoid bupivacaine in the term parturient. *Reg Anesth* 1991; 16: 17-9.
- 59 Abboud TK. Epidural and intrathecal administration of opioids in obstetrics. *Acute Care* 1986; 12(suppl 1): 17-21.
- 60 Abboud TK, Shnider SM, Dailey PA, et al. Intrathecal administration of hyperbaric morphine for the relief of pain in labour. *Br J Anaesth* 1984; 56: 1351-60.
- 61 Scott PV, Bowen FE, Cartwright P, et al. Intrathecal morphine as sole analgesic during labour. *BMJ* 1980; 281: 351-5.
- 62 Baraka A, Noueihid R, Hajj S. Intrathecal injection of morphine for obstetric analgesia. *Anesthesiology* 1981; 54: 136-40.
- 63 Abouleish E, Rawal N, Shaw J, Lorenz T, Rashad MN. Intrathecal morphine 0.2 mg versus epidural bupivacaine 0.125% or their combination: effects on parturients. *Anesthesiology* 1991; 74: 711-6.
- 64 Swayze CR, Skerman JH, Walker EB, Sholte FG. Efficacy of subarachnoid meperidine for labor analgesia. *Reg Anesth* 1991; 16: 309-13.
- 65 Lowson SM, Brown J, Wilkins CJ. Influence of the lumbar interspace chosen for injection on the spread of hyperbaric 0.5% bupivacaine. *Br J Anaesth* 1991; 66: 465-8.
- 66 Lussos SA, Bader AM, Thornhill ML, Datta S. The antiemetic efficacy and safety of prophylactic metoclopramide for elective caesarean delivery during spinal anaesthesia. *Reg Anesth* 1992; 17: 126-30.
- 67 Chestnut DH, Vandewalker GE, Owen CL, Bates JN, Choi WW. Administration of metoclopramide for preven-

- tion of nausea and vomiting during epidural anesthesia for elective cesarean section. *Anesthesiology* 1987; 66: 563-6.
- 68 Hurley RJ. Continuous spinal anesthesia. *Int Anesthesiol Clin* 1989; 27: 46-50.
 - 69 Hurley RJ, Lambert DH. Continuous spinal anesthesia with a microcatheter technique. *Reg Anesth* 1987; 12: 53-4.
 - 70 Rigler ML, Drasner K, Krejcie TC, et al. Cauda equina syndrome after continuous spinal anesthesia. *Anesth Analg* 1991; 72: 275-81.
 - 71 Kennedy F, Effron AS, Perry G. The grave spinal cord paralyses caused by spinal anaesthesia. *Surg Gynecol Obstet* 1950; 91: 385-98.
 - 72 Payne JP, Bergeutz SE. Paraplegia following spinal anaesthesia. *Lancet* 1956; 1: 666-8.
 - 73 Ravindran R, Bond V, Tasch M, Gupta C, Luerssen T. Prolonged neural blockade following regional anaesthesia with 2-chlorprocaine. *Anesth Analg* 1980; 59: 457-60.
 - 74 Moore DC, Spierdijk J, vanKleef JD, Coleman RL, Love GF. Chlorprocaine neurotoxicity: four additional cases. *Anesth Analg* 1982; 61: 155-9.
 - 75 Peyton PJ. Complications of continuous spinal anaesthesia. *Anaesth Intensive Care* 1992; 20: 417-38.
 - 76 Brownridge P. Epidural and subarachnoid analgesia for elective Caesarean section (Letter). *Anaesthesia* 1981; 36: 70.
 - 77 Thorén T, Holmström B, Rawal N, Schollin J, Lindeberg S, Skeppner G. Sequential combined spinal epidural block versus spinal block for cesarean section: effects on maternal hypotension and neurobehavioral function of the newborn. *Anesth Analg* 1994; 78: 1087-92.
 - 78 Lässer P, Bembridge M, Lyons G, Macdonald R. An evaluation of a 30-gauge needle for spinal anaesthesia for Caesarean section. *Anaesthesia* 1990; 45: 767-8.
 - 79 Lyons G, Macdonald R, Miki B. Combined epidural/spinal anaesthesia for Caesarean section. *Anaesthesia* 1992; 47: 199-201.
 - 80 Westbrook JL, Donald F, Carrie LES. An evaluation of a combined spinal/epidural needle set utilizing a 26-gauge, pencil point needle for Caesarean section. *Anaesthesia* 1992; 47: 990-2.
 - 81 Carrie LES. Debate on use of spinal anesthesia in obstetrics: spinal anesthesia had definite indications in obstetrics. *Acta Anaesthesiol Belg* 1988; 39: 177-9.
 - 82 Carp H. Anesthesia for cesarean delivery. *Int Anesthesiol Clin* 1990; 28: 25-9.
 - 83 Gottschalk W. Regional anesthesia. I. Spinal, lumbar epidural and caudal anesthesia. *Obstet Gynecol Annu* 1974; 3: 377-405.
 - 84 Carrie LES. Extradural, spinal or combined block for obstetric surgical anaesthesia. *Br J Anaesth* 1990; 65: 225-33.
 - 85 Marx GF, Luykx WM, Cohen S. Fetal-neonatal status following Caesarean section for fetal distress. *Br J Anaesth* 1984; 56: 1009-12.
 - 86 Blomberg R. The dorsomedian connective tissue band in the lumbar epidural space of humans. *Anesth Analg* 1986; 65: 747-51.
 - 87 Husemeyer RP, White DC. Topography of the lumbar epidural space. *Anaesthesia* 1980; 35: 7-11.
 - 88 Nauta HJW, Dolan E, Yasargel MG. Microsurgical anatomy of spinal subarachnoid space. *Surg Neurol* 1983; 19: 431-7.
 - 89 Ross BK, Hughes SC. Epidural and spinal narcotic analgesia. *Clin Obstet Gynecol* 1987; 30: 552-65.
 - 90 Kestin IG. Spinal anaesthesia in obstetrics. *Br J Anaesth* 1991; 66: 596-607.
 - 91 Malan TP, Johnson MD. The difficult airway in obstetric anesthesia: techniques for airway management and the role of regional anesthesia. *J Clin Anesth* 1988; 1: 104-11.
 - 92 Mets B, Broccoli E, Brown AR. Is spinal anesthesia after failed epidural anesthesia contraindicated for cesarean section? *Anesth Analg* 1993; 77: 629-31.
 - 93 Nuyten F, Gielen M. Spinal catheter anaesthesia for Caesarean section in a patient with spina bifida. *Anaesthesia* 1990; 45: 846-7.
 - 94 Daley MD, Rolbin SH, Hew EM, Morningstar BA, Stewart JA. Epidural anaesthesia for obstetrics after spinal surgery. *Reg Anesth* 1990; 15: 280-4.
 - 95 Crosby ET, Halpern SH. Obstetric epidural anaesthesia in patients with Harrington instrumentation. *Can J Anaesth* 1989; 36: 693-6.
 - 96 Karadash K, King BW, Datta S. Spinal anaesthesia for Caesarean section after Harrington instrumentation. *Can J Anaesth* 1993; 40: 667-9.
 - 97 Pascoe HF, Jennings GS, Marx GF. Successful spinal anesthesia after inadequate epidural block in a parturient with prior surgical correction of scoliosis. *Reg Anesth* 1993; 18: 191-2.
 - 98 Gutsche BB, Cheek TG. Anesthetic considerations in preeclampsia-eclampsia. In: Shnider SM, Levinson G (Eds.). *Anesthesia for Obstetrics*, 3rd ed. Baltimore: Williams & Wilkins, 1993; 305-37.
 - 99 Bader AM, Hunt CQ, Datta S, et al. Anesthesia for the obstetric patient with multiple sclerosis. *J Clin Anesth* 1988; 1: 21-4.
 - 100 Rolbin SH, Levinson G, Shnider SM, Wright RG. Anesthetic considerations for myasthenia gravis and pregnancy. *Anesth Analg* 1978; 57: 441-7.
 - 101 Carp H, Chestnut D. Fever and Infection. In: Chestnut D (Ed.). *Obstetric Anesthesia*. St. Louis: Mosby 1994; 686-99.
 - 102 Sage DJ. Epidurals, spinals and bleeding disorders in pregnancy: a review. *Anaesth Intensive Care* 1990; 18: 319-26.
 - 103 Rolbin SH, Abbott D, Musclow E, Papsin F, Lie LM, Freedman J. Epidural anaesthesia in pregnant patients with low platelet counts. *Obstet Gynecol* 1988; 71: 918-20.

- 104 *Schneider M, Ettlin T, Kaufmann M, et al.* Transient neurologic toxicity after hyperbaric subarachnoid anesthesia with 5% lidocaine. *Anesth Analg* 1993; 76: 1154-7.
- 105 *deJong RH.* Last round for a "heavyweight"? (Editorial). *Anesth Analg* 1994; 78: 3-4.
- 106 *Sjöström S, Bläss J.* Severe pain in both legs after spinal anaesthesia with hyperbaric 5% lignocaine solution. *Anaesthesia* 1994; 49: 700-2.
- 107 *Schell RM, Brauer FS, Cole DJ, Applegate RL.* Persistent sacral nerve root deficits after continuous spinal anaesthesia. *Can J Anaesth* 1991; 38: 908-11.
- 108 *Cozaniitis DA.* Leg pains after spinal anaesthesia (Letter). *Can J Anaesth* 1995; 42: 657.
- 109 *Pinzower GR, Chadwick HS, Woodland R, Lowmiller M.* Bilateral leg pain following lidocaine spinal anaesthesia. *Can J Anaesth* 1995; 42: 217-20.
- 110 *Douglas MJ.* Neurotoxicity of lidocaine - does it exist? (Editorial). *Can J Anaesth* 1995; 42: 181-5.
- 111 *Rigler MR, Drasner K.* Distribution of catheter-injected local anesthetic in a model of the subarachnoid space. *Anesthesiology* 1991; 75: 684-92.
- 112 *Lambert DH, Hurley RJ.* Cauda equina syndrome and continuous spinal anesthesia. *Anesth Analg* 1991; 72: 817-9.
- 113 *Ross BK, Coda B, Heath CH.* Local anesthetic distribution in a spinal model: a possible mechanism of neurologic injury after continuous spinal anesthesia. *Reg Anesth* 1992; 17: 69-77.
- 114 *Weeks SK.* Spinal headache - prevention and treatment. *Can J Anaesth* 1990; 37: Sliii-Slviii.
- 115 *Stein G, Morton J, Marsh A, et al.* Headaches after childbirth. *Acta Neurol Scand* 1984; 69: 74-9.
- 116 *Halpern S, Preston R.* Postdural puncture headache and spinal needle design. *Anesthesiology* 1994; 81: 1376-83.
- 117 *Ross A, Popham P.* Post-dural headache and spinal anesthesia. *Int Anesthesiol Clin* 1994; 32: 137-53.
- 118 *Abouleish E, de la Vega S, Blendinger I, Tio T-O.* Long-term follow up of epidural blood patch. *Anesth Analg* 1975; 54: 459-63.
- 119 *Collonna-Romano P, Shapiro BE.* Unintentional dural puncture and prophylactic blood patch in obstetrics. *Anesth Analg* 1989; 69: 522-3.
- 120 *Berg G, Hammar M, Möller-Nielsen J, Linden U, Thorblad J.* Low back pain during pregnancy. *Obstet Gynecol* 1988; 71: 71-5.
- 121 *MacArthur C, Lewis M, Knox EG.* Investigation of long term problems after obstetric epidural anaesthesia. *BMJ* 1992; 304: 1279-82.
- 122 *Breen TW, Ransil BJ, Groves PA, Oriol NE.* Factors associated with back pain after childbirth. *Anesthesiology* 1994; 81: 29-34.
- 123 *Douglas MJ.* Potential complications of spinal and epidural anesthesia for obstetrics. *Semin Perinatol* 1991; 15: 368-74.
- 124 *Bert AA, Laasberg LH.* Aseptic meningitis following spinal anesthesia - a complication of the past? *Anesthesiology* 1985; 62: 674-7.
- 125 *Roberts SP, Petts HV.* Meningitis after obstetric spinal anaesthesia. *Anaesthesia* 1990; 45: 376-7.
- 126 *Lee JJ, Parry H.* Bacterial meningitis following spinal anaesthesia for Caesarean section. *Br J Anaesth* 1991; 66: 383-6.
- 127 *Parnass SM, Schmidt KJ.* Adverse effects of spinal and epidural anaesthesia. *Drug Saf* 1990; 5: 179-94.
- 128 *Matta BF, Magee P.* Wenckebach type heart block following spinal anaesthesia for Caesarean section. *Can J Anaesth* 1992; 39: 1067-8.
- 129 *Zakowski MI, Ramanathan S, Baratta JB, et al.* Electrocardiographic changes during cesarean section: a cause for concern? *Anesth Analg* 1993; 76: 162-7.
- 130 *Palmer CM, Morris MC, Guidici MC, Leighton BL, DeSimone CA.* Incidence of electrocardiographic changes during Caesarean delivery under regional anesthesia. *Anesth Analg* 1990; 70: 36-43.
- 131 *Eisenach JC, Tuttle R, Stein A.* Is ST segment depression of the electrocardiogram during cesarean section merely due to cardiac sympathetic block? *Anesth Analg* 1994; 78: 287-92.
- 132 *Beck GN, Griffiths AG.* Failed extradural anaesthesia for Caesarean section. Complication of subsequent spinal block. *Anaesthesia* 1992; 47: 690-2.
- 133 *Wagner DL.* Total spinal anesthesia during cesarean section hours after previous unintentional dural puncture (Letter). *Anesthesiology* 1994; 81: 260-1.
- 134 *Juhani TP, Hannele H.* Complications during spinal anesthesia for cesarean delivery: a clinical report of one year's experience. *Reg Anesth* 1993; 18: 128-31.