10

Anaesthesia

ABR Aarvold, J Wiggins, I Sebbag, A Kintu, V Mung'ayi, J Douglas

SYNPOSIS

This chapter is not designed to be an anaesthetic text but focuses on anaesthetic issues specifically related to parturients with hypertensive disorders of pregnancy. Early consultation and involvement of anaesthesia will result in the best possible outcome for women with a hypertensive disorder of pregnancy and their babies. Provision of effective analagesia for labour will not only decrease pain, but also attenuate its effects on blood pressure and cardiac output. In addition, epidural analgesia benefits the fetus by decreasing maternal respiratory alkalosis, compensatory metabolic acidosis, and release of catecholamines. An effective labour epidural can be used should a Caesarean delivery be required, avoiding the need for general anaesthesia. Both neuraxial (epidural, spinal, continuous spinal and combined spinal epidural) and general anaesthesia are appropriate for Caesarean delivery. The choice of technique will depend on the overall condition of the parturient, the urgency of the situation and whether there are contraindications to any particular technique. Challenges associated with anaesthesia include maintaining haemodynamic stability during laryngoscopy and intubation with general anaesthesia, or after sympathetic block secondary to neuraxial anaesthesia. Although neuraxial anaesthesia is preferred to general anaesthesia, owing to potential problems with the airway in the woman with pre-eclampsia, neuraxial anaesthesia may not be possible in the presence of a low platelet count or other coagulation abnormality. The interaction of non-depolarising muscle relaxants (as part of general anaesthesia) and magnesium sulphate will limit their use in the woman with pre-eclampsia. Adequate analgesia and ongoing monitoring are important components of overall postpartum management.

INTRODUCTION

A recurring lesson following investigation of maternal mortality secondary to complications of pre-eclampsia is the importance of teamwork and, in particular, the early involvement of anaesthesia. When possible, the anaesthetic team should be notified when a woman with pre-eclampsia is admitted to hospital. This notification allows for anaesthetic assessment, as well as clinical optimisation and care planning, all well in advance of anaesthetic intervention. Early anaesthetic consultation is associated with a reduction in both fetal and maternal morbidity[1].

Basic equipment and medications must be available in every labour and delivery area, and operating room in order to monitor maternal and fetal well-being, and resuscitate both should complications arise (Table 10.1). Essential

Table 10.1 Essential equipment for maternal resuscitation

Ventilation	Oxygen source Bag/mask Oral, nasopharyngeal airways
Intubation	Laryngoscope and different blades Different sizes of endotracheal tubes Gum elastic bougie McGill forceps Supraglottic airway device for rescue if failed intubation (e.g., laryngeal mask airway)
Intravenous access	Intravenous catheters (different gauges) Intravenous fluids (e.g., normal saline) Intravenous tubing
Emergency medications	Vasopressors (e.g., phenylephrine or ephedrine) Atropine Epinephrine $MgSO_4$ Cardiac medications such as amiodarone Nalaoxone (for neonatal and maternal resuscitation)
Other	Some means of providing left uterine displacement (e.g., wedge, blankets) Suction Defibrillator Equipment to perform perimortem Caesarean delivery

equipment includes oxygen, suction and a means of monitoring maternal blood pressure and heart rate. Ideally, one also would be able to monitor oxygen saturation and end-tidal carbon dioxide. Equipment for maternal resuscitation should always be immediately available (Table 10.1)[2]. A means of monitoring the fetus and equipment for newborn resuscitation also are required. While all of these resources are considered essential in well-resourced settings, they may not be available in less well-resourced areas. Some of the agents, techniques and equipment discussed in this chapter may not be available, but the basic principles of working as a team and using available resources to ensure the best possible outcome still apply.

The perspective taken in this chapter is that the anaesthetist should participate in a team-based multidisciplinary approach, that includes midwifery, obstetrics, nursing, neonatology and other medical specialties (e.g., haematology) or intensive care, as appropriate.

This chapter aims to highlight the potential issues faced by the anaesthetist when managing a patient with a hypertensive disorder of pregnancy, although the focus of this best anaesthetic practice is on pre-eclampsia. Throughout the chapter, analgesia refers to pain relief which may be provided through pharmacological means (e.g., opioids or gases, such as nitrous oxide) or through a central nerve (neuraxial) block (e.g., epidural) (Figure 10.1) whereby local anaesthetic is deposited close to the spinal cord and nerves to block the sensation of pain. Anaesthesia allows surgery to be performed and may be provided by a neuraxial block (e.g., epidural, spinal that can be continuous or 'single shot', or combined spinal epidural) which uses a stronger local anaesthetic than that used for analgesia. Neuraxial anaesthesia provides a denser sensory block in addition to muscle relaxation. Another way of providing anaesthesia is the use of a general anaesthetic that obtunds sensation to the whole body and the brain, resulting in unconsciousness, amnesia, analgesia, muscle relaxation and the inhibition of reflex activity. (For further information on overall anaesthetic concerns, the reader is referred to a basic text on anaesthesia, e.g., *Miller's Anaestheia*[3].)

INITIAL ASSESSMENT

The aim of the initial assessment is to plan in advance all aspects of both routine and emergency care, anticipate possible problems and the potential for anaesthetic intervention, and discuss any issues identified with the maternity care providers, the woman and her family. The risks and benefits associated with each anaesthetic technique can be explained, with the aim of expediting the process of informed consent should the need arise for an emergency procedure.

Anaesthetic planning should cover all aspects of prenatal maternal optimisation, including provision of analgesia for labour (as applicable), the appropriate choice of anaesthesia for assisted delivery or Caesarean delivery, and a plan for general postpartum care and pain management. Quotes from pre-eclampsia survivors illustrate just how much a multidisciplinary team is needed:

> "My blood pressure was 256/120 [mmHg] and doctors couldn't get it lowered. The doctors decided to put me into a medically induced coma to help stop the swelling of my brain and to try and lower my blood pressure. They

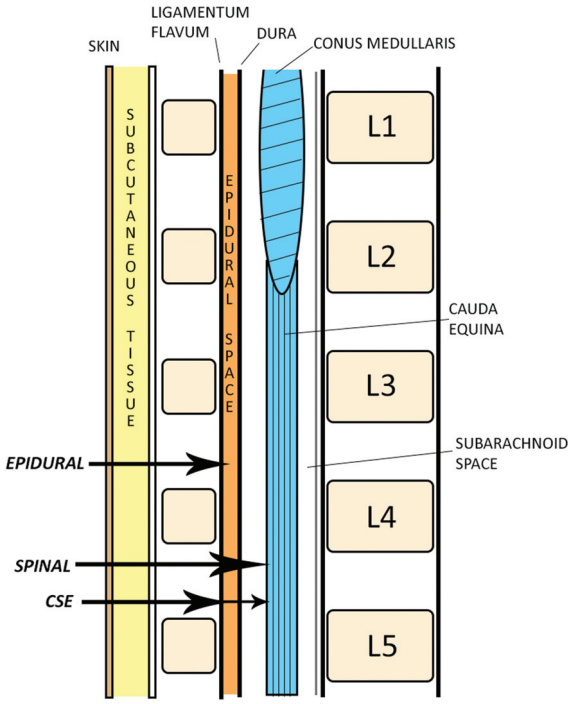

Figure 10.1 Schematic of spinal neuroanatomy, illustrating sites of needle insertion for neuraxial anaesthesia. (Image by DA de Silva © GLOWM)

> didn't successfully wake me until Friday morning when I was in labor and it was time to push. They had tried several times to wake me up but . . . I would thrash and struggle and try to pull the intubation tubes from my throat. The first thing I heard when I woke was that I was in the hospital and my baby had died. I was so sedated and drugged all I could say was, 'that's sad' . . . Looking back I realize I had no idea what was actually happening".
>
> Shelly S., HELLP syndrome survivor

A full anaesthetic history and physical examination should be completed, paying particular attention to the maternal airway in case emergency intubation is required, concurrent disease (which is common in this population, Table 10.2), drug history (including potential drug interactions) and end-organ involvement from pre-eclampsia (or another hypertensive disorder of pregnancy).

Women with a hypertensive disorder of pregnancy often have medical comorbidities for which they are receiving therapy, and women with pre-eclampsia have a multisystem disorder by definition (Table 10.3)[4,5]. Baseline haemoglobin, platelet count, tests of coagulation, renal function and liver enzymes should all be performed whether or not neuraxial analgesia/anaesthesia is considered. The initial results will guide the frequency of further investigations. Also, women with hypertensive disorders of pregnancy (including pre-eclampsia) are often treated with medications that may have implications for anaesthetic management, such as $MgSO_4$ for eclampsia prophylaxis or nifedipine for hypertension (Table 10.4)[6,7].

Table 10.2 Common comorbidities associated with the hypertensive disorders of pregnancy

Comorbidity	*Anaesthetic implications*
Diabetes mellitus	Regular blood glucose monitoring and BP <140/90 mmHg
Chronic hypertension	Consider the possibility of end-organ damage (e.g., renal disease, left ventricular hypertrophy, or coronary artery disease)
Renal disease	Consider the medication(s) given and their doses Avoid non-steroidal anti-inflammatory drugs Seek specialist advice as required (such as for dialysis)
Obesity	Difficulty with non-invasive monitoring (e.g., correct BP cuff size for accurate measurement, challenging venous access) May require invasive monitoring Increased failure/complications associated with neuraxial techniques Increased incidence of airway problems Need for thromboprophylaxis
Anti-phospholipid antibody syndrome	Patient likely to have been on prophylactic heparin therapy throughout pregnancy
Connective tissue disorders	Wide variety of effects that may require specialist advice

BP, blood pressure

ONGOING MONITORING

A basic standard of monitoring should be maintained throughout a woman's hospital stay. At minimum, blood pressure, heart rate, oxygen saturation and level of consciousness should be monitored

Table 10.3 Impact of the systemic effects of pre-eclampsia on anaesthesia

System Effect	*Anaesthetic implications*	*Planning considerations*
Vascular (BP)		
Hypertension	Potential for extreme hypertension during labour, in response to intubation, or during emergence from general anaesthesia	Regular BP monitoring, invasive monitoring may be required Maintain sBP <160 mmHg
Hypotension	Exaggerated hypotension secondary to neuraxial or general anaesthesia given high sympathetic tone Increased sensitivity to vasoactive drugs	Lateral uterine displacement to avoid aorto-caval compression Cautious boluses of ephedrine or phenylephrine to maintain sBP within 10% of patient's baseline
Generalised oedema	Anticipate that generalised oedema may make venous access challenging	May need central line
Airway		
Laryngeal oedema	Increased risk of difficult intubation or ventilation	Early and continuous assessment Anticipate possible need for intervention, and identify experienced assistance if possible Difficult airway equipment should be available Practice 'can't intubate, can't ventilate' drill[4]
Cardiac		
Pulmonary oedema	May require CPAP or invasive ventilatory support Potentially difficult ventilation	Careful input/output monitoring and fluid restriction
Cardiac failure with preserved ejection fraction[5]		Consider non-invasive cardiac monitoring or transthoracic echocardiography Early involvement of intensive care, if indicated
Renal		
Proteinuria	Pulmonary, cerebral, or generalised oedema, even in the absence of nephrotic-range proteinuria	Input/output monitoring
Oliguria		Fluid restriction (to a maximum of 80 mL/h in pre-eclampsia)
Acute kidney injury and electrolyte imbalance	Altered drug clearance Potential arrhythmias	Avoid NSAIDs and other nephrotoxic agents Electrolyte monitoring (including magnesium) and treatment of hyperkalaemia

Hepatic		
Epigastric or RUQ pain Elevated liver enzymes Sub-capsular haematoma or rupture	May have rapidly deteriorating function Mainly haematological implications (see below) May require surgical intervention	Early investigation of RUQ pain Frequent re-assessment of function Preparation for laparotomy if required
Haematology		
Haemolysis Thrombocytopaenia Coagulopathy	Increased risk of neuraxial haematoma with neuraxial techniques Risk of massive haemorrhage May require blood products	Regular platelet monitoring in respect to performing neuraxial anaesthesia Timely removal of epidural catheters, weighing the risk of removal with the risk of leaving the catheter *in situ* Avoid non-steroidal anti-inflammatories if there is thrombocytopaenia Monitor fibrinogen levels during haemorrhage Early advice from haematologists Preparation of blood products if required
Neurology		
Eclampsia or PRES Altered consciousness Stroke Subarachnoid haemorrhage	Emergency management of seizures An ongoing deficit and/or evolving clinical picture may affect informed consent or anaesthetic choice (e.g., if there is raised intracranial pressure)	Seizure prevention preferable (with $MgSO_4$) Avoidance or prompt treatment of severe hypertension Any persistent headache/neurological deficit warrants further investigation
Placenta		
Increased risk of abruption causing DIC	Major obstetric haemorrhage Immediate Caesarean delivery may be indicated	See Haematological system Inadequate time for neuraxial technique

BP, blood pressure; CPAP, continuous positive airway pressure; DIC, disseminated intravascular coagulation; sBP, systolic blood pressure; RUQ, right upper quadrant; PRES, posterior reversible encephalopathy syndrome; NSAIDs, non-steroidal anti-inflammatory drugs; $MgSO_4$, magnesium sulphate

Table 10.4 Pharmacological agents in pre-eclampsia and their impact on anaesthesia

Name of drug	*Effect*	*Anaesthetic considerations*
$MgSO_4$	Eclampsia prevention and treatment	Awareness of potential toxicity and reversal by calcium gluconate Increased risk of Caesarean delivery Prolonged effect of non-depolarising muscle relaxants No proven increase in the need for neonatal resuscitation[6]
Nifedipine	Effective, rapid hypertensive control Prolongation of pregnancy Calcium channel antagonist	Rebound tachycardia on induction of anaesthesia Caution when used with magnesium may have increased antihypertensive and negative inotropic effects
Labetalol	Well tolerated, good hypertensive control Specific alpha 1 and non-specific beta adrenoreceptor antagonist	Avoid in asthmatics Fatigue bronchospasm May cause neonatal hypotension and hypoglycaemia
Hydralazine	Increases intracellular cGMP causing decrease in intracellular calcium producing vasodilation	Tachycardia SLE-like syndrome Peripheral neuropathy with longer term use – assess prior to neuraxial block Delayed hypotension with fetal bradycardia
Alpha methyldopa	Central alpha-2 receptor blocker	May cause bradycardia and haemolytic anaemia
Aspirin	Reduced risk of pre-eclampsia	Low dose (<160 mg/d) should not preclude neuraxial technique in the absence of other clotting abnormalities[7]
Oxytocin	Augmentation of labour Reduced blood loss after delivery	May cause hypotension and should be given slowly and cautiously
Ergometrine	Increases uterine tone after delivery, reduces blood loss	Avoid – may cause severe hypertension
Misoprostol	Increases uterine tone and reduces blood loss after delivery	Hypertension but to a lesser degree than ergometrine
Carboprost	Increases uterine tone after delivery, reduces blood loss	Caution in asthmatics

cGMP, cyclic guanosine monophosphate; $MgSO_4$, magnesium sulphate; SLE, systemic lupus erythematosus

regularly. It is important to stress that postanaesthetic monitoring and documentation should be equivalent to postoperative monitoring seen in non-obstetric surgical patients[8].

Blood pressure monitoring should be frequent (and at times continuous) following neuraxial anaesthesia or general anaesthesia, regardless of the severity of hypertension pre-intervention. It may be appropriate to monitor it continuously using an intra-arterial line which is particularly useful when the woman has a very high systolic blood pressure, a very labile blood pressure, or when it cannot be accurately measured (such as in the obese woman for whom a large cuff is required but which fits poorly due to a short upper arm). An arterial line is also useful when frequent blood sampling is required.

Oliguria is a common finding in women with pre-eclampsia, given high sympathetic tone and intravascular volume depletion. There is currently no way of identifying women who will respond adversely to a fluid challenge with pulmonary oedema, so fluid restriction (i.e., administration of no more than 80 mL/h of intravenous fluid) is recommended in pre-eclampsia. (See Chapter 8 for a more detailed discussion of fluid management.)

Early warning systems – integrating routine observations

'Early warning systems' are red and yellow colour-coded observation charts onto which a patient's routine observations are plotted and

deviations from norms of vital signs, symptoms, or signs are flagged for review. These early warning systems have been used widely to trigger early review of 'at risk' medical and surgical patients and, in some circumstances, have been validated as a means of identifying patients who will require critical care[9].

There is growing enthusiasm for the use of early warning systems to monitor women in pregnancy and postpartum. Although evidence is lacking to fully support the implementation of early warning systems in maternity care, it seems logical that a standardised mechanism to enable early detection and appropriate reporting of the 'at risk' parturient is a prerequisite to reducing maternal morbidity and mortality[1]. Table 10.5 presents one published example of a Modified Early Obstetric Warning Systems (MEOWS), with one reading within the 'red zone' or two within the 'yellow zone' triggering urgent review by a consultant[10].

Central venous catheters

Central venous pressure (CVP) correlates poorly with left atrial pressures in severe pre-eclampsia, making absolute values of CVP measurements inaccurate[11]. However, central venous access may be required for the safe delivery of vasoactive drugs or if generalised oedema makes peripheral access impossible. Under those circumstances, the inserted central venous line may be used to measure *trends* in CVP as a guide to a woman's response to any fluid administered.

Although pulmonary artery catheters are the gold standard for measurement of left and right ventricular filling pressures, there is no evidence from randomised controlled trials to support their use in pre-eclampsia[12]. This is unlikely to change owing to the highly invasive nature of the intervention, the significant risk of complications, and the lack of physicians skilled in pulmonary arterial catheter insertion given their infrequent use.

Transthoracic echocardiography

Transthoracic echocardiography (TTE) provides a quick, non-invasive, accurate assessment of fluid status and contractility[5,13]. Right heart pre-load can be estimated from right and left ventricular end-diastolic volumes, and variations in inferior vena caval diameter with spontaneous respirations. As anaesthetists become more skilled in TTE use, there is potential to have additional information with which to care for women with hypertensive disorders of pregnancy.

Minimally invasive cardiac output monitoring devices

There is increasing availability of devices to estimate cardiac output at the bedside (e.g., PiCCO, LiDCO, FloTrac/Vigileo systems) and these are used widely in intensive care settings for non-pregnant patients. Although most techniques require that patients be undergoing positive pressure ventilation for accurate results, these devices may provide information about trends that can be used to guide fluid replacement when neuraxial anaesthesia is used. At present, unlike TTE[14], use of non-invasive cardiac output assessment has not been validated for use in maternity care.

Other

The addition of end tidal carbon dioxide monitoring is mandatory during general anaesthesia.

LABOUR ANALGESIA

Maternal pain has physiological effects that may be harmful to the mother and her fetus(es). Pain is associated with increased maternal cardiac output and blood pressure[15–17]. Maternal pain is also associated with the following effects that can harm the fetus: (1) respiratory alkalosis (that can shift the maternal haemoglobin-oxygen dissociation curve to the left and reduce oxygenation of umbilical venous blood, as well as cause vasoconstriction and restrict uterine artery blood flow); (2) compensatory metabolic acidosis (that is readily transferred to the fetus); and (3) release of catecholamines that are associated with uncoordinated uterine contractions[18].

Labour analgesia may benefit the hypertensive parturient by attenuating the pain-induced sympathetic response that may contribute to uncontrolled hypertension. In the past, lay individuals and some health care providers assumed that any form of medicinal pain relief was deleterious to the fetus. However, studies focusing on parameters of fetal well-being such as acid–base status, Apgar scores, fetal oxygen saturation and perinatal mortality have demonstrated that effective maternal pain relief (such as with epidural analgesia) is *beneficial* rather than harmful[18].

Table 10.5 Parameters to trigger a response in an early warning system. (Adapted from CEMACH recommended early warning system[10])

	Red trigger		*Yellow trigger*	
Observation	*Low*	*High*	*Low*	*High*
Systolic BP (mmHg)	<90	>160	90–100	150–160
Diastolic BP (mmHg)	—	>100	–	90–100
Heart rate (beats per minute)	<40	>120	40–50	100–120 or 40–50
Respiratory rate (breaths per min)	<10	>30	–	21–30
Oxygen saturation (%)	<95	Not applicable	–	Not applicable
Temperature (degrees C)	<35	>38	35–36	–
Pain score	Not applicable	–	Not applicable	2–3
Neurological response	Unresponsive, but responds to pain	Not applicable	Depressed responsiveness, but responds to voice	–
Lochia	Foul smelling	–	Not applicable	–
Proteinuria >2+	>2+	–	Not applicable	–
Amniotic fluid	Green	–	Not applicable	–
Looks unwell	Not applicable	–	Yes	–

BP, blood pressure

Labour analgesia can be provided pharmacologically through three different forms of administration: inhalation, parenteral (by intravenous (IV) or intramuscular (IM) injection), or neuraxial.

Inhalation analgesia

Inhalation analgesia is not used commonly with the exception of the 50:50 mix of nitrous oxide/oxygen (N_2O/O_2). The benefits of N_2O/O_2 include minimal placental transfer, minimal haemodynamic effects, and rapid onset and offset of analgesia. Disadvantages described include nausea and vomiting, and maternal sedation. A meta-analysis summarised the effectiveness of analgesia in 19 randomised controlled trials that compared N_2O/O_2 with other forms of analgesia – placebo, other gases and mixtures, or transcutaneous nerve stimulation (TENS)[19]; 17 of these studies were of poor quality and two of fair quality. In the N_2O/O_2 arms, maternal satisfaction with analgesia ranged from 30 to 80%. In a prospective cohort study of good quality, 54% of women who had had N_2O/O_2 were satisfied with their pain relief compared with 94% of women who received epidural analgesia[19].

Some hospitals have N_2O/O_2 'piped-in' to labour and delivery areas. Those that provide the 50:50 mixture in tanks should ensure that the tanks are stored and handled correctly to ensure that the correct mixture is delivered. When administering the N_2O/O_2 mixture, a demand valve system should be used to ensure that further gas will not be delivered if the woman becomes drowsy. Also, the room in which inhalational analgesia is used should be well ventilated and, ideally, there should be a system for scavenging waste gases. Simple scavenging systems can be made by connecting a corrugated tube that collects the exhaled gases to a vent or exhaust system.

Many centres no longer use N_2O/O_2 given these environmental concerns and the perceived lack of efficacy[20].

Parenteral analgesia

Parenteral analgesia is administered commonly in many centres where neuraxial analgesia is not readily available.

Historically, pethidine (meperidine) has been the opioid of choice for labour analgesia, but this practice has changed with the recognition that pethidine has both adverse fetal and neonatal side-effects, including depression of fetal muscular activity, reduction in fetal aortic blood flow, decreased short-term fetal heart rate variability, low Apgar scores, neonatal respiratory depression, reduced neonatal neurobehavioural scores, and weak suckling that could affect breastfeeding[18]. Of note, neonatal side-effects may occur up to 72 hours after birth owing to accumulation of pethidine's active metabolite, norpethidine.

The fact remains, however, that all opioids administered parenterally have undesirable maternal and neonatal side-effects. However, IM-administered opioid (pethidine, tramadol, or diamorphine) is not particularly effective compared with placebo[21], making IV opioid administration the route of choice.

When used during early labour, morphine and fentanyl have minimal neonatal effects. However, owing to their long half-lives, neither drug is recommended for routine use in advanced stages of labour or during delivery, as maternal sedation and neonatal respiratory depression may result[21].

Remifentanil is an ultra short-acting opioid that has been investigated for use in IV patient-controlled labour analgesia (PCA). In one meta-analysis of three studies (233 subjects), remifentanil (compared with pethidine) was more effective (as measured by a reduction of mean visual analogue scale scores for labour pain after 1 hour) and associated with higher patient satisfaction[22]. In another meta-analysis that reviewed 12 randomised controlled trials (2001–2011) comparing remifentanil with any other form of labour analgesia[23], 269 women received remifentanil, 209 pethidine, 10 nitrous oxide and 54 epidural analgesia. Remifentanil (compared with pethidine) provided superior analgesia, better patient satisfaction, and lower conversion rates to epidural analgesia[23]. However, compared with epidural analgesia, remifentanil was associated with poorer pain control as well as maternal respiratory depression (defined as a maternal oxygen saturation <95%); long-term adverse neonatal effects were not increased[23].

In summary, parenteral opioids should be used when neuraxial analgesia is contraindicated or unavailable. When parenteral opioids are used, careful attention must be paid to maternal respiration and oxygen saturation, and neonatal resuscitation may be required.

Neuraxial analgesia

Neuraxial analgesia provides the highest quality of pain relief and can be obtained through four different techniques: epidural, combined spinal-epidural, continuous spinal, or 'single-shot' spinal anaesthesia (Figure 10.1). Neuraxial analgesia/anaesthesia is contraindicated when: (1) the patient refuses to consent; (2) there is infection at the proposed site of insertion of the catheter or there is evidence of systemic infection; (3) there is haemodynamic compromise (severe hypotension); or (4) there is evidence of coagulopathy (see Table 10.6, discussed below)[24].

Neuraxial anaesthesia/analgesia may be contraindicated in women with pre-eclampsia owing to the presence of coagulopathy. There is debate about the lowest platelet count that is safe for neuraxial anaesthesia, even in normotensive patients[25]. Many anaesthetists will administer neuraxial anaesthesia when the platelet count is >75,000/mm^3 and relatively stable, and there is no clinical evidence of coagulopathy. Not only do platelets need to be sufficient for insertion of a neuraxial catheter, they need to be sufficient at the time of catheter removal. In all cases, the risk–benefit profile of removal versus leaving the epidural *in situ* needs to be addressed. In some cases of pre-eclampsia, the platelet count may take days to normalise; therefore, the risk of epidural infection or trauma from the catheter may outweigh the risk of neuraxial haematoma. Also, as a decreased platelet count may be an indication of disseminated intravascular coagulation (possibly secondary to placental abruption) or other co-existing conditions, one has to consider the relative merits of providing neuraxial anaesthesia with the potential risk of a neuraxial haematoma in each individual patient[26].

Epidural analgesia

Maternal pain can be treated effectively with epidural analgesia, without an associated increase in adverse fetal or neonatal effects among normotensive or hypertensive women[15,27]. In fact, when given to normotensive women, epidural analgesia (compared with either no labour analgesia or opioids, as discussed above) was associated with *better* fetal acid–base status and neonatal Apgar scores[18].

Table 10.6 Coagulation and neuraxial anaesthesia (reproduced from Magee *et al. J Obstet Gynaecol Can* 2014;36: 416–441, with permission)

Treatment with ASA or heparin	*Normal platelet count*	*Low platelet count & normal INR and aPTT*	*Abnormal INR or aPTT (regardless of platelet count)**
None *or* Low dose ASA	✓	✓ if platelets >75 × 10⁹/L Unclear if platelets 50–75 × 10⁹/L X if platelets <50 × 10⁹/L	
UFH			
≤10,000 IU/d (SC)	✓ 0–4 h after last dose	Unclear	X Contraindicated
>10,000 IU/d (SC)	✓ 4 h after last dose and aPTT normal	Unclear	
Therapeutic dose (IV)	✓ 4 h after last dose and aPTT normal	Unclear	
LMWH			
Prophylactic dose†	✓ 10–12 h after last dose	Unclear	
Therapeutic dose‡	✓ 24 h after last dose	Unclear	
Low dose ASA + prophylactic UFH or LMWH**	Unclear††	Unclear	

ASA, aspirin; aPTT, activated partial thromboplastin time; INR, international normalised ratio;LMWH, low molecular weight heparin; SC, subcutaneous; UFH, unfractionated heparin
These recommendations are based on the absence of a rapidly falling platelet count or KNOWN platelet dysfunction (e.g., von Willebrand's disease)
* Other than a lupus anticoagulant
† Prophylactic dosing is defined as ≤10,000 IU/d
‡ Therapeutic dosing (SC) is defined as >10,000 IU/d
** Prophylactic doses of unfractionated heparin are defined as ≤10,000 IU/d
†† Unless ASA is stopped 7 days or more before delivery

Among hypertensive pregnant women, epidural analgesia attenuates pain-induced elevations in blood pressure and cardiac output[16], as well as providing an option for neuraxial anaesthesia should urgent/emergent Caesarean delivery be necessary for maternal or fetal reasons. An extension of this effect is the potential for hypotension among women with pre-eclampsia who have systemic vasoconstriction and intravascular volume depletion. Although most studies have demonstrated no hypotension among women with pre-eclampsia compared with normotensive women[27–29], a recent retrospective controlled cohort study (200 women, 100 with severe pre-eclampsia) did demonstrate more frequent hypotension, late decelerations and vasopressor administration following epidural analgesia compared with normotensive controls[30]. Although this study did not use hypertensive controls provided with alternative analgesia, or ideally, randomise women, it highlights the theoretical risk of neuraxial-related hypotension among women with 'severe' pre-eclampsia.

It is of particular note that even among women with severe pre-eclampsia, epidural analgesia/anaesthesia does not increase the risk of Caesarean delivery[31].

Medications administered through the epidural catheter consist of a combination of a low-dose local anaesthetic (e.g., bupivacaine 0.08%) and an opioid (e.g., fentanyl 2 μg/mL) that provides effective labour analgesia with minimal haemodynamic effect.

Combined spinal-epidural analgesia

Combined spinal-epidural analgesia (CSE) combines the advantages of spinal analgesia (i.e., rapid onset of

pain relief and good analgesia from the insertion of medications into the subarachnoid space) with those of epidural analgesia so that one can provide ongoing continuous pain relief[32]. CSE analgesia is an acceptable technique for labour analgesia and anaesthesia, but there is some evidence that the use of intrathecal opioids may lead to transient fetal bradycardia (odds ratio 1.8, 95% confidence interval 1.0–3.1)[33,34]. This fetal bradycardia does not lead to the need for emergency Caesarean delivery (6.0% versus 7.8% for any non-intrathecal opioid technique)[34]. The proposed mechanism is that the rapid onset of analgesia causes a rapid decrease in beta-adrenergic agonists leading to a predominance of alpha activity. As a result, there is increased uterine contractility and reduced uteroplacental perfusion, with subsequent fetal bradycardia[34].

Continuous spinal analgesia

Continuous spinal analgesia (CSA) is more effective than epidural analgesia, as the medications for analgesia (opioid and local anaesthetic) are injected directly into the subarachnoid (intrathecal) space around the spinal cord and cauda equina. This technique is performed by inserting a needle directly into the subarachnoid space and then threading a catheter through that needle. Visual confirmation of cerebrospinal fluid in the hub of the needle identifies correct placement of the needle in the subarachnoid space (prior to insertion of the catheter), making it an easier technique to learn and perform in contrast to inserting a needle into the epidural space where loss of resistance is used to identify the space.

CSA is used in some patient populations as an initial labour analgesia technique (e.g., morbid obesity) as there is a defined end-point (i.e. cerebrospinal fluid) when the space is identified. One of the concerns in identifying the epidural space is that one might inadvertently puncture the dura, but obviously that is not a concern when one is deliberately puncturing it. Increasingly, CSA is used as a rescue technique after accidental dural puncture has occurred inadvertently during attempted epidural insertion; attempting again to identify the epidural space may result in multiple attempts and a second dural puncture.

CSA has the same side-effect profile as epidural analgesia, including risk of postdural puncture headache (see below). However, CSA is associated with a greater risk of neuraxial infection, as the catheter is in the subarachnoid space and cerebrospinal fluid is an excellent culture medium. Similar to the CSE technique, injection of intrathecal opioids may result in transient fetal bradycardia (see above). In addition, there is greater potential for drug error owing to the injection of medication, intended for the epidural space, through the spinal catheter (because the same type of catheter may be used by most anaesthetists for both techniques). As less medication is required in the subarachnoid space (1–2 mL) than in the epidural space (10–20 mL), inadvertent injection of medication intended for the epidural space into the subarachnoid space can result in a high anaesthetic block and cardiovascular and respiratory impairment. This mandates that an intrathecal catheter for CSA be well labelled and that information is communicated to all care givers that the catheter is intrathecal.

Although controversial, animal studies suggest that use of an indwelling spinal catheter may be associated with a lower incidence of postdural puncture headache. Although two recent meta-analyses did not find a lower incidence of postdural puncture headache in an intrathecal catheter group, compared with a group that had the epidural reinserted, nevertheless, fewer women in the intrathecal catheter group required an epidural blood patch[35,36].

'Single-shot' spinal analgesia

Low dose, single-shot spinal analgesia is easy to perform and provides rapid pain relief of a limited duration, depending on the medications used (i.e., 1–3 hours)[37,38]. This technique is used occasionally in women who are expected to deliver within an hour (because, for example, they are at full cervical dilatation).

Single-shot spinal analgesia is the neuraxial technique that uses the smallest needle (i.e., 24 gauge or smaller, compared with 16–18 gauge needles with other techniques). Some anaesthetists consider the single-shot spinal technique safer than the epidural technique, as the incidence of postdural puncture headache is lower and there is potentially less risk of trauma to neuraxial blood vessels[39,40]. However, the potential adverse effects are similar to combined spinal-epidural, and include maternal hypotension (that is dose-dependent) and fetal bradycardia[34].

CAESAREAN DELIVERY

Cesarean delivery is common, and particularly so among women with pre-eclampsia given uteroplacental dysfunction and the need to deliver some such women at early gestational ages.

Table 10.7 presents the principles of managing an anaesthetic in women with a hypertensive disorder of pregnancy. All neuraxial anaesthetic techniques are appropriate to consider, even in the woman with eclampsia. Among 66 conscious women who had suffered eclampsia but were stable, no major complications occurred in the 37 who underwent epidural anaesthesia and the 27 who underwent general anaesthesia, although the 1-minute Apgar score was higher in the epidural group (related to the temporary depressive effects of the medication used for general anaesthesia)[41]. This latter finding is not unexpected as babies born to healthy mothers having general anaesthesia have a lower 1-minute Apgar that recovers by 5 minutes. Factors that influence anaesthetic choice include the need for an emergent Caesarean delivery owing to maternal or fetal concerns, any contraindication to neuraxial anaesthesia, the presence of an existing epidural or spinal catheter in a labouring woman, and maternal choice.

General anaesthesia

The indications for general anaesthesia are similar to those in the general obstetric population. (For further details about mode of delivery, see Chapter 9.) These indications include insufficient time to induce neuraxial anaesthesia (generally owing to fetal concerns or maternal haemodynamic instability) or contraindication(s) to neuraxial anaesthesia, including coagulopathy (Table 10.6), systemic infection, cardiovascular instability, failure to obtain consent, and allergy to any of the anaesthetic agents.

The challenges associated with general anaesthesia are similar to those in normotensive women but the risks may be higher in women with pre-eclampsia. These challenges include the possibility of a difficult airway or failed intubation, the hypertensive response to endotracheal intubation, and haemodynamic instability. If a woman is comatose and has increased intracranial pressure, any further increase in blood pressure during intubation could cause irreversible brain damage. Similarly a drop in blood pressure secondary to sympathetic block with neuraxial anaesthesia, could compromise cerebral perfusion[42]. The risks associated with pulmonary aspiration secondary to gastric regurgitation have declined due to the almost universal administration of aspiration prophylaxis (with histamine$_2$ receptor antagonists and prokinetic agents) and 'nothing by mouth' policies once the possibility of Caesarean delivery is raised.

Difficult airway

Although obstetric anaesthetists are concerned about the risks of difficult or failed intubation in any parturient undergoing general anaesthesia, this is a particular concern in women with pre-eclampsia because they may have airway oedema[43,44]. Airway difficulties are responsible for a substantial part of the increased maternal morbidity and mortality associated with general anaesthesia in women with pre-eclampsia[45]. The Obstetric Anaesthetists' Association and the Difficult Airway Society of the UK have published guidelines for the management of difficult and failed intubation in obstetrics[46]. The algorithms and tables which summarize the management of this situation are available on the websites of the OAA[47] and the DAS[48].

Hypertensive response to intubation

In normotensive and hypertensive patients, tracheal intubation may trigger an increase in heart rate and blood pressure[49]. In women with a hypertensive disorder of pregnancy, this hypertensive response may precipitate severe hypertension and an adverse cerebrovascular event (e.g., stroke). As such, it is important to make every effort to attenuate this hypertensive response.

Various pharmacologic approaches to prevention of the hypertensive response to tracheal intubation have been studied in non-obstetric patients, with fewer studied in pregnancy. Randomised controlled trials have compared various agents (with or without control therapy) in patients with pre-eclampsia of various severity. These agents have included opioids (i.e., alfentanil, fentanyl, remifentanil), antihypertensive agents (i.e., nitroglycerin, labetalol, nifedipine), magnesium and lidocaine. The number of subjects in the individual studies were small and the patient populations were heterogeneous; although most women had received antihypertensive medications preoperatively, others had not and not all were

Table 10.7 Principles of anaesthetic management for Caesarean delivery in women with a hypertensive disorder of pregnancy

Stabilise the woman's BP prior to surgery, if possible. If the BP is severely elevated and uncontrolled, the risks of anaesthesia and surgery will have to be balanced against any potential benefits
Aim for haemodynamic stability perioperatively (avoid hypotension/hypertension)
For spinal anaesthesia, use the smallest available spinal needle, e.g., 24-gauge or smaller, preferably with a pencil point in order to decrease the risk of postdural puncture headache
Consider prophylactic phenylephrine infusion to prevent hypotension during neuraxial anaesthesia (possibly use lower dose than for normotensive parturients)
Avoid a hypertensive response to intubation during general anaesthesia by administering an opioid, remifentanil (0.0–1.0 μg/kg) or fentanyl (50–150 μg), with or without labetalol (20 mg followed by 10 mg increments until the dBP is decreased to <100 mmHg or mean arterial BP has decreased by 20% from baseline) prior to induction with an adequate dose of thiopental (5–7 mg/kg) or propofol (2–3 mg/kg). Esmolol (1.5 mg/kg) or nitroglycerin (2 μg/kg) combined with propofol (2 mg/kg) have been recommended[56]
Monitor: • Standard monitors: electrocardiogram, non-invasive BP, oxygen saturation with the addition of temperature and end tidal CO_2 for general anaesthesia • Consider intra-arterial BP monitoring if woman requires repeated blood sampling or there is difficulty controlling BP
Administer oxytocin as an infusion, rather than as a bolus

BP, blood pressure; dBP, diastolic blood pressure; MAP, mean arterial pressure

receiving magnesium. The agents and doses for induction of anaesthesia also varied.

These studies are presented in detail in Appendix 10.1[50–60]. The bottom-line is that the differences in the protocols of these studies make it difficult to draw firm conclusions as to the best method of attenuating the hypertensive response to intubation, in terms of the individual agent, combination of agents, and/or dose(s). Further study is needed of this important topic. In the meantime, a prudent approach would be to ensure that an optimum dose of an induction agent is used (e.g., thiopental 5–7 mg/kg or propofol 2–3 mg/kg) as well as an opioid. There is little to choose between the opioids, but the advantages of rapid onset and offset of remifentanil suggest it be used in a dose of 1 μg/kg, where it is available. Alfentanil (10 μg/kg) and fentanyl (50–100 μg) are alternatives to remifentanil. As most women with pre-eclampsia will be on magnesium, further magnesium should not be given. However, one could consider administering a loading dose of magnesium pre-induction in the circumstance where it has not been given. Sublingual nifedipine 10 mg or labetalol (20 mg loading dose followed by 10 mg increments) to control blood pressure preoperatively are other possible agents. Caution should be exercised, however, as many women with pre-eclampsia may already be on antihypertensive medication; additional antihypertensive medication may lead to hypotension.

Non-depolarising muscle relaxants

Non-depolarising muscle relaxants are used to produce muscle relaxation to facilitate surgery and mechanical ventilation. In women with pre-eclampsia, the combination of a standard dose of a non-depolarising muscle relaxant and $MgSO_4$ results in prolonged motor block[61], so many consider $MgSO_4$ to be a relative contraindication to the use of a non-depolarising muscle relaxant. If this combination of therapies cannot be avoided, the dose of the non-depolarising muscle relaxant must be titrated carefully according to monitoring by a peripheral nerve stimulator[62]. Calcium gluconate (or, alternatively, calcium chloride) is the antidote to magnesium and can be used if prolonged neuromuscular block occurs.

Haemodynamic management (i.e., hypotension and hypertension)

Maintenance of a stable blood pressure is key to the successful management of women with a hypertensive disorder of pregnancy. Ideally, the blood pressure will have been stabilised prior to the need for Caesarean delivery. Thereafter, assuming a baseline blood pressure that is <160/110 mmHg (i.e., not severely elevated), one should strive to avoid both falls and rises in blood pressure relative to that baseline.

Maternal blood pressure can be monitored during Caesarean delivery either non-invasively or invasively. If blood pressure monitoring is undertaken non-invasively, the cuff size has to be appropriate for the size of arm. (For more information, see Chapter 1.) Shivering, which often occurs in women having neuraxial anaesthesia (either epidural or spinal), may interfere with non-invasive blood pressure monitoring. Placing the cuff on the wrist (rather than on the upper arm) may decrease interference, although blood pressure measurements taken in this fashion would be used to evaluate trends in blood pressure as wrist measurement is known to overestimate blood pressure[63]. Invasive blood pressure monitoring achieved by insertion of an arterial line can provide continuous measurement when blood pressure proves difficult to stabilise, and provides the added benefit of allowing repetitive blood sampling.

Some authors suggest that it is more important to focus on cardiac output, rather than blood pressure, during neuraxial anaesthesia for Caesarean delivery in women with severe pre-eclampsia[64]. This can be done using minimally invasive cardiac output monitors[64,65] or transthoracic echocardiography[5], as discussed above. The authors who recommend the use of cardiac output suggest that it reflects uterine perfusion better than arterial blood pressure, but this is controversial[66].

For many years, anaesthetists routinely administered an intravenous bolus (1000–2000 mL) of crystalloid prior to neuraxial block for Caesarean deliveries to avoid hypotension. As most crystalloid intravenous fluid exits the vascular system within 20 minutes of administration, this therapy is ineffective[67,68]. Most authorities now recommend limiting the amount of intravenous fluid (unless there is ongoing bleeding) in healthy women, administering fluid as a co-load (i.e., administering intravenous fluid after rather than before induction of spinal anaesthesia)[69–71]. Hypotension is avoided and/or treated through the use of vasopressors (generally phenylephrine). (For further discussion on fluid management, see Chapter 8.)

Vasopressors

In normotensive women, phenylephrine has become the vasopressor of choice to prevent and/or treat hypotension, given its rapid onset and offset that allow for moment-to-moment control of blood pressure[66,72]. Ephedrine's popularity as a vasopressor in the setting of neuraxial anaesthesia declined following a study comparing prophylactic infusions of ephedrine and phenylephrine in elective Caesarean deliveries. This study found that umbilical arterial pH was significantly lower in the group receiving the ephedrine (vs. phenylephrine) infusion, even in the presence of good blood pressure control[66,72].

In women with pre-eclampsia, there are no studies comparing ephedrine with phenylephrine to prevent or treat hypotension. Although the majority of studies of neuraxial block for Caesarean delivery in women with pre-eclampsia used ephedrine as the vasopressor, the literature is not extensive (as summarised in Appendix 10.2). A prudent approach would be to start with a lower dose of medication (either ephedrine 3–5 mg bolus or phenylephrine 25–50 μg bolus) than one would for normotensive women and titrate the dose to the blood pressure[13].

Neuraxial anaesthesia

Neuraxial anaesthesia and hypotension

Henke *et al.* reviewed prospective studies that compared haemodynamic changes following spinal anaesthesia, or CSE anaesthesia, with epidural and/or general anaesthesia for Caesarean delivery in severe pre-eclampsia[68]. They reported on three trials that studied the haemodynamic changes after spinal anaesthesia for non-emergency Caesarean delivery, comparing women with severe pre-eclampsia (N = 115) with normotensive women (N = 121). In all three of these studies, the group with severe pre-eclampsia had a lower incidence of hypotension and required less ephedrine to treat hypotension than did the normotensive controls[68]. In two of these studies, many of the women with severe pre-eclampsia delivered at an earlier gestational age (lower fetal weight), raising the possibility that women with severe pre-eclampsia had less hypotension because their fetuses were smaller and caused less aortocaval compression[73,74]. Therefore, the third study compared normotensive women delivering at an earlier gestational age (fetal weight was similar); once again, the incidence of hypotension requiring treatment was lower in the pre-eclampsia group ($p < 0.03$).

In addition to the three studies identified by Henke *et al.*, a study by Tihtonen *et al.* used

non-invasive whole-body impedance cardiography to assess the impact of spinal anaesthesia for Caesarean delivery on maternal haemodynamics in women with pre-eclampsia (N = 10; 6 were severe) with comparative data from a historic cohort of normotensive (N = 10) women[75]. The incidence of hypotension differed between the groups (normal = 80% vs. pre-eclampsia = 30%). Women with pre-eclampsia had a low cardiac index and high systemic vascular resistance index preoperatively and, while cardiac index remained stable after induction of spinal anaesthesia, systemic vascular resistance index decreased. Following delivery, the mean cardiac index increased due to an increase in heart rate (with no associated increase in stroke index). The authors raised the possibility that women with pre-eclampsia were unable to increase stroke index and that this might increase the risk of pulmonary oedema[75]. One observational study looked at cardiac output using minimally invasive monitoring in 15 women with severe pre-eclampsia undergoing Caesarean delivery under spinal anaesthesia[65]; there was a modest afterload reduction with minimal cardiac output change following spinal anaesthesia in women with severe pre-eclampsia. This led them to conclude that spinal anaesthesia is associated with adequate haemodynamic stability[65].

Spinal anaesthesia versus epidural anaesthesia in women with pre-eclampsia

Two prospective studies compared epidural anaesthesia (N = 57) with spinal anaesthesia (N = 64) in women with severe pre-eclampsia[76,77]. The larger of these studies found a higher incidence of hypotension (systolic blood pressure <100 mmHg) in the spinal group compared with the epidural group (51% vs. 23%) but the duration of hypotension was short (median 1 min vs. 0 min). From induction of anaesthesia to delivery of the fetus, there was a significant difference in the lowest systolic blood pressure ($p < 0.001$), diastolic blood pressure ($p < 0.005$) and mean blood pressure ($p < 0.001$) between the epidural and spinal groups. The total dose of ephedrine to treat hypotension, although greater in the spinal group, was nevertheless small (12 mg – spinal; 6 mg – epidural)[76]. The smaller study (total of 21 subjects) found a similar incidence of hypotension and ephedrine dose between the two groups[77].

In addition to these prospective studies identified by Henke *et al.*, there have been two retrospective studies comparing spinal with epidural anaesthesia[78,79]. The study by Hood *et al.* looked at women with severe pre-eclampsia who received spinal anaesthesia (N = 103) or epidural anaesthesia (N = 35) for Caesarean delivery[78]. Similar to the prospective studies, the lowest mean blood pressure and ephedrine use were similar between the groups. In a similar retrospective study, the incidence of hypotension and ephedrine use were similar between spinal (N = 70) and epidural (N = 51) anaesthesia in women with pre-eclampsia[79]; the only difference in this study was that there were some women in each group who were classified as having mild-moderate pre-eclampsia (41 in the spinal group vs. 18 in the epidural group).

Only one prospective study compared CSE (N = 27) with epidural (N = 27) and general anaesthesia (N = 26)[80]. It is important to note that the dose of hyperbaric bupivacaine administered in the spinal component of the CSE in this study is similar to that used by many anaesthetists for single-shot spinal (11 mg). The authors do not report on whether the CSE group required epidural top-up doses but given the intrathecal dose, one could consider this group as receiving spinal anaesthesia. Blood pressure was lower at the time of skin incision ($p < 0.003$) and treatment with ephedrine boluses was higher in the CSE and epidural groups (compared to the general anaesthesia group) (0 mg general anaesthesia vs. 8 mg epidural vs. 6 mg CSE) ($p < 0.009$). As well, significantly more IV fluid was administered in the neuraxial groups (2387 ± 110 epidural, 2255 ± 102 mL spinal) compared to the general anaesthetic (1537 ± 101 mL) group ($p < 0.001$)[80].

Spinal anaesthesia (CSE) versus general anaesthesia in women with pre-eclampsia

In Henke *et al.*'s review[68] there was one study that compared general anaesthesia (N = 35) to spinal anaesthesia (N = 35) (other than for the Wallace study that used CSE, rather than single shot spinal)[81]. The primary outcome in this study was umbilical arterial base deficit; they considered a difference of >8 mEq/L to be clinically significant[81]. Of note, this study was done in women undergoing emergent Caesarean delivery for a non-reassuring fetal heart rate. Although there was a higher base

deficit (7.1 vs. 4.7 mEq/L, $p = 0.02$) and lower median umbilical artery pH (7.20 vs. 7.23, $p = 0.046$) in the spinal group compared to the general anaesthesia group, the authors felt that the clinical significance was uncertain, as there was no difference in requirement for neonatal resuscitation[81]. As with other studies, the dose of ephedrine used to treat hypotension was higher in the spinal group (14 vs. 8 mg, $p = 0.002$). The dose of ephedrine did not correlate with umbilical artery base deficit.

In conclusion, spinal anaesthesia is considered to be safe in women with severe pre-eclampsia, providing there are no contraindications to its use (such as coagulopathy). More research is needed in this area, particularly with respect to vasopressor use. Although phenylephrine is used by most anaesthetists for prophylaxis and treatment of hypotension in normotensive women receiving neuraxial anaesthesia, only one study used phenylephrine to treat hypotension[65]; the rest used ephedrine. Studies are required comparing phenylephrine with ephedrine in women with severe pre-eclampsia.

Spinal anaesthesia

Spinal (vs. epidural) anaesthesia provides more rapid onset, more profound block, and a lower incidence of patchy/failed anaesthesia[82]. Also, if a blood vessel is in advertently punctured during spinal anaesthesia, the hole is smaller than that from an epidural needle, potentially decreasing the risk of a neuraxial haematoma.

In the past, spinal anaesthesia was considered to be contraindicated in women with pre-eclampsia owing to the fear of precipitating potentially fatal hypotension. However, several randomised controlled trials of women with pre-eclampsia have shown that the incidence of hypotension following spinal anaesthesia is actually *lower* than among healthy women, and that hypotension is easier to treat[73,74,83].

Some anaesthetists now use continuous spinal anaesthesia for Caesarean delivery. With continuous spinal anaesthesia, the local anaesthetic can be titrated to achieve the desired level of anaesthesia. Although spinal microcatheters (27–32 gauge) have been used in the past for continuous spinal anaesthesia, many anaesthetists now use a macrocatheter (20–22 gauge epidural catheter) as it is easier to insert than the microcatheter. Not only will some anaesthetists insert a standard epidural catheter if an accidental dural puncture occurs during attempted epidural or CSE anaesthesia, but some will electively insert it in a patient when difficulty with insertion is anticipated, such as a morbidly obese parturient. Potentially, continuous spinal anaesthesia using a macrocatheter carries a greater risk of postdural puncture headache and neuraxial haematoma, than when single-shot spinal anaesthesia is done with a smaller needle, although this is controversial.

Epidural anaesthesia

Epidural anaesthesia is not used commonly for Caesarean delivery unless the woman already has an epidural catheter in place for labour analgesia. The larger epidural needle, the slower onset of anaesthesia, the higher incidence of shivering, and the higher incidence of patchy/failed anaesthesia are potential disadvantages of epidural anaesthesia. The major advantage of epidural anaesthesia, compared to single-shot spinal anaesthesia, is the slower onset of sympathetic block, making it easier to titrate vasopressors to avoid/treat hypotension.

Combined spinal–epidural analgesia

CSE combines the advantages and disadvantages of spinal and epidural anaesthesia. Some studies suggest that combined spinal-epidural is advantageous in women with pre-eclampsia as one can use a lower intrathecal dose to initiate anaesthesia and then use the epidural catheter to adjust the height of the block[84,85]. The effective dose of medication does not appear to be different in women with (as opposed to those without) pre-eclampsia[86].

Local anaesthetic infiltration

Rarely general anaesthesia and neuraxial anaesthesia may not be available for Caesarean delivery owing to a lack of anaesthetic services or contraindications to both techniques related to the parturient's underlying disease. Under these circumstances, the only option is for the obstetrician to infiltrate the layers of the wound with local anaesthetic[87,88]. This technique uses a dilute concentration of local anaesthetic (e.g., 0.5% lidocaine) combined with epinephrine (i.e., 1:200,000) to limit absorption

and decrease the risk of local anaesthetic toxicity. As there is less dense anaesthesia, the surgeon has to handle the tissues gently or the patient will complain of pain.

Other considerations

Ergometrine is contraindicated in women with pre-eclampsia.

Oxytocin is usually administered after delivery of the baby to prevent postpartum haemorrhage. However, oxytocin should be administered by infusion and carefully titrated to effect[13]. Oxytocin should not be administered by bolus injection; using continuous minimally invasive haemodynamic monitoring in 18 women with 'severe' pre-eclampsia, 5 IU of oxytocin by IV bolus was associated with an increase in heart rate, increase in systemic vascular resistance, and fall in blood pressure[89]. Five of the 18 women had a decrease in cardiac output as they could not increase their stroke volume.

POSTPARTUM ISSUES

It is essential that postpartum, anaesthesia assesses every woman who has received anaesthetic care for potential complications and pain control. In women whose labour and delivery was uncomplicated, little or no analgesia may be required, but those who have had a long, difficult labour or operative delivery may require a more complex plan.

Anaesthetic complications – early and delayed

Depending on the type of anaesthesia given, there is a range of complications that need to be addressed should they arise in the postoperative period.

Early

In the immediate postoperative period, respiratory depression, labile blood pressure, oxygen desaturation and cardiac changes can all occur. The woman should be closely monitored in a recovery unit by someone trained in recovery care until the patient is fully awake (i.e., able to appropriately answer questions and maintain her own airway) and stable from a cardiovascular perspective[8]. The type of monitoring should include, at minimum, measurement of blood pressure non-invasively, heart rate, oxygen saturation and level of consciousness. Also, as most women undergoing general anaesthesia will have received a neuromuscular blocking agent, it is important to monitor return of neuromuscular function. Several maternal deaths have occurred in the immediate postoperative period secondary to respiratory failure (sometime owing to inadequate reversal of neuromuscular blockade[90].

While postoperative nausea and vomiting may occur following neuraxial opioids, they are more likely to occur following general anaesthesia and postoperative orders should include provision for administration of anti-emetic medications.

The challenge of balancing the need to induce general anaesthesia rapidly for the sake of the fetus/newborn while anaesthetising the mother, may lead to maternal awareness (i.e., recall of events when the patient was thought to have been anaesthetised)[91]. Caesarean delivery is one of the most common surgical procedures that lead to awareness given the lower doses of anaesthetic agents used in an effort to minimise effects on the fetus(es)[92]. Specific questioning of the mother in the postoperative period should be undertaken following any obstetric general anaesthetic in order to detect awareness[93]. If awareness is detected, a full explanation should be provided and an appropriate referral should be made for psychological assistance as post-traumatic stress disorder may otherwise arise[94].

Also, if a complication(s) has(have) occurred during the provision of general anaesthesia (such as dental damage or difficult intubation), the woman should be informed about these. Consideration should be given to providing written information about the nature of the complication and how it was managed. Also, the woman should be instructed to give the letter to her anaesthetist prior to any future anaesthetic.

Delayed

Potentially delayed complications of regional anaesthesia vary in their severity and incidence (Table 10.8).

Dural puncture is one of the most common complications. A meta-analysis of obstetric studies in this area found the incidence of accidental dural puncture to be 1.5%, with 50% of these patients going on to develop a postdural puncture headache[95]. The incidence varies greatly from one centre to another, with the number of epidurals inversely related to the number of complications[96].

Table 10.8 Postoperative complications secondary to regional anaesthesia

Procedure	*Complication*	*Sign*
Epidural or spinal	Spinal haematoma	Back pain, neurological signs
	Epidural haematoma	Back pain, neurological signs
	Dural puncture	Severe postural fronto-occipital headache/neck ache, visual disturbances
	Direct nerve damage	History of pain on injection, neurological signs
	Epidural abscess	Back pain, neurological signs, fever
	Meningitis	Fever, headache
Local anaesthetic wound infiltration	Infection	Fever
	Displacement	Pain
	Local anaesthetic toxicity	Neurological and cardiac symptoms (end result cardiac arrest)

Serious complications are rare. For example, spinal haematoma occurs in about 1:168,000 epidurals[97], and even less frequently following spinal anaesthesia. Nerve damage can occur temporarily in about 1 in 3000 patients, and permanently (i.e., for more than 6 months) in about 1 in 15,000 patients[98]. Meningitis following neuraxial anaesthesia is also a very rare complication, ranging in reported incidence from 1:50,000[99] to fewer than 1:200,000[100].

Pain

Once the patient is stable and she has been transferred to the ward, the main challenge will be pain management, especially in the absence of any supplemental regional anaesthesia.

Pain is defined as an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage. Table 10.9 outlines the physiological effects of pain which include, but are not limited to, an increase in blood pressure.

There is scant literature on postpartum analgesia in women with a hypertensive disorder of pregnancy, so the management approach is based on general principles of postpartum care. Ideally, the plan for pain control will include a means of preventing pain (prophylaxis) and a means of treating breakthrough pain. Regularly administered medication via a variety of routes (multimodal) provides a baseline level of analgesia and is generally ordered for 24–48 hours postpartum. Additional oral or IV analgesics are ordered for breakthrough pain. For women planning an elective Caesarean delivery, some form of preoperative patient education may be useful in managing patients' expectations and advising on coping strategies (e.g., finding alternative ways of performing tasks that may cause pain and limiting certain activities, such as lifting).

Table 10.9 The physiological effects of pain

System	*Effect*
Cardiovascular	Increased heart rate Increased blood pressure Increased peripheral vascular resistance Increased myocardial oxygen consumption → potential for myocardial ischaemia
Respiratory	Diaphragmatic splinting
Gastrointestinal	Delayed gastric emptying Decreased bowel motility
Psychological	Anxiety Sleeplessness Low morale Postpartum depression
Neurological	Chronic pain (in up to 10% of patients postCaesarean delivery

A commonly used approach to pharmacological management is the WHO analgesic ladder, beginning with: (1) non-opioid analgesic, then adding (2) opioid for mild to moderate pain, and then (3) spinal/epidural opioid or patient-controlled analgesia, with or without other techniques, as necessary (e.g., local wound infiltration with anaesthetic) (Figure 10.2)[101].

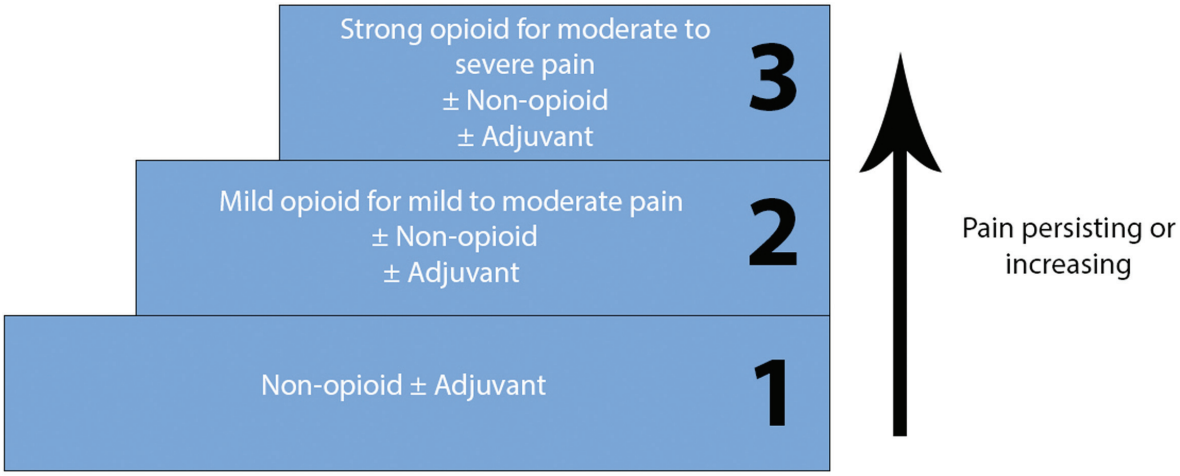

Figure 10.2 WHO analgesic ladder[101]. (Adapted for use with permission)

Oral/rectal analgesics

The non-opioid oral analgesics, paracetamol and non-steroidal anti-inflammatory drugs (NSAIDs) (Step 1, Figure 10.2) give a good base on which to build further medication needs. Both drugs are acceptable for use in breastfeeding mothers. Paracetamol (acetaminophen) is well-tolerated and demonstrates excellent synergy with many other analgesics. NSAIDs are very useful analgesics, but caution should be exercised in women with a hypertensive disorder of pregnancy. NSAIDs (e.g., ibuprofen, diclofenac, ketorolac) have antiplatelet effects (which may be an issue in the face of thrombocytopaenia); they may increase blood pressure[102], and they may reduce renal perfusion (and should therefore, not be used in the woman with renal dysfunction from pre-eclampsia).

Oral opioids (e.g., morphine, hydromorphone, oxycodone) are effective in managing moderate pain (Step 2, Figure 10.2). The American Academy of Pediatrics, the European Medicines Agency and the UK's Medicines and Healthcare Products Regulatory Agency all recommend against use of codeine during breastfeeding[103,104] as a maternal rapid acetylator phenotype may result in excessive levels of active metabolites in breast milk.

Non-opioids and opioids are usually administered orally, but an alternative route of administration is rectal. Of course, opioids can be administered by IV injection.

IV analgesics

When oral/rectal administration is not an option, pain is severe (e.g., postoperatively), or a rapid-onset of analgesia is required, IV analgesics may be used either alone or as a supplement to oral analgesics (Step 3, Figure 10.2). IV analgesics act more quickly because IV administration avoids 'first-pass' hepatic metabolism. IV analgesics are also often more potent than those administered via other routes.

The commonly used IV medications are morphine based. They are administered by the nurse or physician, or via a patient-controlled analgesia (PCA) pump. While IV opioids are an excellent option for urgent analgesia, their use should be limited as there is the potential for tolerance and addiction. In addition to IV opioids, some oral analgesics (e.g., paracetamol, ketorolac, NSAIDs) are available for intravenous use.

Some IV medications, that were not used previously for analgesia, such as ketamine and magnesium, are being investigated for their analgesic properties. When ketamine is used in low doses during general anaesthesia[105], it has a morphine-sparing effect that lasts longer (i.e., up to 24 hours) than one would anticipate based on the half-life of the drug. $MgSO_4$ also has some analgesic effect[106], an 'added bonus' in women who are administered it for eclampsia prophylaxis or treatment, or fetal neuroprotection; at present, $MgSO_4$ is not recommended for administration as an analgesic *per se*. (For more information, see Chapter 8.)

Neuraxial analgesia

A neuraxial catheter generally is removed postoperatively unless there are concerns about haemostasis or coagulation. Without a supplemental opioid, analgesia can be anticipated for 1–2 hours after spinal anaesthesia and 1–4 hours after epidural anaesthesia/analgesia, depending on the local anaesthetic used and the dose injected. When an opioid (e.g., morphine or diamorphine) is included in the spinal injectate or when an opioid is injected through the epidural catheter, effective postpartum analgesia may last up to 24 hours; the actual duration is dependent on the dose[107].

The commonly used opioids for this purpose are morphine, fentanyl and diamorphine, although some countries use pethidine (such as Australia). Other medications under investigation for neuraxial analgesia include $MgSO_4$ for its morphine-sparing action[108] and clonidine for prolonging spinal anaesthesia and improving early analgesia[109].

Another way of providing postoperative analgesia in a patient is to administer a continuous local anaesthetic ± opioid mixture through a pre-existing neuraxial catheter (epidural or spinal) by continuous infusion or patient-controlled epidural analgesia. While use of a neuraxial catheter is an effective way of providing postpartum analgesia, it is more complex. The catheter may limit patient mobility and the longer it is in place, the greater the risk of infection. This approach is generally avoided in obstetric cases unless extensive surgery has been required (e.g., laparotomy for complications) and postoperative pain control is a concern (e.g., in patients with contraindications to opioids and NSAIDs). Even in these rare cases, nurses caring for these patients postoperatively must be experienced in the management of neuraxial analgesia.

Other methods

Following general or neuraxial anaesthesia for Caesarean delivery, wound infiltration and abdominal nerve blocks reduce opioid consumption postpartum (20 trials, 1150 women)[110]. Bupivacaine-soaked sponges have been described to reduce postoperative opioid and diclofenac consumption[111].

Postoperative wound infusion is a technique whereby a catheter is inserted superficially into the abdominal wound and local anaesthetic is continuously infused. It is a technique with mixed reports of success[112–114]. A recent study suggests that subfascial placement is superior and that multiholed catheters provide better analgesic outcomes[115]. The catheter is generally placed intraoperatively just before closure of the fascia and should block superficial nerves around the wound. Inadvertent intravascular injection could result in cardiovascular and central nervous system collapse.

Transversus abdominis plane blocks often are used when neuraxial analgesia is unavailable (e.g., following general anaesthesia). They are often placed under ultrasound guidance into the transversus abdominal plane and are performed bilaterally. This is a single-shot technique and more nerves are blocked than during wound infusion. A correctly placed transversus abdominis plane block should block intercostal nerves (T7–T11), the subcostal nerves (T12) and the iliohypogastric and ilioinguinal nerves (L1). A meta-analysis by Mishriky *et al*. (9 trials, 554 patients) found that bilateral transversus abdominis plane blocks, in the absence of intrathecal morphine, are effective for post-Caesarean analgesia; however, when intrathecal (spinal) morphine has been used, there is no additional benefit of a transversus abdominis plane block. Intrathecal morphine alone provides better analgesia than transversus abdominis plane blocks alone, although this is at the expense of morphine-related side-effects[116]. A randomised controlled trial comparing transverse abdominal plane blocks with wound infiltration (both combined with paracetamol and NSAIDs) found no difference in cumulative morphine consumption following Caesarean delivery[117]. The authors recommended wound infiltration over transverse abdominal plane blocks owing to the resources and time required to do transverse abdominal plane blocks, but they acknowledged that further studies are required.

Intrathecal opioid followed by postoperative bilateral ilioinguinal nerve blocks is an approach associated with reduced morphine use postpartum[118], although there is no reduction in morphine-related side-effects[119].

BEST PRACTICE POINTS

(Please see Appendix 10.3 for the evaluation of the strength of the recommendation and the quality of the evidence on which they are based.)

1. The anaesthetist should be informed when a woman with pre-eclampsia is admitted to the delivery suite.
2. Women with pre-eclampsia should have a platelet count on admission to the delivery suite.
3. Planning for the care of women with pre-eclampsia should include members of the multi-disciplinary team.
4. The anaesthetist should assess the woman with pre-eclampsia from the standpoint of possible anaesthetic care and as her status may change, she should be reassessed.
5. Arterial line insertion may be used for continuous arterial blood pressure monitoring when blood pressure control is difficult or there is severe bleeding. An arterial line also is useful when repetitive blood sampling is required, e.g., in women with HELLP (haemolysis, elevated liver enzymes, low platelet) syndrome.
6. Central venous pressure monitoring is not routinely recommended and, if a central venous catheter is inserted, it should be used to monitor trends and not absolute values.
7. Pulmonary artery catheterisation is not recommended unless there is a specific associated indication and then only in an intensive care setting.
8. Early insertion of an epidural catheter (in the absence of contraindications) is recommended for control of labour pain.
9. In the absence of contraindications, all of the following are acceptable methods of anaesthesia for women undergoing Caesarean section: epidural, spinal, continuous spinal, combined spinal epidural and general anaesthesia.
10. A routine, fixed intravenous fluid bolus should not be administered prior to neuraxial anaesthesia.
11. Neuraxial analgesia and/or anaesthesia are appropriate in women with hypertensive disorders of pregnancy provided there are no associated coagulation concerns (Table 10.5) or specific contraindications as noted earlier in the text.

PRIORITIES FOR UNDER-RESOURCED SETTINGS

While all of the resources discussed in this chapter are considered to be essential for care of women with hypertensive disorders of pregnancy in well-resourced settings, these materials may not be available in less well-resourced areas. However, basic principles apply in all settings – working as a team to provide multidisciplinary care, and using available resources to ensure the best possible outcome for mother and baby(ies). Table 10.10 outlines suggested priorities according to the level of the health care service, with primary health centres designed to provide BEmONC and facilities designed to provide CEmONC.

A key feature of any priority-setting exercise is action and evaluation. As such, routine monitoring and evaluation of obstetric anaesthesia services must be undertaken to help improve the quality of maternity care[120]. A key component of future priorities is the proper training of non-physician anaesthesia providers, with emphasis on provision of resuscitation and regional anaesthesia techniques, since most of anaesthetics in sub-Saharan Africa are provided by this cadre of people[121]; also, these individuals can assist in providing adequate pain management for both Caesarean deliveries and vaginal deliveries, utilising simple and inexpensive methods such as single-shot spinals[122] (Figure 10.3). The availability of blood products is discussed in Chapter 8, but transfusion protocols for blood loss antenatally or postnatally should be in place in every unit[123,124].

WHAT INTERNATIONAL GUIDELINES SAY

In a review of international guidelines, only the Canadian guidelines[24,125] present a detailed list of recommendations for anaesthetic management. The latest update from the National Institute for

Table 10.10 Priorities for obstetric anaesthesia by level of health care system at which care is delivered

	Antepartum and postpartum	
	Initial priority	*Ultimate goal*
Community		
Primary health care centre for provision of BEmONC	Availability of essential equipment for monitoring, consisting of a means of measuring BP and heart rate Some means of providing left uterine displacement (e.g., wedge, blankets) Availability of essential equipment for maternal resuscitation, consisting of oxygen, suction, and intravenous access (see Table 10.1 for details) Provision of pain relief (inhalational or systemic opioids) for vaginal delivery	Ability of oxygen saturation monitoring
Facility		
Secondary-level (for provision of EmONC	Assess gestational age accurately Availability of essential equipment for monitoring, consisting of a means of measuring BP and heart rate Ability to monitor maternal well-being with laboratory testing* (blood and urine) Some means of providing left uterine displacement (e.g. wedge, blankets) Ability to monitor fetus with NST Availability of essential equipment for maternal resuscitation, consisting of oxygen, suction, equipment for intubation and ventilation, intravenous access, and emergency medications (see Table 10.1) Defibrillator Equipment to perform peri-mortem Caesarean delivery Provision of adequate pain relief for vaginal delivery and postCaesarean delivery (by inhalational of systemic means)	Ability to monitor oxygen saturation and end-tidal carbon dioxide Ability to monitor fetus with ultrasonographic assessment Provision of anaesthetic management (including neuraxial analgesia such as single-shot spinal) by non-physician provider Transfusion protocol
Tertiary-level (referral) for provision of EmONC	Assess gestational age accurately Availability of essential equipment for monitoring, consisting of a means of measuring BP and heart rate Ability to monitor maternal well-being with laboratory testing* (blood and urine) Some means of providing left uterine displacement (e.g., wedge, blankets) Monitor fetal well-being with NST and ultrasonographic assessment	Ability to monitor oxygen saturation and end-tidal carbon dioxide Provision of anaesthetic management (including neuraxial analgesia) by non-physician provider Transfusion protocol

continued

	Antepartum and postpartum	
	Initial priority	*Ultimate goal*
	Availability of essential equipment for maternal resuscitation, consisting of oxygen, suction, equipment for intubation and ventilation, intravenous access, and emergency medications (see Table 10.1)	
	Defibrillator	
	Equipment to perform peri-mortem Caesarean delivery	

BP, blood pressure; NST, non-stress test
* Complete blood count, coagulation, serum creatinine, and liver enzymes, at minimum

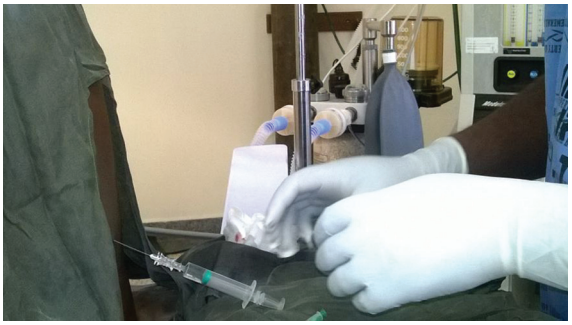

Figure 10.3 Performing single-shot spinal anaesthesia in Uganda

Health and Care Excellence (NICE) in the UK includes references to the use of remifentanil for labour analgesia and to ablate the hypertensive response to intubation[126]. The recommendations from this review of guidelines are presented in Appendix 10.4[127]. In addition, the Australasian guideline presents discussion of anaesthetic issues that are in agreement with the Canadian guideline, in terms of early involvement of the anaesthetist in the care of women with pre-eclampsia on delivery suite, no pre-loading with fluid prior to neuraxial anaesthesia, epidural analgesia as an adjunct to antihypertensive therapy, and low-dose aspirin as compatible with regional analgesia/anaesthesia; also the Australasian guidelines do a particularly good job of highlighting the potential airway problems associated with pre-eclampsia and the importance of attenuating the hypertensive response to endotracheal intubation[128].

PRIORITIES FOR FUTURE RESEARCH

Priorities for future research include:

- How can we improve maternal monitoring intrapartum, including maternal fluid status?
- Does haemodynamic monitoring during antihypertensive therapy improve maternal and perinatal outcomes?
- What is a safe platelet count for neuraxial block?
- What is the most appropriate vasopressor (and dose) for the prevention and treatment of hypotension following neuraxial block?
- What is the most appropriate strategy to manage postpartum pain?

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