FOURTH EDITION

Analgesia, Anaesthesia and Pregnancy

A PRACTICAL GUIDE

Róisín Monteiro
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Surbhi Malhotra
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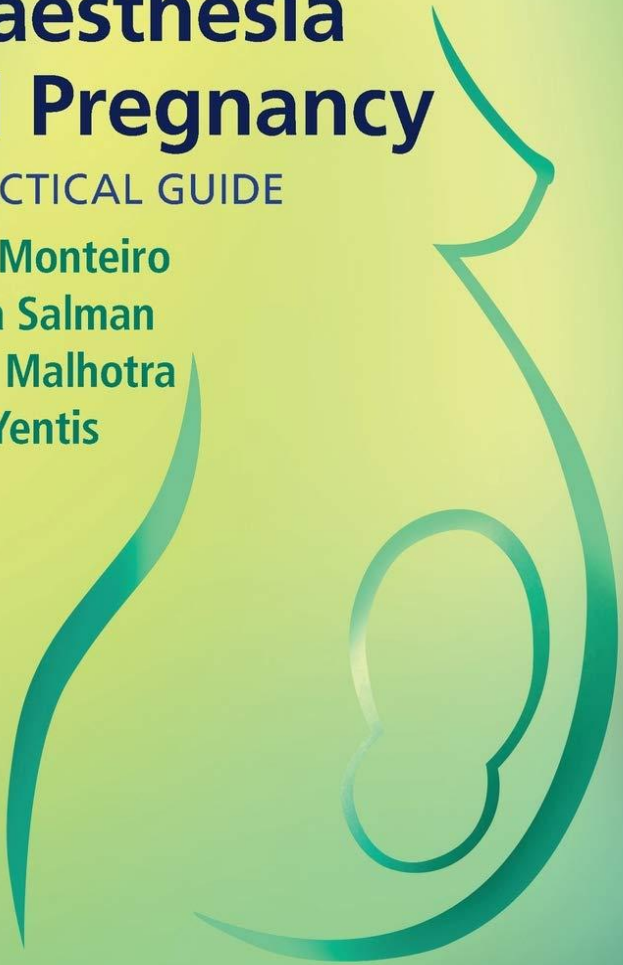

CAMBRIDGE Medicine

Analgesia, Anaesthesia and Pregnancy

A Practical Guide

Fourth Edition

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CAMBRIDGE
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University Printing House, Cambridge CB2 8BS, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India

79 Anson Road, #06–04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.

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www.cambridge.org
Information on this title: www.cambridge.org/9781108710527
DOI: 10.1017/9781108684729

Fourth edition published 2019

Printed and bound in Great Britain by Clays Ltd, Elcograf S.p.A.

A catalogue record for this publication is available from the British Library.

Library of Congress Cataloging-in-Publication Data
Names: Yentis, S. M. (Steven M.), author. | Monteiro, Róisín, author. | Salman, Marwa, author. | Malhotra, Surbhi, Dr., author.
Title: Analgesia, anaesthesia and pregnancy : a practical guide / Róisín Monteiro, Marwa Salman, Surbhi Malhotra, Steve Yentis.
Description: Fourth edition. | Cambridge, United Kingdom : Cambridge University Press, 2019. | Steve Yentis' name appears first in the previous edition. | Includes bibliographical references and index.
Identifiers: LCCN 2018049486 | ISBN 9781108710527 (pbk.)
Subjects: | MESH: Anesthesia, Obstetrical | Analgesia, Obstetrical | Handbooks
Classification: LCC RG732 | NLM WO 39 | DDC 617.9/682–dc23
LC record available at https://lccn.loc.gov/2018049486

ISBN 978-1-108-71052-7 Paperback

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Preface

The first edition of this book was written in order to provide useful, practical information and advice to obstetric anaesthetists, in the form of a ready and easily accessible guide to obstetric anaesthesia and analgesia. The book was aimed primarily at trainees, both those starting in the maternity suite and their more experienced colleagues preparing for anaesthetic examinations. We also hoped the book would be of use to more senior anaesthetists and those of all levels involved in teaching obstetric anaesthesia, as well as non-anaesthetists working in the maternity suite. We are pleased that the book has been popular enough to warrant a fourth edition, and welcome two new authors to join the team.

In this fourth edition, we have reviewed and revised each section but kept to the original aims, structure and format, since we are convinced that the need for a short, practically based text still exists. In doing so, we have attempted to bridge the gaps between routine obstetric anaesthesia and analgesia and the care of women with coexisting medical conditions, and between anaesthetic care and advice before pregnancy and that during pregnancy itself.

As before, we have assumed basic anaesthetic knowledge and thus do not include topics such as anaesthetic equipment and drugs, etc., except where there are areas of specific obstetric relevance. We have tried to base the advice given on what we believe would be considered standard UK practice, supported by evidence wherever possible, although we have deliberately not included supporting references for each point made since this would, in our view, detract from the readability and ease of use of this book; readers wishing to obtain such reference lists are directed to the many larger, more comprehensive texts that are currently available.

We hope that the layout of the book is easy to follow. We have tried to provide a brief list of pertinent further reading where possible – though often this has meant that very large topics have been left relatively unreferenced, since there are few journal reviews broad enough in scope.

Finally, we gratefully acknowledge the contributions of Dr D. Bogod, Dr D. Brighouse and Dr C. Elton to the first edition, and Dr A. May to the first and second editions. For this fourth edition, we are also grateful to Dr Aisha Alzouebi for her contributions to the chapters on obstetric topics.

Chapter 1

Assisted conception

Infertility affects about one in seven couples, with a small increase in infertility and the number of couples seeking help over the past 10 years. The treatment of infertility has developed rapidly, and the anaesthetist may be involved in many aspects of the patient's treatment, which may be complex. The harvesting of oocytes needs to take place within a defined period of time, or ovulation may have occurred and oocytes will be lost. Couples presenting for infertility treatment are generally anxious, and women are often emotional at the time of oocyte retrieval. It is therefore particularly important for the anaesthetist to understand the couple's anxieties, and to be able to explain the effects of the anaesthetic technique that is to be used.

Problems and special considerations

All of the methods of assisted fertility techniques involve extraction of oocytes from the follicles, either laparoscopically or, with the development of transvaginal ultrasonography, via the transvaginal route (ultrasound-directed oocyte retrieval, UDOR). The techniques differ in the site of fertilisation and/or replacement of the gamete/zygote:

- **In-vitro fertilisation (IVF).** This term is often (incorrectly) used to encompass all aspects of infertility treatment. IVF involves either UDOR or laparoscopic oocyte retrieval, fertilisation in the laboratory and transfer of the developing embryo into the uterus via the cervix, 48 hours later. UDOR may be painful so may require analgesia, sedation or anaesthesia. Embryo transfer is performed with the patient awake, although there are occasions when the anaesthetist may be requested to provide sedation. The success rate is approximately 15–25%.
- **Gamete intrafallopian transfer (GIFT).** This involves retrieval of oocytes which are placed together with sperm into the fallopian tube It is performed laparoscopically in the majority of cases and has not been shown to have a higher success rate than IVF, so is used less commonly.
- **Zygote intrafallopian tube transfer (ZIFT) or pronuclear stage transfer.** This process involves oocyte retrieval and IVF, with the zygote then being placed in the fallopian tube as for GIFT. It has no significant difference in pregnancy rates to IVF, but has a trend towards increased ectopic pregnancy rates.
- **Intracytoplasmic sperm injection (ICSI).** Fertilisation occurs in the laboratory via injection of sperm into the oocytes, and the developing embryo is transferred into the uterus as for IVF. This technique is used for male infertility. The success rate is approximately 30%.

Management options

Most women who present for assisted conception techniques are healthy and in their thirties or forties. However, it is now recognised that some women may also have a number of comorbidities associated with increasing age. Therefore, a multidisciplinary approach is necessary. It would be logical to minimise drug use and use sedation or regional anaesthesia whenever possible, although this is not suited for laparoscopy (see Chapter 3, *Anaesthesia before confirmation of pregnancy*).

For UDOR, which has become the most common method used for oocyte retrieval, the main anaesthetic techniques are intravenous sedation and regional anaesthesia. It is important to remember that patients requiring UDOR are day cases, and the basic principles of day-case anaesthesia apply. There has been a considerable amount of work to date on the use of propofol with alfentanil, and this combination of drugs would appear to be the technique of choice for intravenous sedation. Propofol may be administered by intermittent boluses or by continuous infusion, with the patient breathing oxygen via a Hudson mask. Many anaesthetists find that they are using levels of sedation close to anaesthesia. There does not seem to be a difference in patient satisfaction or pregnancy rate if sedation or general anaesthesia is used. It is essential that the sedation is administered in a suitable environment with resuscitation facilities and anaesthetic monitoring. Often the assisted conception unit is some distance from the main theatre suite; therefore it may be difficult for the staff working in an isolated environment to maintain their skills in resuscitation.

The desire to minimise the drugs administered to women undergoing ultrasound-guided techniques has led to the use of regional anaesthesia, although there is limited evidence supporting its association with increased pregnancy rates. Careful administration is required to allow same-day discharge; the low-dose spinal that is used for labour analgesia or the short-acting agents used for cervical cerclage can give good operating conditions while satisfying the criteria needed for day-case anaesthesia.

The main considerations for laparoscopy are the type of anaesthesia, the pneumoperitoneum and the effects of the anaesthetic agents on fertilisation and cell cleavage. The length of exposure to the drugs is also important. The effects of nitrous oxide and volatile anaesthetic agents on fertilisation and cleavage rates have been extensively examined. It is generally recognised that all volatile agents and nitrous oxide have a deleterious effect, although opinion is divided as to the extent of the problem. It is also recognised that the carbon dioxide used for the pneumoperitoneum causes a similar effect, and it is difficult to separate the effects of the anaesthetic agents from those of the carbon dioxide.

Of the intravenous agents, the effect of propofol on fertilisation and cleavage appears to be minimal. Propofol accumulates in the follicular fluid, and the amount in the follicular fluid may become significant if there are a large number of oocytes to retrieve. Propofol decreases the fertilisation rates, but there is no significant effect on the cell division rates. This has led to the increased use of propofol as the main agent in total intravenous anaesthesia.

Analgesia following the procedure may be provided with a combination of codeine and paracetamol. Non-steroidal anti-inflammatory drugs such as diclofenac are considered less suitable, as these are thought to interfere with embryo implantation, owing to a disruption in prostaglandin levels. All assisted conception techniques carry the risk of ovarian

hyperstimulation (see Chapter 2, *Ovarian hyperstimulation syndrome*), and multiple or ectopic pregnancy.

Key points

- Oocyte retrieval may involve laparoscopy requiring general anaesthesia, although intravenous sedation and regional anaesthesia are suitable for transvaginal ultrasound-directed techniques.
- Couples are usually very anxious and require constant reassurance.

Further reading

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Chapter 2

Ovarian hyperstimulation syndrome

Ovarian hyperstimulation syndrome (OHSS) is a complication of ovarian induction that may be caused by any agent that stimulates the ovaries. Over the last 10 years, the incidence has risen due to the increased use and development of in-vitro fertilisation (IVF) treatments, where the ultimate goal is to produce enough oocytes and embryos. It is thought to be the most common complication of IVF treatment, though the true incidence is unknown, because mild to moderate cases are probably under-reported.

OHSS occurs 3–8 days after treatment with human chorionic gonadotrophin (hCG), and the effects continue throughout the luteal phase. A variety of cytokines and pro-inflammatory mediators such as vascular endothelial growth factor are secreted from the hyperstimulated ovaries, leading to increased vascular permeability and a prothrombotic effect. The condition may become severe enough to warrant intensive care admission.

Problems and special considerations

Clinical manifestations of the syndrome are:

- Enlargement of the ovaries
- Pleural effusion
- Ascites

Additional complications that may occur include:

- Hypovolaemic shock
- Renal failure
- Acute lung injury
- Thromboembolism
- Cerebrovascular disorders

Women undergoing ovarian stimulation who develop OHSS may be classified by the severity of their presenting symptoms and signs (Table 2.1).

Management options

Prophylactic plasma expanders such as human albumin solution may reduce the risk of severe OHSS in women at high risk; these include women with a large number of oocytes retrieved, high oestradiol levels or polycystic ovary syndrome.

Once suspected, the diagnosis of OHSS is made on clinical grounds as there are no specific diagnostic tests. However, the combination of elevated haematocrit with reduced

Table 2.1 Grading of ovarian hyperstimulation syndrome

Grade	Features
Mild	Abdominal distension and discomfort
Moderate	Abdominal pain, nausea, vomiting and diarrhoea Ultrasound evidence of ascites
Severe	Clinical ascites ± hydrothorax, oliguria, haematocrit > 0.45, hypo-osmolality, hyponatraemia, hyperkalaemia, hypoproteinaemia
Critical	Tense ascites/large hydrothorax, haematocrit > 0.55, white cell count > 25×10^9/l, oliguria/anuria, thromboembolism, acute respiratory distress syndrome

Adapted with permission from Royal College of Obstetricians and Gynaecologists. *The Management of Ovarian Hyperstimulation Syndrome*. Green-top Guideline 5. London: RCOG, 2016.

serum osmolality and sodium levels is highly suggestive. Pelvic ultrasound may demonstrate multiple ovarian follicles, enlarged ovaries or free fluid.

Mild to moderate forms of OHSS will be self-limiting and can be managed in the outpatient setting with analgesia, antiemetics and oral hydration, but those women with more severe pathology are likely to require hospitalisation for monitoring and intravenous fluids to correct the hypovolaemia and haemoconcentration.

Ultrasound-guided paracentesis should be considered for women with severe pain, abdominal distension, respiratory compromise or oliguria thought to be secondary to ascites. In women with impaired renal function, dopamine has been given to improve renal perfusion. Ultrafiltration and intravenous reinfusion of ascitic fluid has been used in severe cases. Thromboprophylaxis must be considered.

Monitoring is tailored to the severity of the syndrome, and the following progression is recommended:

- Urea and electrolytes
- Full blood count and packed cell volume
- Plasma/urine osmolality
- Clotting screen
- Chest radiography
- Invasive haemodynamic monitoring may be beneficial for those with a reduced urine output or persistently raised haematocrit despite large volumes of fluid replacement.

Clinicians should be aware that pregnancies complicated by OHSS have an increased risk of pre-eclampsia and preterm delivery.

Key points

- Hyperstimulation comprises ovarian enlargement, pleural effusion and ascites, which may be relentless.
- Severe protein loss may result in shock and renal failure.
- The most severe form occurs in 1–2% of cases treated with human chorionic gonadotrophin.

Further reading

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Chapter 3

Anaesthesia before confirmation of pregnancy

Many women will require anaesthesia when they are pregnant, and some will be unaware that they are pregnant before attendance for surgery, especially in the first 2–3 months of their pregnancy. Studies have found incidences of up to 2.4% of unrecognised early pregnancy in preoperative testing.

Concerns with anaesthesia and surgery in early pregnancy are related to fetal loss and teratogenicity. A systematic review suggested that miscarriage rates may be slightly increased when surgery occurs in the first trimester; however, whether this is related to anaesthesia, surgery or the underlying pathological process necessitating surgery is difficult to say. A teratogen is a substance that causes structural or functional abnormality in a fetus exposed to that substance. The thalidomide catastrophe initiated the licensing arrangements for new drugs and their use in pregnancy; the current cautious stance of the pharmaceutical industry is reflected in the British National Formulary's statement that no drug is safe beyond all doubt in early pregnancy.

Current evidence suggests that there is no increase in congenital abnormalities in women undergoing surgery and anaesthesia. However, concern has been raised over prenatal anaesthetic exposure and subtle functional neurocognitive changes. The anaesthetist should have a clear knowledge of the time scale of the developing fetus in order to balance the risks and benefits of any drug given to the mother.

Problems and special considerations

The possible effect of a drug can be considered against the stage of the developing fetus:

- **Pre-embryonic phase (0–14 days post-conception).** The fertilised egg is transported down the fallopian tube and implantation occurs at around 7 days post-conception. The conceptus is a ball of undifferentiated dividing cells during this time and the effect of drugs on it appears to be an all-or-none phenomenon. Cell division may be slowed with no lasting effects or the conceptus will die, depending on the severity of the cell damage.
- **Embryonic phase (3–8 weeks post-conception).** Differentiation of cells into the organs and tissues occurs during this phase, and drugs administered to the mother may cause considerable harm. The type of abnormality that is produced depends on the exact stage of organ and tissue development when the drug is given.
- **Fetal phase (9 weeks to birth).** At this stage, most organs are fully formed, although the cerebral cortex, cerebellum and urogenital tract are still developing. Drugs administered during this time may affect the growth of the fetus or the functional development within specific organs, but structural changes are unlikely.

Management options

The anaesthetist should always consider the possibility of pregnancy in any woman of childbearing age who presents for surgery, whether elective or emergency, and should specifically enquire in such cases. If there is doubt, a pregnancy test should be offered; accepted practice is to delay elective surgery in pregnancy. If pregnancy is confirmed and surgery necessary, it would seem pragmatic to use systemic drugs after weighing up their necessity, benefits and risks while focusing on maintaining normal physiological parameters.

The use of nitrous oxide is now generally considered acceptable, despite its effects on methionine synthase and DNA metabolism, as there is little evidence that it is harmful clinically; however, it may be sensible to avoid as anaesthesia can be delivered safely without its use. Similarly, although the volatile agents have been implicated in impairing embryonic development, clinical evidence is lacking. Some drugs cross the placenta and exert their effect on the fetus – for example warfarin, which may cause bleeding in the fetus.

Key points

- The possibility of pregnancy should be considered in any woman of childbearing age.
- No drug is safe beyond all doubt in pregnancy.

Further reading

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Cohen-Kerem R, Railton C, Oren D, Lishner M, Koren G. Pregnancy outcome following non-obstetric surgical intervention. *Am J Surg* 2005; **190**: 467–73.

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Chapter 4

Ectopic pregnancy

Ectopic pregnancies occur in approximately 11 per 1000 pregnancies, with nearly 12,000 women diagnosed with an ectopic in the UK each year. There are many risk factors, of which tubal pathology or surgery and the use of an intrauterine device are the most important. Other risk factors are infertility, younger or older maternal age and smoking. The incidence is thought to be increasing as a result of pelvic inflammatory disease.

Ectopic pregnancy accounted for almost 5% of deaths prior to 24 weeks' gestation in the Confidential Enquiries into Maternal Deaths and Morbidity report in 2016 (MBRRACE-UK). Most ectopic pregnancies occur in the fallopian tube, but up to 5% occur elsewhere within the genital tract or abdomen. Typically, the tube initially expands to accommodate the growing zygote, but when it is unable to do so any more, there may be bleeding from the site of implantation or even rupture of the tube.

Problems and special considerations

Diagnosis of ectopic pregnancy may be difficult. Most ectopic pregnancies present 6–8 weeks from the last menstrual period and thus many of the physiological changes of pregnancy are absent or mild – the patient may even be unaware that she is pregnant. Signs and symptoms of an ectopic pregnancy vary. The most commonly reported symptoms are abdominal pain, amenorrhoea and vaginal bleeding. Other symptoms include gastrointestinal upset and rectal pressure or shoulder-tip pain from intraperitoneal blood. Sudden decompensation may occur due to concealed haemorrhage, leading to haemodynamic collapse.

A common theme in deaths associated with ectopic pregnancy is the failure to consider the diagnosis before collapse; ectopic pregnancy was not considered as a diagnosis in five out of the nine women who died from ectopic pregnancy in the 2016 Confidential Enquiry report. Non-specific abdominal signs including diarrhoea or vomiting may be misinterpreted as other intra-abdominal conditions such as appendicitis or gastroenteritis. Haemodynamic collapse may be misinterpreted as signs of pulmonary embolism, and MBRRACE-UK reported that a third of women who died of ectopic pregnancy received thrombolysis. Ectopic pregnancy must be considered in all women of childbearing age who present with haemodynamic collapse, particularly if anaemic, and it is now recommended that a focused assessment with sonography in trauma (FAST) ultrasound scan should be performed before thrombolysis if pulmonary embolism is considered likely.

A urinary pregnancy test should be performed in all women of reproductive age in whom the diagnosis is unclear or any of the above symptoms or signs are present; the bladder should be catheterised if necessary to facilitate this. Abdominal ultrasound has low

specificity, and transvaginal ultrasound is the imaging modality of choice. If ultrasound is not convincing, then diagnosis may be aided by blood tests and laparoscopy. In a less acute situation, serum levels of human chorionic gonadotrophin (hCG) and progesterone are often measured, but these measurements often resemble those levels seen in a normal pregnancy. Previously, the gold standard for diagnosis of an ectopic pregnancy was a laparoscopy; however, its diagnostic accuracy has been questioned when the procedure is performed too early.

The implications for the current and future pregnancies pose a great psychological stress on the patient and her partner. There may be a previous history of ectopic pregnancy, since its occurrence is itself a risk factor for subsequent ectopics.

Management options

Initial management is directed at treating and preventing massive haemorrhage; thus the patient requires at least one large-bore intravenous cannula and careful observation, at least until the diagnosis has been excluded. Similarly, once the decision to operate has been made, surgery needs to occur as soon as possible, since the risk of tubal rupture is always present.

Operative management usually involves laparoscopy unless there is severe haemodynamic instability, in which case laparotomy may be performed. Traditionally, laparoscopy was performed purely for diagnostic purposes, but laparoscopic removal of the zygote with or without tubal resection has become routine in many units.

Anaesthetic management is as for any emergency surgery, given the above considerations. Haematological assistance and admission to the intensive care unit should be available if required. Point-of-care haematological testing may be a useful adjunct. In severe cases, anaesthesia must proceed as for a ruptured aortic aneurysm: full preoperative resuscitation may be impossible, and the patient is prepared and draped before induction of anaesthesia, which may be followed by profound hypotension.

Medical management may be considered in selected cases; thus systemic methotrexate may be offered to suitable women in whom the diagnosis of ectopic pregnancy is absolutely clear and the absence of a viable intrauterine pregnancy has been confirmed. The drug antagonises folic acid and prevents further growth of the trophoblast, which is especially vulnerable at this early stage. Similar outcomes to those following surgical management have been claimed. Local injection of hyperosmolar glucose or potassium chloride, with aspiration of the sac, is an option for clinically stable women with a heterotopic pregnancy. Finally, expectant management has been used in selected patients, although women whose pregnancies are self-limiting cannot yet be identified reliably.

Key points

- Ectopic pregnancy must be considered as a diagnosis in all women of reproductive age presenting with non-specific abdominal symptoms or haemodynamic collapse.
- Severe haemorrhage and/or cardiovascular collapse is always a risk.

Further reading

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Chapter 5

Evacuation of retained products of conception

Evacuation of retained products of conception (ERPC) may be required at any stage of pregnancy, but it occurs most commonly in early pregnancy following incomplete miscarriage or early fetal demise. It is also required during the puerperium following retention of placental tissue (see Chapter 40, *Removal of retained placenta and perineal suturing*).

Problems and special considerations

ERPC following spontaneous abortion at 8 weeks' gestation may be a minor routine gynaecological emergency for the anaesthetist, but the mother may have lost a much-wanted baby.

The urgency of the procedure varies greatly. The majority of ERPCs are performed as scheduled emergencies in fit young women, and this may lull the inexperienced anaesthetist into a false sense of security. Death may occur from spontaneous abortion; blood loss may be heavy and is frequently underestimated.

The possibility of coexisting uterine or systemic sepsis must always be considered, especially in postpartum ERPC or in a repeat procedure following incomplete evacuation.

Management options

Diagnostic ultrasound scanning is frequently used to confirm a non-viable early pregnancy or the presence of retained placental tissue. Transabdominal and transvaginal ultrasonography are now considered to be complementary to each other, with most women requiring a transvaginal ultrasound. Most units now operate a policy of fully assessing mothers on the day of admission in an early pregnancy advisory unit (EPAU), allowing them home and re-admitting them the following day for planned ERPC. This facilitates planning of medical and nursing staffing levels, reduces prolonged periods of waiting and starvation for the mother, and can be economically advantageous.

Expectant management may be offered as a first-line management strategy, unless there are particular risks of haemorrhage or infection. Medical treatment is increasingly used, and this enables women to be allowed home after treatment with prostaglandin analogues to await events. Analgesia and antiemetics should be offered as required. Non-surgical methods are associated with longer and heavier bleeding, and 15–50% of these women will need surgical management if the products of conception are not fully expelled. If required, surgical management of miscarriage may occur under local, regional or general anaesthetic.

Preoperatively, a full assessment is required. Assessment of blood loss may be difficult; fit young women may lose a significant proportion of their blood volume without becoming

hypotensive. Tachycardia should alert the anaesthetist to possible hypovolaemia. Signs of sepsis should be sought, and prophylactic antibiotics may be considered.

General anaesthesia is most commonly used in the UK, although in the absence of uncorrected hypovolaemia or other contraindications, regional anaesthesia is entirely suitable. The puerperal mother in particular may wish to stay awake if offered a choice, and she should be advised to do so if she is at risk of regurgitation.

Rapid-sequence induction of general anaesthesia is indicated for the non-fasting mother requiring urgent surgery (uncommon) and for the mother who is at risk of regurgitation (see Chapter 59, *Aspiration of gastric contents*). Anaesthesia using a laryngeal mask airway or facemask using any standard day-case anaesthetic technique is appropriate for the majority of women needing ERPC. Sedative premedication is rarely needed. Intravenous anaesthesia, for example with propofol, or inhalational anaesthesia, are acceptable, though if the latter is used high concentrations of volatile anaesthetic agents (> 1 minimum alveolar concentration (MAC)) should be avoided because of the uterine relaxation that may ensue.

Oxytocic drugs may be requested by the surgeon, although there is little evidence for their efficacy at gestations of less than 15 weeks. A single intravenous bolus of 5 U oxytocin usually suffices. Ergometrine causes increased intracranial and systemic pressure, and nausea and vomiting, and should not be used routinely.

Spinal anaesthesia produces more rapid and dense anaesthesia than epidural anaesthesia, and an anaesthetic level of at least T8 is recommended. Clinical experience shows that the traditionally taught anaesthetic level of T10 is insufficient to prevent pain occurring when the uterine fundus is manipulated or curetted.

Postoperatively, the aim is rapid recovery and discharge home. Requirement for postoperative analgesia rarely exceeds simple non-opioid drugs. Non-steroidal anti-inflammatory agents may be beneficial in relieving uterine cramps. Routine administration of antiemetics should be considered, since these women are at risk of postoperative nausea and vomiting. Thromboprophylaxis may be indicated depending on risk factors.

Key points

- A sensitive and sympathetic approach to the mother is necessary.
- Prolonged preoperative waiting and starvation reflects poor communication and inefficiency.

Further reading

National Institute for Health and Care Excellence. *Ectopic Pregnancy and Miscarriage: Diagnosis and Initial Management*. Clinical Guideline 154. London: NICE, 2012. www.nice.org.uk/guidance/cg154 (accessed December 2018).

Chapter 6

Termination of pregnancy

Termination of pregnancy in the UK is undertaken under the terms of the Abortion Act 1967, with over 200,000 induced abortion procedures occurring each year. For the consideration of anaesthetic procedures and potential problems, patients presenting for a termination of pregnancy broadly fall into two groups:

1. The presence of a maternal problem, the most commonly stated reason being danger to the mental or physical health of the mother. This accounts for up to 98% of terminations and may occur up to 24 weeks' gestation, but usually before 15 weeks.
2. Severe fetal congenital abnormality or early fetal death, two-thirds of which occur before 20 weeks' gestation.

Problems and special considerations

When caring for women who are to undergo a termination of pregnancy, it is important to consider the physiological changes of pregnancy, the psychological state of the woman and the need for routine preoperative assessment of the patient.

Those women in the first group above are usually scheduled to have termination of pregnancy on a gynaecological operating list. Patients in the second group are often looked after in the maternity unit.

Some members of staff may express conscientious objection to performing or being involved in termination of pregnancy, and this must be respected. They cannot be made to participate in such procedures, although they do have a duty to find other staff who will, if that is the patient's wish.

Management options

Termination for maternal indications

Surgical termination of pregnancy is usually a day-case procedure. Assessment should be conducted sympathetically, as these women are often very distressed. Vacuum aspiration may be performed up to 15 weeks' gestation; patients and clinicians are more used to this being performed under general anaesthesia in the UK, although it can be performed with systemic analgesia, local anaesthesia or conscious sedation. After 15 weeks' gestation, dilatation and evacuation (D&E) is necessary, which is also usually performed under general anaesthesia.

As most terminations for maternal indications occur before 15 weeks, these women can usually be regarded as non-pregnant with respect to gastric emptying and acid aspiration unless they have symptoms of reflux.

An anaesthetic technique suitable for day-case anaesthesia should be employed, such as induction with propofol and maintenance with propofol or a volatile anaesthetic agent. There has been concern about concentrations of volatile anaesthetic agents greater than 1 MAC causing uterine relaxation unresponsive to oxytocics. For a termination of pregnancy at less than 15 weeks, standard concentrations of volatile anaesthetic agents do not appear to pose a risk and may be used to maintain anaesthesia. Analgesia may be provided by intravenous fentanyl or alfentanil, with rectal diclofenac (100 mg) at the end of the procedure.

The gynaecologist may request that 5–10 U oxytocin is administered to aid uterine contraction. There is no clear evidence that this is helpful at this stage of pregnancy, and it is not recommended by the Royal College of Obstetricians and Gynaecologists (RCOG).

Termination for fetal abnormality or death

Women who present for termination of pregnancy because of fetal abnormality or intrauterine death present a difficult clinical problem. A medical termination with vaginal delivery is often aimed for at later gestations, partly because this offers the opportunity for pathological examination of an intact fetus, but also because of limited access to D&E within the NHS. Induction of labour is usually required, and this may be a long and tedious process involving the use of prostaglandin pessaries and oxytocin infusion. The RCOG currently recommends feticide for terminations over 21^{+6} weeks. A discussion regarding analgesic options should be offered, including parenteral opioids and epidural analgesia (see Chapter 76, *Intrauterine death*). It must be remembered that as gestational age increases, the risks associated with termination, including complications such as haemorrhage, uterine perforation and infection, increase.

Termination of a pregnancy at less than 28 weeks is often associated with the retention of products of conception, for which surgical evacuation and anaesthesia are required (see Chapter 5, *Evacuation of retained products of conception*). Either regional or general anaesthesia may be offered to the woman, balancing the risks and benefits of each depending on the clinical condition and whether epidural analgesia is already in place. Rapid-sequence induction and tracheal intubation may be appropriate.

Key points

- Women may present for termination of pregnancy for maternal reasons or because of fetal abnormality or death.
- Such women are distressed and should be dealt with sympathetically.
- Early termination is usually performed as a day-case general anaesthetic procedure.
- Issues surrounding late terminations are as for intrauterine death.

Further reading

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Chapter 7

Cervical suture (cerclage)

Cervical suture (Shirodkar or McDonald cerclage) is performed to reduce the incidence of spontaneous miscarriage when there is cervical incompetence. Although it can be done before conception or as an emergency during pregnancy, the procedure is usually performed electively in the second trimester. Indications include women with a history of cervical trauma, spontaneous preterm birth, preterm prelabour rupture of membranes (PPROM) or fetal loss between 16 and 34 weeks of pregnancy, and in whom transvaginal ultrasound scans at 16 and 24 weeks indicate a cervical length of less than 25 mm.

It generally takes 15–20 minutes and is performed transvaginally on a day-case basis. A non-absorbable stitch or tape is sutured in a purse-string around the cervical neck at the level of the internal os. This requires anaesthesia, since the procedure is at best uncomfortable, although the suture can often be removed without anaesthesia (usually at 36–37 weeks' gestation unless in preterm labour); spontaneous labour usually soon follows. In patients with a grossly disrupted cervix, for example following surgery, placement of the suture via an abdominal approach may be required. Delivery is usually by elective caesarean section in these cases.

Problems and special considerations

A woman undergoing cervical suturing may be especially anxious if a previous pregnancy has ended in miscarriage. Apart from the possibility of anxiety, anaesthesia is along standard lines, bearing in mind the risks of anaesthesia in the pregnant woman and the possible effects of drugs on the fetus (see Chapter 8, *Incidental surgery in the pregnant patient*). Cerclage may be difficult if the membranes are bulging; the head-down position and/or tocolysis may be required to counteract this.

Management options

Both regional and general anaesthesia are acceptable for the insertion of a cervical suture, with maintenance of normal haemodynamic parameters being paramount. Many authorities advocate spinal anaesthesia as the technique of choice, since only a small amount of drug is administered, although epidural anaesthesia is also acceptable. If spinal or epidural anaesthesia is chosen, standard techniques are used. The procedure itself requires a less extensive block than caesarean section (from T8–10 down to and including the sacral roots) and thus smaller doses are required; however, the reduction is offset by the greater requirements at this early stage of pregnancy compared with the term parturient. Thus the doses required for regional anaesthesia are in the order of 75% of those used for caesarean section. Low-dose techniques have also been used, as for caesarean section; the women have more

sensation (though painless) but have less motor block. Short-acting local anaesthetic agents such as prilocaine may be used to facilitate good anaesthesia for a short procedure while allowing faster discharge.

General anaesthesia may also be used; advantages include the relaxing effect of volatile agents on the uterus, and patient comfort if a steep Trendelenburg position is required. This involves administration of several drugs, and the effects on the fetus of many agents in current use are not clear (see Chapter 8, *Incidental surgery in the pregnant patient*). There may also be an increased risk of regurgitation and aspiration of gastric contents, depending on the gestation and severity of symptoms (see Chapter 59, *Aspiration of gastric contents*).

Paracervical and pudendal block and/or intravenous analgesia or sedation may also be used, but most authorities would recommend avoiding paracervical block because of potential adverse effects on uteroplacental perfusion.

Key points

- Cervical suture is usually performed in the second trimester.
- Patients may be especially anxious because of previous miscarriage.
- Standard techniques for the parturient are used; spinal anaesthesia may be preferable.

Further reading

National Institute for Health and Care Excellence. *Preterm Labour and Birth*. NICE Guideline NG 25. London: NICE, 2015. www.nice.org.uk/guidance/ng25 (accessed December 2018).

Chapter 8

Incidental surgery in the pregnant patient

Non-obstetric surgery may occur in 0.5–2% of pregnancies; pregnant women may present with the same surgical conditions as the non-pregnant population, or with problems related to their pregnancy. Most pregnant women are relatively young and fit, although there is an increasing number of women with systemic disease who are becoming pregnant because of advances in medical or surgical management of their condition. Points of particular relevance to anaesthetists are therefore any underlying condition in addition to the reason for surgery, the effects of pregnancy on its management and the effect upon the fetus.

Problems and special considerations

Surgical diagnosis of the acute abdomen may be difficult because of the physical presence of the gravid uterus. Non-specific signs such as white cell count may be unreliable (up to 15×10^9/l in normal pregnancy). The differential diagnosis may also include obstetric conditions such as placental abruption and HELLP (haemolysis, elevated liver enzymes and low platelet count) syndrome.

The risks of aortocaval compression, difficulties with airway management and aspiration of gastric contents are present as for any pregnant woman, and depend to a certain extent on the stage of pregnancy and the reason for surgery; most will treat such risks as clinically relevant during the second trimester (see Chapter 59, *Aspiration of gastric contents*).

Surgical technique may be hindered by the pregnancy, and the operation itself may be more difficult than in the non-pregnant patient. For example, laparoscopic procedures may be impossible. Surgery that normally requires the non-supine position, such as back surgery, may pose particular problems.

Since surgery is generally withheld during pregnancy unless absolutely necessary, patients who do present for surgery tend to be more severely affected; thus careful preoperative assessment and management are especially important. Problems of emergency surgery include inadequate preparation and investigation and an increased incidence of vomiting and dehydration.

The fetus is at risk from the primary effects of the mother's illness (e.g. dehydration, sepsis), the possible teratogenic effects of any drugs that are given to the mother, especially during the first trimester (see Chapter 3, *Anaesthesia before confirmation of pregnancy*), alterations in uteroplacental blood flow or oxygenation during anaesthesia and surgery, and possible premature onset of labour provoked by the illness, drugs or surgery itself.

Management options

In general, surgery is delayed until the second trimester if possible, because by then the major fetal organs will have already developed; in addition, the risk of premature labour is lower and the surgery easier than in the third trimester. Elective surgery should be postponed until after pregnancy. Once 24 weeks' gestation is reached, surgery should be undertaken at a location where emergency caesarean section is possible.

Perioperative management requires attendance by senior surgical and obstetric staff, with investigations and scans as required. The neonatal team should be informed once the fetus reaches 24 weeks' gestation. Anaesthetic management includes thorough preoperative assessment, taking into account the altered physiology of pregnancy (see Chapter 11, *Physiology of pregnancy*) when interpreting history, examination and investigations, and planning management. Particular attention should be paid to general assessment, as for emergency surgery in any patient. A sensitive discussion regarding risk to the pregnancy should be included in the preoperative assessment (see Chapter 3, *Anaesthesia before confirmation of pregnancy*). Current evidence suggests that miscarriage rates and premature delivery may be slightly increased, particularly when surgery occurs in the first and third trimester respectively. However, whether this is due to the anaesthetic, the surgery or the underlying pathological process is difficult to establish.

Depending on the stage of pregnancy, the airway may be more difficult, antacid administration should be considered, and the supine position should be avoided, although the efficacy of lateral tilt when the uterus is still small is uncertain. The disadvantages of regional anaesthesia (e.g. hypotension, increased peristalsis, problems with managing the block during difficult or prolonged surgery) must be weighed against those of general anaesthesia (airway problems, risk of awareness, less familiarity with general anaesthesia in the pregnant population etc.).

Although general anaesthesia involves the administration of more drugs with possible effects on the fetus, it also allows the use of volatile agents that relax the uterus. In general, drugs with good safety records during pregnancy should be used; most anaesthetic drugs do not have licences for use in pregnancy (mainly because of the costs involved in extending their licences), but newer drugs should probably be avoided until more is known about their actions. The only standard anaesthetic drug that has excited controversy in recent years is nitrous oxide, because of its effects on methionine synthase and DNA metabolism. Although there is a theoretical risk of its affecting the fetus, there is no evidence to support this clinically and many authorities, if not most, would now consider its use acceptable if needed.

General anaesthetic management would thus usually consist of rapid-sequence induction with standard agents, tracheal intubation and maintenance of anaesthesia with a volatile agent, as for any emergency general anaesthetic. Other drugs would be used as standard, but those that might increase uterine tone (e.g. ketamine, β-blockers) or vasoconstriction should be avoided if possible. Certain drugs given near to delivery may cross the placenta and affect the fetus (e.g. non-steroidal anti-inflammatory drugs, which can prevent the ductus arteriosus from closing). Prophylactic administration of tocolytic drugs has not been shown to be of any benefit, but uterine tone should be monitored perioperatively to allow administration of tocolytics if indicated. Traditional fears about the detrimental effects of high levels of maternal oxygen causing uteroplacental vasoconstriction are now known to be unfounded, and fetal arterial partial pressure of oxygen increases (up to

a maximum of about 8 kPa (60 mmHg)) as maternal arterial oxygen content increases, so long as maternal hypotension is avoided. Phenylephrine is considered the vasopressor of choice as it has the most evidence supporting its use; however, other α-agonists (e.g. metaraminol) may also be used. Maternal arterial partial pressure of carbon dioxide should be kept in the normal (pregnant) range during controlled ventilation, to avoid fetal acidosis with associated myocardial depression, and uterine artery vasoconstriction.

With regard to fetal monitoring, between 18 and 24 weeks' gestation, the fetal heart rate should be recorded pre- and post-procedure. From 24 weeks, cardiotocography monitoring with simultaneous electronic fetal heart rate and contraction monitoring should be performed before and after the procedure as a minimum. Intraoperative monitoring necessitates the presence of staff suitably trained to interpret preterm monitoring in the presence of anaesthesia and surgery, and abdominal surgery makes it more difficult to place the monitor. It may be difficult to arrange midwifery and surgical nursing care both before and after surgery, and the most appropriate area for the mother's postoperative care needs careful consideration.

Key points

- Surgical diagnosis and management may be difficult.
- Maternal risks are those of anaesthesia in the pregnant state.
- Fetal risks are related to the mother's condition and maternal drugs, and include the premature onset of labour.
- Anaesthetic management should focus on maintaining normal uteroplacental blood flow.

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Chapter 9

Intrauterine surgery

Fetal surgery is an attractive option in cases where an isolated abnormality would be otherwise fatal to the fetus or neonate, and is clearly amenable to correction, such as neck tumours with airway obstruction, sacrococcygeal teratomas, obstructive uropathy and diaphragmatic hernia. However, results of intrauterine surgery are variable depending on the type of surgery, and there is no clear consensus on its place. There are three main types of intrauterine surgery:

- Ex-utero intrapartum treatment (EXIT). This occurs immediately before delivery, and the fetus remains attached to the placenta, allowing brief procedures such as tracheal intubation or tracheostomy for airway obstruction to occur. Corrective surgery may then occur post-delivery.
- Open procedures such as correction of a meningomyelocoele. A vertical uterine incision may be required for access, necessitating caesarean delivery if the pregnancy proceeds.
- Minimally invasive procedures such as intrauterine blood transfusion in haemolytic disease or laser ablation of communicating vessels in twin-to-twin transfusion syndrome.

Problems and special considerations

Each procedure must be assessed on a risk–benefit basis, since there is a risk of up to 50% fetal loss associated with premature labour, haemorrhage, abruption and infection. Surgery is technically difficult because of the small size of the fetus and its mobility when small, but leaving the surgery until later may result in increased end-organ damage caused by the malformation. The optimal timing for most procedures is uncertain, although most open ones have been performed at around 18–24 weeks. Percutaneous procedures (e.g. transfusions) may be performed later or at intervals.

Maternal risks include haemorrhage, uterine scarring and amniotic fluid embolism. Postoperatively, the mother may be confined to bed and receive β_2-agonists, with the risks of deep-vein thrombosis and pulmonary oedema, respectively.

Each lesion must be carefully defined and a chromosomal abnormality or other malformation excluded. For example, intrauterine placement of intraventricular shunts is no longer considered suitable for treatment of hydrocephalus, since the risk–benefit ratio cannot be calculated for individual fetuses because of the difficulty in predicting outcome antenatally. Since most conditions that might be amenable to intrauterine surgery are rare or uncommon and already associated with poor outcome, it is difficult to demonstrate that outcome after fetal surgery is better than that after conventional postpartum therapy, because any expected improvement will be small.

Management options

Anaesthetic management is along the lines of that for incidental surgery during pregnancy, with maintenance of uteroplacental perfusion the main concern (see Chapter 8, *Incidental surgery in the pregnant patient*). Local anaesthetic infiltration of the abdominal wall, with or without conscious sedation, may be adequate for percutaneous procedures, although there may be a need for emergency caesarean section if fetal bradycardia occurs, and so adequate preparation and facilities are required for this. Regional anaesthesia is a suitable alternative if extensive percutaneous procedures are required.

Fetal and maternal general anaesthesia for corrective surgery is administered by using standard techniques, though placental transfer of anaesthetic agents may be desirable in this scenario, unlike during caesarean section. Total uterine relaxation may be required, and this may be achieved with 2–3 MAC of an inhalational agent; this may result in maternal haemorrhage or hypotension, both of which must be anticipated and treated aggressively. Alternatively, magnesium sulfate or glyceryl trinitrate may be used. Fetal injection of a neuromuscular blocking drug may be required to stop fetal movement. Analgesics may also be injected into the fetus, since there is increasing evidence that the fetus can experience pain. Fetal monitoring may be difficult, but pulse oximetry, ultrasonography and cardiotocography have been used. Bleeding may be excessive in prolonged open procedures.

Key points

- The place of intrauterine surgery is uncertain.
- To be suitable for intrauterine surgery, malformations must be clearly defined, fatal if untreated and amenable to corrective surgery.
- General principles of anaesthesia are as for incidental surgery during pregnancy.

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Chapter 10

Anatomy of the spine and peripheral nerves

Although not exclusive to obstetric anaesthesia, a sound knowledge of the anatomy pertinent to epidural and spinal anaesthesia is fundamental to obstetric anaesthetists. In addition, knowledge of the relevant peripheral nerves is important in order to differentiate central from peripheral causes of neurological impairment.

The structures involved in obstetric neuraxial anaesthesia comprise the vertebrae and sacral canal, vertebral ligaments, epidural space, meninges and spinal cord. The important peripheral aspects are the lumbar and sacral plexuses and the muscular and cutaneous supply of the lower part of the body.

Vertebrae (Figure 10.1)

The vertebral column has two curves, with the cervical and lumbar regions convex anteriorly and the thoracic and sacral regions concave. Traditionally, T4 is described as the most posterior part (most dependent in the supine position), although T8 has been suggested by recent imaging studies. L3–4 is the most anterior part (uppermost in the supine position), although this curve may be flattened by flexing the hips. In the lateral position, the greater width of women's hips compared with their shoulders imparts a downward slope from the caudal end of the vertebral column to the cranial end.

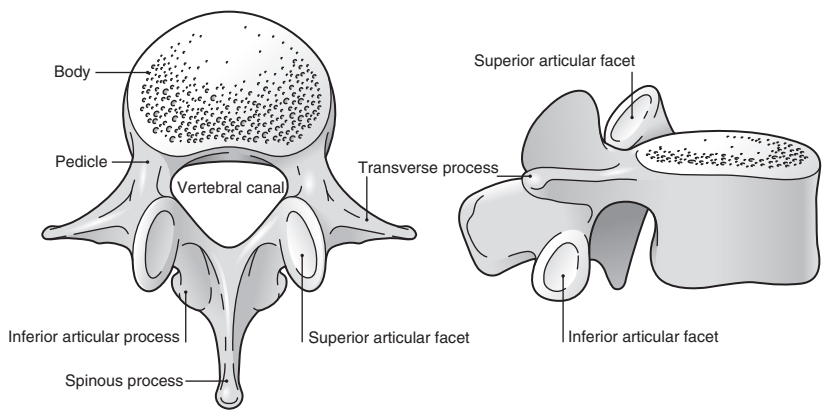

Figure 10.1 A lumbar vertebra, seen from superior and lateral aspects. Reproduced with permission from Yentis SM, Hirsch NP, Smith GB. *Anaesthesia and Intensive Care A–Z,* 4th edn. Churchill Livingstone. © Elsevier 2009.

There are seven cervical vertebrae, twelve thoracic, five lumbar, five fused sacral and three to five fused coccygeal. A number of ligaments connect them (see below). Vertebrae have the following components:

- **Body.** This lies anteriorly, with the vertebral arch behind. It is kidney-shaped in the lumbar region. Fibrocartilaginous vertebral discs, accounting for about 25% of the spine's total length, separate the bodies of C2 to L5. Each disc has an outer fibrous annulus fibrosus and a more fluid inner nucleus pulposus (the latter may prolapse through the former: a 'slipped disc'). The bodies of the thoracic vertebrae are heart-shaped and articulate with the ribs via superior and inferior costal facets at their rear. The bodies of the sacral vertebrae are fused to form the sacrum, which encloses the sacral canal; the coccygeal vertebral bodies are fused to form the triangular coccyx, the base of which articulates with the sacrum.
- **Pedicles.** These are round in cross-section. They project posteriorly from the body and join the laminae. Each intervertebral foramen is formed by the pedicles of the vertebra above and below.
- **Laminae.** These are flattened in cross-section. They complete the vertebral arch by meeting in the midline at the spinous process. The superior and inferior articular processes bear facets for articulation with adjacent vertebrae; those of the thoracic vertebrae are flatter and aligned in the coronal plane, whereas those of the lumbar vertebrae are nearer the sagittal plane.
- **Transverse processes.** In the lumbar region these are thick and pass laterally. The transverse processes of L5 are particularly massive but short. The transverse processes of thoracic vertebrae are large and pass backwards and laterally; they bear facets that articulate with the tubercles of the ribs (except T11 and T12).
- **Spinous process.** These project horizontally backwards in the lumbar region; in the thoracic region they are longer and inclined at about 60 degrees to the horizontal. The spinous process of T12 has a notched lower edge.

The cervical vertebrae have a number of features that distinguish them from the others, including the foramen transverarium in the transverse processes, bifid spinous processes and the particular characteristics of C1 and C2.

A line drawn between the iliac crests (Tuffier's line) usually crosses the L3–4 interspace (slightly higher than in the non-pregnant state because of rotation of the pelvis), although this is unreliable, and it has been shown that even experienced anaesthetists can be one or more interspaces lower (or more commonly, higher) than that intended.

Sacral canal (Figure 10.2)

The sacral canal is 10–15 cm long, triangular in cross-section, runs the length of the sacrum and is continuous cranially with the lumbar vertebral canal. The fused bodies of the sacral vertebrae form the anterior wall, and the fused sacral laminae form the posterior wall. The sacral hiatus is a deficiency in the fifth laminar arch, has the cornua laterally and is covered by the sacrococcygeal membrane. Congenital variants are common, possibly contributing to unreliable caudal analgesia.

Vertebral ligaments (Figure 10.3)

- **Anterior longitudinal ligament.** This is attached to the anterior aspects of the vertebral bodies, and runs from C2 to the sacrum.

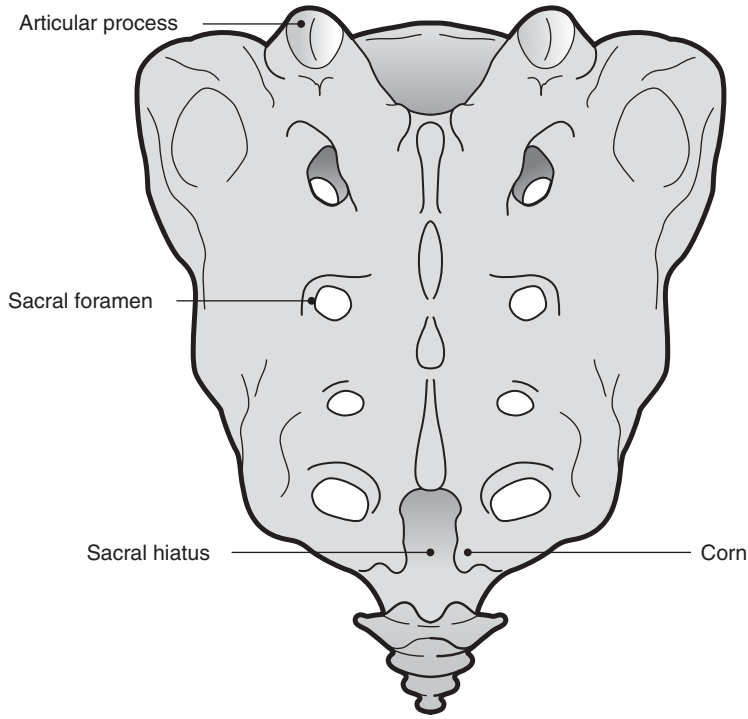

Figure 10.2 Sacrum, posterior aspect. Reproduced with permission from Yentis SM, Hirsch NP, Smith GB. *Anaesthesia and Intensive Care A–Z*, 4th edn. Churchill Livingstone. © Elsevier 2009.

- **Posterior longitudinal ligament.** This is attached to the posterior aspects of the vertebral bodies, and runs from C2 to the sacrum.
- **Ligamentum flavum (yellow ligament).** This is attached to the laminae of adjacent vertebrae, forming a V-shaped structure with the point posteriorly. It is more developed in the lumbar than in the thoracic region.
- **Interspinous ligament.** This passes between the spinous processes of adjacent vertebrae.
- **Supraspinous ligament.** This is attached to the tips of the spinous processes from C7 to the sacrum.

In addition, there are posterior, anterior and lateral sacrococcygeal ligaments. Other ligaments are involved in the attachments of C1 and C2 to the skull. The ligaments may become softer during pregnancy because of the hormonal changes that occur.

Epidural space

- **Boundaries.** The space extends from the foramen magnum to the sacrococcygeal membrane. It is triangular in cross-section in the lumbar region, its base anterior; it is very thin anteriorly and up to 5 mm wide posteriorly. It lies external to the dura mater of the spinal cord and internal to the ligamenta flava and vertebral laminae posteriorly, the posterior longitudinal ligament anteriorly and the intervertebral foramina and vertebral pedicles laterally. Magnetic resonance imaging suggests the space is divided into

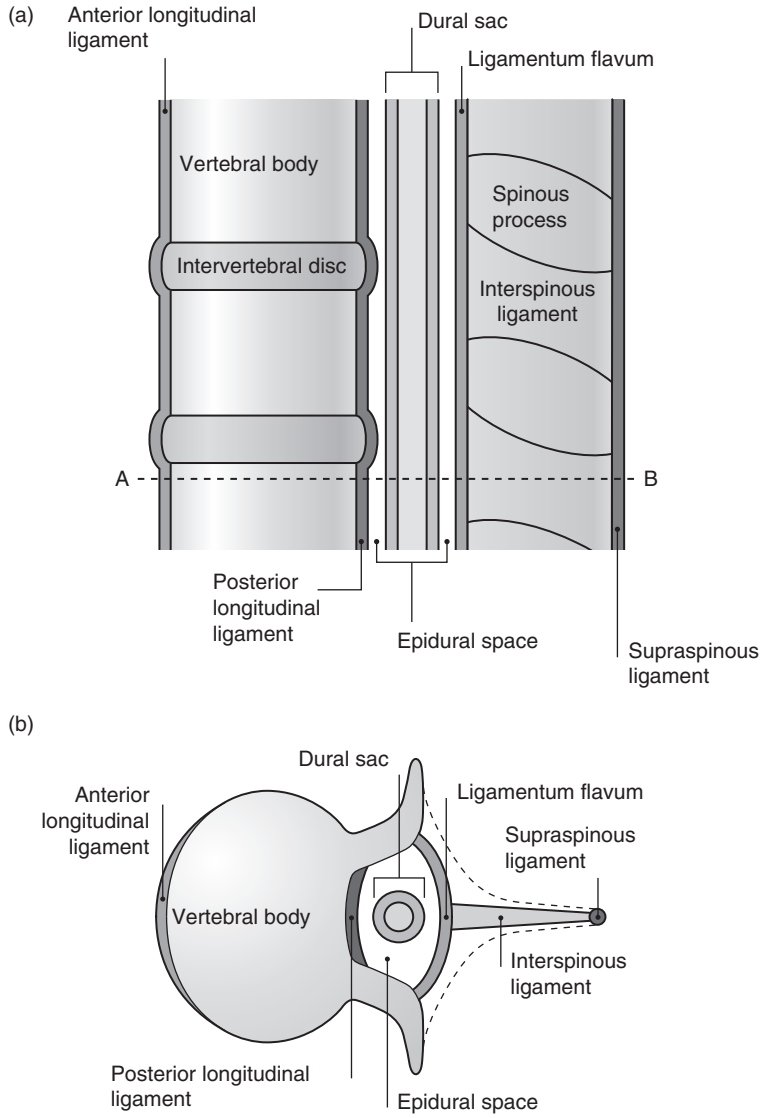

Figure 10.3 Vertebral ligaments: (a) longitudinal section and (b) transverse section through A–B. Reproduced with permission from Yentis SM, Hirsch NP, Smith GB. *Anaesthesia and Intensive Care A–Z*, 4th edn. Churchill Livingstone. © Elsevier 2009.

segments by the laminae. The space may extend through the intervertebral foramina into the paravertebral spaces.

- **Contents.** These include epidural fat, epidural veins (Batson's plexus), lymphatics and spinal nerve roots. The veins become engorged in pregnancy as a result of the hormonal changes and any aortocaval compression. Connective tissue layers have been

demonstrated by radiology and endoscopy within the epidural space, in some cases dividing it into right and left portions.

- **Pressure.** A negative pressure is usually found in the epidural space upon entering it; the reason is unclear but may involve anterior dimpling of the dura by the epidural needle, sudden posterior recoil of the ligamentum flavum when it is punctured, stretching of the dural sac during extreme flexion of the back, transmitted negative intrapleural pressure via thoracic paravertebral spaces and/or relative overgrowth of the vertebral canal compared with the dural sac. Occasionally a positive pressure is found.

Meninges

- **Pia mater.** This delicate and vascular layer adheres closely to the brain and spinal cord. Between it and the arachnoid mater is the cerebrospinal fluid (CSF) within the subarachnoid space containing blood vessels, the denticulate ligament laterally along its length and the subarachnoid septum posteriorly. The pia terminates as the filum terminale, which passes through the caudal end of the dural sac and attaches to the coccyx.
- **Arachnoid mater.** This membrane is also delicate and lies between the dura externally and the CSF internally. The potential subdural space lies between the dura and arachnoid mater, which fuses with the dura at S2.
- **Dura mater.** This fibrous layer has an outer component that is adherent to the inner periosteum of the vertebrae, and an inner one that lies against the outer surface of the arachnoid. The dura projects into the epidural space, especially in the midline. It ends at about S2.

Spinal cord

The spinal cord ends inferiorly level with L3 at birth, rising to the adult level of L1–2 (sometimes T12 or L3) by 20 years. Below this level (the conus medullaris), the lumbar and sacral nerve roots (comprising the cauda equina) and filum terminale occupy the vertebral canal. The main ascending and descending tracts are shown in Figure 10.4.

The blood supply of the spinal cord is of relevance to obstetric anaesthetists, since cord ischaemia may result in neurological damage:

- **Anterior spinal artery.** This descends in the anterior median fissure and supplies the anterior two-thirds of the cord. The anterior spinal artery syndrome (e.g. arising from profound hypotension) thus results in lower motor neurone paralysis at the level of the lesion, and spastic paraplegia, reduced pain and temperature sensation below the level, with normal joint position sense and vibration sensation.
- **Posterior spinal arteries.** These descend along each side of the cord, one anterior and one posterior to the dorsal nerve roots.
- **Radicular branches.** These arise from local arteries (from the aorta) and feed the spinal arteries. Those at T1 and the lower thoracic/upper lumbar level (artery of Adamkiewicz – usually unilateral) are the most important. The cord at T3–5 and T12–L1 is thought to be most at risk from ischaemia. The conus medullaris and cauda equina are supplied by a vascular plexus arising from the artery of Adamkiewicz above and pelvic vessels below. In 15% of the population, the artery of Adamkiewicz is the

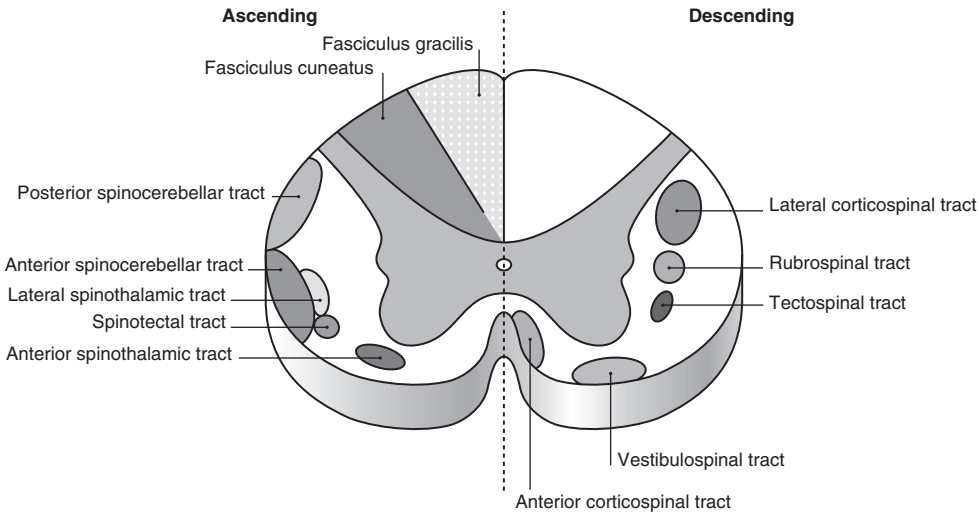

Figure 10.4 Ascending and descending tracts of the spinal cord. Reproduced with permission from Yentis SM, Hirsch NP, Smith GB. *Anaesthesia and Intensive Care A–Z*, 4th edn. Churchill Livingstone. © Elsevier 2009.

main source of arterial blood to the conus medullaris and cauda equina; compression during delivery may result in permanent paraplegia.

Venous drainage is via the internal iliac, intercostal, azygos and vertebral veins.

Peripheral nerves of the lower body

The lumbar and sacral plexuses are shown schematically in Figure 10.5. They form at the posterior of the pelvis, and their branches pass round the interior of the pelvis, where they may be exposed to pressure during labour and delivery (Figure 10.6; see also Chapter 53, *Peripheral nerve lesions following regional anaesthesia*).

Peripheral cutaneous innervation may be characterised according to the dermatomal distribution or peripheral nerves (Figures 10.5 and 10.7, Table 53.1). Both representations may vary considerably between individuals. Peripheral motor innervation may also be considered according to myotomal innervation or peripheral nerves (Table 10.1).

Dermatomal innervation of the upper body is also important when determining the upper extent of regional blockade.

Key points

- A clear understanding of the anatomy of the spine and peripheral nerves is essential when delivering neuraxial anaesthesia and analgesia, and when assessing neurological complications related to delivery.

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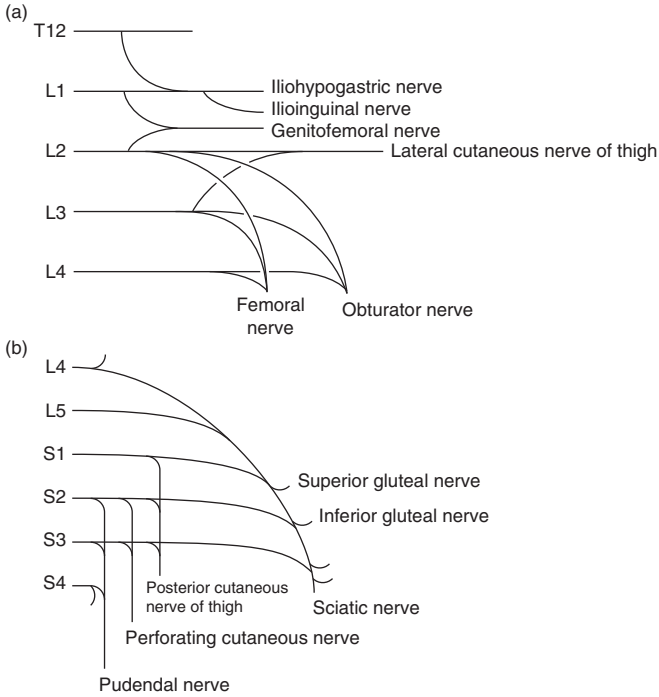

Figure 10.5 Plan of (a) lumbar plexus and (b) sacral plexus. Reproduced with permission from Yentis SM, Hirsch NP, Smith GB. *Anaesthesia and Intensive Care A–Z*, 4th edn. Churchill Livingstone. © Elsevier 2009.

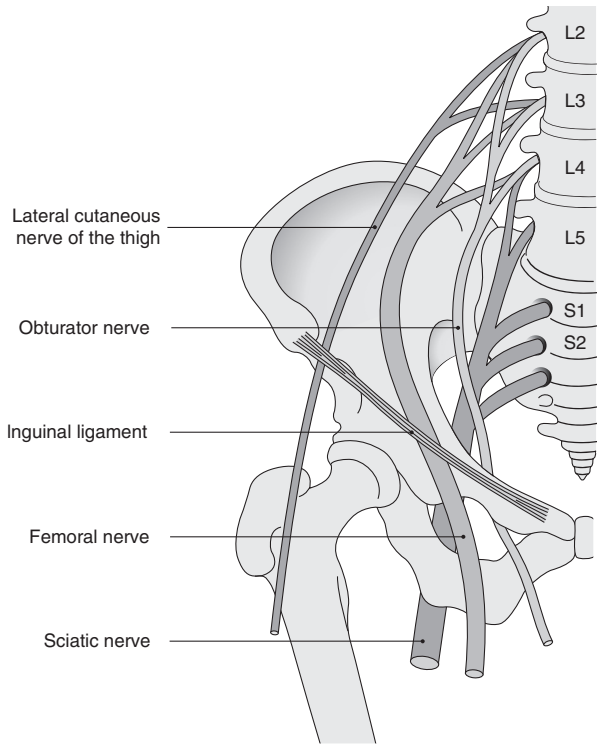

Figure 10.6 Relationship of peripheral nerves with the pelvis. Adapted with permission from Holdcroft A, Thomas TA. *Principles and Practice of Obstetric Anaesthesia*. Blackwell Science Ltd. © John Wiley & Sons Ltd 1999.

Table 10.1 Motor innervation of lower limbs by myotomes and peripheral nerves

Joint	Movement	Myotomes	Nerve supply
Hip	Flexion	L1–3	Lumbar plexus
		L2–4	Femoral nerve
	Extension	L5–S2	Sacral plexus
		L5–S2	Sciatic nerve
	Abduction	L5–S2	Sacral plexus
	Adduction	L2–4	Obturator nerve
Knee	Extension	L2–4	Femoral nerve
	Flexion	L5–S2	Sciatic nerve
		S1–2	Tibial nerve[a]
Ankle/foot	Dorsiflexion	L4–5	Deep peroneal nerve[b]
	Eversion	L5–S1	Superficial peroneal nerve[b]
	Plantar flexion	S1–2	Tibial nerve[a]
	Inversion	L4–5	Tibial nerve[a]

[a] Branch of sciatic nerve.
[b] Branch of common peroneal nerve, itself a branch of the sciatic nerve.

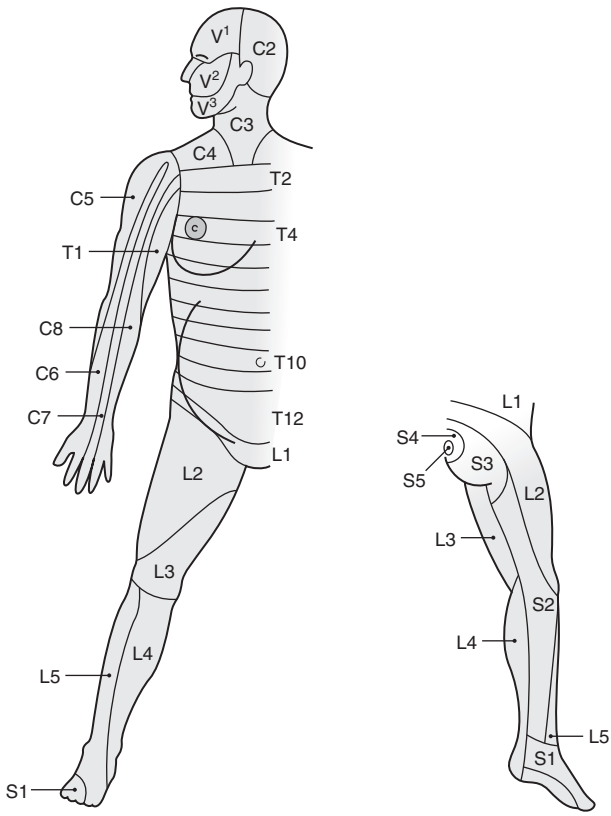

Figure 10.7 Dermatomes of upper and lower body. Reproduced with permission from Yentis SM, Hirsch NP, Smith GB. *Anaesthesia and Intensive Care A–Z*, 4th edn. Churchill Livingstone. © Elsevier 2009.

Chapter 11

Physiology of pregnancy

Pregnancy is associated with major physiological changes throughout the body. These are caused both by hormonal factors (influential from conception onwards) and by the mechanical changes due to the enlarging uterus (of increasing significance as pregnancy progresses). It is important to understand the normal physiological changes occurring during pregnancy, in order to predict the risks and effects of analgesic and anaesthetic intervention, and also to anticipate the impact of pregnancy on any coexisting medical condition.

Hormonal changes

Following fertilisation, the corpus luteum in the ovary secretes progesterone, oestrogens and relaxin. The placenta takes over the hormone-producing function of the corpus luteum from 6–8 weeks' gestation onwards and secretes in addition human chorionic somatomammotrophin (hCS; previously known as human placental lactogen and chorionic growth hormone-prolactin).

Human chorionic gonadotrophin (hCG) can be measured by radioimmunoassay and detected in the blood 6 days after conception, and in the urine 2–3 weeks after conception. It is therefore a useful early diagnostic test of pregnancy. It is produced by the syncytiotrophoblast, and levels rise rapidly during the first 8 weeks of pregnancy, falling to a plateau thereafter.

Progesterone is responsible for most of the hormonally mediated changes occurring during pregnancy. It causes:

- Smooth muscle relaxation
- Generalised vasodilatation
- Bronchodilatation
- Dilatation within the renal tract
- Sluggish gastrointestinal tract motility and constipation

It is thermogenic, causing an increase in basal temperature during pregnancy. It may be responsible for the nausea and vomiting that are common in early pregnancy. Progesterone is a neurotransmitter and, together with increased endogenous endorphins, is implicated in the elevated pain threshold experienced by pregnant women. It also decreases the minimum alveolar concentration (MAC) of inhalational anaesthetic agents. Progesterone has also been demonstrated to enhance conduction blockade in isolated nerve preparations, and it is therefore thought likely to play a role in the decreased requirement for local anaesthetic agents for neuraxial anaesthesia.

Mechanical changes

The uterine fundus progressively enlarges and becomes palpable abdominally by the beginning of the second trimester, at the level of the umbilicus by 20 weeks' gestation and the xiphisternum by 36 weeks.

Fetal head engagement in the maternal pelvis at the end of pregnancy reduces the fundal height and may alleviate some symptoms attributable to mechanical factors. In multiple pregnancies, the uterus expands to a greater extent and more rapidly, and therefore the mechanical effects are usually greater.

Following delivery the uterus involutes rapidly, and should not be palpable above the maternal umbilicus. It has usually returned to within the pelvis by 72 hours after delivery.

Cardiovascular and haemodynamic changes

Pregnancy

- Blood volume increases throughout pregnancy secondary to hormone-mediated fluid retention, and reaches approximately 45–50% more than pre-pregnant values by term.
- Cardiac output, heart rate and stroke volume all increase as pregnancy progresses. Cardiac output increases by approximately 40–50% by term, with most of the increase occurring by 20 weeks' gestation. The increased blood flow is distributed primarily to the uterus, where blood flow increases from approximately 50 ml/minute at 10 weeks' gestation to 850 ml/minute at term. Approximately 1 litre of blood is contained within the uterus and the maternal side of the placenta.
- There is a propensity for arrhythmias that is caused by hormonal effects, increased sympathetic discharge and the stimulation of stretch-activated cardiac ion channels secondary to increased blood volume and cardiac chamber size. The resulting membrane depolarisation may lead to a shortened refractory period, slowed conduction and a mismatch of depolarisation and refractoriness.
- The electrocardiogram in pregnancy may show sinus tachycardia, ectopic beats, shortening of the PR and uncorrected QT intervals, a Q wave and T wave inversion in the lateral leads or lead III, or left axis deviation.
- Renal blood flow increases by 80% over non-pregnant levels by the middle of the second trimester. Glomerular filtration rate and creatinine clearance increase by 50% during pregnancy.
- Systemic vascular resistance falls (peripheral vasodilatation mediated by progesterone, prostacyclin and oestrogens), and there is a decrease in both systolic and diastolic blood pressures, which reach a nadir during the second trimester and then increase gradually towards term, although remaining lower than pre-pregnancy values.
- Aortocaval compression can occur from the middle of pregnancy onward if the supine position is adopted. This is due to mechanical compression of the aorta and inferior vena cava. Venous return is dependent on the competence of collateral circulation via the azygos and ovarian veins. Studies have demonstrated that uterine blood flow decreases primarily as a result of aortic rather than venous compression (see Chapter 13, *Aortocaval compression*).
- Central venous and pulmonary arterial pressures are unchanged during normal pregnancy.

Labour and delivery

- Cardiac output increases by 25–50% in labour, with an additional 15–30% increase during contractions. This increase in cardiac output is mediated through increased sympathetic nervous system activity, and is therefore significantly attenuated by epidural analgesia.
- Central venous pressure increases during contractions, partly due to sympathetic activity and partly from the transfer of up to 500 ml of blood from the intervillous space. The latter is unaffected by epidural analgesia, as is the increase in central venous pressure which occurs when the Valsalva manoeuvre is performed during pushing.
- Autotransfusion of around 500 ml of blood (from the placenta) occurs during the third stage. There is a sustained increase in cardiac output and central venous pressure for several hours after delivery secondary to intravascular fluid shifts. These haemodynamic changes may be significant in women with cardiac disease or those with pre-eclampsia.

Respiratory changes

Pregnancy

- Progesterone increases the sensitivity of the respiratory centre to carbon dioxide and also acts as a primary respiratory stimulant. These effects are enhanced by oestrogens, and the combined hormonal effect causes an increase in minute ventilation of 45–50%. A sensation of breathlessness is common and is experienced by up to 70% of pregnant women. Physicians should, however, maintain a high index of suspicion when evaluating breathlessness in pregnancy, especially if it is associated with other clinical features. Persistent breathlessness on lying down is an abnormal sign and must be investigated.
- The partial pressure of carbon dioxide in arterial blood ($PaCO_2$) is re-set to approximately 4 kPa during the first trimester and remains at that level throughout pregnancy. A partially corrected respiratory alkalosis is found in normal pregnant women.
- Oxygen consumption increases progressively during pregnancy to 35% above pre-pregnancy levels.
- Functional residual capacity (FRC) decreases to 80% of pre-pregnancy values as pregnancy progresses, caused by increased intra-abdominal pressure and upward displacement of the diaphragm by the enlarging uterus. Total lung capacity remains unchanged. FRC remains greater than closing capacity throughout pregnancy while the woman remains in an upright position, but falls when a recumbent position is adopted. It has been estimated that airway closure within normal tidal ventilation may occur in as many as 50% of all supine pregnant women during the second half of pregnancy. Consideration should therefore be given to continuous administration of oxygen to women particularly at risk (e.g. those who are obese, and those with respiratory disease).

Labour and delivery

- Massive hyperventilation occurs during labour (unless there is effective analgesia), with minute ventilation increasing to 3–4 times prelabour values.

- $PaCO_2$ falls to below 2 kPa in some women. This respiratory alkalosis is associated with a metabolic acidosis, since maternal aerobic requirement for oxygen (increased by hyperventilation, hyperdynamic circulation and uterine activity) cannot be met, resulting in a progressive lactic acidosis.
- Effective epidural analgesia abolishes these effects during the first stage of labour but not during the second, when the additional uterine activity and work of pushing produce a further oxygen demand that cannot be met.
- The increased oxygen consumption and reduced oxygen reserves put pregnant women at a significant risk of hypoxia during periods of apnoea, e.g. at the induction of general anaesthesia.

Gastrointestinal changes

Pregnancy

- Lower oesophageal sphincter pressure is reduced because of the smooth muscle relaxant effect of progesterone.
- Intragastric pressure rises as a mechanical consequence of the enlarging uterus.
- The overall effect of these changes is a decrease in gastro-oesophageal barrier pressure, with a concomitant increase in risk of regurgitation and aspiration of gastric contents.
- 75–85% of pregnant women complain of heartburn during the third trimester, and a significant number will have a demonstrable hiatus hernia.
- Gastric emptying is not delayed during pregnancy.
- There is some evidence that gastric volume is increased, and the pH of the intragastric volume may be lower than in the non-pregnant individual.
- Plasma albumin concentration falls due to physiological haemodilution, thus increasing the unbound fraction of highly protein-bound drugs. This may have implications for dose calculation and serum-level monitoring of drugs such as phenytoin, which should be based on measurement of the free drug concentration.

Labour and delivery

- Gastric emptying is now thought to be normal in labour in most cases. However, opioid administration by any route will delay gastric emptying.
- The risk of pulmonary aspiration of gastric contents means that rapid-sequence induction of general anaesthesia, preceded by measures to reduce the acidity of the gastric contents, is required (see Chapter 59, *Aspiration of gastric contents*).
- Studies suggest that gastric volume (but not acidity) may remain elevated for 48 hours after delivery.

Haematological changes

Total blood volume increases by approximately 1.5 litres during pregnancy, with plasma volume increasing by 30–50% and red cell mass increasing by 20–30% (thus causing the so-called 'physiological anaemia' of pregnancy). The magnitude of the increase is greater in women with multiple pregnancy and greatly reduced in women with pre-eclampsia. Plasma

volume changes are maximum by mid-pregnancy, returning to normal by approximately 6 weeks postpartum.

The haemoglobin concentration falls by 10–20 g/l by mid-pregnancy; the red cell indices remain approximately constant apart from a small increase in the mean cell volume, unless women become iron/folate-deficient. Postpartum, the haemoglobin concentration usually takes up to 4–6 weeks to reach pre-pregnancy levels.

The white blood cell count increases, peaking at 10–15 $\times$ 10^9/l around mid-pregnancy and increasing further in labour (to up to 30 $\times$ 10^9/l), returning to normal non-pregnant levels by 6–7 days postpartum. Most of the increase is in neutrophils. (Note that the use of steroids in preterm labour can also increase white cell count.)

The platelet count usually remains within the normal range in pregnancy, although population mean counts are slightly lower, with the lower normal limit usually given as approximately 100–120 $\times$ 10^9/l.

Pregnancy represents a state of hypercoagulability; there is increased hepatic production of coagulation factors, especially fibrinogen (increases by approximately 50%) and factor VIII (approximately doubles), but others also increase (II, X and von Willebrand factor). Resistance to activated protein C also increases. Fibrinolytic inhibitors decrease, as do factor XI and protein S activity.

Musculoskeletal changes

The pregnant woman has increased ligamentous laxity, secondary to increased relaxin release, which may lead to increased joint mobility and instability. This may put the woman at risk of musculoskeletal trauma if she has received epidural analgesia, and this risk is considerably higher if she has received either regional or general anaesthesia, when she is unable to safeguard her position. Care is therefore required when positioning, with special attention being paid to the hips and back. The wedged supine position and the use of lateral tilt are compromises and do not reliably relieve aortocaval compression. Women should be encouraged to remain sitting upright or in the full lateral position whenever possible. Walking and standing in labour should also be encouraged.

Key points

- An understanding of the normal physiological changes of pregnancy is essential when caring for the parturient, both in normal pregnancy and delivery and when pathology occurs.

Further reading

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