Textbook of Surgery

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Preface

Medical students and trainees must possess an understanding of basic surgical principles, knowledge of specific surgical conditions, be able to perform a few basic procedures and be part of a multidisciplinary team that manages the patient in totality. Students must also be aware of the rapid developments in technology and basic sciences and understand where these developments impinge on surgical practice.

The *Textbook of Surgery* is intended to supply this information, which is especially relevant given current surgical curriculum for undergraduates. Each topic is written by an expert in the field from his own wisdom and experience. All contributors have been carefully chosen from the Australasian region for their authoritative expertise and personal involvement in undergraduate and postgraduate teaching.

In this textbook we have approached surgery from a practical viewpoint while emphasising the relevance of basic surgical principles. We have attempted to cover most aspects of general surgery and selected topics of specialty surgery, including cardiothoracic surgery, neurosurgery, plastic surgery, orthopaedic surgery and urology. Principles that underlie the assessment, care and treatment of surgical patients are outlined, followed by sections on various surgical disorders. The final section presents a practical problem-solving approach to the diagnosis and management of common surgical conditions. In clinical practice, patients present with symptoms and signs to the surgeon who then has to formulate care plans, using such a problem-solving approach. This textbook provides a good grounding for students in surgical diseases, problems and management. Apart from forming the core curriculum for medical students, surgical trainees will also find the *Textbook of Surgery* beneficial in their studies and their practice.

With ever-expanding medical knowledge, a core amount of instructive and up-to-date information is presented in a concise fashion. Important leading references of classic publications or up-to-date literature have been provided. It is our aim that this textbook will stimulate students to refer to appropriate reviews and publications for further details in specific subjects.

We have presented the textbook in an attractive and easily readable format by extensive use of tables, boxes and illustrations. We hope that this edition will continue to be valuable to undergraduate, graduate and postgraduate students of surgery, and for general practitioners and physicians as a useful summary of surgery.

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Our patients, students, trainees and surgical mentors have all been an inspiration to us; but above all we owe a debt of gratitude to our loving families, specifically our wives Yvonne Pun-Tjandra, Jess Clunie, Judy Kaye and Sally Smith, as it was precious time spent away from them which allowed completion of this textbook. Finally the lead editor (JJT) would like to dedicate this book to his mentor, friend and colleague, Professor Victor Fazio who has contributed enormously to surgical education globally.

Principles of Surgery

1 Pre-operative management

Iain G. Martin

Introduction

This chapter covers care of the patient from the time the patient is considered for surgery through to immediately prior to operation and deals with important generic issues relating to the care of all surgical patients. Whilst individual procedures each have unique aspects to them, a sound working understanding of the common foundation of the issues involved in pre-operative care is critical to good patient outcomes.

Informed consent

Although often thought of in a purely medico-legal way, the process of ensuring that a patient is informed about the procedure that they are about to undergo is a fundamental part of good quality patient care. Informed consent is far more than the act of placing a signature on a form; that signature in itself is only meaningful if the patient has been through a reasonable process that has left them in a position to make an informed decision.

There has been much written around issues of informed consent, and the medico-legal climate has changed substantially in the past decade. It is important for any doctor to have an understanding of what is currently understood by informed consent.

Although the legal systems in Australia and New Zealand are very different with respect to medical negligence, the standards around what constitutes informed consent are very similar.

Until relatively recently, the standard applied to deciding whether the patient was given adequate and appropriate information with which to make a decision was the so-called Bolam test, that is practitioners are not negligent if they act in accordance with practice accepted by a reasonable body of medical opinion. Recent case law from both England and Australia and the standards embedded in the New Zealand's Health and Disability Commissions code of patient rights have seen a move away from the existing position. Although this area is complex, the general opinion is that a doctor has a duty to disclose to patients material risks. A risk is said to be material if 'in the circumstances of that particular case, a reasonable person in the patient's position, if warned of the risk would be likely to attach significance to it or the medical practitioner is, or should reasonably be aware that the particular patient, if warned of the risk would attach significance to it'. It is important that this standard relates to what a person in the patient's position would do and not just any reasonable person.

Important factors in considering the kinds of information to disclose to patients are:

- The nature of the potential risks: more common and more serious risks require disclosure.
- The nature of the proposed procedure: complex interventions require more information as do procedures when the patient has no illness.
- The patient's desire for information: patients who ask questions make known their desire for information and they should be told.
- The temperament and health of the patient: anxious patients and patients with health problems or other relevant circumstances that make a risk more important for them may need more information.
- The general surrounding circumstances: the information required for elective procedures might be different from that required in the emergency department.

What does this mean for a medical practitioner? Firstly, you must have an understanding of the legal framework and standards. Secondly, you must be able to document how appropriate information was given to patients – always write it down. On this point, whilst information booklets can be a very useful addition to the process of informed consent they do not

remove the need to undertake open discussions with the patient.

Doctors often see the process of obtaining informed consent as difficult and complex, and this view is leant support by changing standards. However, the principles are relatively clear and not only benefit patients but their doctors as well. A fully informed patient is much more likely to adapt to the demands of a surgical intervention, and should a complication occur, they almost invariably accept such misfortune far more readily.

Pre-operative assessment

The appropriate assessment of patients prior to surgery to identify coexisting medical problems and to plan peri-operative care is of increasing importance. Modern trends towards the increasing use of day-of-surgery admission even for major procedures have increased the need for careful and systematic peri-operative assessment.

The goals of peri-operative assessment are:

- To identify important medical issues in order to
  - optimise their treatment.
  - inform the patient of the risks associated with surgery.
  - ensure care is provided in an appropriate environment.
- To identify important social issues which may have a bearing on the planned procedure and the recovery period.
- To familiarise the patient with the planned procedure and the hospital processes.

Clearly the peri-operative evaluation should include a careful history and physical examination, together with structured questions related to the planned procedure. Simple questions related to exercise tolerance (such as can you climb a flight of stairs without shortness of breath) will often yield as much useful information as complex tests of cardiorespiratory reserve. The clinical evaluation will be coupled with a number of blood and radiological tests to complete the clinical evaluation. There is considerable debate as to the value of many of the routine tests performed, and each hospital will have its own protocol for such evaluations.

On the basis of the outcomes of this consultation a number of risk stratification systems have been proposed; the only one in widespread daily use is the relatively simple ASA (American Society of Anesthesiologists) system (see Table 2.1, Chapter 2).

The pre-operative assessment and work-up will be guided by a combination of the nature of the operation proposed and the overall 'fitness' of the patient. Whilst there are a number of ways of looking at the type of surgery proposed, a simple three-way classification has much to commend it:

- Low risk: poses minimal physiological stress and risk to the patient, rarely requires blood transfusion, invasive monitoring or intensive care. Examples of such procedures would be groin hernia repair, cataract surgery, arthroscopy.
- Medium risk: moderate physiological stress (fluid shifts, cardiorespiratory effects) and risk. Usually associated with minimal blood loss. Potential for significant problems must be appreciated. Examples would be laparoscopic cholecystectomy, hysterectomy, hip replacement.
- High risk: significant peri-operative physiological stress. Often requires blood transfusion or infusion of large fluid volumes. Requires invasive monitoring and will often need intensive care. Examples would be aortic surgery, major gastrointestinal resections, thoracic surgery.

A low-risk patient (ASA I or II) will clearly require a far less intensive work-up than a high-risk patient (ASA III or IV) undergoing a high-risk operation.

Areas of specific relevance to peri-operative care are cardiac disease and respiratory disease. It is important that pre-existing cardiorespiratory disease is optimised prior to surgery to minimise the risk of complications. Patients with cardiac disease can be stratified using a number of systems (Goldman or Detsky indices) and this stratification can be used to guide work-up and interventions and provide a guide to prognosis. One of the most important respiratory factors is whether the patient is a smoker; there is now clear evidence that stopping smoking for at least 6 weeks prior to surgery significantly reduces the risk of complications.

Patient safety

Once in hospital, and particularly once under anaesthetic, patients rely upon the systems and policies of individuals and health care institutions to minimise the risk of inadvertent harm. Whilst every hospital will have slightly different policies the fundamental goals of these include:

- The correct patient gets the correct operation on the correct side or part of their body. An appropriate

method of patient identification and patient marking must be in place. It must be clear to all involved in the procedure, particularly for operations on paired limbs or organs, when the incorrect side could be operated upon.
- The patient is protected from harm whilst under anaesthetic. When under a general anaesthetic the patient is vulnerable to a number of risks. Important amongst these are pressure effects upon nerves, for example those on the common peroneal nerve as it winds around the head of the fibula.
- Previous medical problems and allergies are identified and acted upon.

Prophylaxis

Infection

Infections remain a major issue for all surgical procedures and the team caring for the patient needs to be aware of relevant risks and act to minimise such risks.

Before discussing the use of prophylactic antibiotics for the prevention of peri-operative infection, it is very important that issues of basic hygiene are discussed (see Chapter 7, p. 51). Simple measures adopted by all those involved in patient care can make a real difference to reducing the risk of hospital-acquired infection. The very widespread and significant problems with antibiotic organisms such as methicillin-resistant *Staphylococcus aureus* (MRSA) have reinforced the need for such basic measures.
- Wash your hands in between seeing each and every patient.
- Wear gloves for removing/changing dressings.
- Ensure that the hospital environment is as clean as possible.

These measures, especially hand washing, should be embedded into the psyche of those involved in patient care.

In addition to the very important matters of hygiene and appropriate sterile practice, antibiotics should be used in certain circumstances to reduce the risk of peri-operative infection. Each hospital will have individual policies on which particular antibiotics to use in the prophylactic setting (see Chapter 7, p. 51). It is also important to state that whilst the use of prophylactic antibiotics can, when used appropriately, significantly reduce infectious complications, inappropriate or prolonged use can leave the patient susceptible to infection with antibiotic resistant organisms such as MRSA.

Both factors related to the patient and the planned procedure governs the appropriate use of antibiotics in the prophylactic setting.

Procedure-related factors

Table 1.1 indicates the risk of post-operative wound infections with and without the use of prophylactic antibiotics. In addition to considering the absolute risk of infection the potential consequences of infection must also be considered; for example, a patient undergoing a vascular graft (a clean procedure) must receive appropriate antibiotic cover because of the catastrophic consequences of graft infection.

Patient-related factors

Patients with immunosuppression and pre-existing implants and patients at risk for developing infective endocarditis must receive appropriate prophylaxis even when the procedure itself would not indicate their use.

Table 1.1 Risks of post-operative wound infection

Type of procedure	Definition	Wound infection rate (%) Prophylactic antibiotics	
		No	Yes
Clean	No contamination, gastrointestinal, genitourinary or respiratory tracts not breached	1–5	0–1
Clean-contaminated	Gastrointestinal or respiratory tract opened but without spillage	10	1–2
Contaminated	Acute inflammation, infected urine, bile, gross spillage from gastrointestinal tract	20–30	10
Dirty	Established infection	40–50	10

Venous thrombo-embolism

Deep vein thrombosis (DVT) is a not uncommon and potentially catastrophic complication of surgery. The risk for developing DVT ranges from a fraction of 1% to 30% or greater depending upon both patient- and procedure-related factors. Both patient- and procedure-related factors can be classified as low, medium or high risk (Table 1.2). High-risk patients undergoing high-risk operations will have a risk for DVT of up to 80% and a pulmonary embolism risk of 1–5% when prophylaxis is not used; these risks can be reduced by at least one order of magnitude with appropriate interventions.

Whilst a wide variety of agents have been trialled for the prevention of DVT, there are currently only three widely used methods:

- Graduated compression stockings: these stockings, which must be properly fitted, reduce venous pooling in the lower limbs and prevent venous stagnation.
- Heparin: this drug can be used in its conventional unfractionated form or as one of the newer fractionated low-molecular-weight derivatives. The fractionated low-molecular-weight heparins offer the convenience of once-daily dosing for the majority of patients. It must however be remembered that the anticoagulant effect of the low-molecular-weight heparins cannot easily be reversed and, where such reversal may be important, standard unfractionated heparin should be used.
- Mechanical calf compression devices: these machines work by intermittent pneumatic calf compression and thereby encourage venous return and reduce venous pooling.

The three methods are complementary and are often used in combination, depending upon the patient and operative risk factors (Table 1.2).

The systematic use of such measures is very important if the optimal benefit is to be made for the potential reduction in DVT.

Table 1.2 Prevention of deep vein thrombosis

		Operative risk factors		
		Low (e.g. hernia repair)	Medium (e.g. general abdominal surgery)	High (e.g. pelvic cancer, orthopaedic surgery)
Patient risk factors	Low (age <40, no risk factors)	No prophylaxis	Heparin	Heparin and mechanical devices
	Medium (age >40, one risk factor)	Heparin	Heparin	Heparin and mechanical devices
	High (age >40, multiple risk factors)	Heparin and mechanical devices	Heparin and mechanical devices	Higher dose heparin, mechanical devices

Pre-operative care of the acute surgical patient

A significant number of patients will present with acute conditions requiring surgical operations. Whilst the principles outlined above are still valid, a number of additional issues are raised.

Informed consent

Whilst there is still a clear need to ensure that patients are appropriately informed, there are fewer opportunities to discuss the options with the patient and their family. In addition, the disease process may have resulted in the patient being confused. The team caring for the patient needs to judge carefully the level of information required in this situation. Although it is very important that family members are kept informed, it has to be remembered that the team's primary duty is towards the patient. This sometimes puts the team in a difficult position when the views of the patient's family differ from that which the team caring for the patient hold. If such an occasion arises then careful discussion and documentation of the decision process is vital. Increasingly, patients of very advanced years are admitted acutely with a surgical problem in the setting of significant additional medical problems. It is with this group of patients that specific ethical issues around consent and appropriateness of surgery occur. It is important that as full as possible a picture of the patient's overall health and quality of life is obtained and that a full and

frank discussion of the options, risks and benefits takes place.

Pre-operative resuscitation

It is important that wherever possible significant fluid deficits and electrolyte abnormalities are corrected prior to surgery. There is often a balance to be made between timely operative intervention and the degree of fluid resuscitation required. An early discussion between surgeon, anaesthetist and, when required, intensivist can help plan timing.

Pre-existing medical co-morbidities

There is clearly less time to address these issues and it may not be possible to address significant ongoing medical problems. Clearly such co-morbidities should be identified, and all involved with planning the operation should be informed. The issues are most acute for significant cardiac, respiratory, hepatic or renal disease.

Pre-operative nutrition

An awareness of the nutritional status of patients is important and such awareness should guide the decisions about nutritional support (see Chapter 5).

Before operation the malnourished patient should whenever possible be given appropriate nutritional support. There is no doubt that significant pre-operative malnutrition increases the risk of post-operative complications (>10–15% weight loss). If possible such nutrition should be given enterally, reserving parenteral nutrition for the minority of patients in whom the gastrointestinal tract is not an option. Parenteral nutrition is associated with increased costs and complications and is of proven benefit in the seriously malnourished patient only, when it should be given for at least 10 days prior to surgery for any benefits to be seen. There is increasing evidence that enteral feeds specifically formulated to boost certain immune parameters offer clinical benefits for patients about to undergo major surgery.

After operation any patient who is unable to take in normal diet for 7 or more days should receive nutritional support, which as before operation should use the enteral route whenever possible.

Specific pre-operative issues

Stomas

A number of gastrointestinal operations will require the use of a temporary or permanent stoma (see Chapter 30). Prior to operation it is important that the patient is fully informed of the likelihood/possibility of a stoma. Clearly there will be operations that result in a stoma which could not be predicted being formed but such occasions should be very rare.

The concept of having an intestinal stoma is regarded by most patients as one of the most daunting aspects of facing surgery. Prior to surgery the patient should be seen by an experienced stoma/colorectal nurse to discuss in detail the nature of the stoma, the type of appliances likely to be used and the optimal site for its placement. The nurse specialist plays a very important role both in the immediate peri-operative period and beyond.

Diabetes mellitus

Diabetes mellitus is one of the most frequently seen medical co-morbidities which complicate peri-operative care. It is clearly important that patients with diabetes mellitus are appropriately worked up for surgery.

In the weeks leading up to elective surgery the management of the diabetes should be reviewed and blood glucose control optimised. Particular attention should be paid to cardiovascular and renal co-morbidities during the pre-operative assessment.

Generally patients with diabetes should be scheduled for surgery in the morning. For patients taking oral hypoglycaemic drugs, the drugs should be stopped the night before surgery and the blood glucose monitored. Patients with insulin-dependent diabetes should be commenced on an intravenous infusion regimen. There are two approaches to this:

- Variable-rate insulin infusion. The patients blood glucose levels are monitored regularly and the rate of insulin infusion adjusted. An infusion of dextrose is continued throughout the period of insulin infusion.
- Single infusion of glucose insulin and potassium (GIK). Whilst this method has the advantage of simplicity it is not possible to adjust the rates of glucose

and insulin infusion separately and the technique can lead to the administration of excessive amounts of free water.

The variable-rate infusion is the most widespread approach and although more involved in terms of monitoring offers better glycaemic control; this in itself is associated with better patient outcomes.

MCQs

Select the single correct answer to each question.

1 Without the use of prophylaxis the risk of deep calf vein thrombosis in a patient undergoing an anterior resection for rectal cancer is likely to be at least:
- **a** 10%
- **b** 20%
- **c** 30%
- **d** 50%

2 Which of the following measures is most likely to reduce the risk of post operative wound infection with MRSA?
- **a** 5 days of broad spectrum prophylactic antibiotics
- **b** ensuring the patient showers with chlorhexidine wash prior to surgery
- **c** a policy of staff handwashing between patients
- **d** screening patients for MRSA carriage prior to surgery

3 Which of the following constitute the legal standard for the information that should be passed to a patient to meet the requirements of 'informed consent'?
- **a** what a patient in that position would regard as reasonable
- **b** what a reasoned body of medical opinion holds as reasonable
- **c** a list of all possible complications contained within a patient information booklet
- **d** all serious complications that occur in more than 1% of patients

2 Anaesthesia and pain management

Daryl Williams

Pre-operative phase

The aims of anaesthesia are fourfold: (i) no conscious awareness of pain; (ii) a still surgical field; (iii) anxiolysis, sedation or complete hypnosis; and (iv) cardiorespiratory stability. Most of the major morbidity and mortality during anaesthesia is related to inadequate pre-operative assessment or optimisation. Assessment of the patient should focus on the important risks to the patients. The seven A's of anaesthesia are critical to deduce in the pre-operative phase and these are: allergies; aspiration risk; airway assessment; aortic stenosis; apnoea, especially obstructive sleep apnoea; activity level or functional exercise tolerance; and ease of access (intravenous or invasive access).

History

Elective surgery patients are generally admitted on the day of surgery, and data collection, evaluation and patient education takes place in outpatient (pre-admission) clinics. History taking commences with review of a standard health questionnaire; positive responses can then be explored further during the personal interview. In addition to the basic information above, every patient assessment prior to elective surgery should include a history of previous anaesthetic exposure, recent illness, familial disease (including malignant hyperpyrexia), and pregnancy.

Obstructive sleep apnoea (OSA) is increasingly common in westernised society, where the incidence of obesity is increasing. Most OSA is undiagnosed and therefore routine questioning about snoring, choking feelings while sleeping, and excessive daytime somnolence are important for screening. Any elective patient thought to have OSA should be referred to a sleep physician for a sleep study pre-operatively, and also be optimised with nasal continuous positive airway pressure (CPAP) if appropriate. The long-term effects of untreated OSA are due to chronic hypoxaemia and hypercapnia and include systemic hypertension and pulmonary hypertension with right ventricular hypertrophy. These patients have significant increased risk during general anaesthesia because of difficult mask ventilation, difficult intubation and acute right heart dysfunction. More important, post-operatively OSA patients have an increased risk of respiratory obstruction because they are very sensitive to sedative/hypnotic agents. These patients should be monitored in a critical care environment if they receive any sedative/hypnotics or opioids. Patients should also be encouraged to continue to use nasal CPAP if prescribed pre-operatively.

Aspiration is more likely in patients with recent solid food intake, gastrointestinal obstruction, emergency surgery or a difficult airway. Patients are fasted prior to elective surgery, primarily to reduce the risk of aspiration of stomach contents and consequent pneumonitis. Particulate (solid matter) aspiration is the greatest risk to the patient. The volume and acidity of gastric fluid are also important, with a volume more than 25 mL or pH less than 2.5 posing greater risk to the patient. Fasting is effective in reducing the amount of gastric solids but not the volume of fluid. Inadequate preparation of the patient for direct laryngoscopy and extubation of the trachea before the return of airway protective reflexes are the main errors of anaesthetic management that may result in pulmonary aspiration.

The physical status of the patient is usually described according to the American Society of Anesthesiologists (ASA) classification (Table 2.1). Functional exercise capacity is the best and simplest measure of overall cardiorespiratory robustness and peri-operative risk. Metabolic equivalents (METs) are used to quantify activity level. An activity level of 4 METs, which is equivalent to carrying shopping bags up two flights of stairs, is generally considered adequate for most surgery. The age of the patient, ASA class, and the nature and

Table 2.1 American Society of Anesthesiologists Classification

ASA	Patient status
I	Fit for age
II	Patient has systemic disease that does not interfere with normal activity
III	Patient has systemic disease that limits normal activity
IV	Patient has systemic disease that is a constant threat to life
V	Patient not expected to survive 24 hours
E	Added to above to indicate emergency procedure

duration of the surgery are all important determinants of the choice of anaesthetic technique and the extent of patient monitoring.

Examination

The commonest fundamental mishaps in anaesthesia relate to poor airway management, and therefore a thorough assessment of the airway is critical to a good outcome. This includes ability to open the mouth, absence or presence of teeth, the size of the tongue, the ability to sublux the temporomandibular joint and the relative position of the larynx. The ability to mask ventilate the patient, intubate the patient's trachea, and access the patient trachea in the neck are all key determinates of airway management.

Valvular heart disease, especially moderate or severe aortic stenosis, poses a substantial risk for even the most basic general anaesthetic or for neuraxial regional blockade (spinal or epidural anaesthesia). A relatively fixed output through a narrow aortic valve and consequent left ventricular hypertrophy that occurs in aortic stenosis means that the oxygen supply-demand is precariously balanced. Small reductions in pre-load (end-diastolic stretch) and after-load (arterial dilation) occur commonly during anaesthesia, and the reduction in cardiac output and diastolic coronary perfusion can set up a cascade of events that leads to significant myocardial ischaemia that worsens the picture.

Routine investigations and patient optimisation

Pre-operative laboratory investigations are ordered only in response to the history or examination findings, not as a routine. However, in patients more than 50 years of age an electrocardiograph (ECG) is generally routine. Full blood examination, serum electrolytes, glucose, creatinine and chest X-ray should be used selectively. Table 2.2 is a checklist for use when clerking patients prior to surgery. Optimum treatment

Table 2.2 Guide to clerking of a surgical patient: items for discussion with the anaesthetist

Previous anaesthesia	Procedures, analgesia, history of adverse events
Family history	Muscle disorders, bleeding, reactions to anaesthesia
Medications	Potential drug interactions, systemic steroids, altered coagulation, drug reactions, peri-operative instructions
Cardiovascular	Ischaemic heart disease: risk factors (angina class), cardiac failure (dyspnoea class), arrhythmias, peripheral vascular disease, valvular heart disease (especially aortic stenosis)
Central nervous system	Stroke, TIA, seizures
Respiratory	Smoking history, asthma and triggers, bronchitis, lung function tests, arterial gases, obstructive sleep apnoea
Airway examination	Mouth opening, teeth, temporomandibular subluxability, size of tongue, neck
Endocrine	Thyroid function, diabetes (type, treatment, complications), obesity
Fluid status	Pre-operative status, peri-operative requirments and balance
Haematology	Strategy for blood replacement
Gastrointestinal	Aspiration risk
Musculoskeletal	Arthritis (especially cervical spine instability) and fixed deformities

of systemic disease may alter ASA class prior to surgery and referral to other specialists is often appropriate at this time.

Preparation

Education of patients about the surgical procedure, the choices for anaesthesia and the pain management options decrease anxiety and decrease the need for premedication with drugs. Opioid analgesia is only required to relieve pre-operative pain; benzodiazepines provide a better alternative for pre-operative sedation and anxiolysis. It is important to note that gastric emptying ceases soon after treatment with any opioid drug, and generally these patients are considered to be 'at risk of aspiration'.

Oral medications may be continued up to the time of surgery if gastric emptying and absorption are normal. Antacids, histamine$_2$-receptor antagonists and proton pump inhibitors should be continued pre-operatively to limit the occurrence of acid pulmonary aspiration. There is considerable benefit for anaesthesia in continuing most antihypertensive and cardiac drugs in terms of providing peri-operative cardiovascular stability. Asthma and chronic obstructive airway disease may be treated with inhalational drugs throughout the peri-operative period. Anticoagulants such as warfarin and potent platelet inhibitors should generally be ceased prior to surgery, although the balance of risk and benefits should be discussed with the anaesthetist.

Anaesthesia techniques

The choice of regional versus general anaesthesia should be discussed with the patient prior to arrival in the operating room. There are specific complications associated with each technique, and patients will usually indicate how much they wish to know about rare, but serious, adverse events as well as the minor morbidity. Where it is possible to provide regional anaesthesia for minor surgery by direct infiltration of local anaesthetic or by peripheral nerve blocks, the risk of major morbidity or mortality from anaesthesia is avoided.

There are a few absolute contraindications to the use of major regional anaesthesia (e.g. spinal, epidural or plexus block); these are disorders of coagulation, allergy to local anaesthetic agents, sepsis (either systemic or at the site of local anaesthetic insertion) and inability to communicate with or obtain the cooperation of the patient (Table 2.3). A prior neural deficit, or possibility of neural damage due to the surgery, are relative contraindications because of the difficulty in separating these from residual effects of the local anaesthetic. Some form of general anaesthesia can usually be offered to any patient after appropriate preparation and resuscitation. The potential for a reduction in risk with the use of regional anaesthesia comes from an avoidance of some effects of the general anaesthetics; however, there is minimal evidence to support claims of improved outcome in seriously ill patients having major surgery with regional anaesthesia.

Table 2.3 Use of regional anaesthesia

Absolute contraindications	Patient refusal, uncooperative patient Full anticoagulation Infection at injection site Septicaemia (catheter insertion) Hypovolaemia (with neuraxial block) Allergy to local anaesthetic
Relative contraindications	Partial anticoagulation Pre-existing neurological deficit Back pain
Indications	Adverse reactions to general anaesthesia (e.g. muscle disease, susceptibility to malignant hyperpyrexia)
	Reduce pulmonary complication or need for post-operative intermittent positive-pressure ventilation (respiratory disease, obesity)
	Obstetrics: avoidance of foetal depression

General anaesthesia

General anaesthesia may be divided into three phases: induction, maintenance and recovery. It aims to produce rapidly reversible loss of consciousness and amnesia, with absence of response to surgical stimulation and without deleterious effects on organ function. Analgesia and muscle relaxation are important adjuncts, although often provided by separate drugs.

Induction of general anaesthesia

Induction is often achieved with a bolus intravenous (i.v.) injection of a lipid-soluble drug that will be effectively removed from the arterial blood on first passage through the brain and other organs. Initial distribution therefore reflects the distribution of cardiac output,

and loss of consciousness is induced in one arm–brain circulation. Induction of anaesthesia with an anaesthetic vapour or gas depends upon the agent's having adequate potency, avoidance of airway irritation, coughing or apnoea, and ability to achieve the necessary partial pressure in the CNS rapidly. Sevoflurane is most often used for inhalational induction of anaesthesia in paediatric practice because of difficulties with i.v. access. Halothane provides a slower induction and is sometimes preferred to sevoflurane because of the lower risk of rapid induction and airway obstruction. Sevoflurane may also be used to achieve a single-breath induction as the patient inhales and holds a high concentration of sevoflurane in oxygen.

Induction of anaesthesia is associated with relaxation of the upper airway, loss of protective reflexes and reduced respiratory effort. The airway is maintained by elevation of the jaw and application of a face mask, or by insertion of a supralaryngeal airway (e.g. laryngeal mask airway) or by a laryngeal (endotracheal) tube through the larynx into the trachea. The end-point for loss of consciousness is taken as loss of the eyelash response, but a greater depth of anaesthesia is required for instrumentation of the airway.

Maintenance of general anaesthesia

Anaesthesia is maintained by inhaled anaesthetic, i.v. infusion of anaesthetic or a combination. The advantage of anaesthetic delivery via the lung is that the partial pressure of the anaesthetic gas can be accurately measured and titrated using agent monitoring. The minimum alveolar concentration (MAC_{50}) required for lack of response to surgical incision in 50% of patients is highly reproducible for each agent, so that it is possible to be very confident that a given depth of anaesthesia is achieved during surgery. The rate of infusion of an i.v. general anaesthetic may be calculated according to a pharmacokinetic model to avoid accumulation, overdosage and prolonged hangover effect. Infusion pumps programmed for anaesthetic delivery are now available and these provide an estimate of the plasma or effect-site concentration achieved (target controlled infusion).

General anaesthesia requires continual adjustment because of the changing nature of the surgical stimulus. This is often difficult to achieve with a volatile anaesthetic alone, but the provision of balanced anaesthesia with analgesia (e.g. a potent i.v. opioid) and muscle relaxation often provides a smooth anaesthetic, with fewer adverse cardiovascular responses. Blood pressure and heart rate are usually within 20% of resting values, although different limits may be set according to the nature of the surgery and the physical status of the patient. If respiration is spontaneous, it should be regular and the end-tidal carbon dioxide is kept below a predetermined limit. With muscle relaxation, ventilation is controlled.

Recovery from general anaesthesia

Recovery is a gradual process, dependent on the continued redistribution of the anaesthetic drug in the body together with elimination or metabolism. The process is timed to result in emergence from anaesthesia as close as possible to the completion of the surgery. A considerable residue of drug may remain, especially in skeletal muscle, so that secondary peaks can occur in the plasma concentration following rewarming and restoration of muscle blood flow. The slow release of the drug from muscle and fat prevents full recovery of cognitive function for many hours and will potentiate the effects of any additional sedative drugs. Although there are differences between anaesthetic drugs for the time taken to initial emergence, the duration of anaesthesia, the extent of surgery and the requirement for opioid analgesics more often determine how soon the patient can be discharged from hospital.

Supplemental oxygen is always required in the initial recovery phase because of the continued respiratory depressant action of anaesthetic drugs, increased ventilation-perfusion mismatch, and to the displacement of oxygen from the alveoli by the excretion of large volumes of nitrous oxide if this has been used as a component of the anaesthetic. Frequent complications in the recovery phase include laryngospasm (incomplete return of protective reflexes), nausea or vomiting, and shivering with increased oxygen consumption. The use of anti-emetics such as the 5HT-3 antagonists and the application of forced-air warming blankets may reduce the incidence of complications. The plan for pain management should commence prior to emergence from anaesthesia.

Regional anaesthesia

Although major surgery can be performed using multiple peripheral nerve blocks, it is likely to be difficult for both the anaesthetist and the patient and it is easy to exceed the maximum recommended dose of local anaesthetic. Regional anaesthesia is therefore focused on providing neural blockade at the level of the spinal cord, by either spinal (subarachnoid) or

epidural injection. Depending on the choice of local anaesthetic and its concentration, a marked differential between sensory and motor block can be achieved. If the regional technique is continued for post-operative analgesia, this differential becomes more important, increasing mobility and cooperation with physiotherapy. Low concentration of local anaesthetic in combination with an opioid provides analgesia with minimal motor block.

Epidural injection requires approximately a 10-fold greater mass of local anaesthetic to obtain an equivalent neural block compared to spinal injection, resulting in a greater danger from accidental intravascular injection and consequent systemic toxicity. The advantage of epidural analgesia is that the dura is not punctured and there is no incidence of headache due to loss of cerebrospinal fluid (CSF). The placement of an epidural catheter enables the block to be continued with an infusion or repeated bolus doses of drug. It is desirable to match the distribution of the sensory blockade as close as possible to the surgical incision in order to reduce the total dose as well as any side effects. Epidural injections can be made at any level of the spine from the cervical region to the caudal canal.

Spinal anaesthesia is often favoured during surgery because the onset is rapid and the blockade is more complete than can be achieved with an epidural injection. This may be critical to the success of the anaesthesia, especially if the anaesthetist wishes to avoid the use of sedation or combined regional and general anaesthesia because of the physical status of the patient.

Combined regional and general anaesthesia does offer advantages in some types of surgery. The dose of general anaesthetic required is significantly reduced, but the patient may still be paralysed and ventilation controlled to facilitate surgery. The stress response to the surgery is ablated to an extent not possible even with very deep general anaesthesia. The patient emerges from the general anaesthesia with excellent analgesia which can be extended into the post-operative period if an epidural catheter is *in situ*.

Patient monitoring during anaesthesia

The purpose of patient monitoring is to ensure patient safety and patient well-being during surgery. Clinical and equipment monitoring are both important facets of anaesthesia care. Most physiologic parameters measured act as surrogate indicators of oxygen delivery, end-organ well-being or depth of anaesthesia.

Blood pressure

Arterial blood pressure measurement is an indicator of the driving pressure through global and regional vascular beds. The flow is dependent on the perfusion pressure and the resistance. Pre-operative measurement by auscultation of Korotkoff sounds establishes the baseline arterial blood presure value for an individual patient. Automated non-invasive monitoring of blood pressure usually uses an occlusive cuff and oscillometric measurement. Automated systems are preferred intraoperatively, often because access to the arm is impeded and other tasks are likely to divert the anaesthetist from taking regular measurements. There is a tendency to underestimate high pressures and overestimate low pressures, and measurement may fail with cardiac arrhythmias such as atrial fibrillation. Direct measurement via a catheter in the radial artery is accurate and gives a continuous beat-to-beat output.

When the blood pressure is anticipated to change rapidly, as in procedures with a high risk of significant blood loss, or when strict control is needed, as in neurosurgery, the benefits of direct measurement clearly outweigh the risk. Use of a small catheter (20- or 22-gauge) made of Teflon reduces the incidence of thrombosis or intimal damage.

Electrocardiograph

Electrocardiograph monitoring used during anaesthesia generally allows the simultaneous display of two leads. One should be the standard limb lead II and the other a unipolar lead in the V5 position (the anterior axillary line at the fifth intercostal space). Lead II will indicate the presence of P waves and changes in cardiac rhythm. The V5 lead detects more than 70% of myocardial ischaemia in high-risk patients having non-cardiac surgery. Automatic detection and recording of ST segment changes are provided with many monitoring systems. These have increased the anaesthetist's awareness of intraoperative changes. However, ECG artefact from poor electrode application or placement, shivering and diathermy remain a major problem.

Respiratory monitoring

Monitoring of oxygen and carbon dioxide concentrations in the patient breathing circuit and non-invasive measurement of haemoglobin (Hb) saturation (oximetry) enables continuous assessment of the adequacy of ventilation and oxygenation. The use of an

oxygen analyser, a pulse oximeter and an end-tidal carbon dioxide monitor during general anaesthesia is mandatory in most countries.

Capnography is usually based on the absorption of infrared light by carbon dioxide. The initial detection of carbon dioxide in the expired gas is critical evidence that an endotracheal tube has been placed in the trachea. Breath-by-breath analysis detects sudden changes due to a disconnection of the breathing circuit, or loss of the pulmonary circulation (e.g. with air embolism). In a patient breathing spontaneously, the respiratory-depressant effects of the anaesthetic agents are monitored and respiration assisted if required.

Pulse oximetry provides continuous monitoring of arterial oxygenation using a 'pulse-added absorbance' technique. If peripheral perfusion is poor an adequate pulse may not be detected; instruments should therefore display both the peripheral pulse waveform and the percentage Hb saturation. Monitors to determine anaesthetic gas concentrations in the breathing circuit is compulsory in most countries. Output of anaesthetic from vaporisers, and the equilibration of inspired and expired concentrations can be monitored.

Depth of anaesthesia monitoring

General anaesthesia is a state of drug-induced unconsciousness where the patient has no recall or perception of senses. The depth of anaesthesia required for surgery is dependent on the patient, the drug delivered and the surgical stimulation. Information about the depth of anaesthesia may be obtained from a processed electroencephalograph (EEG) or by monitoring auditory or visual evoked potentials. The bispectral index (BIS) is a form of processed EEG incorporating three different EEG domains and derives a number between zero (deep anaesthesia) and 100 (awake patient). BIS has been validated with varying levels of drug concentrations of anaesthetic agents and at different levels of hypnotic state. Awareness is the post-operative conscious recall of events during general anaesthesia. The incidence of awareness is approximately 0.1% in the overall surgical population. However the risk of awareness is as high as 1% in certain high-risk groups such as cardiac surgery, caesarean section, trauma patients with massive blood loss, patients with poor left ventricular function, and opioid/benzodiazepine tolerant patients. Patients having relaxant general anaesthesia in this high-risk group should be considered for BIS monitoring if available .

Acute pain management

Non-opioid analgesia

Non-steroidal anti-inflammatory drugs (NSAID) are being used increasingly in the peri-operative period. They do not have respiratory-depressant effects, do not interfere with gastric motility, do not cause emesis, and are available for either parenteral or enteral administration. Although their analgesic effect has a ceiling below that of the opioids, they can often still be an effective alternative or provide a baseline analgesia to reduce opioid requirements. Newer cyclo-oxygenase type 2 (COX-2) inhibitors have an improved side-effect profile, with negligible effects on platelet function and haemostasis. These agents can be safely used in most surgery including neurosurgery and the use of flaps in plastic surgery.

Opioid analgesia

The target plasma concentration for satisfactory analgesia with any of the opioids is highly variable between patients. Therefore patient-controlled analgesia systems (PCAS) have proved the most effective for systemic opioid delivery. With PCAS the patient initiates bolus i.v. doses of the drug; the bolus size and a lockout interval between doses being predetermined by the physician. The patient is able to titrate the opioid dose to achieve the plasma concentration that just produces sufficient analgesia. The target may change during the day reflecting periods of physiotherapy or dressing changes versus periods of undisturbed rest in bed. Excessive sedation is avoided because patients will not continue to initiate further doses as they become drowsy. It is important that attendants or relatives are warned not to attempt to assist the patient by giving extra doses of analgesia.

A relatively long-acting opioid such as morphine is usually chosen for post-operative analgesia. Pethidine (meperidine) should not be used for prolonged analgesia, especially in patients with renal impairment, because of the accumulation of the toxic metabolite norpethidine. When morphine is used with PCAS, a common bolus dose is 1.0 mg with a lockout interval of 5 to 8 minutes. It is important to ensure that the entire bolus dose is rapidly administered intravenously to the patient on request. This is best achieved if the opioid infusion device is connected to a side-arm of an i.v. fluids

line that includes an anti-reflux valve to prevent the opioid being pumped backwards up the i.v. line. Continuous i.v. access is favoured for post-operative analgesia because of the need for a short-dose interval or continuous infusion to keep plasma concentrations above the therapeutic threshold. Subcutaneous infusion may be a useful alternative if i.v. access is being maintained only for analgesia. In contrast, an order for intramuscular morphine every 4 hours is unlikely to provide satisfactory analgesia for more than 20% of that interval.

Tramadol has several properties that distinguish it from other opioids used in the post-operative period. In addition to opioid activity, it inhibits noradrenaline uptake and serotinin uptake and these contribute most to the analgesia. Tramadol has high bioavailability after oral administration, so that a patient may be transferred from i.v. to oral medication as early as the surgical condition permits. Most important, it has only minimal effects on respiration and may therefore be used in many situations where other opioids are contraindicated or when respiratory depression severely limits their dosage. For many groups of surgical patients analgesia with tramadol is comparable to that with morphine, but the incidence of nausea and vomiting may be higher after tramadol.

Epidural analgesia

If the epidural route is chosen, a catheter is inserted and a bolus of local anaesthetic given to establish sensory blockade. For continuous epidural infusion the concentration of local anaesthetic is reduced to minimise motor block, and a longer-acting anaesthetic such as bupivacaine is preferred. Opioids are usually added to the local anaesthetic solution to improve analgesia and reduce the concentration of local anaesthtic agent to reduce motor block. A useful combination is 0.1% bupivacaine with 2 mcg/mL of fentanyl. Epidural opioids do not produce sympathetic blockade or have significant cardiovascular effects, but they can cause problems of severe pruritus, urinary retention and respiratory depression. Lipid-soluble opioids such as fentanyl and pethidine are quickly localised around the region where they are injected; there is limited systemic absorption, and respiratory depression.

Persistent pain

Persistent pain is commonly divided into cancer and non-cancer pain, but there is a large overlap in the treatment methods used. In approximately 20% of cases of established chronic pain, surgery is implicated as the cause. Specific surgical procedures are known to be at higher risk for chronic pain development such as thoracotomy, mastectomy, limb amputation and multitrauma. Analgesic drugs are introduced according to a 'ladder', on which the NSAID and adjuvant drugs, such as antidepressants and anticonvulsants, are used prior to increasing doses of opioids. It is important to determine a correct opioid dose that is the minimum required for adequate analgesia, because this will slow down the development of tolerance to the opioids. Unfortunately, tolerance to all side effects does not develop at the same rate as the reduction in analgesia. With chronic treatment, respiratory depression is unlikely to be a problem, but constipation is and measures to treat it should be commenced early. Tolerance to the analgesic effects of the opioids is expected and the dose is increased accordingly. It should not be confused with physical or mental dependence.

In cancer treatment there is an increasing use of a chronic spinal catheter for the delivery of morphine. Provided that the catheter and a drug reservoir are buried subcutaneously, the incidence of infection is very low. The central administration of the morphine is extremely effective and tolerance is slow to develop. It has also reduced the need for neurolytic blocks for cancer pain. These are justified only if the pain is well localised and there is a danger of deafferentation pain, which is extremely difficult to treat, occurring some months later.

There is a considerable body of evidence suggesting that chronic pain becomes an individual disease entity irrespective of the underlying cause of pain. It is known that changes occur in the nervous system in early persistent pain, such as spontaneous firing of damaged neurons, neuro-anatomical reorganisation of the dorsal horn under the control of growth factors, death of inhibitory neurons, and reorganisation of central (brain) representation of 'painful areas'. It is therefore important that specific chronic pain strategies are utilised as distinct from disease-specific strategies. Patients with chronic pain suffer from multifaceted problems, requiring a multidisciplinary approach. Assessment of the physical, psychological and environmental factors by a team of health professionals is essential to avoid such issues as unnecessary surgery, excessive use of medications, multiple and repeated investigations, drug toxicity, and physical and mental conditioning.

Patient safety

The craft of anaesthesia has led the field in patient safety in the medical arena. The dynamic environment in the operating suite has many work practices similar to industries such as aviation and nuclear power generation. Anaesthetists have adapted many of the principles of human peformance analysis from these industries to investigate adverse outcomes in anaesthesia and healthcare more generally.

High-fidelity simulation (HFS) training provides an excellent opportunity to learn the knowledge, skills and attitudes of appropriate clinical resource management and to be aware of the non-technical aspects of anaesthesia delivery such as fixation error and distraction. In aviation, HFS training has been shown to effectively reduce adverse outcomes. The key advantages of high-fidelity simulation are that there is no risk to the patient, that the simulation can be frozen at any point in time, and that recording playback and critical analysis of performance can facilitate learning without the issues of patient confidentiality. HFS also allows teams to interact in complex environments and provides a unique opportunity to reflect upon one's practice. This reflective process allows one to 'learn from experience' rather than 'learn by experience', which is the more traditional approach of performing tasks and slowly modifying practice over time.

In the complex world of the operating theatre it is increasingly recognised that the good outcomes rely heavily on the performance of the entire team. Concepts such as graded assertiveness, where there is shared responsibility for all team members and a requirement for all team members to openly verbalise concerns, will increasingly become a part of operating suite practice. Team 'time outs' prior to surgical incision and at the time of surgical counts are examples of team responsibility to prevent wrong surgery or retained materials, respectively.

Further reading

Paige JT, Saak TE. Anesthesia. In: Doherty GM, Meko JB, Olson JA, Peplinski GR, Worrall NK, eds. *The Washington Manual of Surgery*. Philadelphia: Lippincott Williams & Wilkins; 1999:79–92.

MCQs

Select the single correct answer to each question.

1 The best indicator of cardiorespiratory capacity and reserve for surgery is:
- **a** transthoracic echocardiography
- **b** arterial blood gas analysis
- **c** thallium persantin nuclear imaging of the heart
- **d** functional exercise capacity
- **e** electrographic stress test

2 The commonest reason for poor outcome after anaesthesia is:
- **a** inadequate pre-operative assessment and optimisation
- **b** poor anaesthetic assistance
- **c** blood product unavailability
- **d** poor choice of anaesthetic agents
- **e** inadequate intravenous access

3 Absolute contraindications to performing neuraxial (epidural or spinal) local anaesthetic blockade include all of the following except:
- **a** coagulopathy
- **b** patient refusal
- **c** systemic sepsis
- **d** local infection at insertion site
- **e** pre-existing neurologic deficit

4 Patients with obstructive sleep apnoea are often undiagnosed. Clinical features of obstructive sleep apnoea include all of the following except:
- **a** snoring during sleep
- **b** excessive daytime somnolence
- **c** feelings of choking during sleep
- **d** pulmonary hypertension
- **e** aortic stenosis

5 Airway assessment should include all of the following except:
- **a** ability to open mouth
- **b** subluxability of the temporomandibular joint
- **c** thyro-mental distance
- **d** cervical spine mobility and stability
- **e** size of the uvula