TEXTBOOK OF SURGERY

FOURTH EDITION

EDITED BY
JULIAN A. SMITH | ANDREW H. KAYE
CHRISTOPHER CHRISTOPHI | WENDY A. BROWN

WILEY Blackwell

Textbook of Surgery

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Preface

Medical students and trainees must possess an understanding of basic surgical principles, a 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. All students of surgery must also be aware of the rapid developments in basic sciences and technology and understand where these developments impinge on surgical practice.

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

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 including its subspecialties and selected topics of other surgical specialties, including cardiothoracic surgery, neurosurgery, plastic surgery, ophthalmology, orthopaedic surgery, otolaryngology/head and neck surgery, urology and vascular surgery.

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.

The fourth edition of the *Textbook of Surgery* includes new or extensively revised chapters on the assessment of surgical risk, the management of surgical wounds, introduction to the operating theatre, emergency general surgery, obesity and bariatric surgery, lower gastrointestinal surgery, endovascular therapies, benign urological conditions, genitourinary oncology, sudden-onset severe headache and the red eye.

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 for further reading. It is our aim that this textbook will stimulate students to refer to appropriate reviews and publications for additional details on 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 fourth 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 contemporary 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 spouses and partners – Sally Smith, Judy Kaye, Helena Fisher and Andrew Cook – as it was precious time spent away from them which allowed completion of this textbook.

The editors wish to dedicate this edition to two highly esteemed previous editors, the late Joe J. Tjandra and the late Gordon J.A. Clunie. Both were inspirational surgical educators who left an enduring legacy amongst the many students, trainees and colleagues with whom they interacted over many years.

Section 1
Principles of Surgery

1 Preoperative management

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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 issues involved in preoperative care is critical to good patient outcomes. The important elements of preoperative management are as follows.

- History taking: the present surgical condition and a general medical review.
- Physical examination: the present surgical condition and a general examination.
- Reviewing available diagnostic investigations.
- Ordering further diagnostic and screening investigations.
- Investigating and managing known or discovered medical conditions.
- Obtaining informed consent.
- Scheduling the operation and any special preparations (e.g. equipment required).
- Requesting an anaesthetic review.
- Marking the operative site/side.
- Prescribing any ongoing medications and prophylaxis against surgical site infection and deep venous thrombosis.
- Planning postoperative recovery and possibly rehabilitation.

Informed consent

Although often thought of in a purely medico-legal way, the process of ensuring that a patient is informed about the procedure 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 individual jurisdictions may differ 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 – practitioners are not negligent if they act in accordance with practice accepted by a reasonable body of medical opinion. Recent case law from both Australia and overseas has seen a move away from that position. Although this area is complex, the general opinion is that a doctor has a duty to disclose to a patient any 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 when considering the kinds of information to disclose to patients include the following.

- 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 symptoms or illness.

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- 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 those conducted emergently.

Verbal discussions concerning the therapeutic options, potential benefits and risks along with common complications are often supplemented with procedure-specific patient explanatory brochures. These provide a straightforward illustrated account for the patient and their relatives to consider and may be a source of clarification and/or further questions about the proposed operation.

What does this mean for a medical practitioner? Firstly, you must have an understanding of the legal framework and standards. Secondly, you must document how appropriate information was given to patients – always write it down. If discussion points are not documented, it may be argued that they never occurred. On this point, whilst explanatory brochures can be a very useful addition to the process of informed consent they do not remove the need to undertake open conversations 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 and their relatives almost invariably accept such misfortune far more readily.

Preoperative assessment

The appropriate assessment of patients prior to surgery to identify coexisting medical problems and to plan perioperative 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 preoperative assessment, much of which occurs in a pre-admission clinic (PAC).

The goals of preoperative assessment are:

- To identify important medical issues in order to
  - optimise their treatment
  - inform the patient of additional 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 preoperative 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 being short 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. 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.

Common patient observations, investigations and screening tests prior to surgery include:

- vital signs (blood pressure, pulse rate, respiratory rate, temperature) and pulse oximetry
- body weight
- urinalysis
- full blood examination and platelet count
- urea and electrolytes, blood sugar, tests of liver function
- blood grouping and screen for irregular antibodies ('group and hold')
- tests of coagulation, i.e. international normalised ratio (INR) and activated partial thromboplastin time (APTT)
- chest X-ray
- electrocardiogram (ECG).

On the basis of the outcomes of this preoperative evaluation a number of risk stratification systems have been proposed. One in widespread daily use is the relatively simple ASA (American Society of Anesthesiologists) system (see Chapter 3, Table 3.3).

The preoperative 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, and rarely requires blood transfusion, invasive monitoring or intensive care. Examples of such procedures would be groin hernia repair, cataract surgery and 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 and hip replacement.

- **High risk**: significant perioperative 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 and 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 perioperative 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 (New York Heart Association Functional Class for angina or heart failure; 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 4 weeks prior to surgery significantly reduces the risk of respiratory specific or generic complications.

Evaluation of the healthy patient

Patients with no clinically detectable systemic illnesses except their surgical problem are classified into ASA class I. Mortality for low-risk surgical procedures in this group is very low and complications are likely to be due to technical errors. The mortality for major high-risk surgical procedures in such patients is also low, of the order of a few per cent.

All such patients require detailed systems review by history and physical examination prior to the operation. Preoperative special tests may be added in order to detect any subclinical disease that may adversely affect surgery and to provide baseline values for comparison in the event of postoperative complications. These tests should be sufficiently sensitive to detect an abnormality, yet specific enough to avoid the chances of over-diagnosis. The prevalence of the disease or condition being looked for is likely to be low in a healthy asymptomatic patient population. Thus, most tests are likely to be within the normal range. Inappropriate and excessive tests increase the likelihood of a false-positive result due to chance. With extensive multiphasic screening profiles of healthy individuals, about 5% of healthy normal people will show one abnormal result.

Evaluation of the elderly asymptomatic patient

Ageing increases the likelihood of asymptomatic conditions and screening investigations are therefore more stringently applied to older, apparently healthy patients. Elderly patients (aged over 70 years) have increased mortality and complication rates for surgical procedures compared with young patients. Problems are related to reduced functional reserve, coexisting cardiac and pulmonary disease, renal impairment, poor tolerance of blood loss and greater sensitivity to analgesics, sedatives and anaesthetic agents.

Complications of atelectasis, myocardial infarction, arrhythmias and heart failure, pulmonary emboli, infection and nutritional and metabolic disorders are all more frequent. Separation of the effects of ageing, frailty and of associated diseases is difficult. Most of the increased mortality and morbidity is due to associated disease.

Special attention needs to be paid to the assessment of cardiac, respiratory, renal and hepatic function along with patient frailty before operation in elderly patients.

Patient safety (see also Chapter 12)

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

- 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 on 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.
- Protocols for the prevention of perioperative infection and venous thromboembolism are followed.

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 perioperative infection, it is very important that issues of basic hygiene are discussed (see also Chapters 9 and 12). 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-resistant organisms such as meticillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus faecalis* (VRE) 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 hygiene, should be embedded into the psyche of all 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 perioperative surgical site infection. Each hospital will have individual policies on which particular antibiotics to use in the prophylactic setting (see also Chapters 9 and 12). The antibiotics are usually administered at or shortly before the induction of anaesthesia and continued for no more than 24 hours postoperatively. 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 or VRE.

Factors related to both the patient and the planned procedure govern the appropriate use of antibiotics in the prophylactic setting.

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.

Procedure-related factors

Table 1.1 indicates the risk of postoperative surgical site 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.

Venous thromboembolism

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 on 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

Table 1.1 Risks of postoperative surgical site infection.

		Wound infection rate (%)	
Type of procedure	Definition	Without prophylactic antibiotics	With prophylactic antibiotics
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

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

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

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

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

Preoperative care of the acute surgical patient

A significant number of patients will present with acute conditions requiring urgent or emergency surgical operations. There may be little time for an in-depth preoperative preparation. Whilst the principles already outlined 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 and potential complications 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 those which the team caring for the patient hold. If such an occasion arises then careful discussion and documentation of the decision-making 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.

Preoperative 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 the timing of surgical intervention.

Pre-existing medical comorbidities

There is clearly less time to address these issues and it may not be possible to address significant ongoing medical problems. Clearly such comorbidities 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.

Preoperative nutrition

An awareness of the nutritional status of patients is important and such awareness should guide the decisions about nutritional support (see Chapter 7). The well-nourished adult patient should be fasted for at least 6 hours prior to anaesthesia to minimise the risk of aspiration. Where possible regular medications, especially those for cardiovascular and respiratory conditions, should be continued.

Before an operation the malnourished patient should, whenever possible, be given appropriate nutritional support. There is no doubt that significant preoperative malnutrition increases the risk of postoperative 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 only in the seriously malnourished patient, 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 days or more should receive nutritional support, which as before operation should use the enteral route whenever possible.

Specific preoperative issues

Allergies

A history of adverse or allergic reactions to medications or other substances must be documented and repeat administration and/or exposure avoided as a life-threatening anaphylaxis may result. Examples of allergens within surgical practice include antibiotics, skin preparations (e.g. iodine), wound dressing adhesives and latex. A complete latex-free environment is required for those patients with a known latex allergy.

Diabetes mellitus

Diabetes mellitus is one of the most frequently seen medical comorbidities that complicate perioperative 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 HbA1c levels as an index of diabetic control as well as cardiovascular and renal comorbidities during the preoperative assessment.

Generally, patients with diabetes should be scheduled for surgery first case in the morning. Diet-controlled patients require no special preoperative preparation. 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 receive a reduced dose of insulin and/or a shorter-acting insulin or be commenced on an intravenous insulin infusion. There are two approaches to this.

- Variable-rate insulin infusion: the patient's 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.

Cardiac disease

Surgical risk is increased in the presence of cardiac disease. Consideration must be given to balancing the risk to the patient if the procedure is abandoned or delayed with the additional risk caused by the presence of cardiac disease. Emergency operations for life-threatening conditions should proceed regardless but elective surgery should be deferred in the presence of recent-onset angina, unstable angina, recent myocardial infarction, severe aortic valve stenosis, high-degree atrioventricular block, severe hypertension and untreated congestive cardiac failure. Time should be spent investigating the condition and optimising therapy, frequently with

cardiological assistance. The introduction of beta-blocker therapy to slow heart rate and occasionally myocardial revascularisation (by percutaneous coronary intervention or coronary artery bypass grafting) may be required in advance of surgery on another system.

Anticoagulant or antiplatelet therapy

Patients on warfarin should be transferred to heparin or enoxaparin well in advance of surgery to ensure that the warfarin effect has worn off. Heparin can be ceased for a short time in the perioperative period: withhold an infusion 4 hours before surgery and recommence once the risk of postoperative bleeding is low. Subcutaneously administered heparin or enoxaparin is withheld the day or evening before surgery and recommenced later that day or the day after. Warfarin recommences once the patient can take oral medication. Rapid reversal of warfarin prior to an emergency operation may be achieved with vitamin K, pooled fresh frozen plasma or clotting factors.

The new oral anticoagulants (dabigatran, apixaban or rivaroxaban) are difficult to reverse acutely and need to be ceased 2–5 days preoperatively. A specific dabigatran reversal agent has recently become available. A bridging regimen such as that described above is also required.

The antiplatelet agents (aspirin, clopidogrel or ticagrelor) taken alone or in combination should be ceased at least 5 days prior to an operation. Bleeding will be highly problematic at the time of surgery especially if multiple antiplatelet agents are continued. Combined usage often follows coronary artery stenting and so their withdrawal in the context of surgery should be discussed with the treating interventional cardiologist. Elective surgery may need to be postponed if dual antiplatelet therapy cannot be safely ceased.

Active smoking and respiratory disease

All active smokers should be encouraged to cease for at least 4 weeks in advance of elective surgery in order to lessen the risk of respiratory problems (atelectasis, acute pneumonia and respiratory failure) in the postoperative period. Patients unwilling or incapable of stopping smoking should be referred to a dedicated support service to assist with such.

Patients with chronic obstructive pulmonary disease (COPD), asthma and obstructive sleep apnoea require a detailed respiratory assessment (including peak flow, spirometry and arterial blood gas estimation) especially if the patient reports significant exercise limitation. Elective surgery should be deferred in the presence of an active respiratory infection or an acute exacerbation of asthma or COPD.

Additional respiratory preparation may include chest physiotherapy, postural drainage, antibiotics for an acute infection with a positive sputum culture and inhaled bronchodilators or corticosteroid therapy. A formal preoperative pulmonary rehabilitation program may be indicated. Regional anaesthesia is frequently preferred in patients with severe respiratory dysfunction.

Long-term corticosteroid therapy

Long-term corticosteroid therapy results in adrenal suppression and an impaired response to surgical stress. High-dose intravenous hydrocortisone administration (100 or 250 mg every 6 hours) will be required during the perioperative period and when the patient is unable to take their regular medication or in the presence of postoperative complications especially infection.

Cerebrovascular disease

Stroke may complicate major surgery especially in elderly patients with severe intracranial or extracranial atherosclerotic disease faced with fluctuations in blood pressure or cerebral blood flow. An asymptomatic carotid bruit related to an internal carotid artery stenosis confirmed with Doppler ultrasonography may be the first indicator of such disease. Patients with symptomatic carotid disease (e.g. transient ischaemic attacks) should undergo carotid endarterectomy prior to the planned surgery. However, there is no evidence that a prophylactic carotid endarterectomy is of benefit in the asymptomatic patient.

Chronic liver disease and obstructive jaundice

Chronic liver disease of any cause may predispose the patient to surgical complications such as poor wound healing, sepsis, excessive bleeding, renal impairment and acute delirium. Each of the previously discussed screening investigations will be required in addition to specific liver and biliary tree imaging and possibly liver biopsy. The decision to operate on a patient with severe liver insufficiency must be carefully considered. Elective surgery should be deferred whilst liver function is optimised. Emergency surgery can often result in acute liver decompensation especially in the presence of sepsis, haemorrhage, electrolyte disturbances, hypoxia and hypoglycaemia.

Patients with obstructive jaundice (see Chapter 67) frequently have an abnormal coagulation profile and require vitamin K, coagulation factors or pooled fresh frozen plasma to correct the defect. Close attention needs to be paid to the patient's fluid and electrolyte status in order to prevent acute renal failure. The hepatic clearance of some commonly administered medications may be impaired.

Chronic kidney disease

All patients aged over 40 years should have their kidney function evaluated (urinalysis, serum creatinine, estimated glomerular filtration rate and serum albumin) when major surgery is planned. Documented chronic kidney disease does not mandate deferral of elective surgery. Patients with chronic kidney disease may experience an acute deterioration in kidney function if they become water or saline depleted. Acute kidney failure is the most significant complication of chronic kidney disease: prevention demands strict attention to fluid and electrolyte balance (especially avoiding dehydration and maintaining a stable level of serum potassium), maintaining kidney perfusion and accurate replacement of blood loss during surgery. Apart from acute kidney failure, the main complications of surgery in patients with chronic kidney disease are sepsis (including urinary tract infection), poor wound healing and cardiovascular complications (myocardial infarction and stroke).

Anaemia

As a general rule mild anaemia does not increase the risk of surgery. However, if time permits the cause of the anaemia should be identified before elective surgery. Iron deficiency anaemia is best detected early and treated by oral or intravenous iron. Patients with the anaemia of renal injury are an exception to the general rule and can cope with quite low haemoglobin levels, due to an increase in red cell 2,3-diphosphoglycerate (2,3-DPG) that promotes better transfer of oxygen at the tissue level. However, in all patients the combination of any degree of anaemia with decompensated cardiovascular disease (e.g. angina or obstructive airways disease) warns that intensive perioperative care will be necessary.

Preoperative haemoglobin measurement should be performed as a routine examination in all patients. Patients may have significant anaemia but no symptoms if the anaemia has developed slowly over a period of months and the body has compensated for the decreased oxygen-carrying capacity through such physiological mechanisms as increased cardiac output. The signs and symptoms of anaemia vary with its severity and are more marked if the anaemia has developed over a short period. Symptoms of weakness and tiredness, breathlessness, palpitations and angina can occur with moderate or severe anaemia. Pallor is the outstanding physical sign. Pallor of the conjunctiva and the palmar creases becomes apparent when the haemoglobin level falls below 10 g/dL. Tachycardia and cardiac failure may accompany severe anaemia. Patients with significant or symptomatic anaemia should be evaluated by a specialist physician or haematologist, frequently in a dedicated anaemia clinic.

In the surgical patient, it is often possible to institute iron therapy prior to admission to hospital. Anaemia is thus always best diagnosed and its cause determined during the first office consultation in patients needing elective surgery. For iron deficiency anaemia caused by blood loss, oral iron therapy begins immediately so that anaemia can be safely corrected prior to surgery. Patients with moderate iron deficiency or haemolytic anaemias do not pose an excessive risk provided the haemoglobin level and the blood volume are adequate (>10 g/dL) and cardiorespiratory function is normal.

In patients with megaloblastic anaemia surgery should be deferred, if possible, until specific therapy such as vitamin B_{12} or folic acid has repaired the generalised tissue defect. In these cases, transfusion alone may not render surgery safe, as protein metabolism of all cells is affected by the vitamin deficiency that causes the macrocytic anaemia. Adequate tissue levels can be achieved with 1–2 weeks of oral treatment with vitamin B_{12} or folic acid or both.

If it is not possible to correct the anaemia in a timely manner, the patient may be given concentrated red cells prior to surgery. A period of 3 days should be allowed to elapse before operation as the transfused blood will not reach its maximum oxygen-carrying capacity until at least 2 days following transfusion. This period allows the transfused red cells to accumulate normal levels of 2,3-DPG, necessary for efficient delivery of oxygen to the tissues, and allows plasma dispersal restoring normovolaemia. Elective surgery should seldom be undertaken when the haemoglobin concentration is less than 9–10 g/dL. Patients with long-standing anaemia are able to tolerate a reduced level of haemoglobin better than those who have become acutely anaemic. This tolerance in chronic anaemia is a result of altered 2,3-DPG concentration in the red cells, with a favourable shift in the oxyhaemoglobin dissociation curve to the right.

Psychological preparation and mental illness

All surgical patients must be in a relaxed state of mind irrespective of the nature of the procedure they are about to undergo. Anxiety and a fear of the unknown or of the potential complications of surgery are common, especially in the context of life-threatening illnesses or procedures. Reassurance can be achieved by empathetic surgeon communication with the patient and their relatives and, in certain instances, by the provision of specialised input from other healthcare professionals such as support nurses or psychologists.

Patients with pre-existing mental illness such as anxiety, depression, psychoses, substance abuse or dementia who are preparing for an operation require guidance from their treating healthcare professionals such that their condition is optimally managed in the perioperative period. The stress of surgery may worsen or unmask any pre-existing mental condition. Care must be taken in the prescription of analgesics, anxiolytics, sedatives, antidepressant and antipsychotic medications in these patients.

Further reading

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MCQs

Select the single correct answer to each question. The correct answers can be found in the Answers section at the end of the book.

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 postoperative 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 hand washing between patients
- **d** screening patients for MRSA carriage prior to surgery

3 Which of the following constitutes 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 explanatory brochure
- **d** all serious complications that occur in more than 1% of patients

2 Assessment of surgical risk

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Introduction

This chapter reviews the assessment of risk for patients being considered for surgery or other invasive interventions.

Surgical risk

The definition of surgical risk is complex and differs depending on the point of view of the assessor. The risks of a particular surgical procedure may have a different value when considered by the surgeon, anaesthetist, intensivist, patient or family member.

What a surgeon may consider to be a small complication may be devastating to a patient depending on their personal circumstances. For example, a very rare risk of a unilateral recurrent laryngeal nerve injury leading to vocal cord palsy is well tolerated by the majority of patients but is a disaster for a professional singer. From a patient's perspective surgical risk encompasses the mortality and morbidity relevant to their circumstances as well as the chance of successfully achieving the desired outcome.

The General Medical Council (GMC) of the UK defines the risk of a proposed investigation or treatment using three criteria as well as the potential outcome of taking no action (Box 2.1). This is an integral component of the consent process required for each intervention or surgical procedure and allows the patient and clinician to make a consensual decision after considering the benefits of a procedure balanced against the associated risks. However, there may be a number of treatment options for each surgical pathology so the assessment of surgical risk also facilitates surgical decision-making.

For most surgical procedures the benefits of performing surgery far outweigh the risks and the decision is easier, but for complex surgical procedures the risks may outweigh any benefit. As outlined by the General Medical Council document the risks of not performing surgery also need to be considered. Another important aspect is the likely outcome from surgery. For example, most patients with adenocarcinoma of the head of the pancreas are not suitable for surgical management due to the presence of metastatic disease or involvement of the major adjacent blood vessels. After appropriate preoperative staging only 5–10% of patients are suitable for surgery. Resection of the pancreatic head (pancreaticoduodenectomy or Whipple's procedure) had a mortality of 50% in the 1950s, whereas in 2018 the reported mortality in specialist centres was 0.0–6.0%. Furthermore, operative morbidity is close to 50%. Despite the high morbidity and mortality, the median survival for those patients undergoing successful resection is only 14–24 months even in high-volume centres. Clearly any patient being considered for surgery needs also to understand the likelihood of successful treatment and to be able to balance this against their own personal circumstances as well as the likelihood of morbidity and mortality.

Another reason to assess surgical risk is identification of high-risk patients who may benefit from risk reduction measures such as preoperative and intraoperative optimisation as well as postoperative management in intensive care or high-dependency units.

Assessment of surgical risk

There are three components to assessment of surgical risk. The first is the associated mortality and morbidity of all surgical procedures. This can be

Textbook of Surgery, Fourth Edition. Edited by Julian A. Smith, Andrew H. Kaye, Christopher Christophi and Wendy A. Brown.

Box 2.1 GMC-UK definition of risk of investigation/treatment

1 Side effects
2 Complications
3 Failure of an intervention to achieve the desired outcome
4 The potential outcome of taking no action

Source: https://www.gmc-uk.org/ethical-guidance/ethical-guidance-for-doctors/consent/part-2-making-decisions-about-investigations-and-treatment#paragraph-28

obtained from multiple data sources that include personal audit, hospital audit, regional health data or specialty group audits. Furthermore, there is extensive published data available detailing the mortality and morbidity of surgical procedures or interventions, although this is often reflective of leading high-volume centres. Therefore, publications that report pooled data from all possible sources may offer a clearer representation of surgical risks. A brief overview of surgical risk is outlined in Table 2.1.

The next two components of surgical risk assessment involve both subjective and objective parameters. Subjective assessment includes information taken from the history and examination of a patient as well as recognition of patterns, clinical experience and intuition of the assessor. Often the experience of the assessor in surgical practice may be pivotal in identifying those patients at greater risk. Objective risk assessment includes biochemical and haematological testing as well as assessment of physiological function, particularly cardiac and respiratory function. Assessment of comorbidities also plays a role. There are also many risk prediction models and scoring systems available that can be general or surgery specific.

Discussing the risks of surgery

The General Medical Council of the UK has published guidance on the consent process and in particular on the discussion of the side effects, complications and other risks of surgery or interventions. It details the need for clear, accurate information about the risks of a proposed procedure being presented in a way that the patient understands to enable them to make an informed decision. It is important to understand the patient's views and preferences as well as the adverse outcomes that they are most concerned about. It is impossible to cover every possible side effect or adverse outcome for each procedure but discussion of the common adverse outcomes whether severe or less serious is required as well as any possible serious adverse outcomes.

There are a number of resources available to aid in the discussion, such as procedure-specific information pamphlets produced at a hospital level, surgical regulatory authorities or government agencies.

Risk scoring systems

Many tools have been developed to estimate both mortality and morbidity rates for individual patients prior to a surgical procedure or intervention. Most are scoring systems that estimate risk for all patients whilst others are specific for high-risk patients or particular surgical procedures or disciplines. Like all tools they only provide an estimated risk and none are perfect. Most incorporate both physiological and comorbid data selected from large databases of patients. These have then been analysed with regression techniques to identify the key variables. Often a weighting is added to each of the variables. Ideally these scoring systems should be validated in multiple other centres to analyse their usefulness for particular patient groups.

ASA

One of the first scoring systems developed was by the American Society of Anesthesiologists (ASA) in 1963. It was a five-point classification system for assessment of a patient prior to surgery. It was

Table 2.1 Overview of the morbidity and mortality of common surgical procedures.

Surgical procedure	Morbidity (%)	Mortality (%)
Inguinal hernia repair	8–32	0–0.5
Appendicectomy	3.0–28.7	0.9–2.8
Laparoscopic cholecystectomy	14.7–21.4	0.3
Pancreaticoduodenectomy	20–54	0–6.0
Oesophagectomy	25–45	0.7–10.0
Coronary artery bypass grafting	30	1.5–2.5

Table 2.2 American Society of Anesthesiologists classification of mortality rates.

ASA rating	Number	Deaths (%)
1	92 227	0.001
2	367 161	0.002
3	195 829	0.028
4	45 118	0.304
5	353	6.232
1E	3 018	0.000
2E	12 188	0.033
3E	7 109	0.155
4E	5 000	3.280
5E	899	19.911

Source: Hopkins TJ, Raghunathan K, Barbeito A *et al.* Associations between ASA physical status and postoperative mortality at 48 h: a contemporary dataset analysis compared to a historical cohort. *Perioper Med* 2016;5:29.

subsequently revised with a sixth category coding for emergency patients. It is a combination of subjective anaesthetic opinion with an objective assessment of the patient's fitness for surgery. The majority of hospitals and anaesthetists in Australia use it routinely.

The ASA classification is as follows.

- ASA I: a normal healthy patient.
- ASA II: a patient with mild systemic disease.
- ASA III: a patient with severe systemic disease.
- ASA IV: a patient with severe systemic disease that is a constant threat to life.
- ASA V: a moribund patient who is not expected to survive without the operation.
- ASA VI: a declared brain-dead patient whose organs are being removed for donor purposes.

The coding for emergency patients is marked with the addition of an E.

The ASA system correlates with mortality, as outlined in Table 2.2 that details the outcome of 732,704 patients.

APACHE

First introduced in 1979, the Acute Physiology And Chronic Health Evaluation (APACHE) system was developed to measure the severity of illness in intensive care patients. It consisted of both acute physiological abnormalities as well as a chronic health evaluation measure. This was updated in 1985 with APACHE II with a reduction in the physiological values from 34 to 12 as well as adding a points score for diminished physiological reserve due to immune deficiency and ageing as well as chronic cardiac, pulmonary, renal or liver disease. Further expansion and improvement in the prognostic estimates led to the development of APACHE III.

APACHE was never designed to predict mortality in individual patients. Furthermore, the ability to predict an individual's probability of survival depends upon response to therapy over time. The APACHE system is predominantly a guide for intensive care patients and therefore assessment of critically ill patients rather than a guide for elective surgery.

POSSUM

The Physiological and Operative Severity Score for the enumeration of Mortality and morbidity (POSSUM) was first described in 1991. Rather than a system for intensive care patients it was designed as a scoring system to estimate morbidity and mortality following surgery. It provides a risk-adjusted prediction of outcome. It is the most widely used surgical risk scoring system in the UK. Various modifications have been described and validated for colorectal, oesophagogastric and vascular patient groups. The Portsmouth P-POSSUM was developed in 1998 and is now the most commonly used in the UK.

Pre-admission clinics

Pre-admission clinics have been established for more than 20 years. They have many different roles that include administration, surgical clerking, consent, preoperative education as well as anaesthetic review. They provide an excellent environment for assessing surgical risk as well as for optimising patients' medical conditions prior to surgery. There are very few studies assessing the efficacy of pre-admission clinics in determining a patient's fitness but there are studies demonstrating increased patient satisfaction as well as a decrease in hospital length of stay.

Risk scoring systems lack sensitivity and specificity when applied to individuals. Assessment by an anaesthetist in a pre-admission clinic allows any scoring system to be used as an adjunct to information obtained through clinical assessment of each individual patient. The three objectives of an anaesthetic preoperative assessment are firstly to identify the risk of the patient developing an adverse outcome. The second is to assess any comorbidities that may be optimised prior to surgery. The third objective is to individualise perioperative management to attempt to minimise any remaining adverse outcomes.

There are a number of common comorbidities that should be assessed to minimise surgical risk.

Cardiac disease

Ischaemic heart disease is the commonest cause of serious cardiac adverse outcomes at the time of surgery. There is a greater risk amongst patients with a past history of myocardial infarction, particularly within 3–6 months. The presence of angina is less clear as a marker of increased risk but congestive cardiac failure has consistently been found to be an indicator of worse outcomes.

There are a number of investigations that can be used to assess cardiac risk, the commonest being an electrocardiogram. Non-invasive assessments of reversible cardiac ischaemia that may allow optimisation prior to surgery include exercise electrocardiogram, radionuclide stress cardiac imaging and stress echocardiography.

Respiratory disease

Patients with pulmonary disease are at risk of perioperative complications such as hyperreactive airways, prolonged ventilation, atelectasis, pneumonia and respiratory failure. The site of the surgical incision is important in determining risk due to impairment of pulmonary function. Median sternotomy, upper abdominal incisions and thoracotomy are associated with the greatest risk.

Pulmonary function tests are the main investigation for assessment of pulmonary disease and treatment of reversible airway disease may be required prior to surgery.

Renal risk assessment

Acute renal failure after surgical procedures is associated with a higher mortality rate. Many tertiary referral hospitals also have large nephrology services and surgical procedures on patients with end-stage renal failure are common. Again optimisation of the biochemical consequences of renal failure with preoperative renal dialysis is often required for those patients with end-stage renal failure.

Hepatic risk assessment

There are a number of risk assessments for chronic liver disease, including the Child–Pugh classification and the Model for End-stage Liver Disease (MELD). Patients with liver failure are at a high risk of death even following basic surgical procedures so management in a specialist centre is required to reduce the risk of an adverse outcome.

Neurological risk assessment

There are a number of risk factors for cerebrovascular complications in the postoperative period that include age, cerebrovascular disease, hypertension, atrial fibrillation and the type of surgery.

Haematological risk assessment

A past history of deep venous thrombosis, pulmonary embolism or haematological disorders (i.e. protein C and S deficiency) increases the risk of thromboembolism in the postoperative period.

Operative risk in the elderly

Operative risk is greater in the elderly, with a two to five times greater risk of death in comparison with younger patients. In general, elderly patients have a lower reserve when challenged by a surgical procedure or complication. In the original National Confidential Enquiry into Patient Outcome and Death (NCEPOD) released in 1987, 79% of perioperative deaths occurred in the over-65 age group, although that only represented 22% of the surgical population.

Summary

Assessment of surgical risk is a key component to both preoperative surgical and anaesthetic care. The assessment of surgical risk is critical in providing consent as well as for identifying those at risk who can be optimised prior to surgery or managed in an appropriate environment to allow for the best possible outcome.

Further reading

Burnand KG, Young AE, Lucas J, Rowlands BJ, Scholefield J (eds) *The New Aird's Companion in Surgical Studies*, 3rd edn. Edinburgh: Elsevier Churchill Livingstone, 2005.

Paterson-Brown S (ed.) *A Companion to Specialist Surgical Practice: Core Topics in General and Emergency Surgery*, 6th edn. Edinburgh: Elsevier, 2018.

MCQs

Select the single most appropriate answer to each question. The correct answers can be found in the Answers section at the end of the book.

1 Discussion of the risks of a surgical procedure should include:

a the side effects

b likely complications

c failure of the proposed surgery to achieve the desired outcome
d the potential outcome if no action is taken
e all of the above

2 The American Society of Anesthesiologists (ASA) risk scoring system:
a consists of 12 acute physiological abnormalities as well as a chronic health evaluation measure
b was designed for assessment of critically ill intensive care patients
c can be adjusted according to various different surgical procedures
d is a 6-point classification system for assessment of patients prior to surgery
e is assessed by the surgical team prior to surgery

3 Optimisation of cardiac ischaemia prior to surgery:
a is not necessary as ischaemic heart disease does not increase operative risk
b can be adequately assessed by electrocardiography alone
c is not required if the patient continues to smoke
d is only required for high-risk cardiac surgical patients
e may involve assessment of reversible cardiac ischaemia with radionuclide stress cardiac imaging or stress echocardiography

4 Operative risk in patients over 65 years of age is:
a no greater than for younger patients
b dependent on regular aspirin intake
c greater than younger patients
d only a greater risk if surgery is required for trauma
e greater for procedures performed under local anaesthesia rather than general anaesthesia

3 Anaesthesia and pain medicine

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Introduction

Anaesthetists aim to minimise the risks of surgery and anaesthesia for individual patients and provide optimal operating conditions leading to the best possible surgical outcomes. This requires direct patient care before, during and after surgery. The foundations of anaesthesia practice are general anaesthesia, regional anaesthesia, airway management, perioperative medicine, pain medicine, resuscitation crisis management, and safety and quality. In contemporary anaesthesia these all centre on evidence-based cost-effective practice.

Before surgery

The aim of preoperative assessment is to identify and reduce risks and develop an individualised plan for the patient for the perioperative period (before, during and after surgery) to achieve the goals of care, including being (ideally) cured of the surgical condition (particularly cancer) and returning to the best possible quality of life. About 20% of adult patients undergoing surgery and anaesthesia are at high risk of postoperative complications, disability or death after surgery. Preoperative factors increasing the risk of poor outcome range from severe heart disease to severe anxiety to long-term complex pain syndromes. However, for patients with robust health, failure to achieve an expected return to competitive sport or full employment would be a poor outcome.

Preoperative assessment

All patients should receive timely appropriate preoperative assessment. Increasingly, this includes a team approach including not only surgeons and anaesthetists but also general practitioners, general physicians, specialty physicians, pain medicine specialists, and nursing and allied health practitioners such as physiotherapists and cancer support nurses. The anaesthetist's assessment will include reviewing assessments from others including the surgical team and physicians. Anaesthetists want to know about coexisting conditions (comorbidity), including (i) the nature and extent of the patient's condition, (ii) the preferred treatment for this condition, and (iii) whether the patient is maximally optimised. Anaesthetists are experts in translating this information into a perioperative plan. As with all good clinical assessment, anaesthetists consider history, examination and tests.

The history often starts with a health questionnaire and then follow-up questions during a face-to-face meeting. Current medications and any adverse reactions to medications, particularly allergic reactions, are important. Another important area is prior experience of surgery and anaesthesia. The initial focus of anaesthesia assessment is ABC (airway, breathing and circulation) or, more specifically, potential airway problems and respiratory or cardiovascular dysfunction. Examination will focus on these areas. Tests will depend on the patient's comorbidity, age and planned surgery.

Airway

The aim is to detect potential airway problems that may adversely affect the intraoperative and/or postoperative period. An increasing number of patients have anatomy and disease states that may make intraoperative airway management both difficult and risky. Several factors (Box 3.1) are associated with difficult endotracheal intubation, and which are also associated with difficult mask ventilation and airway obstruction during sedation.

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Box 3.1 Factors associated with difficulty of airway management including during sedation

- Previous difficult endotracheal intubation
- Poor mouth opening
- Poor jaw advancement
- Prominent teeth
- Large tongue
- Limited neck movement
- Short, large neck (bull neck)
- Extreme obesity
- Obstructive sleep apnoea
- Large breasts

Box 3.2 Preoperative fasting recommendations

- For adults having an elective procedure, limited solid food may be taken up to 6 hours prior to anaesthesia and clear fluids may be taken up to 2 hours prior to anaesthesia. Clear fluids are regarded as water, pulp-free fruit juice, clear cordial, black tea and coffee. This excludes particulate or milk-based drinks.
- Prescribed medications may be taken with a sip of water less than 2 hours prior to anaesthesia unless otherwise directed (e.g. oral hypoglycaemics and anticoagulants).

Breathing (lung disease)

The most common lung conditions are asthma, chronic obstructive pulmonary disease (COPD) and recent cigarette smoking. Patients with severe asthma can deteriorate progressively or suddenly during the perioperative period; however, endotracheal intubation that directly stimulates the trachea can be a strong trigger for asthma. Patients with COPD may have a reactive asthma-like component as well as underlying structural lung disease. Oxygen saturation on finger pulse oximetry of less than 92% on room air is associated with severe lung disease and is a strong predictor of postoperative pulmonary complications including pneumonia. The anaesthesia plan will depend on the severity of the asthma or COPD and the nature of the surgery, with a preference for regional anaesthesia where possible for patients with severe lung disease. Care of patients with severe disease will often require coordination with optimisation plans, including preoperative oral steroids. While cigarette smoking is associated with perioperative respiratory complications, smoking is also associated with surgical site infection and patients should be supported with smoking cessation plans. Patients with very severe lung disease who may require prolonged mechanical ventilation in the intensive care unit (ICU) need very careful consideration of whether to proceed with surgery.

Another factor in respiratory assessment is aspiration risk. Aspiration occurs when stomach contents are vomited or passively regurgitated and contaminate the trachea and lower airways. Aspiration can be acidic gastric fluid and/or bile and/or food. Aspiration may be associated with chemical pneumonitis, bacterial pneumonia or airway obstruction and is a medical emergency. Aspiration continues to be an important cause of complications and death before and after surgery. The greatest aspiration risk is for patients undergoing emergency surgery particularly abdominal surgery and in patients with known gastrointestinal obstruction, pain requiring opioids, and active vomiting. A relatively new aspiration risk is previous gastric banding for obesity (see Chapter 18). When possible, patients are fasted before surgery, including all elective surgery, to reduce the risk of aspiration, particularly from large amounts of solid material. Over the last 10 years fasting guidelines have been relaxed and fasting is not a barrier for patients receiving their regular medications (Box 3.2). However, patients with vomiting or gut obstruction often need parenteral drug substitution for important medications and pharmacist advice should be sought.

Cardiovascular

Symptomatic heart disease caries significant perioperative risk of complications and death, usually in the first few days after surgery. Cardiac complications are more common in patients with symptomatic ischaemic heart disease, heart failure or severe heart valve disease. The aim of cardiac assessment is to identify and minimise the risks of cardiac complications, such as myocardial injury after non-cardiac surgery including myocardial infarction, worsening cardiac failure and significant arrhythmia notably atrial fibrillation. Previous stroke is a risk factor for both further stroke and cardiac complications. Several drugs for cardiovascular disease may be withheld prior to surgery depending on individual circumstances, including opinion from the patient's cardiologist, to reduce perioperative risks, for example anticoagulants (including aspirin) to reduce bleeding risk and some antihypertensives (ACE inhibitors and angiotensin receptor blockers) to reduce the risk of persisting hypotension. Patients

with significant cardiovascular disease often require more intensive monitoring and intervention during surgery, such as continuous monitoring of intra-arterial pressure and use of vasopressors and then ongoing care in high dependency or ICU after surgery.

Other frequent and important comorbidities include diabetes, anaemia and kidney disease.

Diabetes

Type 2 diabetes now affects up to 30% of surgical patients, with many previously undiagnosed. Poorly controlled diabetes in surgical patients is associated with increased complications including infection. Patients with type 2 diabetes frequently have, or need to be screened for, chronic kidney disease and cardiovascular disease. Preoperative assessment includes measurement of haemoglobin (Hb)A1c to screen for diabetes in patients aged over 50 years and for diabetes control in those with known diabetes. The key to managing diabetes in the perioperative period is to frequently measure the blood sugar and respond to both hyperglycaemia and hypoglycaemia. To avoid hypoglycaemia, most oral diabetes drugs will be withheld before surgery and insulin dosing will be modified. Many patients undergoing major surgery will need temporary change to insulin while in hospital in collaboration with the diabetes team.

Chronic kidney disease

Even mild chronic kidney disease, defined as an estimated glomerular filtration rate (eGFR) of less than 60 mL/min per m^2, carries a significant increase in the risk of death after surgery. Patients should be on optimal treatment for the severity of their kidney disease. Maintaining adequate hydration is the most important strategy in reducing the risks of chronic kidney disease.

Anaemia

Identifying preoperative anaemia, and the underlying cause, by measuring the haemoglobin and often undertaking iron studies is important for risk minimisation. Some surgical conditions, particularly colorectal cancer, have a high incidence of anaemia (see Chapter 1). Preoperative anaemia carries an increased risk of complications and mortality after surgery, in addition to an increased risk of red cell transfusion which also carries risks of complications. The risks of anaemia and transfusion may be reduced by identifying and managing preoperative iron deficiency and minimising intraoperative blood loss: patient blood management. The most effective way to treat iron deficiency is with iron infusion. However, some patients will have functional anaemia, also known as anaemia of chronic disease, which is harder to treat.

Postoperative nausea and vomiting

Postoperative nausea and vomiting (PONV) is called the 'big little problem'. PONV is common but usually preventable and treatable. However, patients find PONV distressing and may have delayed mobilisation and prolonged admission and occasionally serious complications such as pneumonia. The Apfel risk score for PONV includes four factors: (i) female sex; (ii) history of motion sickness or PONV; (iii) non-smoker; and (iv) planned postoperative opioid treatment. The incidence of PONV ranges from 10% with no Apfel factors to 80% with four factors. Patients at high risk will often receive multimodal intraoperative anti-emetic prophylaxis. Further, the anaesthesia and analgesia plan will have greater emphasis on non-opioid modalities, particularly regional analgesia. Patients at high risk of PONV will also have regular rather than just rescue postoperative anti-emetics.

Pain

Preoperative pain syndromes, particularly those treated with opioids and often requiring orthopaedic or spinal surgery, require close attention and specific planning. Multimodal pain management plans with regional analgesia blocks should be discussed with patients before surgery to outline risks and benefits. Chronic post-surgical pain is an under-recognised complication of surgery. Approximately 10% of patients have chronic pain (months to years) after major surgery, with about one-third of these patients having severe pain. This incidence is higher in specific types of surgery, notably thoracic and breast surgery. Pain management plans individualised to the patient and the surgery are important for reducing these risks. Some drugs, such as gabapentin, will need to be started preoperatively. The pain plan must include rescue for both poor postoperative pain control and complications of pain control such as excessive sedation.

Quantifying risk of complications and mortality

While we often focus on the risks of complication, death and disability, patient-focused outcomes also include pain, nausea and safe return to activities of daily living, as well as anaesthesia-specific risks including regional anaesthesia and adverse drug reaction. Following comprehensive anaesthesia

Table 3.1 American Society of Anesthesiologists Physical Score (ASA-PS).

ASA-PS class	Definition	Examples
ASA I	Healthy	Healthy, non-smoking, minimal alcohol use
ASA II	Mild systemic disease	Current smoker, well-controlled hypertension, or mild asthma
ASA III	Severe systemic disease	Poorly controlled diabetes, active hepatitis, or moderate reduction of left ventricular ejection fraction
ASA IV	Severe systemic disease that is a constant threat to life	Ongoing cardiac ischaemia, sepsis, end-stage cirrhosis
ASA V	A moribund patient who is not expected to survive without the operation	Examples include ruptured abdominal aneurysm, or gut ischaemia with septic shock

Source: https://www.asahq.org/http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwjX__LSmLPeAhWlTt8KHRBzDX0QFjAAegQICBAC&url=http%3A%2F%2Fwww.asahq.org%2F~%2Fmedia%2Fsites%2Fasahq%2Ffiles%2Fpublic%2Fresources%2Fstandards-guidelines%2Fasa-physical-status-classification-system.pdf&usg=AOvVaw2VpwTL1ioJ7-XXfFM7Smwq Reproduced with permission of American Society of Anesthesiologists.

assessment, patients should be allocated a score using the American Society of Anesthesiologists Physical Score (ASA-PS) (Table 3.1). This single-variable score is a remarkably strong predictor of postoperative complications and mortality. However, increased accuracy can be achieved by including other risk factors for complications and mortality such as increasing age, frailty and emergency surgery. Risk calculators, such as the American College of Surgeons online risk calculator (Box 3.3), allow quantitative risk assessment of complications and mortality, usually the risk of dying within 30 days of surgery (30-day mortality). Patients with a 5% or greater risk of 30-day mortality require higher levels of specialised care including admission to ICU after surgery. Patients with a 5% risk of mortality are likely to have a risk of major complications exceeding 20% and risk of poor functional recovery. Increasingly, in assessing the goals of care these high-risk patients undergo more limited surgery or non-surgical treatment.

Box 3.3 Example of calculating risks for patients and related decisions

Risk calculation for a 74-year-old woman for elective partial colectomy with colostomy using the American College of Surgeons Risk Calculator

- If assessed as ASA 2 (e.g. has hypertension), risk of death within 30 days of surgery is at least 0.5% and risk of complications is 20%. This patient is suitable for ward care.
- If assessed as ASA 4 (e.g. has diabetes, cardiac failure and chronic renal impairment), risk of death is at least 5% and risk of complication 35%. Clinicians should strongly consider critical care admission after surgery.
- If assessed as ASA 4, frail and having emergency surgery (a growing number of patients), risk of death is 13% and risk of complications 42%. The goals of care should be discussed with the patient (and family) and some may decide for supportive care only or limitations on medical treatment if she deteriorates after surgery.

Intraoperative care

The intraoperative care plan will depend on the nature and extent of the surgery and the patient. The broad aspects of anaesthesia are one or more of pain relief, sleep or sedation, no memory (amnesia), muscle relaxation and stable physiology, particularly haemodynamic stability. The fundamental keys to safe anaesthesia are appropriate intravenous access and control of the airway.

The broad options for anaesthesia involve one or more of the following: local anaesthesia, sedation, regional anaesthesia (spinal, epidural or nerve block) and general anaesthesia, all of which have many additional options.

Intravenous access

For many procedures intravenous access is predominantly used to administer drugs to provide appropriate and safe anaesthesia, with fluid therapy being a minor component. The small cannulas (blue, 22G, 0.41 mm diameter) have a maximum flow rate of about 30 mL/min but because flow is related to the fourth power of the radius, a large cannula (orange,

14G, 1.6 mm diameter) has 10 times the flow (300 mL/min). Flow is enhanced in cannulas sited in larger veins. For adult trauma patients, the standard of care is two 16-gauge cannulas in large cubital fossa veins with a total flow of up to 400 mL/min (2 × 200 mL/min). This would be similar to intravenous access for major surgery. Long catheters placed in central veins (central lines), particularly the internal jugular vein, are used for reliable and robust intravenous access for drugs that could cause harm if they passed into interstitial tissue through damaged peripheral veins or if the drugs were suddenly stopped. Such drugs include potent vasoconstrictors whose sudden cessation can lead to severe shock and where extravasation can lead to tissue necrosis. Central lines also allow easy venous blood sampling for analysis and for measurement of central venous pressure.

Intraoperative monitoring

The most important intraoperative monitor is the pulse oximeter, which allows continuous non-invasive measurement of blood oxygen saturation and heart rate. Falling oxygen saturation is most frequently due to inadequate ventilation or inadequate inspired oxygen in patients who are anaesthetised but spontaneously breathing. Other fundamental monitoring includes ECG to detect changes or abnormalities in heart rate and rhythm, and blood pressure monitoring with either intermittent non-invasive cuff measurements (usually the brachial artery) or continuous invasive arterial monitoring (usually the radial artery).

Contemporary anaesthesia machines can perform extensive electronic monitoring of multiple patient and machine variables. In addition to the fundamental monitoring previously outlined, anaesthesia machines monitor inspired and expired gases (oxygen, carbon dioxide and anaesthetic gases). Further, anaesthesia machines have complex alarm systems that enhance safety monitoring individualised to the patient and procedure. Modern machine ventilators allow both full mechanical ventilation and assisted spontaneous ventilation. Depth of anaesthesia can be routinely monitored with specialised EEG, and depth of muscle relaxation with neuromuscular monitoring

Oxygen therapy and airway interventions

Intraoperative airway interventions range from supplemental oxygen via nasal prongs through to endotracheal intubation. Even patients undergoing procedures under local anaesthesia and sedation, such as minor plastic surgery, or those undergoing major surgery under spinal anaesthesia may require some supplemental oxygen due to respiratory depression or in order to wash out carbon dioxide and to reduce claustrophobia under drapes. Contemporary supplemental oxygen is often accompanied by continuous monitoring of expired carbon dioxide. This safety measure detects hypoventilation and airway obstruction due to apnoea.

Postoperative pain medicine

All anaesthetists, and many surgeons, are trained in acute pain medicine. Advanced pain medicine is now a medical speciality with many practitioners also being anaesthetists. Good pain control after surgery is a central part of postoperative care. The most important cause of chronic post-surgical pain is severe acute postoperative pain.

Pharmacological therapy will be combined with strategies such as physiotherapy and proactive nursing care to effectively and efficiently return the patient to the best possible function and recovery from their surgical condition. Other aims include minimising the risks of pain therapies for the individual and the spread of drugs of addiction (particularly opioids) into the broader community. Collaboration with an anaesthetist-led acute pain service greatly facilitates these aims. Further, acute pain medicine is more complex at extremes of age and in those with complex comorbidity, those suffering from opioid tolerance or dependence, obese patients and those with complex pain syndromes.

While anaesthetists will usually plan and establish a postoperative pain management plan, ward clinicians need to measure a patient's pain, often with a 0–10 visual analogue scale and alter the plan if patients have poor pain control or side effects, particularly excess sedation. Postoperative care also involves weaning from analgesia as appropriate and moving the patient to oral pain relief appropriate for community discharge and subsequent cessation. Chronic post-surgical pain is an important complication after surgery. While some operations, particularly surgery via thoracotomy, carry a major risk of chronic post-surgical pain, one in ten patients will have chronic pain after abdominal surgery.

Multimodal analgesia aims to combine the benefits of different mechanisms to treat pain to provide high-quality pain relief and minimise side effects. The following list gives an indication of the postoperative analgesic options that can be individualised to patients and operations.

- Paracetamol: regular paracetamol is an effective foundation for multimodal analgesia. With appropriate dosing paracetamol has minimal side effects.

- Non-steroidal anti-inflammatory drugs (NSAIDs): these drugs form the next tier of analgesics. While being very effective analgesics, NSAIDs can increase the risk of bleeding and acute kidney injury. For most patients the benefits greatly outweigh these relatively rare risks.
- Opioids: morphine has been a mainstay of pain relief for centuries. In contemporary practice morphine is administered in many ways: oral, subcutaneous, intramuscular, intravenous, epidural and spinal. Many patients receive morphine via patient-controlled analgesia (PCA) that aims to empower the patient and reduce risks. All routes of morphine administration carry the risk of life-threatening respiratory depression and death. Hospital protocols aim to minimise these risks. However, far more frequent complications include nausea, constipation and itch. Other frequently used alternative opioids are fentanyl and oxycodone. Tramadol is an atypical opioid with less respiratory depression, constipation and potential for abuse. However, tramadol can have important drug interactions that can limit its use, including a serotonin syndrome with some antidepressants. There is a strong trend towards minimising use of opioids around the time of surgery to reduce the frequency of in-hospital opioid complications (nausea and vomiting, constipation and itch), reduce long-term opioid use and reduce community opioid abuse.
- Ketamine: this drug acts on different receptors from the opioids and provides complementary but different analgesia and is opioid sparing. Ketamine infusion is often introduced for inadequately treated pain after major surgery and for patients at significant risk with opioid analgesia. The major complication with ketamine is hallucinations.
- Anticonvulsants: gabapentin and pregabalin are two anticonvulsants used to treat chronic as well as acute pain from nerve injury, which can occur in many types of surgery. These drugs are also opioid sparing and reduce opioid side effects.
- Local anaesthetics: increasingly, patients on wards have infusions of local anaesthetic through specialised catheters placed by anaesthetists that provide direct analgesia to major nerves and nerve plexuses, or wound catheters placed by surgeons. Epidural infusions are still used in some major thoracic and abdominal surgery, usually on an individualised basis. These infusions may provide better postoperative analgesia, less opioid use and less PONV, itch and sedation than only using systemic analgesia. The most important side effects of local anaesthetics are fitting, cardiac arrhythmias and cardiac arrest but are dose related and rare with contemporary practice.

Further reading

American College of Surgeons. Surgical Risk Calculator. Available at https://riskcalculator.facs.org/RiskCalculator/

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MCQs

Select the single most appropriate answer to each question. The correct answers can be found in the Answers section at the end of the book.

1 A fit and healthy patient having their anterior cruciate ligament repaired:
- **a** has no cardiopulmonary perioperative risks
- **b** is American Society of Anesthesiologists Society Physical Status 1
- **c** will require minimal analgesia
- **d** will require a postoperative critical care bed and prolonged hospital stay
- **e** is likely to have obstructive sleep apnoea

2 Anaesthesia assessment:
- **a** is usually just before induction of anaesthesia
- **b** requires blood tests
- **c** excludes patients with complex pain syndromes
- **d** requires history, examination and further tests
- **e** is independent of surgical assessment

3 Which of the following risk factors for postoperative nausea and vomiting (PONV) is *incorrect*?
- **a** old age
- **b** gender
- **c** previous nausea and vomiting
- **d** non-smoking
- **e** use of opioids

4 Opioids:
- **a** are the foundation of all pain management plans
- **b** have excitation as a major side effect
- **c** cause diarrhoea
- **d** can be administered by several routes
- **e** are contraindicated for patients taking paracetamol

4 Postoperative management

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Introduction

Good postoperative management will have started before the procedure with appropriate counselling and preparation (see Chapter 1). This preparation will have included an assessment of fitness for the procedure and identification and management of any risk factors. The patient will have been provided with a clear explanation of the procedure (emergency or elective), the risks and benefits, and the likely outcome. This will have included a description of what the patient should expect in terms of short- and long-term recovery from the procedure, possible complications and the necessity for any drains, stomas, catheters or other bits of tubing, the details of which would be alien to most of the population. The anticipated length of time in hospital will have been discussed, as well as details of how long it will take to make a full recovery from the procedure and how long the patient will be away from or unable to participate in their usual activities. The patient will have been reassured about pain control measures and, perhaps most difficult of all, the doctor will have tried to ensure that the patient's expectations match those of the health professional.

This chapter will focus on the care of the patient in the immediate postoperative period, up until the time of discharge from hospital. The immediate and short-term needs of the patient and care to be provided will depend on the magnitude and type of surgery.

Immediate management of the patient

Pain management

Pain relief is of paramount importance (see Chapter 3) and an appropriate drug regimen will have been prescribed by the surgeon and/or anaesthetist by the end of the procedure. In checking the charts of the patient after the procedure, care will be taken that these and any other medications required are prescribed and administered. These may include antibiotics (prophylactic or therapeutic), sedatives, anti-emetics and anticoagulants.

Monitoring

Depending on the nature of the procedure and the underlying state of health of the patient, the vital signs (blood pressure, pulse and oxygen saturation) will be measured and recorded regularly. If an arterial catheter has been inserted, blood pressure and pulse readings can be observed on a monitor constantly. The intensity and frequency of monitoring will be maximal in the recovery room and this level of scrutiny maintained if the patient is in an intensive care or high-dependency area.

Measurement of the central venous pressure may be required for patients with poor cardiorespiratory reserve or where there have been large volumes of fluid administered or major fluid shifts are expected.

The patient chart will also record all fluid that has been given during and since the operation, together with fluid lost. Ideally, these figures will have been balanced by the end of the procedure, so that the duty of the attending doctor will be to monitor ongoing losses (digestive and urinary tracts, drains, stomas) and replace these. The normal daily fluid and electrolyte requirements will also be provided. If there has been major fluid shifts or if renal function is precarious, a urinary catheter will be inserted and regular (hourly) checks made of fluid losses. Serum electrolytes and haematological values will be checked frequently, again the frequency depending on any abnormalities present and the magnitude of any fluid and electrolyte replacement.

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Mobilisation

Early mobilisation is encouraged. Unless there are specified orders to the contrary, all patients are encouraged to get up and move around as much as their underlying condition will allow. Obvious exceptions to this policy include patients with epidural catheters and those with severe multiple injuries. The aim of early mobilisation is to encourage good pulmonary ventilation and to reduce venous stasis. For those who cannot mobilise, physiotherapy should be provided to help with breathing and measures taken to either increase venous flow (pneumatic calf compression devices) or reduce risks of deep vein thrombosis (heparin). The timing of any planned heparin administration will depend on the nature of the procedure and the risks of haemorrhage from that procedure.

Communication

When problems arise, they are frequently compounded by a failure of communication. Whilst the doctor's duty of care is to the patients themselves, the needs of the relatives must be taken into account. Simple things – which are often forgotten – include a reassuring telephone call to the nearest relative after a procedure, informing them (usually in general terms) of how the procedure went. Whilst this is most obvious in the paediatric setting, the same principles should be followed with adult healthcare. The patients themselves will seek some form of reassurance in the immediate postoperative period. They will want to know how the procedure went and how they are progressing. They will also want reassurance that all the tubes, lines and equipment to which they are attached are quite normal and not an indication of impending disaster. Ideally, this will have been discussed with them prior to the procedure. Any unexpected findings or complications encountered during the procedure should be discussed with the patient. The timing and detail of this discussion is a matter of fine judgement and may be best done in the presence of the patient's relatives and by the individual who performed the procedure.

Further care in the postoperative period

This covers the time from recovery from anaesthesia and initial monitoring to discharge from hospital. Wound care is discussed in Chapter 6.

Prophylaxis against venous thromboembolism

This is a key part of the management of any hospitalised individual, particularly the surgical patient. A risk analysis will have been performed preoperatively (see Chapter 1) and depending on the nature of the procedure and the individual's risk, some form of chemoprophylaxis may be started in the postoperative period. This will require day-to-day monitoring and for major procedures, such as hip joint replacement or many cancer operations, the prophylaxis may be continued after discharge from hospital. For patients being managed in intensive care settings and who, for various reasons, will have limited or no mobility, intermittent mechanical calf compression will be used in addition to chemoprophylaxis.

Enhanced recovery after surgery (ERAS) programs

These structured programs are starting to replace traditional surgical practices, with implementation of protocols for early postoperative feeding, early mobilisation and more effective pain control measures. Evidence now exists showing that these ERAS systems can significantly reduce length of hospital stay and complications rates, with overall reduction in healthcare costs.

Respiratory care

In the otherwise fit and healthy patient, maintenance of respiratory function is usually not a problem, particularly if there is optimal management of pain. Even with upper abdominal or thoracic procedures, most patients will require little respiratory support provided they are able to mobilise themselves and breathe unimpeded by pain. When assistance is required simple breathing exercises, with or without the help of a physiotherapist, is usually sufficient. Mechanical ventilation may be required in the early phase of recovery from a particular procedure. This can vary from prolonged endotracheal intubation, to intermittent positive pressure ventilation, to supplemental oxygenation by face mask or nasal prongs. In these instances the patient may require prolonged monitoring in an intensive care or high-dependency unit with regular assessment of oxygen saturation (pulse oximetry and arterial blood gas analysis).

For less fit patients, and particularly those with chronic obstructive pulmonary disease (COPD), the risks of respiratory failure will be considerable and measures such as epidural local anaesthesia will be employed. Control of pain, attention to regular

hyperinflation (inhalation spirometry and physiotherapy) and early mobilisation are the keys to preventing respiratory complications.

Fluid balance

The three principles of management of fluid balance are:

- correct any abnormalities
- provide the daily requirements
- replace any abnormal and ongoing losses.

Ideally, any abnormalities will have been identified and corrected before or during the surgical procedure. In the calculation of a patient's fluid requirements, there is a distinction to be made between the volume required to *maintain* the body's normal functions and that required to *replace* any abnormal losses. The normal maintenance fluid requirements will vary depending on the patient's age, gender, weight and body surface area.

Basic requirements

The total body water of a 70-kg adult comprises 45–60% of body weight. Lean patients have a greater percentage of their body weight as body water and older patients a lesser proportion. Of the total body water, two-thirds is in the intracellular compartment and one-third is divided between plasma water (25% of extracellular fluid) and interstitial fluid (75% of extracellular fluid). Therefore, a lean individual weighing 70 kg would have a plasma water of 3 L, an interstitial volume of 11 L and an intracellular volume of 28 L, making a total volume of 42 L.

The normal daily fluid requirement to *maintain* a healthy 70-kg adult is between 2 and 3 L. The individual will lose about 1500 mL in the urine and about 500 mL from the skin, lungs and stool. Loss from the skin will vary with the ambient temperature.

The electrolyte composition of intracellular fluid (ICF) and extracellular fluid (ECF) varies (Table 4.1). Sodium is the predominant cation in ECF while potassium predominates in the ICF. The normal daily requirements of sodium and potassium are 100–150 mmol and 60–90 mmol, respectively. This will balance the daily loss of these two cations in the urine.

Table 4.1 Electrolyte concentrations.

Electrolyte	Extracellular fluid (mmol/L)	Intracellular fluid (mmol/L)
Sodium	135	10
Potassium	4	150
Calcium	2.5	2.5
Magnesium	1.5	10
Chloride	100	10
Bicarbonate	27	10
Phosphate	1.5	45

Replacement

If an otherwise healthy adult is deprived of the normal daily intake of fluid and electrolytes, suitable intravenous maintenance must be provided. One relatively simple regimen is 1 L of 0.9% saline and 1–2 L of 5% dextrose solution.

Both these solutions are isotonic with respect to plasma. The electrolyte solution contains the basic electrolyte requirements (154 mmol/L of sodium and 154 mmol/L of chloride) and the total volume can be adjusted with various amounts of dextrose solution. Potassium can be added as required. Other solutions (e.g. Ringer's lactate) may contain a more balanced make-up of electrolytes, but are rarely needed for a patient who is otherwise well and only requires intravenous fluids for a few days.

In the immediate postoperative period there is an increased secretion of antidiuretic hormone (ADH), with subsequent retention of water. In an adult of average build, maintenance fluids can be restricted to 2 L per day with no potassium supplements until a diuresis has occurred. This is not an absolute rule, and potassium supplements can be given early, provided the patient has normal renal function.

Fluid and electrolyte *replacement* is that required to correct abnormalities. Volume depletion and electrolyte abnormalities are relatively common in surgical patients, particularly those admitted with acute illnesses. Volume depletion usually occurs in association with an electrolyte deficit, but can occur in isolation. Reduced fluid intake, tachypnoea, fever or an increase in the ambient temperature may all lead to a unilateral volume loss. This will cause thirst and dehydration, which may progress to a tachycardia, hypotension and prostration. In severe cases there may be hypernatraemia and coma. Intravenous administration of 5% dextrose is used to correct the problem.

More often volume depletion is accompanied by an electrolyte deficit. Excessive fluid and electrolyte may be lost from the skin (e.g. sweating, burns), the renal tract (e.g. diabetic ketoacidosis) and the gastrointestinal tract (e.g. vomiting, ileus, fistula, diarrhoea). There is considerable scope for abnormal fluid losses in a surgical patient, particularly after a major abdominal procedure.

Table 4.2 Approximate electrolyte concentrations.

Secretions	Sodium (mmol/L)	Potassium (mmol/L)	Chloride (mmol/L)	Bicarbonate (mmol/L)	Hydrogen (mmol/L)
Salivary	50	20	40	50	—
Gastric	50	15	120	20	70
Duodenal	140	5	80	—	—
Biliary	140	10	100	40	—
Pancreatic	140	10	80	80	—
Jejuno-ileal	130	20	105	30	—
Faeces	80	10	100	25	—
Diarrhoea	100	30	50	60	—

There may be pooling of fluid at the operation site itself, an ileus might develop, fluid could be lost through a nasogastric tube or drains, and there might be increased cutaneous loss if there is a high fever.

The source of fluid loss will determine the type of electrolyte lost. There is considerable variation in the electrolyte content of different gastrointestinal secretions (Table 4.2). Loss from the upper digestive tract tends to be rich in acid, while loss from the lower tract is high in sodium and bicarbonate. Thus, patients with severe and prolonged vomiting from gastric outlet obstruction may develop a metabolic alkalosis.

While the management of maintenance fluid requirements can often be done on a daily basis, the fluid and electrolyte replacement needs of an acutely ill surgical patient is likely to be more involved and necessitate close monitoring and adjustment. Clinical assessment and appreciation of the types of fluid loss will give an approximate guide to the scale of the problem, but regular biochemical electrolyte estimations will be required to determine the precise composition of what needs to be replaced. In most instances, measurement of plasma electrolyte concentrations will provide sufficient information, but occasionally it may be necessary to estimate the electrolyte contents of the various fluids being lost.

Drains and catheters

Drains serve a number of purposes. They may be inserted into an operative site or into a wound as it is being closed to drain collections or potential collections. Drains may also be put into the chest cavity to help the lungs re-expand. They may be put into ducts and hollow organs to divert secretions or to decompress that structure. Examples of decompression include insertion of a tube into the common bile duct after duct exploration or nasogastric intubation to decompress the stomach after surgery for intestinal obstruction. Sump drains are used to irrigate sites of contamination or infection.

Drains can act as a point of access for infection, and whilst this may be of little consequence if the tube has been placed to drain an abscess cavity, all efforts are made to reduce contamination of any wound. There is increased use of closed drainage systems and dressings around drains are changed regularly. Any changes to tubes or bags on drains must be carried out using aseptic techniques. Once a drain has served its purpose, it should be removed. The longer a drain stays *in situ*, the greater the risk of infection.

The contents and volumes discharged through a drain must be recorded. Large volumes, such as those from the gastrointestinal tract, may need the equivalent amount replaced intravenously.

Gut function

Some degree of gut atony is common after abdominal surgery, particularly emergency surgery. The condition is usually self-limiting and of little clinical consequence. There are three conditions that can produce massive gut dilatation and pose serious problems for the patient:

- gastric dilatation
- paralytic (small intestine) ileus
- pseudo-obstruction (large intestine).

Gastric dilatation

Gastric dilatation is rare and when it occurs tends to be associated with surgery of the upper digestive tract. It may occur suddenly 2–3 days after the operation and is associated with massive fluid secretion into the stomach, with the consequent risk of regurgitation and inhalation. Treatment is by insertion of a nasogastric tube and

decompression of the stomach. Unfortunately, when gastric dilatation does occur, often the first indication of the problem is a massive vomit and inhalation after the dilatation has occurred. By then the damage is done and the value of a nasogastric tube at this stage is questionable. Traditionally, nasogastric tubes were used routinely for patients following laparotomy, particularly in the emergency setting. However, the nasogastric tube is often the patient's major source of irritation and discomfort in the postoperative period and its routine use is gradually being abandoned.

Paralytic ileus

Paralytic ileus is less sinister and more common. In the acutely ill patient who has undergone surgical intervention for peritonitis, paralytic ileus may be present from the first postoperative day. Otherwise, it tends to make its presence felt about 5 days after operation, and the patient may have been making an apparently uneventful recovery. Abdominal distension occurs and the patient may vomit. Oral fluid restriction should be instituted and intravenous replacement may be required. Most cases resolve spontaneously. Occasionally a prokinetic agent may be considered.

Pseudo-obstruction

Classically, pseudo-obstruction occurs in the elderly patient who has recently undergone surgery for a fractured neck of femur. The condition is also often seen where there has been extensive pelvic or retroperitoneal injury and sometimes the condition appears to be more related to the use of opiate analgesia rather than the type of surgery itself. The atony, with abdominal distension and absence of bowel function, tends to occur 2–3 days after surgery (or from the time the injury was sustained). Pseudo-obstruction is often mistaken for mechanical obstruction and the dilatation of the colon and caecum can be massive. If the condition does not resolve spontaneously, colonoscopic decompression is usually successful. Occasionally, surgical intervention is required to prevent caecal perforation.

Important postoperative complications

Respiratory complications

Deterioration or impairment of respiratory function is the commonest and more important postoperative complication, occurring with greatest frequency in the patient undergoing an emergency procedure. The preoperative assessment will have judged the individual's risk and measures that might need to be taken to minimise respiratory problems (see Chapter 1). Apart from any comorbidities, such as COPD, the likely cause of a patient's hypoxaemia will vary with the time of onset (Box 4.1).

Measures must be taken to minimise the risks of postoperative pulmonary complications, including judicious use of pain medications, where local wound infiltration or nerve blocks may be more appropriate than systemic measures. Early mobilisation and encouragement to cough and breathe deeply must be actively promoted.

Depending on the initial state of respiratory function and the degree of deterioration, the patient may require anything from supplemental oxygen supplied by face mask to endotracheal intubation. A P_{CO_2} above 45 mmHg, a P_{O_2} below 60 mmHg and a low tidal volume all indicate that mechanical ventilation will be required. Once appropriate ventilatory support has been achieved, the cause of the respiratory failure can be addressed.

Wound failure

Provided the surgical procedure has a minimal risk of infection (see Chapter 9) and has been performed in an uneventful manner in a low-risk patient, then the chances of problems with the wound are minimal and most such wounds can be left undisturbed

Box 4.1 Factors contributing to postoperative hypoxaemia

Immediate
Respiratory depression (anaesthetic agents, opioids)

Within first 24 hours
Established respiratory disease (e.g. COPD)
Obesity
Excessive sedation
Opiates
Aspiration
Pneumothorax

Between days 2 and 5
Infection
Diaphragmatic splinting (secondary to abdominal distension)
Pleural effusion
Acute respiratory distress syndrome

After day 5
Pulmonary embolus

until the patient leaves hospital. If there are identifiable risks the wounds may need to be attended to regularly. The problems that are likely to occur with wounds relate to:

- discharge of fluid
- collection of fluid
- disruption of the wound.

Risk factors that may contribute to these problems include those that:

- increase the risk of infection (see Chapter 9)
- increase the risk of wound breakdown.

There are general and local factors that increase the risk of breakdown of a wound. General factors include those that interfere with wound healing, such as diabetes mellitus, immunosuppression, malignancy and malnutrition. Local factors include the adequacy of wound closure, infection and anything that might put mechanical stress on the wound. For example, abdominal wound failure is a potential problem in the obese, and in those with chest infections, ascites or ileus.

In the early stages of wound healing any abnormal fluid at the wound site is likely to discharge rather than collect. The fluid may be blood, serous fluid, serosanguinous fluid or infected fluid of varying degrees up to frank pus. As discussed elsewhere in this chapter, the discharge of blood from a wound may have all sorts of consequences for the patient, which will vary from prompt opening of the neck wound of a patient with a primary haemorrhage after a thyroidectomy to evacuation of a haematoma after a mastectomy.

Serous fluid may be of little significance and be the result of a liquefying haematoma from within the depths of the wound. However, a serosanguinous discharge from an abdominal or chest wound may herald a more sinister event, particularly if it occurs between 5 and 8 days after the operation. The discharge may have been preceded by coughing or retching. Such a wound is in imminent danger of deep dehiscence with evisceration. Should such an event occur, the wound must be covered in sterile moist packs and arrangements made to take the patient to the operating room for formal repair of the wound.

Collections in and under a wound may be blood, pus or seroma. As mentioned, the rapidity with which a haematoma appears and any pressure effects such a haematoma may cause will determine its treatment. Collections of pus must be drained. Depending on its proximity or distance from the skin surface, an abscess may be drained by opening the wound or inserting (under radiological control) a drain into a deeper-lying cavity. Seromas tend to occur where there has been a large area of dissection in subcutaneous tissues (e.g. mastectomy) or where lymphatics may be damaged (e.g. groin dissections). The seroma may not appear a week after the procedure. Seromas will lift the skin off the underlying tissues and impede wound healing. They also make fertile ground for infection. Seromas should be aspirated under sterile conditions and the patient warned that several aspirations may be required as the seroma may re-collect.

Confusion

Confusion in surgical patients is common and has many causes. Often the confusion is minor and transient and does not need treatment. The patient is typically elderly, has become acutely ill and in pain, is removed from the security and familiarity of their home surroundings, is subject to emergency surgery and more pain, is put in a noisy environment with strangers bustling around and is sleep-deprived. These factors alone would make many otherwise healthy individuals confused. Add to that recipe the deprivation of the patient's regular medications (particularly alcohol), the upset to their body biochemistry, the presence of hypoxia and a variety of postoperative medications such as opioids, and it becomes understandable that some degree of confusion is very common in the postoperative period. Confusion combined with restlessness, agitation and disorientation is referred to as delirium.

Important causes of confusion include:

- Sepsis (operative site, chest, urinary tract)
- Hypoxia (chest infection, pulmonary embolus, pre-existing pulmonary disease)
- Metabolic abnormalities (hyponatraemia, hyperglycaemia/hypoglycaemia, acidosis, alkalosis)
- Cardiac
- Hypotension (haemorrhage, dehydration)
- Cerebrovascular event
- Drug withdrawal (alcohol, opiates, benzodiazepines)
- Drug interaction (opiate sedation)
- Exacerbation of pre-existing medical conditions (dementia, hypothyroidism).

When a patient does become confused in the postoperative period, it is important to ensure that no easily correctable cause has been overlooked. Confusion is often secondary to hypoxia, where chest infection, over-sedation, cardiac problems and pulmonary embolism need to be considered. Other important causes to consider include sepsis, drug withdrawal, metabolic and electrolyte disturbances and medications.

The management of the confused patient will include a close study of the charts, seeking information on any coexisting disease (particularly cardiorespiratory), drug record, alcohol consumption and the progress of the patient since the operation. Current medications should be noted, together with the nursing record of the vital signs.

If possible, try to take a history and examine the patient. Ensure that the patient is in a well-lit room and give oxygen by face mask. Attention should be focused on the cardiorespiratory system, as this may well be the site of the underlying problem. Some investigations may be required to help determine the cause of the confusion. These might include arterial blood gas analysis, haematological and biochemical screens, blood and urine cultures, a chest X-ray and an electrocardiogram (ECG).

Most patients with postoperative confusion do not require treatment other than that for the underlying cause. However, the noisy violent patient may need individual nursing care, physical restraint or sedation. Sedation should be reserved for patients with alcohol withdrawal problems, and either haloperidol or diazepam should be considered in such circumstances. Most hospitals have clearly defined protocols for the management of patients going through alcohol withdrawal. These correlate the anxiety, visual disturbances and agitation of the patient with the degree of monitoring and sedation required.

Pyrexia

The normal body temperature ranges between 36.5 and 37.5°C. The core temperature tends to be 0.5°C warmer than the peripheral temperature. Thus an isolated reading of 37.5°C has little meaning by itself and needs to be viewed in context with the other vital signs. Changes in temperature and the pattern of change are more important. A temperature that rises and falls several degrees between readings suggests a collection of pus and intermittent pyaemia, while a persistent high-grade fever is more in keeping with a generalised infection.

Fever can be due to infection or inflammation. In determining the cause of the fever the following should be considered:

- the type of fever
- the type of procedure which the patient has undergone
- the temporal relationship between the procedure and the fever.

Perhaps the most useful factor in trying to establish the cause of a patient's fever is the relationship between the time of onset of the fever and the procedure. Fever within the first 24 hours of an operation is common and may reflect little more than the body's metabolic response to injury.

A fever that is evident between 5 and 7 days after an operation is usually due to infection. While pulmonary infections tend to occur in the first few days after surgery, fever at this later stage is more likely to reflect infection of the wound, operative site or urinary tract. Cannula problems and deep vein thrombosis (DVT) should also be considered.

A fever occurring more than 7 days after a surgical procedure may be due to abscess formation. Apart from infection as a cause of fever, it is important to remember that drugs, transfusion and brainstem problems can also produce an increase in body temperature.

A careful history, review of the charts and physical examination will usually determine the cause of the fever. The next stage in management will depend on the state of health of the patient. The fever of a septic process, which has led to circulatory collapse, will require resuscitation of the patient before any investigation. Otherwise, appropriate investigations may include blood and urine cultures, swabs from wounds and drains, and imaging to define the site of infection.

Treatment will depend on the severity and type of infection. The moribund patient will require resuscitation and empirical use of antibiotics, the choice varying with the likely source of infection. Surgical or radiological intervention (e.g. to drain an abscess) may be required before the patient improves. However, the well patient may have antimicrobial therapy deferred until an organism has been identified (e.g. Gram stain or culture).

Deep vein thrombosis and pulmonary embolism

These complications can still occur despite prophylaxis (see Chapter 1). Presentation of DVT may be silent (60%) or as a clinical syndrome (40%). If suspected on clinical grounds (painful, tender and swollen calf), duplex ultrasonography is the investigation of choice, with a sensitivity and specificity greater than 90%. In cases of suspected pulmonary embolism, a CT pulmonary angiogram is the appropriate investigation.

The treatment of DVT has now moved from unfractionated heparin infusion to subcutaneous low-molecular-weight heparin. This is maintained until the patient is fully anticoagulated on warfarin and the latter is continued for 3–6 months to minimise the risk of further thrombosis and the development of complications (see Chapters 73 and 75). A caval filter might have to be considered,

particularly for clot extending into the iliofemoral segments.

The treatment of a pulmonary embolus will depend on the severity of the event. A relatively minor episode, with no cardiovascular compromise, can be managed with heparinisation, whereas a more serious embolus may need surgical intervention (embolectomy) or use of a fibrinolytic agent.

Oliguria

Oliguria is a common problem in the postoperative period and is usually due to a failure by the attending medical staff to appreciate the volume of fluid lost by the patient during the surgical procedure and in the immediate postoperative period. For example, the development of an ileus will lead to a large volume of fluid being sequestered in the gut and this 'loss' not being immediately evident. Before the apparent oliguria is put down to diminished output of urine, it is important to ensure that the patient is not in urinary retention. Such an assessment can be difficult in a patient who has just undergone an abdominal procedure. If there is any doubt, a urinary catheter must be inserted. Alternately, most wards are now equipped with ultrasonographic devices capable of providing an accurate estimation of the bladder content.

Diminished output of urine may be due to:

- poor renal perfusion (pre-renal failure due to hypovolaemia and/or pump failure)
- renal failure (acute tubular necrosis)
- renal tract obstruction (post-renal failure).

In the assessment of a patient with poor urine output (<30 mL/h), these three possible causes must be considered. Major surgery with large intraoperative fluid loss and periods of hypotension during the procedure might suggest renal tissue damage (acute tubular necrosis), while severe peritonitis with large fluid shifts and no hypotension would be more in keeping with inadequate fluid replacement.

The treatment of oliguria depends on the cause. Pre-renal hypovolaemia is treated by fluid replacement, while poor output secondary to pump failure requires diuretic therapy and perhaps medications (e.g. inotropes, antiarrhythmics) to improve cardiac function. To give a hypovolaemic patient a diuretic in an attempt to improve urine output may be counterproductive and detrimental.

In acute renal failure the oliguria will not respond to a fluid challenge. Management demands accurate matching of input to output, monitoring of electrolytes and even dialysis.

In summary, most cases of postoperative oliguria are secondary to hypovolaemia, and should be considered due to hypovolaemia until proven otherwise.

Hyponatraemia

Any reduction in the sodium concentration in the ECF may be absolute or secondary to water retention. Loss of the major cation from the ECF leads to a shift of water into the ICF. Any clinical manifestation will reflect the expansion of the ICF (e.g. confusion, cramps, and coma secondary to cerebral oedema) or the contraction of the ECF in absolute hyponatraemia (e.g. postural hypotension, loss of skin turgor).

Hyponatraemia due to a total body deficiency of sodium ions is an unusual scenario in the postoperative surgical patient. Any hyponatraemia that occurs tends to be due to dilution and is caused by the administration of an excessive amount of water. While this is a fairly frequent biochemical finding, it rarely leads to any clinically significant problem.

Any hyponatraemia secondary to dilution may also occur with inappropriate ADH secretion. The trauma of major surgery will produce an increase in ADH secretion and intravenous fluid must be administered judiciously in the immediate postoperative period. A safe rule of thumb is to restrict the patient to 2 L per day of maintenance fluid until a diuresis has been established. Hyponatraemia can usually be corrected by the administration of the appropriate requirements of isotonic saline. If the patient has a severe hyponatraemia and associated mental changes, an infusion of hypertonic sodium solution may be required.

Hypernatraemia

Hypernatraemia in the postoperative patient is a less common problem than hyponatraemia. Any hypernatraemia is usually relative rather than absolute and occurs secondary to diminished water intake. Patients with severe burns or high fever may also develop hypernatraemia. An increase in the plasma sodium concentration will lead to a loss of ECF volume and relative intracellular desiccation. The first clinical manifestation is thirst and if the hypernatraemia is allowed to persist, neurological problems (e.g. confusion, convulsions, coma) may ensue. Treatment is by administration of water by mouth or intravenous 5% dextrose.

Hyperkalaemia

With normal renal function, severe and life-threatening hyperkalaemia is rare. High concentrations of potassium in the ECF can be associated

with cardiac rhythm disturbances and asystole. Hyperkalaemia may occur in severe trauma, sepsis and acidosis. Emergency treatment of arrhythmia-inducing hyperkalaemia consists of rapid infusion of a 1 L solution of 10% glucose with 25 units of soluble insulin. The insulin will help drive potassium into the cells and the glucose will help counteract the hypoglycaemic effect of the insulin. At the same time 20 mmol of calcium gluconate can be given to help stabilise cardiac membranes. If an arrhythmia has already developed, the calcium gluconate should be given before the dextrose and insulin. Sodium bicarbonate (20–50 mmol) can be given if the patient is acidotic. If the level of potassium is not too high, an ion-exchange resin (resonium) can be given. These resins can be administered by enema and they exchange potassium for calcium or sodium. Alternatively, the patient may be dialysed (peritoneal or haemodialysis). In the management of hyperkalaemia it is obviously as important to treat the cause as it is to treat the effect.

Hypokalaemia

Low levels of potassium in postoperative patients are common but hypokalaemia is rarely so severe as to produce muscle weakness, ileus or arrhythmias. Patients with large and continuous fluid loss from the gastrointestinal tract are prone to develop hypokalaemia. If potassium supplements are required they may be given either orally or intravenously. If by the latter route, the rate of infusion should not exceed 10 mmol/h. Faster rates may precipitate arrhythmias and should only be undertaken on a unit where the patient can be monitored for any ECG changes.

Haemorrhage

The management of haemorrhage in the postoperative period may be approached in several ways. In broad terms, bleeding may be classified as either localised or generalised. If the former, it may be classified as follows:

- primary (bleeding which occurs during the operation)
- reactionary (bleeding within the first 24 hours of the operation)
- secondary (bleeding occurring at 7–10 days after the operation).

If localised, the bleeding is usually related to the operative site and/or the wound. Occasionally, the bleeding may be at a point removed from both these areas, for example gastrointestinal haemorrhage from a stress-related gastric erosion. Bleeding from the wound site is usually indicative of a mechanical problem or local sepsis. Generalised bleeding may reflect a coagulation disorder and may be manifest by the oozing of fresh and unclotted blood from wound edges and with bleeding from sites of cannula insertion.

Most cases of reactionary (and primary) haemorrhage are from a poorly ligated vessel or one that has been missed, and are not secondary to any coagulation disorder. The bleeding point may go unnoticed during the operation if there is any hypotension, and makes itself known only when the patient's circulating volume and blood pressure have been restored to normal. The bleeding in secondary haemorrhage is due to erosion of a vessel from spreading infection. Secondary haemorrhage is most often seen when a heavily contaminated wound is closed primarily, and can usually be prevented by adopting the principle of delayed wound closure.

Postoperative haemorrhage can also be classified according to its clinical presentation. The most common forms are wound bleeding, concealed intraperitoneal bleeding, gastrointestinal haemorrhage and the diffused ooze of disordered haemostasis.

The approach to management will depend on the overall condition of the patient and the assessment of the type of bleed. A stable patient with a localised blood-soaked dressing will be managed differently from a hypotensive patient with 2 L of fresh blood in a chest drain, who in turn will be managed differently from a patient with a platelet count of 15×10^9/L and fresh blood oozing from all raw areas.

In the first case the tendency might be to apply another dressing in an attempt to achieve control by pressure. A more positive approach is to remove the dressing and inspect the wound. In most instances, a single bleeding point can be identified and controlled. In the next case, the patient has a major bleed and this is probably from a bleeding vessel within the operative site. Return to the operating room and formal re-exploration must be seriously considered. In the third case, the prime problem is an anticoagulation defect requiring urgent correction.

The diagnosis of postoperative haemorrhage is a clinical one, based on knowledge of the surgical procedure, the postoperative progress and an assessment of the patient's vital signs. The blood loss may not always be visible and could be concealed at the operative site or within the digestive tract. The treatment of postoperative haemorrhage depends on the severity of the bleed and the underlying cause. Hypovolaemia and circulatory failure will demand urgent fluid replacement and consideration of the likely cause and site of bleeding. Careful consideration must be given to control of localised haemorrhage and whether re-operation is warranted.

Vomiting

The causes of vomiting after surgery are many, and can be best determined by establishing the relationship between onset of vomiting and the time of the operation. The two most common causes of postoperative vomiting are drug-induced and gut atony.

Vomiting that occurs in the immediate postoperative period is usually drug related. If it is due to the effects of anaesthesia, vomiting will usually settle within 24 hours. Current anaesthetic techniques and modern anti-emetics have rendered nausea and vomiting a relatively minor postoperative problem for most patients.

Vomiting that occurs several days after operation may still be drug related, but in this instance is usually due to an opiate rather than an anaesthetic agent. Vomiting may be secondary to gut stasis, and this atony is usually self-limiting. If prolonged, a prokinetic agent can be effective.

If vomiting starts 7 days or so after abdominal surgery, a mechanical cause for the problem should be considered.

Further reading

Abeles A, Kwasnicki RM, Darzi A. Enhanced recovery after surgery: current research insights and future directions. *World J Gastrointest Surg* 2017;9:37–45.

Marcantonio ER. Delirium in hospitalized older adults. *N Engl J Med* 2017;377:1456–66.

MCQs

Select the single correct answer to each question. The correct answers can be found in the Answers section at the end of the book.

1 A previously well 56-year-old businessman is admitted with a perforated peptic ulcer and undergoes surgery and repair of the perforation. He is making a satisfactory recovery but 3 days after the operation becomes aggressive, shouting and demands to be let home. He is still requiring intravenous fluids for slow return of gut function. Which one of the following is the most likely explanation for his behaviour?
- **a** anxiety over work commitments
- **b** opiate toxicity
- **c** pneumonia
- **d** alcohol withdrawal
- **e** intravenous fluid overload

2 A 21-year-old man undergoes a laparoscopic appendicectomy for appendicitis. At operation, the dissection is difficult and the appendix is found to be perforated and 100 mL of purulent fluid aspirated from the abdominal cavity, after which a saline lavage is performed. The patient cannot void postoperatively and requires a urinary catheter for 24 hours. He is kept on intravenous antibiotics for 3 days and then discharged home on a 5-day course of oral antibiotics. Three days after discharge he goes to see his family doctor complaining of persistent diarrhoea. Which one of the following is the most likely diagnosis?
- **a** resolving paralytic ileus
- **b** prostatitis
- **c** *Clostridium difficile* enteritis
- **d** leakage from the appendix stump
- **e** urinary tract infection

3 A 56-year-old man undergoes a laparoscopic cholecystectomy 2 days after being admitted with acute cholecystitis. At operation some acute inflammatory changes are found around the gallbladder, which makes the procedure more difficult than expected. A drain is placed in the gallbladder bed at the end of the operation. The following day the patient does not look well and is complaining of right upper quadrant pain. He has required regular morphine overnight to control his pain. His blood pressure is 120/70 mmHg, heart rate 110 beats/min and temperature is 38.2°C. He has passed 100 mL of urine since the operation. On pulmonary auscultation there are bibasal crackles and there is guarding in the right upper quadrant. Nothing has come out of the drain. Which one of the following would be the most likely explanation for his current problem?
- **a** aspiration pneumonia
- **b** acute retention of urine
- **c** bile leak
- **d** duodenal perforation
- **e** pulmonary embolism

4 A 68-year-old man undergoes a semi-elective laparoscopic cholecystectomy for acute cholecystitis. The procedure is uncomplicated. Twelve hours later his blood pressure is 114/72 mmHg and his urine output since operation has been 90 mL. He has intravenous isotonic saline running at 80 mL/h. Which one of the following is the most appropriate next step in management?
- **a** continue current management
- **b** intravenous frusemide
- **c** infusion of dopamine
- **d** infusion of noradrenaline
- **e** 1 L isotonic saline over 4 hours

5 Surgical techniques

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Introduction

This chapter reviews techniques used in surgical practice and invasive procedures.

The operating room (see also Chapter 12)

The operating room is a dedicated area for surgical procedures and must be conducive to performing surgery to the highest standards of safety for patients and staff. The principal purpose of such a dedicated area is to reduce the risk of infection of patients. The operating room must be large enough for complex procedures to be undertaken, for storage of appropriate equipment, movement of staff, as well as the maintenance of a sterile area around the operative field. By changing the operating room air 20–25 times each hour at positive pressure relative to outside the room, low concentrations of airborne bacteria and particulate matter can be maintained. The number of people in the room and their movement should be minimised. Ambience within the operating theatre should be calm and professional, and procedures should be performed in a manner that is respectful to the patient and to all the staff involved. The air temperature should be such that inadvertent patient hypothermia does not occur. The operative field must be well illuminated; surgeons sometimes wear a head light for procedures in body cavities that cannot be illuminated easily by standard operating room lights.

The surgeon's assistant has the important role of assisting and supporting the surgeon in the smooth conduct of operations. It is important to concentrate on the task at hand, to carry out the surgeon's instructions with speed and accuracy, to have a sense of anticipation, and to notify the surgeon of any potential problem during the operation.

A face mask, which covers the nose and mouth, prevents droplet spread of secretions and bacteria, is worn for any invasive procedure and is changed after each case. Eye protection in the form of plain plastic glasses or a visor attached to the face mask must be worn to protect against droplet spray of infected body fluids. Gloves are worn if there is a possibility of coming into contact with patients' body fluids. Clean theatre attire, dedicated theatre shoes and a disposable hair cover are worn while in the operating suite.

Aseptic techniques

Joseph Lister, in 1865, first demonstrated the reduction in surgical site infections with disinfection techniques. Aseptic techniques are clinical practices that aim to prevent infection occurring in the patient as a result of the surgical procedure by:

- preparation and cleaning the patient's skin with antiseptic fluid before it is incised or punctured
- use of sterilised instruments, equipment or surgical materials which might come into contact with the operative field and surgical wound.

Personnel involved directly in the operative procedure (surgeon, surgical assistant and 'scrub' nurse) wash their hands and forearms with antiseptic soap for 5 minutes before the first operation of the day and for 3 minutes before each subsequent case to reduce skin flora. More recently, alcohol-based hand rubs have been developed that require application for 1 minute. Hands are dried with sterile towels, and a moisture-impermeable sterile gown is worn. One or two pairs of sterile gloves prevent transfer of bacteria from the surgeon's hands to the patient and also protect the surgeon from infected blood and body fluids from the patient.

After induction of anaesthesia, hair is removed from the operative site by shaving with a razor

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or electric clippers. The skin is cleansed with an antiseptic solution starting at the site where the incision will be made and working away from the area, so that approximately 10–20 cm of skin around the incision site is prepared. The patient is covered with sterile linen or impermeable drapes, leaving exposed only the cleansed area around the incision site, which may be covered by a sterile adhesive plastic drape.

Surgical antiseptics

The commonest source of bacterial contamination in the operating room is from the patient. Therefore, topical antiseptic agents are used to reduce the number of skin organisms prior to any skin incision or puncture, and include the following.

- Aqueous chlorhexidine (0.5%) is used to disinfect mucous membranes and parts of the body adjacent to structures which would be adversely affected by more stringent antiseptics (e.g. the skin around the eyes). Aqueous chlorhexidine is bactericidal and has low tissue toxicity.
- Cetrimide (2%) is bactericidal.
- Iodine-based antiseptics, such as povidone iodine 10% (Betadine) and alcoholic iodine solution, destroy a wide range of bacteria, especially staphylococci, by iodisation of microbial proteins.
- Alcohol-based (70%) antiseptics kill bacteria by evaporation.
- Chlorhexidine 2% can also be used in combination with 70% alcohol.

Sterility

Anything that comes into contact with the surgical wound must be sterile. The method of sterilisation depends on the item being sterilised (Box 5.1).

Universal precautions

The risk of transmission of infectious agents from patients to staff (and vice versa) is reduced by practising universal precautions. Thus, it is assumed that all patients harbour potentially dangerous pathogens (e.g. hepatitis C, HIV) no matter how innocuous they appear, because carrier status cannot definitely be excluded without repeated, expensive and time-consuming investigations. The principle of universal precautions is to establish a physical barrier between the patient and the carer to prevent direct contact with any potentially infected body fluid or tissue in either direction (Box 5.2).

Hazards

In addition to infection, there are many potential sources of hazard in the operating environment.

Box 5.1 Methods of sterilisation

Autoclave
Uses superheated steam at high pressure to reach a temperature of 121°C. Sterilisation is achieved when droplets of superheated water evaporate immediately upon reduction of pressure, thereby destroying microorganisms and leaving instruments dry. Most surgical instruments and linen drapes are sterilised by autoclaving.

Dry heat
Items which tolerate heat but not moisture can be sterilised by dry heat, but it is less efficient and takes longer than autoclaving.

Ethylene oxide gas
Takes several hours and is used for heat-sensitive items such as endoscopes, electrical and optical equipment and some plastics.

Glutaraldehyde
A 2% solution is used to sterilise equipment that can tolerate moisture but not heat, such as urological catheters, plastics and rubber.

Ionising radiation
Uses gamma rays and is particularly useful for sterilising single-use disposables such as plastics, dressings, scalpel blades and synthetic conduits.

Hazards, other than those intrinsic to the anaesthetic and surgical operation, are organisational or related to operating room equipment or the transfer and positioning of the patient on the operating table.

Organisational hazards

Organisational hazards should be entirely preventable. A full history and examination of the patient must be made before surgery, including the past medical history, drug history and allergies, so that elementary errors are not made (e.g. unwittingly operating on a patient with a pacemaker or who is anticoagulated, or prescribing a drug to which the patient is allergic). Before surgery commences, the reason for and nature of the operation, together with its potential common and serious complications, and the reasonable expectations from the procedure, are discussed with the patient and family who are free to ask any questions. A consent or request for treatment form, which states the nature of the operation and the side on which the operation is to be performed if the operation is a unilateral procedure, is signed by the patient and the surgeon or deputy.

Once in the operating suite, a check is made to confirm that all the necessary safeguards have been

Box 5.2 Universal precautions

Barrier protection
Appropriate protective barriers are used during invasive procedures and handling contaminated materials: gloves, face mask, eye shield, impermeable gown, shoe covers, hair cover.

Minimising potential exposure
Decrease the risk of spreading potentially infected body fluids by avoiding spillages, careful disposal of materials and equipment contaminated by body fluids, having only essential personnel present during invasive procedures, excluding personnel with open wounds or abrasions, using impermeable dressings to cover wounds, and using closed rather than open drains.

Elimination of needlestick injuries
Do not handle uncapped needles, never re-sheath used needles, and never remove a used needle from a syringe. Use needles as little as possible. Immediately dispose of used needles in a designated 'sharps' disposal container which has a one-way opening.

Elimination of other penetrating injuries
Sharp objects (e.g. scalpels, needles) are transferred between operating personnel in a 'sharps dish', not from hand to hand. Hand-held needles are not used. Blunt suture needles are used where possible. Sharp instruments are not placed on the operative field or anywhere on the patient. Alert personnel to the presence of any sharp object in the operative field.

performed for the patient. The World Health Organization surgical safety checklist or variations are now mandatory in most Australian hospitals. The checklist can be used at three stages: before the induction of anaesthesia ('sign in'), before the incision of the skin ('time out') and before the patient leaves the theatre ('sign out'). The varied processes in each hospital include checklists that ensure the correct patient is having the correct procedure, the correct site or side of the operation has been marked, that relevant equipment is available and that the relevant imaging and clinical notes are available. At the start of each theatre list the 'time out' for the first patients also includes an introduction of all present in the theatre. Discussion of all anticipated surgical and anaesthetic concerns are also discussed along with plans for prevention of deep venous thrombosis during and after theatre.

Equipment

Diathermy is used universally in surgical practice. High-frequency alternating current passes from a small point of contact (active electrode) through the patient to a large contact site (indifferent electrode or 'diathermy plate') to produce localised heat which coagulates protein. Diathermy produces (i) coagulation (haemostasis with a small amount of adjacent tissue damage), (ii) cutting (tissue cutting with minimal tissue damage), or (iii) fulguration (haemostasis with considerable tissue necrosis). Potential dangers include electrocution, inadvertent burn to the patient at a remote site and to the surgeon, fire associated with pooled alcohol-based antiseptics, explosion of flammable anaesthetic gases, and interference with the function of cardiac pacemakers.

A variety of lasers with different wavelengths and effects on cells and tissues are used in surgical practice for highly accurate tissue destruction (e.g. mucosal surgery, CNS tumours, dermatological lesions, aerodigestive tumours), coagulating blood vessels (e.g. gastrointestinal tract, retinal photocoagulation), and for photoactivation of intra-tumour haematoporphyrin for malignant tumour destruction (photodynamic therapy). Hazards include eye damage, explosion of anaesthetic gases, and shattering and destruction of other equipment.

Limb tourniquets are used to provide a bloodless field in which to operate. The limb is elevated and exsanguinated by a rubber bandage or compressive sleeve, and the proximal tourniquet inflated to 50 mmHg (upper limb) or 100 mmHg (lower limb) above systolic blood pressure. A tourniquet should not be kept inflated for more than 60–90 minutes. A record should be kept during the operation of how long the tourniquet has been inflated. Tourniquet complications include arterial thrombosis, distal ischaemia, nerve compression and skin traction.

Positioning of the patient

The patient is positioned on the operating table in such a way that the procedure is facilitated and the airway can be protected. Pressure points are padded, and limbs are positioned so that peripheral nerves, major blood vessels, joints and ligaments are not stretched or compressed. The anaesthetised patient must be in a stable position on the operating table and may need to be strapped in position with broad adhesive tape. There must be no contact between the skin and any metallic surface because of the risk of diathermy burn and pressure necrosis. Sections of the operating table can be angled so that the patient is optimally positioned for the particular procedure (e.g. flexed while lying supine or on one side, head-down, head-up).

Endoscopy

Endoscopy is performed by inserting a fibre-optic telescope containing a light source and instrument channels into the gastrointestinal, respiratory and urinary tracts. The operator undertakes the procedure by manipulating the endoscope while viewing a video screen but occasionally the eyepiece of the instrument may be used.

Gastrointestinal endoscopy

Endoscopy of the gastrointestinal tract allows the endoscopist to view the lumen of the oesophagus, stomach and proximal half of the duodenum (oesophagogastroduodenoscopy or upper gastrointestinal endoscopy or gastroscopy), colon (colonoscopy), rectum and distal sigmoid colon (sigmoidoscopy), and distal rectum and anal canal (proctoscopy). It is usually performed under sedation. Intestinal endoscopy can also be performed at laparotomy (enteroscopy) by making a small incision in the intestine and passing the endoscope along the intestinal lumen. Procedures such as dilatation of strictures, biospy and diathermy ablation of polyps, injection of adrenaline around bleeding gastric and duodenal ulcers, cholangiopancreatography, removal of common bile duct calculi, biliary dilatation or stenting, injection of haemorrhoids and tumour phototherapy can be performed using fibre-optic endoscopes.

Bronchoscopy

The upper airway, trachea and proximal bronchi can be inspected by bronchoscopy, which may be performed under local or general anaesthesia. Bronchoscopy is used for diagnosis (e.g. inspection and biopsy of lung tumours) or therapy (e.g. removal of foreign bodies, aspiration of secretions). Anaesthetists occasionally use the fibre-optic bronchoscope to facilitate difficult endotracheal intubation.

Urological endoscopy

The urethra (urethroscopy), bladder (cystoscopy) and ureters (ureteroscopy) can be inspected for diagnostic purposes. Extensive therapeutic procedures (e.g. resection of the prostate, diathermy and excision of bladder tumours, extraction of calculi) can be performed safely with far less morbidity than the equivalent open procedures.

Endoscopic surgery

There are two forms of endoscopic surgery that both involve the insertion of a microchip video camera with a light source into the lumen or through the wall of the aerodigestive tract into a body cavity. The latter is performed through an incision in the wall of the gastrointestinal tract with placement of specially crafted surgical instruments into a body cavity. For both techniques the surgeon undertakes the procedure by manipulating the instruments while viewing a video screen. Some forms of endoscopic surgery utilise endoscopic ultrasound for guidance of incisions or placement of internal drains. Examples of endoscopic surgical procedures include resections of larger gastrointestinal tumours (endoscopic mucosal resection), drainage of infected pancreatic collections into the stomach (endoscopic cystgastrostomy), oesophageal myotomy (per oral endoscopic myotomy or POEM), endoscopic sinus surgery and natural orifice transluminal endoscopic surgery (NOTES).

The advantages of endoscopic or 'closed' surgery are reduced postoperative pain and analgesic requirements, earlier discharge from hospital and earlier return to normal function. However, many surgical procedures either cannot be undertaken endoscopically because of their very nature, or cannot be completed endoscopically because of difficulty or patient safety, in which case the operation is converted to an 'open' procedure. Some procedures use endoscopic techniques to assist with the procedure and an incision is made to either complete the operation or deliver the resected specimen. The range of endoscopically performed operations in many surgical specialties has increased enormously over the last 20 years.

Open surgery

Open surgery is the traditional or conventional method of operating. In general terms, open surgery involves making a surgical wound, dissecting tissues to gain access to and mobilise the structure or organ of interest, completing the therapeutic procedure, ensuring haemostasis is complete, and then closing the wound with sutures. Open surgery is performed more with the hands and direct touch than endoscopic procedures, and fingers may be used for 'blunt' dissection. The surgical wound accounts for much of the morbidity of open

surgery, particularly the cutting of muscle. The range of open operations is extremely wide, as evidenced by the procedures described throughout this book.

Minimally invasive surgery

Minimally invasive surgery avoids the larger incisions of open surgery to minimise morbidity. Different types of microchip video cameras can be used to visualise the required cavity or space within the body. The cameras vary in size and their complement of different angled lenses, which are either fixed or manoeuvrable. Magnification of the image often provides a superior view to that obtained at open surgery.

Abdominal surgery

Laparoscopy refers to the technique of insufflating the peritoneal cavity with gas, inserting a camera through most commonly a 10–15 mm subumbilical incision and inspecting the abdominal contents. Usually additional ports are inserted through 5–10 mm incisions in the abdominal wall and instruments (e.g. scissors, grasping devices, retractors, staplers, needle holders, energy devices) are introduced and manipulated by the surgeon to perform the operation. Procedures such as cholecystectomy, gastric fundoplication, hiatus hernia repair, division of adhesions, appendicectomy, splenectomy, adrenalectomy, nephrectomy, oophorectomy, tubal ligation, bariatric surgery and hernia repair can be undertaken laparoscopically with less morbidity than if undertaken as an open or conventional operation. Endoscopic surgery has allowed some procedures to be undertaken as day cases, whereas the same procedure performed as an open operation would require an inpatient stay of several days (e.g. cholecystectomy, hernia repair).

Thoracic surgery

Thorascopy involves inserting a camera with a light source and instruments into the thoracic cavity. The technique is used diagnostically and therapeutically for procedures such as drainage of the thoracic cavity (haemothorax, pleural effusion and empyema), lung biopsy, pleurodesis and excision of lung bullae. The mediastinum can be inspected and mediastinal lymph nodes can be biopsied by mediastinoscopy, which may prevent the need for an exploratory thoracotomy.

Orthopaedic surgery

Large joints (e.g. knee, hip, ankle, shoulder, wrist) can be inspected by arthroscopy. Therapeutic procedures include removal of bone chips, cartilage excision and removal, and ligament repair. Arthroscopic surgery has been enormously beneficial for orthopaedic patients and has allowed far more rapid return to function.

Robotic surgery

Robotic surgery is a form of minimally invasive surgery where the surgeon is positioned remote to the patient but usually within the operating theatre. A robotic system operated by the surgeon is used to control the camera as well as the instruments that are placed through multiple ports. A surgical assistant still makes the port site incisions and a theatre nurse is scrubbed to change to robotic instruments when required. The robot is particularly useful for work in cramped narrow spaces where robotic suturing is far superior to laparoscopic suturing techniques in such instances. The commonest example of robotic surgery is radical prostatectomy with the robotic reconstruction of the bladder and urethra in a narrow male pelvis. Other common examples include partial nephrectomy and thoracic surgery. However, nearly all abdominal, thoracic and some upper aerodigestive and cardiac operations have been described using robotic techniques. Recently, transaxillary breast, thyroid and parathyroid surgery have also been described.

Surgical methods

Surgical operations are performed by well worked out, standardised steps which progress in logical sequence. An operative plan is determined by the surgeon for every operation.

Surgical instruments

There are literally thousands of surgical instruments, some simple and others extremely complex, but each designed for a specific function. The surgical incision is made with a scalpel, which consists of a reusable handle and a disposable blade. Scissors are used to cut other tissues and sutures, and for blunt dissection with the blades closed. Diathermy is used for haemostasis and to cut through tissue layers beneath the skin. Tissues are held with dissecting or tissue-grasping forceps rather than the fingers. Hand-held forceps either

have teeth for better grasping ability or are non-toothed for handling delicate tissues. Needle holders are used to hold needles for suturing and eliminate the need for hand-held needles, and are therefore safer. They have a ratchet so that the needle can be contained securely in the holder while not in the surgeon's hand. Retractors allow the surgeon to operate in an adequately exposed field. Self-retaining retractors keep the wound edges apart without the aid of an assistant. Retractors held by the assistant provide tissue retraction in awkward parts of the wound and in situations where retraction of specific tissues is required so that intricate parts of the operation can be performed. A sucker is used to aspirate blood and body fluids from the operative field and to remove smoke created by the diathermy. There are many instruments designed specifically for surgical specialties and procedures.

Incisions

Surgical incisions are made so that:

- the operation can be undertaken with adequate exposure of the area or structure of interest
- the procedure can be performed and completed safely and expeditiously
- the wound heals satisfactorily with a cosmetically acceptable scar.

Thus, incisions are to be of adequate but not excessive length and, if possible, placed in skin creases, particularly when operating on exposed areas of the body such as the face, neck and breast. Parallel skin incisions ('tram tracking') and V- or T-shaped incisions are avoided because of ischaemia of intervening tissue and pointed flaps.

Tissue dissection

Ideally, surgical dissection should be performed along tissue planes, which tend to be relatively avascular. The aim is to isolate (mobilise) the structure(s) of interest from surrounding connective tissue and other structures with the least amount of trauma and bleeding. Tissues should be handled with great care and respect and as little as possible. Dissection is undertaken by using a scalpel or scissor (sharp dissection), a finger, closed scissor, gauze pledget or scalpel handle (blunt dissection), or the diathermy. Gentle counter-traction on tissues by the assistant facilitates the dissection.

Haemostasis

Surgical haemostasis refers to stopping bleeding which occurs with transection of blood vessels. The majority of cases of operative and postoperative bleeding are due to inadequate surgical haemostasis rather than disorders of clotting and coagulation. Haemostasis is essential in order to prevent blood loss during surgery and haematoma formation postoperatively. Methods of surgical haemostasis include the following.

- Application of a haemostatic clamp to a blood vessel and then ligation with a surgical ligature.
- Suture ligation of a vessel: under-running a bleeding vessel with a figure-of-eight suture which is tied firmly.
- Application around a blood vessel of small metal U-shaped clips that are then squeezed closed.
- Diathermy coagulation.
- Localised pressure for several minutes to allow coagulation to occur naturally.
- Application of surgical materials (e.g. oxidised cellulose, Surgicel) which promote coagulation.
- Application of topical agents to promote vasoconstriction (e.g. adrenaline) or coagulation (e.g. thrombin).
- Packing of a bleeding cavity with gauze packs as a temporary measure until definitive haemostasis can be achieved.

Sutures and wound closure

Sutures have been used to close surgical wounds for thousands of years, and initially were made from human or animal hair, animal sinews and plant material. Today, a wide variety of material is available for suturing and ligating tissues (Box 5.3).

Sutures are selected for use according to the required function. For example, arteries are sutured together with non-absorbable polypropylene or polytetrafluoroethylene (PTFE) sutures, which are non-thrombogenic, cause virtually no tissue reaction and maintain their intrinsic strength indefinitely so that the anastomotic scar (which is under constant arterial pressure) does not stretch and become aneurysmal. Skin wounds, for example, are sutured with either non-absorbable sutures, which are removed after several days, or absorbable sutures hidden within the skin (subcuticular sutures) and which are not removed surgically but are absorbed after several weeks.

Sutures are available in diameters ranging from 0.02 to 0.50 mm. The minimum calibre of suture should be used, compatible with its function. Non-absorbable sutures are avoided for suturing the luminal aspects of the gastrointestinal and urinary tracts because substances within the contained fluids (e.g. bile, urine) may precipitate on persisting sutures and produce calculi.

Box 5.3 Sutures

Substance	Description*	Duration†	Trade name	Uses
Plain catgut	Nat, Multi, Ab	1–2 weeks	—	Subcutaneous fat
Chromic catgut	Nat, Multi, Ab	2–3 weeks	—	Subcutaneous fat, gastrointestinal and urinary tract anastomoses
Silk and linen	Nat, Multi, Non	Prolonged	—	Skin and cardiac sutures, ligatures
Stainless steel	Nat, Mono, Non	Prolonged	—	Sternum, skin and gastrointestinal staples, orthopaedic wire
Polyglycolic acid	Syn, Multi, Ab	3–4 weeks	Dexon	Gastrointestinal and urinary tracts, muscle, fascia, subcutaneous fat
Polyglactin	Syn, Multi, Ab	4–6 weeks	Vicryl	Gastrointestinal and urinary tracts, muscle, fascia, subcutaneous fat
Polypropylene	Syn, Mono, Non	Indefinite	Prolene	Ophthalmology, vascular sutures, abdominal closure, neurosurgery, fascia, skin
Polyamide	Syn, Mono, Non	Years	Nylon	Abdominal and skin closure, hernia repair
Polytetrafluoroethylene (PTFE)	Syn, Mono, Non	Indefinite	Gore-Tex	Vascular anastomoses, hernia repair

* Ab, absorbable; Mono, monofilament; Multi, multifilament; Nat, natural; Non, non-absorbable; Syn, synthetic.

† Time during which tensile strength is maintained.

The requirements of suture material are as follows.

- Tensile strength: the suture must be strong enough to hold tissues in apposition for as long as required.
- Durability: the suture must remain until either healing is advanced or indefinitely if the healed tissue is under constant pressure.
- Reactivity: tissue reaction (i.e. an inflammatory response) allows absorbable sutures to be removed by phagocytosis but results in chronic inflammation if non-absorbable sutures remain *in situ*.
- Handling characteristics: sutures must be easy to grasp, handle and tie.
- Knot security: sutures must be able to be tied effectively so that knots do not come undone or slip.

Sutures are classified as follows.

- Absorbable or non-absorbable: the rate of absorption of absorbable sutures depends on their composition and their thickness. Disappearance of the suture occurs through inflammatory reaction, hydrolysis or enzymatic degradation.
- Synthetic or natural material: sutures of natural (animal) origin are being phased out of surgical practice because of the very minimal risk of disease transmission. A wide variety of synthetic suture materials are available.
- Monofilament or multifilament: monofilament sutures pass through tissues easily, are generally less reactive, and are more difficult to handle and knot securely. Multifilament sutures are braided or twisted thread, and are easier to handle and knot, but are more likely to harbour microorganisms within the suture.

Recently, cyanoacrylate adhesives ('superglue') have been used to seal small leaks in blood vessels and vascular suture lines, and for closure of small superficial skin wounds. The adhesive polymerises and hardens rapidly on contact with tissues.

Surgical knots

Knots are tied to ensure that ligatures and sutures remain in place and do not slip or unravel. The ability to tie a secure knot is a fundamental technique in surgery, and patients' lives literally depend on knot security (e.g. the knot in a ligature used to tie off an artery). Knot security depends on friction between the throws of the ligature material, the number of throws used to tie the knot, the strength of the ligature material and the tightness of the knot. Usually, multiple throws are used to secure the knot (e.g. two reef knots, one on the other).

Suturing

The technique of suturing depends on the tissue and wound being sutured. Sutures may be either continuous (e.g. subcuticular skin sutures, abdominal closure, vascular anastomosis) or interrupted (e.g. skin sutures, sternal wires). The function of sutures is to hold the adjacent edges of sutured tissues in apposition and to immobilise them in that position so that wound healing (i.e. neovascularisation, connective tissue ingrowth and collagen formation) is facilitated. It is essential that sutures are not tied so tightly that the tissues encompassed by them become ischaemic. Skin sutures may be supported by adhesive paper tapes.

Retention sutures (incorrectly referred to as *tension sutures*) are used to close abdominal incisions that are thought to be at increased risk of dehiscence, and are inserted to encompass a large amount of fascial tissue and are placed 3–5 cm apart. Retention sutures have now been replaced by techniques using lateral incisions of the abdominal wall, mesh reconstruction and negative pressure wound devices.

Within the last two decades, stainless steel staples have been used to close skin wounds and to perform gastrointestinal anastomoses. Staples are quicker to use than sutures, but are relatively expensive and produce a worse cosmetic result for skin closure than subcuticular absorbable sutures.

Suture removal

Sutures are removed as early as possible to minimise the risk of infection and scarring, so long as tissue healing is sufficiently advanced that the wound will not open when the sutures are removed. Sutures are therefore removed at different times, depending on tissue and general patient factors (Box 5.4). For example, sutures are left *in situ* for a longer time in patients who are immunosuppressed, malnourished, jaundiced or undergoing chemotherapy; in those who have renal failure; and in tissues judged to be relatively ischaemic, subject to increased stress and tension, and which have been irradiated.

Box 5.4 Timing of suture removal at various sites

Face	3–5 days
Neck (skin crease)	5–7 days
Scalp	7–10 days
Abdomen	10 days
Extremity	10–14 days
Amputation stump	21 days

Surgical drains

Drains are used widely in surgical practice to:

- Remove blood or serous fluid, which would otherwise accumulate in the operative area (e.g. wound drain)
- Provide a track or line of minimal resistance so that potentially harmful fluids can drain away from a particular site (e.g. drain placed into an intra-abdominal abscess cavity).

Several different methods of drainage may be used depending on the required function.

- Open drainage: a drain tube or strip of soft flexible latex rubber is placed so secretions or pus can drain along the track of the drain into gauze or other dressing covering the external end of the drain tube (e.g. drain placed in an abscess cavity, drain placed prophylactically near a bowel anastomosis in case of subsequent anastomotic leak).
- Closed drainage: a tube is placed into an area or viscus to drain fluid contents into a collecting bag so that there is no contamination of the drained area from outside the system (e.g. chest drain, urinary catheter, cholecystostomy drain).
- Closed suction drain: the drain tube is connected to a bottle at negative atmospheric pressure so that fluid is sucked out of the area (e.g. wound drain, drain under skin flaps).

It is important to note both the amount and the type of fluid that drains. Large volumes of fluid drainage may need to be replaced as intravenous fluids (e.g. duodenal fistula fluid). Depending on the particular situation, it may be necessary to culture drain fluid or send it for estimation of haemoglobin, creatinine, electrolytes, amylase or protein. A radiological contrast study may be performed along the drain tube, for example to estimate the size of a cavity being drained.

Drain tubes are removed when they are no longer required, for example when there is minimal fluid being drained, or when a cavity being drained has contracted and is small. Drains are removed simply by cutting the suture which anchors them to the skin and withdrawing the tube from the patient.

Venepuncture

Venepuncture involves removing blood from a superficial vein, usually in the antecubital fossa or dorsum of the hand, by inserting a needle attached to a syringe or collection tube at negative pressure (Vacutainer system). A venous tourniquet is applied around the arm, which is hung in a dependent

position; the patient vigorously opens and closes the hand, and the vein is gently patted to encourage venous dilatation. The skin is cleansed with antiseptic and the needle is inserted through the skin into the dilated vein at an angle of 30–45°. Once the required volume is aspirated, the tourniquet is released, the needle withdrawn, the puncture site immediately covered with a cotton wool swab, and light pressure applied for 1–2 minutes. The site is covered with an adhesive dressing. Complications include bruising, haematoma and, rarely, infection and damage to deeper structures. Inadvertent needlestick injury to the venepuncturist is avoided by careful technique.

Intravenous cannulation

Intravenous (i.v.) cannulation is used commonly for administration of fluids and drugs. Superficial veins on the forearms and dorsum of the hands are used for i.v. cannulation. Antecubital fossa veins are best avoided for cannulation because the elbow has to be kept extended to avoid kinking of the cannula. Leg veins may have to be used in the absence of useable upper limb veins. Cannulas have a soft outer Teflon sheath attached to a hub, and a central hollow needle attached to a small chamber.

A suitable vein is identified as for venepuncture. Local anaesthetic cream is applied to the skin overlying the vein or local anaesthetic (1% lidocaine without adrenaline) is injected intradermally next to the vein after cleansing the skin with antiseptic. The cannula (needle and sheath) is inserted through the skin into the vein at an angle of 10–30°. The small chamber fills with blood when the needle is in the lumen of the vein. The cannula is then advanced into the vein. The needle is removed from the sheath and a closed three-way tap or i.v. giving set is joined to the hub of the sheath. The cannula is secured to the skin with adhesive tape.

Intravenous infusion is painful when the infusate is cold or contains irritants (e.g. potassium, calcium, drugs of low or high pH), or if the cannula pierces the vein wall and fluid extravasates subcutaneously. Thrombophlebitis develops at the insertion site after about 3 days, and i.v. cannulas should be resited if infusions are required for longer periods.

Central venous catheterisation

Percutaneous catheterisation of a central vein is used for:

- Short- or long-term venous access when peripheral veins are unsuitable or cannot be used (e.g. prolonged fluid infusion, total parenteral nutrition, ultrafiltration, haemodialysis, plasma exchange, chemotherapy)
- Short-term monitoring of central venous pressure.

A central venous catheter (CVC) may be inserted into the internal or external jugular vein or the subclavian vein. Temporary CVCs are made of semi-rigid Teflon, are approximately 25 cm in length and, depending on their function, are between 1 and 4 mm in diameter and have one, two or three lumens. Long-term CVCs are made of barium-impregnated silastic and are quite flexible. They have a Dacron cuff bonded to the part of the catheter which lies subcutaneously and becomes incorporated by fibrous tissue after several weeks so that organisms cannot track along the catheter from the skin into the circulation.

Some long-term single-lumen CVCs are available with a small-volume chamber attached to the extravenous end of the catheter (Portacath, Infusaport). The catheter and chamber are implanted subcutaneously after the vein is catheterised and can be accessed for chemotherapy or blood sampling by inserting a needle into it through the skin.

CVC insertion is best performed in an operating theatre, under local or general anaesthesia, and with ultrasound localisation of the central vein. The patient is placed in a supine, slightly head-down position, and the surface anatomy of the vein is marked. Aseptic technique is essential. A hollow wide-bore needle is inserted into the vein, a guidewire is passed down the needle and the needle is removed. The guidewire position is checked radiologically. A plastic dilator is passed over the guidewire to dilate a track for the catheter and is then removed, and the CVC is passed over the guidewire which is removed after the CVC is in place. A chest X-ray is performed to check the final position of the CVC and also to ensure that a pneumothorax or haemothorax has not occurred due to inadvertent puncture of the pleura or lung. The catheter is sutured to the skin to prevent dislodgement and the exit site is dressed with an adhesive dressing.

Peripherally inserted central catheters are now placed under radiological guidance for the majority of patients who require long-term venous access for parenteral nutrition or antibiotics, or for those patients with difficult peripheral venous access.

Further reading

Cochran A, Braga R (eds) *Introduction to the Operating Room*. New York: McGraw-Hill, 2017.

Keen G, Farndon JR (eds) *Operative Surgery and Management*, 3rd edn. Oxford: Butterworth-Heinemann, 1994.

MCQs

Select the single correct answer to each question. The correct answers can be found in the Answers section at the end of the book.

1 Universal precautions:
- **a** protect operating theatre staff from electric shocks
- **b** prevent polluted air from entering the operating theatre
- **c** impose a physical barrier between patients and carers
- **d** are only to be used when operating on patients
- **e** protect only against bacterial pathogens

2 Laparoscopic surgery:
- **a** has a very limited role in general surgical practice
- **b** is inherently unsafe because the surgeon cannot touch the structures being operated on
- **c** is associated with greater postoperative pain and immobility
- **d** enables cholecystectomy to be performed as day-case surgery in some patients
- **e** can only be used for part of an operation

3 Sutures:
- **a** should be left in the skin for a minimum of 1 week
- **b** often need to be removed with local anaesthetic
- **c** must be tied tightly so that arterial inflow into tissues is not possible
- **d** made of Prolene will dissolve
- **e** of all types must eventually be removed

4 Surgical drains:
- **a** are removed when they are no longer necessary
- **b** should always be removed the day after surgery
- **c** are removed under general anaesthesia
- **d** are not necessary with modern surgical techniques
- **e** are required after the majority of general surgery procedures