SURGERY

Edited by James O Robinson and Ashley Brown

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WILLIAM HEINEMANN MEDICAL BOOKS LTD
London

First published 1980

ISBN 0 433 28104 9

Printed by Clark Constable Ltd,
Hopetoun Street, Edinburgh EH7 4NL

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Preface

This book covers the whole field of surgery in its simplest form. An attempt has been made to produce a modern textbook which is based on the standard teaching of general surgical principles, but which reduces the details of operative techniques. The book is designed to be readable and at the same time to provide an easy method of quick revision or reference to a particular subject or disease.

Surgery has advanced considerably during the last thirty years, due to the better understanding of certain diseases and their complications, and the introduction of new investigations, surgical techniques and drugs. Several conditions which were once common and formed the basis of much of the old teaching are now rarities, so that the student is faced with the inevitable problem of learning some of the old, sorting out what are the essentials of today, and selecting in the many controversial subjects a theory and practice which he himself can understand and apply. It is near the truth to say that just over one hundred years ago, a man could know all there was to know about science, whereas today no one could be expected to know everything about one particular branch of surgery. There are many subjects which still remain a mystery, but every year more is being unveiled, and the student is confronted with more and more to learn within a reducing space of time. As knowledge grows, books increase in size, but the student's capacity remains relatively stationary. This book has been written in an attempt to condense our present knowledge on surgery to the essential facts which should be familiar to any average student or medical practitioner and may be of use to graduates preparing for the final Fellowship examination. Much has inevitably been omitted and there are some who will criticize the omission of certain facts which they believe to be essential, but it is hoped that this book provides a broad spectrum of knowledge built on a firm basis of general principles to which each student, according to his capacity, may add.

It may therefore seem paradoxical that in certain sections, more detailed information is provided than is customary in a student's textbook, particularly in the chapter on Radiotherapy. This is so for two reasons. In the new orientation of surgery the treatment of neoplastic disease is increasingly important, and while radiotherapy is a co-partner, no suitable account is readily available to the student or house surgeon. Moreover, I cannot subscribe to the view that up-to-date information is a postgraduate prerogative but an undergraduate impropriety; so that principles are stressed but factual data are provided for those who wish to consult them.

This book could never have been completed without the immense amount of work carried out by Mr Ashley Brown, who in essence is co-author. I owe him a very real and special debt of gratitude. I am also deeply indebted to all those who have edited the various chapters to which their names are appended.

No book can be written without the patience and fortitude of one's secretaries and helpers – the monotony must have been extreme, the patience immense – neither lightened by the mercurial nature of the author. Miss M. Westwood and Mrs C. Morris who typed most of the manuscript have earned my admiration and respect for their endurance and I am also grateful to Miss A. Leeman who did a great deal of the draft typing. No consultant is complete without his senior registrar. Apart from Mr Ashley Brown, Mr Simon Janvrin gave me a great deal of help and encouragement.

1980

JAMES O ROBINSON
London W.1.

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ASHLEY BROWN
O J A GILMORE

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Surgical wounds
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SURGICAL WOUNDS

THE INCISION

An incision should be placed in such a position that it affords adequate exposure to the operative site. At the same time consideration must be given to the effects such an ideal incision must have on the patient and modified where justified. The skin incision should preferably be placed along the lines of Langer to minimize tension, which thereby reduces the chance of an ugly broad scar and the formation of keloid. Keloid is an excess of scar tissue in a wound or burn which leads to a raised, hard and growth-like structure and is more prevalent in dark-skinned races. Muscles may be separated in the line of their fibres, retracted or divided. A muscle heals with minimal scar formation, but it is important that its nerve supply is not divided otherwise it will atrophy and leave a weakness in the wound. Attention should be paid to the direction of maximum muscular pull, which in the abdomen is lateral. Transverse abdominal incisions are therefore preferable to vertical ones, providing the surgeon knows the exact nature of the operation which he is about to undertake and therefore the extent of the incision. In a patient with an abdominal emergency the exact diagnosis or site of the lesion may not be known so that exploration through a vertical incision is often more suitable as it affords access to the upper and lower halves of the peritoneal cavity. A transverse upper abdominal incision, by virtue of its greater comfort to the patient, allows the lower ribs to move more freely and reduces the incidence of basal chest complications. The commoner abdominal wounds are illustrated in Figs. 1.1 and 1.2.

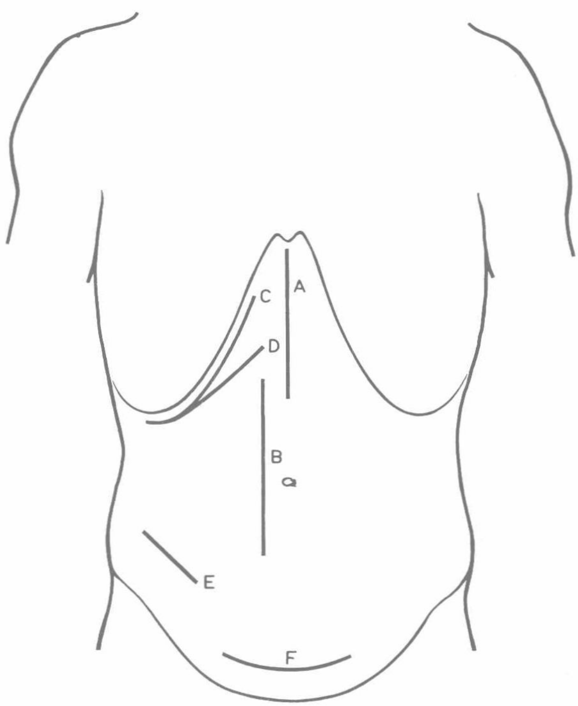

Fig. 1.1. *The common types of abdominal incision.*
A. Midline.
B. Paramedian. (Right or left.)
C. Kocher.
D. Modified Kocher.
E. Gridiron.
F. Pfannenstiel.

CLOSURE OF A WOUND

An incision which has been made carefully with clean cut edges is easier to close and will heal better than one which is ragged with sliced edges. Too much attention and discussion is wasted on the nature of the material used in closing the wound, when the method of suture is the factor of prime importance.

The peritoneum should be closed completely to prevent a portion of omentum or bowel herniating through, but large bites should be avoided as they produce necrosis and eventual weakness. Closure is occasionally difficult to achieve, particularly in frail patients and those with distended bowel, but can usually be overcome by the use of relaxant drugs administered by the anaesthetist.

Muscles and fascia should be closed independently, layer by layer, with either interrupted or continuous sutures. Interrupted sutures should be used in cases where there is raised intra-abdominal pressure, unavoidable tension on a wound or when dehiscence is anticipated.

The subcutaneous tissues should be approximated, particularly in fat patients in whom large dead spaces may be left, which will fill with blood and serum from the oozing surfaces and possibly become infected. The skin is closed with fine needles and sutures to avoid unnecessarily large punctures in the skin. Various methods of inserting sutures are employed all of which are satisfactory if they are not tied too tightly as oedema, which always occurs in the layers of a wound, will tighten the sutures and cause them to either break or to cut through tissue like a wire through cheese. Oedema may readily be seen around any skin suture which has been tied too tightly.

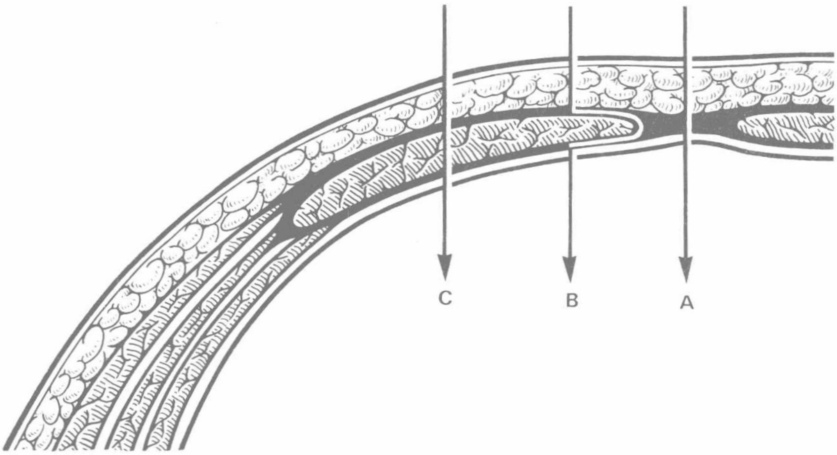

Fig. 1.2. *The pathway through which the surgeon using a vertical incision enters the peritoneal cavity.*
A. Midline.
B. Paramedian.
C. Transrectal.

Skin sutures are removed as early as possible as they leave unsightly marks if left too long. In exposed places such as the face and the neck it is usual to close underlying muscles with catgut which hold the wound together and prevent dead space formation. A large number of closely applied skin sutures can then ensure perfect skin alignment and apposition. These can be removed after two or three days. No sutures need remain in the skin for more than twelve days, even in an area where there is poor blood supply to the skin, such as the lower third of the leg, for they will do no further good after this time. Some surgeons close the skin with a sub-cuticular suture which is a continuous stitch placed in the length of the wound in the deeper layers of the skin. If unabsorbable it is removed at the same time as conventional sutures. If an absorbable suture such as polyglycolic acid is used the suture is left in situ and is particularly suited to children who dislike suture removal. Clips are occasionally used to close the skin, particularly in the neck, and should be removed after a few days. If left longer they have no advantage over cheaper suture materials and are painful.

Deep tension sutures, or more accurately full thickness sutures, are used mainly to suture difficult wounds such as after dehiscence or in cases of abdominal distension in which it is difficult if not impossible to close the peritoneum. They are usually inserted as a loose figure-of-eight stitch through all layers of the abdominal wall and are tied on small plastic tubes to prevent the nylon cutting through the skin. If these sutures are tied too tightly they are not only useless but harmful and this may be one of the reasons for their current unpopularity.

SUTURE MATERIALS

For the first four days, there is no inherent strength in a wound. This is known as the 'lag' period during which time the wound relies for its strength on the suture material, but immediately after this period the wound gains rapidly in strength provided (a) haemostasis is satisfactory and (b) there is no wound infection.

Suture materials may be absorbable or non-absorbable.

1. Absorbable sutures

Catgut is manufactured from the intestine of sheep. It is available in plain or chromic (tanned) forms and in various thicknesses. The chromic form retains its tensile strength longer than the other and is less irritant to body tissues. Catgut is widely used in intestinal surgery and its handling and tying properties are favoured by most surgeons. Polyglycolic acid is a synthetic absorbable suture which retains its tensile strength longer than catgut. However, its tying and handling properties are different.

2. Non-absorbable sutures

These include linen thread, silk, nylon and wire. These materials produce less tissue reaction than catgut. As permanent foreign bodies, however, they are likely to perpetuate infection within a wound with the possible risk of sinus formation. This risk is increased with thicker or braided sutures.

Most manufacturers market sutures already attached to needles which are themselves disposable. This is a distinct advantage to the patient since the sutures are swaged into the end of the needle which, in contrast to a threaded needle, causes less tissue trauma, hence the name atraumatic.

DRAINAGE

Drains are used to act as a channel alongside or through which substances may pass to the surface. Indications for the use of a drain are as follows:

1. A drain is inserted to an operation site where leakage may occur. This may apply where an anastomosis has been performed such as in the gastrointestinal tract or where the biliary tree or urinary tract has been opened.

2. An abscess cavity is usually drained for two reasons. The drain allows the discharge of pus and it also allows the lips of the wound to be kept open to prevent premature skin closure over a cavity which would lead to reformation of the abscess.

TYPES OF DRAIN

semi-rigid tube	vacuum	bottle or rigid plastic	these may be used for air (underwater), bile, blood, urine or pus. They are brought through a separate stab incision to prevent leakage and possible ingress of infection.
	underwater	bottle	
	non-vacuum	bag	
non-tubular	corrugated plastic or rubber		Specially suited for drainage of material which cannot pass through a tube, e.g. faeces. Generally brought out through a separate stab, away from a wound, except in abscesses.

3. Drains are left in spaces which cannot be adequately closed at operation and in which there is an inevitable loss of blood and serum, such as after a mastectomy.

Types of drain are numerous but they may be classified as shown on page 3.

A drain is inserted to drain a specific site and must therefore not be placed 'somewhere near'. When a non-tubular (corrugated) drain is used, the opening through the integuments must be adequate to allow the escape of any contents. The time of removal of a drain varies according to the indication for its insertion. If the drain is in an abscess cavity then it is usually shortened to accommodate to the shrinkage of the cavity. Drains inserted as a precaution against leakage are usually removed after five days. Drains inserted into a tube such as the common bile duct or ureter are left for at least ten days and distal patency is checked radiologically before removal.

WOUND COMPLICATIONS

These will be dealt with as follows:

1. Infection
2. Haematoma
3. Disruption
4. Herniation

Although any of these complications may arise in the best regulated circles it is to be emphasized that their prevention lies in two cardinal surgical principles. Handling tissues with care and gentleness prevents tissue damage which may be the forerunner of wound complications. Secondly, haemostasis must as far as possible be ensured, since blood collecting in a wound serves as an excellent culture medium.

1. Infection

Approximately half of all postoperative complications are related to the wound, and of these infection is the commonest. Wound infection has been defined as the presence of pus in the wound which discharges spontaneously or has to be released by removing sutures and opening the wound. The complications which follow wound infection are both local and general. Local complications range from an ugly scar through sinus formation to dehiscence (superficial, deep and complete). General complications include bacteraemia, septicaemia and very occasionally death. The other effect of wound infection is the inevitable cost which results from prolonged bed occupancy.

Incidence

The incidence of infection varies with the type of surgery. It is lowest in clean elective surgery (1–2%). In potentially contaminated surgery when the urinary, respiratory, biliary or gastrointestinal tracts are opened the incidence increases to 5–10%. In abdominal surgery when the peritoneal cavity is already soiled with bacteria at the time of operation the infection rate is approximately 20%. Operations performed in the presence of pus carry an infection rate of 40–50%. Prospective studies, however, have clearly shown that infection rates can vary widely even with standard operations.

Aetiology

For infection to occur, bacteria must enter the wound and multiply. Bacteria may enter the wound during or after operation and they may be of autogenous or exogenous origin. Autogenous sources include the patient's skin, mouth, perineum or incised urinary, respiratory, biliary and gastrointestinal tracts. Exogenous bacteria may be derived from the surgeon, the assistants, breaks in aseptic technique in theatres or wards whilst some contaminant organisms are airborne. Whether a contaminant organism causes infection depends on the type of organism and the size of the inoculum. An inoculum of less that 10^6 organisms/ml is unlikely to cause subsequent sepsis.

Other important considerations are the factors which allow contaminant bacteria to multiply. General factors affecting the multiplication of bacteria are the virulence of the organism, the immunity of the patient, the patient's age, body build and the presence of concurrent disease. Certain drugs, especially steroids and chemotherapeutic agents also inhibit resistance, as do the effects of prolonged anaesthesia and hypotension.

Local factors which encourage bacterial multiplication or inhibit local defence mechanisms vary. Without doubt, however, surgical technique is the most important. Poor technique resulting in tissue damage, ischaemia or haematoma formation inhibits local defences, while providing the bacteria with a perfect milieu for division. The presence of foreign bodies or drains also inhibits resistance.

Wound infection is a common complication of gastrointestinal operations. Patients who are particularly at risk include those undergoing oesophageal or gastric surgery for obstruction or carcinoma and patients with acute intestinal obstruction, jaundiced patients with stones or strictures and all those undergoing colonic or rectal procedures. From a computer analysis it has been shown that the most important factor in the aetiology of infection in abdominal surgery is the presence of bacteria in the wound at the time of closure.

Bacteriology

The bacteria causing wound infection vary with the type of surgery. In clean surgery (where a hollow viscus is not incised or resected) skin flora (staphylococcus epidermidis, staphylococcus aureus) dominate. In patients with pyloric, oesophageal or gastric obstruction, oral commensals, coliforms and streptococci are the usual infective organisms. Aerobes, in particular *E. Coli*, Klebsiella aerogenes and *Streptococcus faecalis*, are the commonest organisms isolated from patients with biliary tract abnormalities. Normally the upper jejunum contains only a moderate number of coliforms, while the terminal ileum contains aerobic and anaerobic organisms in excess of 10^5 organisms/ml. These numbers, however, are much increased in patients with acute intestinal obstruction. In the appendix and large bowel anaerobes outnumber the aerobes by a factor of 10 000. The commonest anaerobes include bacteroides species, *Cl. welchii*, lactobacillus species and peptostreptococcus species, while the most numerous aerobes are *Streptococcus faecalis*, *E. Coli* and staphylococcus species. In gynaecological surgery Gram negative organisms and anaerobes, in particular bacteroides species, are the main infective organisms.

Prevention of Wound Infection

Wound infection may be prevented by the avoidance of bacterial contamination of the incision, by preventing contaminant bacteria multiplying or by the combination of both.

Avoidance of Bacterial Contamination

i) Operating Theatre Procedure

Meticulous operative technique is the most important factor in the avoidance of bacterial contamination. The surgical team must change into operating clothes and put on masks before scrubbing up with an effective antiseptic (chlorhexdine, hexachlorophane or povidone iodine). The operation site must likewise be disinfected and strict asepsis must be maintained throughout the operation.

Avoiding contamination of the wound by intestinal contents and thus bacteria is an essential principle in gastrointestinal surgery. The site of anastomosis must be isolated from the wound and the rest of the abdominal cavity by judicious use of packs. Instruments, gloves and gowns used for anastomosis must be discarded before closure of the abdomen.

ii) Skin and Wound Protectors

Plastic skin drapes are advocated by some, but have not been shown in controlled trials to reduce bacterial contamination of the wound. Some surgeons prefer skin towels, while in abdominal surgery plastic wound protectors of the apron type have been shown to significantly reduce contamination if not infection.

iii) Ventilation

Although airborne bacteria play a relatively unimportant role in wound infection, except perhaps in clean cases, all theatres should have positive pressure ventilation. This ensures that organisms are not sucked into the theatre from other parts of the hospital and that organisms dispersed by the patient and members of the surgical team are diluted and blown out of the theatre.

iv) Reduction of Intestinal Bacteria

Mechanical preparation of the colon is desirable in all patients undergoing large bowel surgery. Intraluminal antibiotics reduce the flora still further. Pthalylsulphathiazole, a poorly absorbed sulphonamide, is still widely used, it greatly reduces the number of coliform bacteria but is ineffective against many others. Neomycin and kanamycin are most effective in reducing aerobes, but like pthalylsulphathiazole are ineffective against the anaerobes. Erythromycin base, tetracycline and metronidazole are three oral antimicrobials which are effective against anaerobes including bacteroides species. When used in combination with neomycin or kanamycin these agents have been shown to reduce significantly wound infection in colo-rectal surgery.

Preventing the Multiplication of Contaminant Organisms

i) Enhancement of patient's resistance

In elective surgery it is important that the patient's general condition is at an optimum at the time of surgery. Drugs which inhibit a patient's resistance must if possible be ceased preoperatively. Prolonged anaesthesia should be avoided and hypotension kept to a minimum.

ii) Operative Technique

Tissue damage must be kept to an absolute minimum. All tissues must be handled with care; thick ligatures around large bites of tissue must be avoided as must excess use of the diathermy, for both result in unnecessary necrosis. Haemostasis must be complete. Where possible dead spaces should be closed, otherwise they should be drained preferably with a closed suction drain. Sutures must never be tied too tightly and skin edges must be brought into absolute apposition, for 'overlapping' produces a potential portal of entry. In abdominal surgery all drains should be brought out through a separate stab site away from the main wound, except in appendicectomy where the incision is small and the chance of dehiscence minimal.

Prophylactic Chemotherapy

Prophylactic chemotherapy includes the topical use of antibiotics and antiseptics and the systemic use of antibiotics and chemotherapeutic agents. Indiscriminate antibiotic prophylaxis, both topical and systemic, must be condemned for both induce the emergence of antibiotic resistant bacterial strains, as do antibiotics used in inadequate doses. Whether an antibiotic is effective or not will depend on its concentration at the site of contamination, its spectrum of activity in relation to the type of surgery and the contaminant organisms.

i) Topical Antibiotics

The use of topical antibiotics is advocated by some. If used they should be instilled intra-incisionally just before closure of the wound. Penicillin, ampicillin, tetracycline, kanamycin, cephaloridine and ampicillin with cloxacillin have all been shown to be effective in different types of surgery in clinical trials. The disadvantage of topical antibiotics is that while having the same side effects as systemic agents they only give protection at their site of application.

ii) Topical Antiseptics

Antiseptics have a theoretical advantage over antibiotics in that their spectra of activity is wider and in some instances complete. Povidone iodine is the only antiseptic which has been shown to significantly reduce wound infection in controlled clinical trials. It reduces wound infection without inhibiting healing or inducing bacterial resistance.

iii) Systemic Antibiotics

Antibiotics with serious side effects should be avoided.

If started more than a few hours before surgery systemic prophylaxis may be ineffective because of the emergence of overgrowth of resistant strains. To prevent infection the agent or agents must be started just before or during the operation. Experimental studies have shown antibiotics to be ineffective if they reach the wound four or more hours after contamination. Three doses given at the appropriate times are adequate. The first dose should be given at the time of the induction of anaesthesia, the second at the end of the operation or at six hours and the third at twelve or twenty-four hours.

The choice of antibiotic(s) or whether systemic prophylaxis is used at all depends on the type of surgery and the expected contaminant organisms. The antibiotics of choice plus alternatives are given in Table 1, but before any agent is used the patient must be questioned regarding allergy. The other fact to remember is that there is no substitute for good surgical technique.

2. Haematomas

These occur as a result of inadequate haemostasis or reactionary haemorrhage. A haematoma may be aspirated if its content is fluid, evacuated surgically if it is semisolid or if small and insignificant left alone to reabsorb. Any drainage procedure risks infection developing. A haematoma should not be left adjacent to the cartilage of the ear since it will cause necrosis and lead to a 'cauliflower ear'.

TABLE I

CHOICE OF CHEMOTHERAPEUTIC AGENT ACCORDING TO EXPECTED CONTAMINANT ORGANISMS

Organisms	*Chemotherapeutic Agent*	*Alternative*
Staphylococcus epidermidis	Benzylpenicillin	Cephalosporins
Staphylococcus aureus	Cloxacillin/methicillin	Cephalosporins
Haemolytic Streptococci	Benzylpenicillin	Erythromycin
Enterococci	Benzylpenicillin+ gentamicin	Ampicillin
Clostridia spp.	Benzylpenicillin	Erythromycin
Klebsiella spp.	Gentamicin	Cephalosporins
Serratia spp.	Gentamicin	Kanamycin
Proteus spp.	Gentamicin	Cephalosporins
Pseudonomas spp.	Carbenicillin+ Gentamicin	Tobramycin or Colistin sulphate
Bacteroides	Metronidazole or Erythromycin	Lincomycin or Clindamycin

3. Disruption

This may occur in the following circumstances:

(a) presence of a wound haematoma
(b) wound infection
(c) after operations for malignant disease
(d) when there is abdominal distension: ileus, ascites
(e) coughing, straining or vomiting
(f) hypoproteinaemia, uraemia
(g) hypovitaminosis C
(h) corticosteroid drugs
(i) type of wound – vertical more common than oblique or horizontal and upper more common than lower
(j) poor surgical technique

Complete disruption involves the whole length of the wound and allows the abdominal contents to escape. Disruption may occur at any time between the 1st and 21st post-operative days but the majority occur between the 5th and 12th days. A serosanguinous discharge often precedes the actual dehiscence by one or two days and is an important warning sign of peritoneal fluid escaping through a small defect in the wound. About 20% of those suffering dehiscence die, although many of these deaths may be due to the disease which necessitated surgery. When disruption occurs a sterile towel should be laid over the wound, intravenous fluid started and arrangements made for immediate resuture in the operating room.

4. Herniation

This is an internal form of wound disruption as opposed to the full thickness wound dehiscence. It leads to an incisional hernia. The causes are much the same as for wound dehiscence. Those which are causing pain or have a narrow neck should be repaired surgically. Those which are symptomless and which are reducible should be managed with an adbominal belt or corset.

HAEMORRHAGE

Haemorrhage is the escape of blood from the vascular system. The loss may be from the arteries when it is bright red and spurting, from the veins when it is dark and bluish in colour or from the capillaries when there is a steady ooze of bright red blood. The loss may be internal or external. An external loss may occur from a wound, a nose bleed (epistaxis), coughed up from the lungs (haemoptysis), vomited from the stomach (haematemesis), passed profusely from the rectum as loose tar-like material (melaena) or passed mixed with urine (haematuria). Although these losses are external they are sometimes not visible because they are slight and can then only be detected by specially sensitive tests. The commonest examples of chronic occult blood loss are in the faeces from peptic ulceration or from a tumour somewhere in the gastrointestinal tract. An internal loss occurs in such conditions as simple bruising, limb fractures, rupture of an internal viscus such as an aortic aneurysm or tubal pregnancy. Free blood in the peritoneal cavity is known as a haemoperitoneum whereas in the chest it is termed a haemothorax.

The total adult blood volume is about seven litres and the effects of blood loss depend upon the volume lost and the speed with which it is lost. A normal person can withstand the loss of one litre quickly without ill effect. However, a rapid larger loss than this will produce shock which is described later. Slow bleeding such as from a tumour of the caecum may lead to a haemoglobin level less than 6 g/100 ml. Since the patient will have had time to compensate he may have remarkably few symptoms from such a profound anaemia.

The body attempts to arrest haemorrhage by the retraction of the vessel walls and the clotting mechanism. The retraction of the vessel wall depends upon the muscle within the wall so that an artery will retract much more efficiently than a vein. A completely severed artery will contract better than a partial wound of its wall. Bleeding is less likely to stop spontaneously in the vessels of those patients who have developed arteriosclerosis in which fibrosis and calcification may have replaced the muscle layers.

VARIETIES OF HAEMORRHAGE

Haemorrhage may be subdivided according to the three times at which it is likely to occur:

1. *Primary.* This occurs during an operation and is usually due to a vessel being accidentally cut or a ligature slipping.

2. *Reactionary.* This develops within 24 h of operation and is thought to be due to the blood pressure returning to normal which forces out thrombi from the ends of vessels which were cut but not ligated in the operation.

3. *Secondary.* This usually occurs between the seventh and twelfth days after operation. It is almost invariably due to infection which breaks up and weakens the occluding thrombus within a vessel and causes it to slough thereby allowing the vessel to bleed again. The amount of blood lost from a secondary haemorrhage depends upon the size and number of the vessels involved and is most commonly seen after prostatectomy, where a large and possibly infected raw surface is left in the prostatic bed.

Treatment

The treatment of haemorrhage is to arrest the bleeding as soon as possible and to prevent shock developing.

A wound which is bleeding should be compressed and it should not be necessary to resort to a tourniquet or to exert pressure on the classical 'pressure points'. If the volume of blood lost is large the patients legs should be elevated and bandaged to provide an 'autotransfusion'. Operative haemorrhage is controlled in different ways. Larger vessels are ligated. Smaller vessels are sealed with diathermy and bleeding capillary beds are covered with warm wet packs. Patients who have lost more than two units of blood should have this restored by blood transfusion.

SHOCK

This word should be applied to encompass a clinical state in which the output from the heart is insufficient to meet body requirements and which is characterized by the patient being pale, cold, clammy and with a fast and thready pulse. Shock is an acute disease which affects every cell and every tissue in the body.

Causes

1. Fluid loss.
   (a) haemorrhage
   (b) excessive exudates, e.g. burns or pancreatitis
   (c) gastrointestinal loss – vomiting, diarrhoea
   (d) Addison's disease.

2. Septicaemia – the proliferation of pathogenic organisms in the blood stream.

3. Cardiopulmonary.
   (a) myocardial infarction
   (b) pulmonary embolus – thrombus or fat.

4. Neurogenic or vasovagal.
5. Anaphylactic.

It is to be noted that initially only those cases of shock in category (1) are hypovolaemic, the others being normovolaemic.

Pathology of Shock

1. *The cardiovascular system* – The characteristic response of a patient to a shock-inducing injury is mainly mediated through the autonomic system. Stimulation of the alpha-receptors results in constriction of smaller vessels whereas stimulation of the beta-receptors causes the reverse. Different parts of the body are endowed with different proportions of these types of receptor, e.g. the skin is rich in alpha-receptors whereas the heart contains a greater proportion of beta-receptors. With this in mind it is easy to see how the intense adrenergic activity associated with shock-inducing injuries leads to the classical picture of the shocked patient. These are physiologically beneficial responses, at least in the early stages and lead to the maintenance of the blood supply to the heart, the kidneys and the brain. Beta stimulation has an inotropic effect on the heart. There is some evidence that prolonged adrenergic stimulation is harmful in that intense vasoconstriction in different parts of the body leads to tissue anoxia and possible release of local toxic metabolites such as kinins. Ultimately this circulatory stagnation is superseded by vasodilatation especially in the capacious venous system. There is then a rise in volume of the 'capacitance' side of the circulation in which blood can pool. Into this side of the circulation, therefore, which includes the whole venous and pulmonary circulations, the patient can lose fluid in a way just as effective as if he had bled externally.

There has been some evidence that the heart may be damaged by the release of cardiotoxins from elsewhere in the body. One of these called Myocardial Depressant Factor (MDF) is said to be released from lysosomal activity in the pancreas. Generally the search for circulating toxins in shock has been unrewarding and MDF, no less than many others, has still to stand the test of time.

2. *The kidneys* – The kidneys of man are peculiarly sensitive to the effects of hypotension and may be sufficiently damaged by the inadequate blood supply to lead to acute renal failure. This is due to acute tubular necrosis. The latter is a reversible change but in previous times was lethal due to consequent hyperkalaemia and uraemia. Provided the patient can, with dialysis, be tided over the healing period, which is in the order of three weeks, reasonable renal function may return.

3. *The lungs* – Following the advent of better resuscitation methods which allowed shocked patients to survive longer, together with the introduction of blood gas measuring facilities, it became clear that many shocked patients suffered severe hypoxaemia. This is associated with structural changes in the lungs, particularly interstitial pulmonary oedema which thickens the membrane through which gases have to diffuse as well as making the lungs less compliant. Intravascular changes also occur taking the form of micro-thrombo-embolism of the pulmonary vascular tree. This may lead to the rise in vascular resistance in the pulmonary artery observed in shocked patients and which probably contributes to defective lung function.

4. *Coagulation* – Following the observation by Hewson in 1772 that blood shed last from an injured animal clots first, there has been much speculation about the possible harmful effects of coagulability changes after injury. A syndrome of disseminated intravascular coagulation (DIC) has been described in which many of the smaller vessels are occluded by thrombi formed within the stagnant capillary circulation. These may be 'washed out' after resuscitation has started and end up in the pulmonary capillary bed thus compounding intravascular lung damage. The widespread use of clotting factors in the DIC process may lead to a situation in which, paradoxically, the patient is unable to clot his blood and thus is very prone to bleed. DIC is probably rarer than is supposed although it is well documented in obstetric patients.

5. *Rheological changes* – Blood does not behave as a Newtonian fluid and its viscosity increases sharply with a decrease in flow rate. In shock, as flow decreases, especially in the microcirculation, there is a great rise in viscosity with consequent stagnation of flow. Aggregate formation occurs

which increases the possibility of tissue ischaemia and acidosis.

6. *Acid-base balance* – Most shocked patients pass into a state of metabolic acidosis and this may be accentuated by defective renal function. The acidosis is caused by tissue hypoxia and an accumulation of the organic acids, lactic acid, beta hydroxybutyric acid and acetoacetic acid. The observable effect of a metabolic acidosis is the production of hyperpnoea due to the stimulation of the respiratory centre. Respiration may be very deep and rapid and is then known as Kussmaul in type.

MANAGEMENT OF THE SHOCKED PATIENT

Elementary first-aid may be indicated, e.g. arrest of haemorrhage by local pressure and subsequent surgery or elevation of the legs to increase venous return. Before active and specific treatment is started the clinician should institute several investigations:

1. Blood should be taken for ...
   (a) full blood count
   (b) grouping and cross matching
   (c) blood urea and electrolytes (including bicarbonate)
   (d) blood gases (arterial sample)
   (e) blood culture (if septic cause seems likely)
2. A central venous pressure line should be used to estimate CVP.
3. A catheter should be passed into the bladder to estimate urine output.
4. An electrocardiogram should be obtained. This may throw light on the cause of the shock state and will serve as a useful baseline.
5. A chest X-ray should be taken for the same reasons as (4).

Treatment

1. Intravenous fluids. The type of fluid used depends upon the cause of the injury. Haemorrhage merits blood replacement, gastrointestinal losses – normal saline, burns – dextran or plasma, septicaemia – saline.

2. The amount of intravenous fluid given depends upon the overall condition of the patient and in particular the CVP reading. This should be kept in the region of +2 to +8 cm water and the volume of fluid given intravenously should be titrated against CVP readings.

3. Hourly urine output should be measured. An approximate output of 1 ml/minute should be aimed at. Oliguria or anuria resistant to diuretic stimulation should be recognized early and the intravenous infusion rate cut accordingly.

4. If the blood gas estimations reveal a low oxygen saturation then oxygen should be administered via a mask. If this fails to produce an improvement then intermittent positive pressure respiration via an endotracheal tube is indicated.

5. If sepsis is suspected as a cause of the shock, then after blood for culture has been taken, antibiotics should be started. Clinicians generally favour a combination which until the culture results are available, is empirical. An example would be the combination of gentamycin, ampicillin and metronidazole.

6. A metabolic acidosis should be corrected with the use of bicarbonate added to the intravenous infusion.

7. If the patient is in pain or is anxious, then opiate drugs should be used.

8. Reinforcement of the alpha adrenergic response to injury by the use of alpha stimulating drugs is considered harmful since this may lead to even more intense vasoconstriction and tissue anoxia. This poses the question of the desirability of either alpha blockade or beta stimulation. Alpha blockers have met with little enthusiasm possibly because they block what is initially a useful physiological response. Isoprenaline, which is a beta stimulator, may be useful if there is evidence of cardiac failure. More recently, dopamine has come to be used in the specific situation of hypotension which appears to be resistant to routine shock management. This is most likely to be encountered in either septicaemia or from a cardiogenic cause. Dopamine increases blood pressure by its inotropic effect on the heart as well as having alpha adrenergic, beta adrenergic and dopaminergic effects. Cardiac output is increased and this, together with an increased blood pressure, results in better organ perfusion particularly with respect to the kidneys. Digoxin may be useful in the presence of cardiac failure. Corticosteroids have been widely advocated in the shocked patient but there is little evidence that

they are of any benefit at all especially in view of the well documented rises in endogenous steroid secretion.

THE CRUSH SYNDROME

This syndrome was first described in the London Blitz when it became clear that prolonged muscle ischaemia, such as that occurring after a limb is trapped for several hours under fallen masonry, leads to shock and acute renal failure. The renal failure is independent of the shock since the former may be prevented by routine treatment but the renal failure still takes place. Renal failure occurs due to the release of myoglobin from ischaemic muscle into the circulation once the limb has been freed. It takes a day or two to develop and is associated initially with the passage of small volumes of dark brown urine which is discoloured because of its myoglobin content. The kidney lesion is recoverable provided the patient can be prevented from dying from hyperkalaemia and uraemia. The hyperkalaemia which occurs in the Crush Syndrome is different from that seen in other types of kidney failure in that it develops often within an hour of the patient being freed. This is because potassium, the commonest intracellular cation, is washed from ischaemic muscles as soon as the circulation is restored once the limb is freed. It is not unusual for the patient to have a serum K^+ in excess of 8 mmol/L by the time the Accident Department has been reached. Later, as renal failure supervenes, hyperkalaemia is likely to be compounded by inadequate K^+ excretion.

Currently, there is no known way of preventing the acute renal failure of the Crush Syndrome. Initially, shock must be treated together with urgent measures to lower the serum potassium level. This usually means resorting to either peritoneal dialysis or haemodialysis. Artificial renal support has to be given for the three or more weeks that it takes for renal recovery to occur. The clinician should take great care to avoid infection in any wound sustained in the accident. The reason for this is that whereas the renal lesion may be recoverable, if the patient has a concomitant wound infection, the combination of renal failure and infection is likely to be lethal. Not all patients suffering from the Crush Syndrome have open wounds but it should be recalled that part of the treatment of a limb which has been ischaemic for several hours is to undertake fasciotomy to prevent ischaemic muscle contracture of a Volkmann type. Fasciotomy wounds are likely to become infected in the same way as wounds sustained in the accident and great effort should be made to avoid such infection. In these circumstances it is not unreasonable to advocate amputation of the limb in situations in which (a) there is severe wound infection and (b) where muscle biopsy has shown that muscle viability is questionable.

Two other forms of the Crush Syndrome should be noted. The unconscious drug addict may compress one of his own limbs for a long period and this may lead to the Crush Syndrome. Also the limb tourniquet, which is widely used in elective orthopaedic surgery, may accidentally be left inflated for many hours after operation. The limb should be amputated above the tourniquet but if someone mistakenly deflates the tourniquet then the Crush Syndrome is likely to supervene. Both these types of Crush Syndrome should be managed in the way outlined above.

FAT EMBOLISM

This is a condition which follows the fracture of one of the long bones. Fat from the bone marrow adjacent to the fracture enters the circulation and is responsible for complications which may prove lethal. It occurs in about 2% of fractured long bones and it carries a mortality of about 10–15%. Since most of these patients are young and previously fit the syndrome is of great significance.

Pathology

The source of the fat and the way in which it causes the syndrome has been the subject of dispute since Zenker first described the disease in 1862. Generally it is believed that the embolic fat comes from the bone marrow and not from circulating lipids which as a result of trauma may coalesce. The fat from the bone marrow enters the circulation almost immediately after the fracture, since examination of the lungs and other organs of victims of air crashes who have sustained limb fractures and who have been considered to have died more or less immediately, have large amounts of embolic fat in their circulatory systems. However, this