29 T orso and pelvic trauma

ABDOMINAL COMPARTMENT SYNDROME AND THE OPEN ABDOME

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Raised intra-abdominal pressure has far-reaching conse - quences for the patient; the syndrome that results is known as ACS. ACS is a major cause of morbidity and mortality in the critically ill patient and its early recognition is essential (Table 29.8). In all cases of abdominal trauma in w hich the development of ACS in the immediate postoperative phase is considered a risk, the abdomen should be left open and managed as for damage control surgery . -

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Biliary injuries

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Resuscitation of all injuries to the chest and abdomen should follow the latest Advanced Trauma Life Support (ATLS) prin ciples (Table 29.1 ; see Chapters 26 and 27). Haemorrhage is the major problem. This may be obvi - ous at the time of evaluation; however, in the young physi - cally fit individual, bleeding may produce no or only minimal changes in vital measures and, therefore, be di ffi cult to assess (Table 29.2). Although obvious injury may be present, tradi - tional indicators (such as pulse rate), in isola tion, are unreliable. Bleeding occurs from five major sites – ‘ one on the floor and four more ’: /uni25CF external – ‘floor’; /uni25CF chest; /uni25CF abdomen (including the retroperitoneum); /uni25CF pelvis; /uni25CF extremities.

TABLE 29.1 Advanced Trauma Life Support principles of resuscitation. C Catastrophic haemorrhage A Airway B Breathing C Circulation D Disability (neurology) E Environment and exposure Liver Spleen Kidney bleeding in torso trauma. Physiological Increasing respiratory rate Increasing pulse rate Falling blood pressure Rising serum lactate Anatomical Visible bleeding Injury in close proximity to major vessels Penetrating injury with a retained missile

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Classification

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Pelvic ring fractures can be classified into three types, using - the Tile classification (for subtypes and other classifica - tions see Further reading), based on the severity of the fracture (and reflecting the energy required to cause it) (Figure 29.11). Ho wever, no fracture pattern can exclude significant haemorrhage. Type A are the most common fractures and are completely stable. They result from lateral compression, which causes compression fractures of the pubic rami or compression frac ture of the sacrum posteriorly . Type B These fractures are partially stable, and there is disruption of the anterior pelvis and partial disruption of the posterior pelvis. The pelvis can open and close ‘like a book’, but because the sacroiliac ligaments remain intact there is no vertical displacement. Internal or external stabilisation is required. Blood loss can be significant. Type C This fracture is completely unstable. Both the anterior pelvis and the entire posterior pelvic complexes are disrupted and the disrupted pelvic bones are free to displace horizontally and vertically . In both type B and type C pelvic injuries, there is a high risk of associated abdominal injuries (bowel perforation or mesenteric laceration) and rupture of the diaphragm. Classification

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Clinical examination

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Pelvic fractures should be easily identified if ATLS guidelines are followed. There is no role of ‘springing’ the pelvis. If a binder has not been applied and an ‘open book’ fracture is suspected, a binder must be immediately applied as the pres ence of major pelvic fracture is associated with life-threatening blood loss and requires appropriate measures. Inspection of the skin may reveal lacerations in the groin, perineum or sacral area, indica ting an open pelvic fracture, the result of gross deformation. Evidence of perineal injury or haematuria mandates radiological ev aluation of the urinary tract from below upwards (retrograde urethrogram followed by cystogram or CT cystogram and an excretory urogram, as appropriate) when the physiology allows. Inspection of the urethral meatus may reveal a drop of blood, indicating ure thral damage. Inspection of the anus may reveal lacerations to the sphinc ter mechanism. Rectal examination may reveal blood in the rectum and/or discontinuity of the rectal wall, indicating a rectal laceration. In male patients, the prostate is palpated; a high-riding prosta te indicates a complete urethral avulsion. A full neurological examination is performed of the perineal area, sphincter mechanism and femoral and sciatic nerves. Clinical examination

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Colon

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Blunt injuries to the colon are relatively infrequent; penetrating injuries occur more often. If relatively little contamination is present and the viability is satisfactory , such wounds can be repaired primarily . If, however, there is extensive contamina tion, the patient is physiologically compromised or the bowel is of doubtful viability , then the bowel can be closed o ff (‘clip and drop’). A defunctioning colostomy can be formed later or the bowel reanastomosed once the patient is stable. Colon

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Computed tomography scan

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CT has become the ‘gold standard’ for the intra-abdominal diagnosis of injury in the stable patient. The scan can be performed using intravenous contrast. CT is sensitive for blood and individual organ injury as well as for retroperitoneal injury . An entirely normal abdominal CT is usually su ffi cient to exclude intraperitoneal injury . The following points are important when performing CT: /uni25CF it remains an inappropriate investigation for physiologically compromised patients; /uni25CF if duodenal injury is suspected from the mechanism of injury , oral contrast may be helpful; /uni25CF if rectal and distal colonic injury is suspected in the absence of blood on rectal examination, air around the colon may indicate injury; in all cases clinical suspicion supersedes investigation results.

Figure 29.8 Compression injury to the liver, bursting the liver sub stance.

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DAMAGE CONTROL

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Following major injury , protracted surgery in the physio logically unstable patient can in itself prove fatal. Patients with the ‘deadly triad’ (hypothermia, acidosis and coagulopathy) are those at highest risk. Damage control or damage limitation surgery is a concept that originated from a naval shipbuilding stra tegy , whereby ships were designed so that the damage was kept ‘local’ and only minimal repairs were needed to prevent the ship from sinking while definitive repairs waited until it had reached port. The technique has been adopted follow ing major trauma and includes initial care and resuscitation (damage control resuscitation) and the surgical correction of the injury (damage control surgery). The minimum amount of surgery needed to stabilise the patient’s condition ma y be the safest course until the physiolog ical derangement can be corrected. Damage control surgery is restricted to only three goals: /uni25CF stopping any active surgical bleeding; /uni25CF controlling any contamination; /uni25CF restoring normal physiology . Once the first two have been achieved then the operation is suspended and the abdomen temporarily closed to allow for restoration of physiology to occur. The pa tient’s resuscitation then continues in the ICU, where other therapeutic interven tions can take place. Once the physiology has been corrected, the patient warmed and the coagulopathy corrected, the patient is returned to the operating theatre for any definitive surgery DAMAGE CONTROL

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Diagnosis

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Radiograph Examination of a plain radiograph of the pelvis requires an understanding of the mechanism of injury and a decision on the stability of the pelvic rim. It is important to note that the vast majority of patients with suspected pelvic fractures may have a pelvic binder in place and hence plain radiograph findings may be normal. FAST may be unreliable as it does not localise intra-abdominal bleeding in these patients. CT is the diagnostic modality of choice in the physiologically helpful in providing details of both the anatomy of the fracture and the origin of the bleeding (venous or arterial). An open book-type mechanism causes one or both ilia to - rotate externally (opening, like a book). A la teral compression mechanism causes the pelvis to collapse. An ‘open book frac - ture’ is seen as a widening of the pubic symphysis or widening at the site of a fracture in the pubic ramus. Not only is there dis - ruption of the bony pelvis, but also tearing of the pelvic floor and thus the pelvic venous plexus is at risk. T he more unstable the pelvis, the more likely the structures are to be damaged. When the pelvis collapses from a lateral compression injury , the pubic bones usually fracture . Displacement of the anterior pelvis by greater than 2 /uni00A0 cm indicates at least partial instability . A vertical shear disruption of the sacroiliac joint with apparent shortening of the limb on the a ff ected side implies significant energy of injury .

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Diagnostic peritoneal lavage (DPL) is a test rarely used in modern-day practice but can be of value in resource-limited settings. It is a test used to assess the presence of blood or contaminants in the abdomen. A nasogastric tube is placed to empty the stomach and a urinary catheter is inserted to drain the bladder. A cannula is inserted below the umbilicus, directed caudally and posteriorly . The cannula is aspirated for blood (>10 /uni00A0 mL is deemed as positive) and, following this, 500 /uni00A0 mL of warmed Ringer's lactate solution is allo wed to run into the abdomen from a 1-litre bag. The bag, with 500 /uni00A0 mL remaining, is placed on the floor and the intra-abdominal fluid is allowed to flow under the influence of gravity – this aids drainage. The pres - ence of frank blood or similar contents to a nasogastric tube or urinary catheter denotes a positive DPL. If time allows and laboratory diagnosis is available, the presence of >100 /uni00A0 000 red cells/µL or >500 white cells/µL is deemed positive (this is equiv alent to 20 /uni00A0 mL of free blood in the abdominal cavity), as is a raised amylase level. In the absence of laboratory facilities, a urine dipstick may be useful. Drainage of lavage fluid via a chest drain indicates penetration of the diaphragm. Although DPL has largely been replaced by eFAST (see Focused abdominal sonography for trauma and extended FAST (FAST and eFAST)), it remains the standard in many institutions where eFAST is not available or is unre - liable. Diagnostic peritoneal lavage

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Emergency department thoracotomy (EDT) should be reserved - for those patients with penetrating injury in whom signs of life are still present. Patients who have received cardiopulmonary resuscitation (CPR) in the prehospital phase of their care are unlikely to survive, and electrical activity must be present. In certain situations, EDT is considered futile: - /uni25CF CPR for more than 15 minutes (despite endotracheal intu - bation) in the presence of penetrating thoracic trauma; /uni25CF CPR for more than 10 minutes (despite endotracheal intu - bation) in the presence of blunt thoracic trauma; /uni25CF blunt trauma when there have been no signs of life at the scene. trauma in whom the blood pressure is falling despite adequate resuscitation are shown in Table 29.4 . The aim of EDT is to perform: /uni25CF internal cardiac massage in the cardiovascularly ‘full’ patient (no role for internal massage in the ‘empty’ patient); /uni25CF control of haemorrhage from injury to the heart or lung; /uni25CF control of intrathoracic haemorrhage from other sources; /uni25CF control of massive air leak; /uni25CF clamping of the thoracic aorta to preserve the blood sup ply to the heart and brain, and cutting o ff the arterial sup ply distally , in a moribund patient with a major distal pen etrating injury .

TABLE 29.4 Survival rates for thoracotomy in patients with penetrating trauma. Blood pressure despite resuscitation Survival

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Emergency department thoracotomy (EDT) should be reserved - for those patients with penetrating injury in whom signs of life are still present. Patients who have received cardiopulmonary resuscitation (CPR) in the prehospital phase of their care are unlikely to survive, and electrical activity must be present. In certain situations, EDT is considered futile: - /uni25CF CPR for more than 15 minutes (despite endotracheal intu - bation) in the presence of penetrating thoracic trauma; /uni25CF CPR for more than 10 minutes (despite endotracheal intu - bation) in the presence of blunt thoracic trauma; /uni25CF blunt trauma when there have been no signs of life at the scene. trauma in whom the blood pressure is falling despite adequate resuscitation are shown in Table 29.4 . The aim of EDT is to perform: /uni25CF internal cardiac massage in the cardiovascularly ‘full’ patient (no role for internal massage in the ‘empty’ patient); /uni25CF control of haemorrhage from injury to the heart or lung; /uni25CF control of intrathoracic haemorrhage from other sources; /uni25CF control of massive air leak; /uni25CF clamping of the thoracic aorta to preserve the blood sup ply to the heart and brain, and cutting o ff the arterial sup ply distally , in a moribund patient with a major distal pen etrating injury .

TABLE 29.4 Survival rates for thoracotomy in patients with penetrating trauma. Blood pressure despite resuscitation Survival

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INDIVIDUAL ORGAN INJURY Liver

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Blunt liver trauma occurs as a result of direct injury . The liver is a solid organ and compressive forces can easily burst the liver substance (Figure 29.8). The liver is usually compressed between the impacting object and the ribcage or vertebral column. Most injuries are relatively minor and can be managed non-operatively . James Hogarth Pringle , 1863–1941, Australian-born surgeon, The Royal Infirmary , Glasgow , UK. Robert William Sengstaken , 1923–1978, surgeon, Garden City , NY , USA, and The College of Physicians and Surgeons, Columbia University , New Y ork, NY , USA, designed a tube with two in-built balloons for the treatment of oesophageal varices. The tube was passed and the distal balloon inflated. The tube was drawn backwards until the distal balloon was held at the oesophageal hiatus. The proximal balloon was inflated, allowing tamponade of any varices in the distal oesophagus. lets have a shock wave and when they pass through a solid structure such as the liver they cause significant damage some distance from the actual track of the bullet. Not all penetrating y stop bleeding wounds require operativ e management and ma spontaneously . In the physiologically non-compromised patient, CT is the investigation of choice. It provides information on the liver injury itself, as well as on injuries to the adjoining major vascu - lar and biliary structures. Injury in which there is a suggestion of a vascular component should be reimaged, as there is a sig - nificant risk of the development of subsequent ischaemia, false aneurysms, arteriovenous fistulae or haemobiliary fistula. It is advised that all patients should be rescanned prior to discharge. Liver injury can be graded and managed using the American Association for the Surgery of Trauma (AAST) Injury Scoring Scale (ISS) (https://www .aast.org/resources - detail/injury-scoring-scale).

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INTERVENTIONAL RADIOLOGY

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Interventional radiology can be useful in the management of torso trauma as both an investigative and a therapeutic tool for patients with vascular injury . Angioembolisation following demonstration of ongoing bleeding in splenic and renal injury is a valuable technique. Non-operative management is generally preferred for the management of solid organ injury in physiologically non-compromised children. Non-operative management of solid abdominal organ injury has rapidly gained acceptance in the management of adults as well. A stable patient and accurate CT imaging are prerequisites for this approach. Failure of non-operative management is uncommon and typically occurs within the first 12 hours after injury . Therefore, if correctly selected, the vast majority of these patients will avoid surgery , require less blood transfusion and sustain fewer complications than operated patients. INTERVENTIONAL RADIOLOGY

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Immediate life-threatening injuries

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Airway obstruction Early intubation is very important, particularly in cases of neck haematoma or possible airway oedema. Airway distortion can be insidious and progressive and can make delayed intubation more di ffi cult if not impossible. Tension pneumothorax A tension pneumothorax develops when a ‘one-way valve’ air leak occurs either from the lung or through the chest wall. Air is sucked into the thoracic cavity without any means of escape, completely collapsing and then compressing the a ff ected lung. The mediastinum is displaced to the opposite side, decreasing venous return and compressing the opposite lung. The most common causes are penetrating chest trauma, blunt chest trauma with a parenchymal lung injury and air leak that did not spontaneously close, iatrogenic lung injury (e.g. due to central venepuncture) and mechanical positiv e-pressure ventilation. /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF The clinical presentation is dramatic. The patient is increas ingly restless with tachypnoea, dyspnoea and distended neck veins (similar to pericardial tamponade). Clinical examination may reveal tracheal deviation; this is a late finding and is not - necessary to clinically confirm diagnosis. There will also be hyper-resonance and decreased or absent breath sounds over the a ff ected hemithorax. Tension pneumothorax is a clinical diagnosis and treatment should never be delayed by waiting for radiological confirmation. Always treat it with a high index of suspicion of being present (Figure 29.3). Treatment consists of immediate decompression. This was historically taught by rapid insertion of a large-bore cannula into the second intercostal space in the mid-clavicular line of the a ff ected side, follo wed by insertion of a chest tube through the fifth intercostal space in the anterior axillary line. However, current teaching advocates undertaking decompression in the safe triangle – defined posteriorly by latissimus dorsi, anteriorly by the lateral border of pectoralis major and inferiorly by a line perpendicular to the nipple going to the back, just anterior to the mid-axillary line – or, in extremis, a finger thoracostomy at the same location. Pericardial tamponade Pericardial tamponade needs to be di ff erentiated from a tension pneumothorax in the shocked patient with distended neck veins. It is most commonly the result of penetrating trauma. Accumulation of a relatively small amount of blood (50 /uni00A0 mL) into the non-distensible pericardial sac can produce compression of the heart and obstruction of the venous return, leading to decreased filling of the cardiac chambers during diastole. All patients with penetrating injury anywhere near the - heart plus shock must be considered to have a cardiac injury until proven otherwise. Classically , the presentation consists of central venous pressure elevation, a decline in arterial pressure with tachycardia and mu ffl ed heart sounds. However, in cases

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Summary box 29.4 Pericardial tamponade /uni25CF /uni25CF /uni25CF Open pneumothorax ('sucking chest wound') This is due to a large open defect in the chest (>3 /uni00A0 cm), lead ing to immediate equilibration between intrathoracic and atmospheric pressure. If the opening in the chest wall exceeds about two-thirds of the diameter of the trachea, then with each inspiratory cycle air will be pr eferentially drawn through the defect rather than through the trachea. Air accumulates in the hemithorax (rather than in the lung) with each inspiration, leading to profound hypoventilation on the a ff ected side and hypoxia. If there is a valvular e ff ect, increasing amounts of air in the pleura will result in a tension pneumothorax (see Tension pneumothorax). Initial management consists of promptly closing the defect ◊ with a sterile occlusive plastic dressing (e.g. OPSITE or similar product), taped on three sides to act as a flutter-type valve. A chest tube is inserted as soon as possible in a site remote from the injury site. Massive haemothorax The most common cause of massive haemothorax in blunt injury is continuing bleeding from torn intercostal vessels or occasionally from the internal mammary artery secondary to fractures of the ribs. In penetrating injury , a variety of viscera, both thoracic and abdominal (with blood leaking through a hole in the diaphragm from the positive pressure abdomen into the negative pressure thorax), may be involved. ◊ Trademark of Smith+Nephew. compromise respiratory e ff orts, compressing the lung and preventing adequate ventilation. Presenta tion is with haemorrhagic shock, flat neck veins, unilateral absence of breath sounds and dullness to percussion. The initial treatment consists of correcting the hypovolaemic shock, insertion of an intercostal drain and, in some cases, intubation. 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Traditionally , mechanical ventilation was used to ‘internally splint’ the chest but had a price in terms of intensive care unit (ICU) resources and ventilation-dependent morbidity . Currently , treatment consists of oxygen administration, adequate analgesia (including opiates) and physiotherapy . If a chest tube is in place, topical intrapleural local analgesia introduced via the tube can also be used. V entilation is reserved for patients developing respiratory failure despite adequate analgesia and oxygen. Surgery to stabilise the flail segment using internal fixation of the ribs may be useful in a selected group of patients with isolated or severe chest injury and pulmonary contusion.

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Figure 29.4 Chest radiograph showing a widened mediastinum (courtesy of Dr Elizabeth Dick, Consultant Radiologist, Imperial College Healthcare NHS Trust, London, UK).

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TABLE 29.3 The ‘deadly dozen’ threats to life from chest injury. Immediately life- Airway obstruction threatening Tension pneumothorax Pericardial tamponade Open pneumothorax Massive haemothorax Flail chest Potentially life- Aortic injuries threatening Tracheobronchial injuries Myocardial contusion Rupture of the diaphragm Oesophageal injuries Pulmonary contusion Figure 29.3 Radiological appearance of a tension pneumothorax (courtesy of Dr Elizabeth Dick, Consultant Radiologist, Imperial College Healthcare NHS Trust, London, UK).

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Pericardial tamponade /uni25CF /uni25CF /uni25CF Open pneumothorax (‘sucking chest wound’) This is due to a large open defect in the chest (>3 /uni00A0 cm), lead ing to immediate equilibration between intrathoracic and atmospheric pressure. If the opening in the chest wall exceeds about two-thirds of the diameter of the trachea, then with each inspiratory cycle air will be pr eferentially drawn through the defect rather than through the trachea. Air accumulates in the hemithorax (rather than in the lung) with each inspiration, leading to profound hypoventilation on the a ff ected side and hypoxia. If there is a valvular e ff ect, increasing amounts of air in the pleura will result in a tension pneumothorax (see Tension pneumothorax). Initial management consists of promptly closing the defect ◊ with a sterile occlusive plastic dressing (e.g. OPSITE or similar product), taped on three sides to act as a flutter-type valve. A chest tube is inserted as soon as possible in a site remote from the injury site. Massive haemothorax The most common cause of massive haemothorax in blunt injury is continuing bleeding from torn intercostal vessels or occasionally from the internal mammary artery secondary to fractures of the ribs. In penetrating injury , a variety of viscera, both thoracic and abdominal (with blood leaking through a hole in the diaphragm from the positive pressure abdomen into the negative pressure thorax), may be involved. ◊ Trademark of Smith+Nephew. compromise respiratory e ff orts, compressing the lung and preventing adequate ventilation. Presenta tion is with haemorrhagic shock, flat neck veins, unilateral absence of breath sounds and dullness to percussion. The initial treatment consists of correcting the hypovolaemic shock, insertion of an intercostal drain and, in some cases, intubation. Initial drainage - of more than 1500 /uni00A0 mL of blood or ongoing haemorrhage of more than 200 /uni00A0 mL/h over 3–4 hours is generally considered an indication for urgent thoracotomy . Blood in the pleural space should be removed as completely and rapidly as possible to prevent ongoing bleeding, an empy - There is no role for clamping a ema or fibr othorax later. chest tube to tamponade a massive haemothorax . The following points are important in the management of an open pneumothorax/haemothorax: /uni25CF if the lung does not reinflate, the drain should be placed on low-pressure (5 /uni00A0 cmH O) suction; 2 /uni25CF clot occlusion of a chest drainage tube may result in ‘no’ drainage, even in the presence of ongoing bleeding; /uni25CF a second drain is sometimes necessary (but see Tracheobronchial injuries); /uni25CF a chest radiograph or eFAST can help identify the pres - ence of blood; /uni25CF physiotherapy and active mobilisation should begin as soon as possible. Flail chest This condition usually results from blunt trauma associated with multiple rib fractures, and is defined as three or more ribs fractured in two or more places. The blunt force typically - also produces an underlying pulmonary contusion. The diagnosis is made clinically in patients who are not ventilated, not by radiography . To confirm the diagnosis the chest wall can be observed for paradoxical motion of a chest wall segment. On inspiration, the loose segment of the chest wall is displaced inwards and therefore less air moves into the lungs. On expiration, the segment moves outwards (paradoxical respiration). V oluntary splinting of the chest wall occurs as a result of pain, so mechanically impaired chest wall movement and the associated lung contusion all contribute to the hypoxia. There is a high risk of developing a pneumothorax or haemothorax. The CT scan remains the gold standard for diagnosis of this condition. Traditionally , mechanical ventilation was used to ‘internally splint’ the chest but had a price in terms of intensive care unit (ICU) resources and ventilation-dependent morbidity . Currently , treatment consists of oxygen administration, adequate analgesia (including opiates) and physiotherapy . If a chest tube is in place, topical intrapleural local analgesia introduced via the tube can also be used. V entilation is reserved for patients developing respiratory failure despite adequate analgesia and oxygen. Surgery to stabilise the flail segment using internal fixation of the ribs may be useful in a selected group of patients with isolated or severe chest injury and pulmonary contusion.

The presentation is similar to a tension pneumothorax – deteriorating cyanosis, tachycardia and agitation eFAST is diagnostic and may also detect free /f_l uid in the abdomen or pericardium There is no role for pericardiocentesis in traumatic cardiac tamponade. A left anterolateral thoracotomy or sternotomy should be performed with evacuation of the haematoma and repair of the myocardium

Figure 29.4 Chest radiograph showing a widened mediastinum (courtesy of Dr Elizabeth Dick, Consultant Radiologist, Imperial College Healthcare NHS Trust, London, UK).

Introduction

INTRODUCTION

Injury seldom respects anatomical boundaries, hence the divi sion of the body into the abdomen and the thorax is artificial. Therefore, injury to the torso with its associated physiological consequences is more appropriate. The torso is generally regarded as the focal point of the human body , consisting of the chest, abdomen and pelvis and not including the head, neck, arms and legs. About 42% of all deaths are the result of brain injury , but some 39% of all trauma deaths are caused by major haemorrhage, usually from torso injury (Figure 29.1 Historically , injury was treated on an anatomical basis; however, it has become clear that physiology should be the over-riding consideration. The driver of successful resuscitation is ther efore the preservation of normal physiology . Techniques such as damage control resuscitation and its key component damage control surgery have dramatically improved survival through an understanding of the best techniques required to restore physiological stability (see Chapters 1, 26 and 27

Other 6% CNS Unknown MOF 7% 42% 0% Bleeding 39% Bleeding + CNS 6% Figure 29.1 Causes of death in trauma. CNS, central nervous system; MOF , multiple organ failure. The operative approaches to the thoracic cavity • The special features of an emergency department • thoracotomy for haemorrhage control The indications for, and techniques of, the trauma • laparotomy The philosophy of damage control resuscitation • The management of trauma to the pelvis •

Investigation

Investigation

Routine investigation in the emergency department of injury to the chest is based on clinical examination, supplemented by appropriate imaging.

Figure 29.2 The anatomical extent of the abdomen.

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The intercostal muscles are then separated just above the fifth rib and the pleural cavity entered. A finger is then inserted and a pleural swee p made to ensure the pleural cavity has been entered. Chest radiograph In those cases where the patient is physiologically non- compromised or the spine is at risk, an anteroposterior (AP) supine chest radiograph is usually the simplest initial investigation. It will provide good information regarding tracheal deviation, lung and mediastinal pathology as well as skeletal injury . In penetrating injury , it may be more helpful for the radio graph to be performed with the patient positioned erect, as this will best reveal a small pneumothorax, fluid meniscus, air–fluid level or the presence of free gas under the diaphragm, indi ca ting the presence of a hollow abdominal viscus perforation. Note that up to 300 /uni00A0 mL of blood may pool behind the domes of the diaphragm, and may not be visible even in the erect view . T he presence of thoracic skeletal injury should alert the clinician to the possibility of adjacent thoracic or abdominal visceral injury . Rupture of the thoracic aorta can be related to fractures of the first and second rib, bilateral clavicular fracture and fracture of the sternum, thoracic spine or scapula. Frac ture of the lower ribs can be related to injury of the liver or spleen. Fracture of the ribs, irrespective of site, can be related to injury to the lung parenchyma or thoracic wall vascula causing pneumothorax, haemothorax or lung contusion. Computed tomography scan The computed tomography (CT) scan with contrast allows for three-dimensional reconstruction of the chest and abdomen, as well as of the bony skeleton. It has become the principal and most reliable examination for major injury in trauma. In blunt chest trauma, the CT scan will allow the definition of frac tures, as well as showing haematomas, pneumothoraces and pulmonary contusion. In penetrating trauma, the scan may show the track or presence of the missile and allow the pr planning of definitive surgery . However, although the presence of an isolated rupture of the diaphragm with migration of in injury without migration the diagnosis will not be obvious. The pitfalls of investigation are: /uni25CF failure to assess tracheal shift immediately above the sternal notch clinically (deviation of the trachea occurs away from the a ff ected side in tension pneumothorax and towards the - a ff ected side in lung collapse); /uni25CF failure to percuss and auscultate both front and back in a supine patient (an inflated lung will ‘float’ on a haemo - - thorax, so auscultation from the front may sound normal); /uni25CF failure to pass a nasogastric tube if rupture of the dia - phragm is suspected; a chest radiograph will show the nasogastric tube apparently within the chest cavity; /uni25CF a supine chest radiograph can show a haemothorax as a homogeneous increase in opacity of the hemithorax – this - can cause confusion between the darker side and the lighter side as to which may be a haemothorax (less radiolucent) or a pneumothorax (more radiolucent); look carefully for lung markings and do not drain the wrong side; /uni25CF pursuing radiological investigation (radiography or CT scan) instead of resuscitation in the unstable patient. 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The key junctional zones are:). /uni25CF between the neck and the thorax; /uni25CF between the thorax and the upper limbs; /uni25CF between the thorax and the abdomen; /uni25CF between the abdominopelvic structures and the groin. These zones represent surgical challenges in terms of both diagnosis of the area of injury and the required surgical approach. Such factors have to be balanced against the physi -). ological stability of the pa tient. Root of the neck Most injuries a ff ecting the base of the neck may also a ff ect the upper mediastinum and thoracic inlet. Choice of access is determined by the need for surgical control of the vascular structures contained within. The mediastinum The mediastinum, with its major vessels and the heart, is also an extremely high-risk area for penetrating wounds. Any wound in this region should immediately raise the suspicion of a major vascular or an associated cardiac injury , even in the absence of initial gross physical signs. Diaphragm The thorax and abdomen are separated by the diaphragm, which is mainly responsible for breathing, allowing movement space. Any penetrating injury below the nipples on the chest may therefore have penetrated the diaphragm and entered the abdomen. Injuries in this junctional zone, therefore, should be investigated as if both cavities had been penetrated (Figure 29.2). In blunt trauma, rupture of the diaphragm can result in migration of abdominal viscera into the chest, with left-sided hemidiaphragm rupture being more common. Pelvic structures The pelvis contains a large plexus of vessels, both venous and arterial. Should injury occur, control of haemorrhage can prove to be exceptionally di ffi cult and may require control of both arterial inflow and venous outflow . Angioembolisation can be a very useful adjunct to treatment, especially with deep pelvic injuries. Summary box 29.1 Junctional zones /uni25CF /uni25CF /uni25CF /uni25CF

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Laparoscopy

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Laparoscopy or thoracoscopy may be a valuable screening investigation in physiologically non-compromised patients with penetrating trauma to detect or exclude peritoneal penetration and/or diaphragmatic injury . Laparoscopy may be divided into: /uni25CF screening: used to exclude a penetrating injury with breach of the peritoneum; /uni25CF diagnostic: finding evidence of injury to viscera; /uni25CF therapeutic: used to repair the injury . In most institutions, evidence of penetration requires a lap arotomy to evaluate organ injury as it is di ffi cult to exclude all intra-abdominal injuries laparoscopically . When used in this role laparoscopy reduces the non-therapeutic laparotomy rate. There is no place for laparoscopy in the unstable patient. Laparoscopy

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Learning objectives

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To understand: The importance of physiology over anatomy in the • management of trauma The gross surgical anatomy of the chest and abdomen • The pathophysiology of torso injury • The clinical assessment in the injured patient • The use of special investigations and their limitations •
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Management

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The operative management of liver injuries can be summarised as ‘the four Ps’: /uni25CF Pressure; /uni25CF Pringle; /uni25CF Plug; /uni25CF Pack. At laparotomy the liver is reconstituted and bleeding is con - trolled by direct bimanual compression to achieve its normal architecture as best as possible (Pressure). The inflow from the portal triad is contr olled by a Pringle’s manoeuvre, with direct compression of the portal triad, either digitally or using a soft clamp (Figure 29.9). This has the e ff ect of reducing arterial and portal venous inflow into the liver, although it does not control the backflow from the inferior vena cava and hepatic veins. Any holes due to penetrating injury can be plugged directly using silicone tubing or a Sengstaken–Blakemore tube; after controlling any arterial bleeding, the liver can then be - packed (see Damage control surgery). Bleeding points should be controlled locally when possible, and such patients, if required, subsequently undergo angioembolisation. It is not usually necessary to suture penetrating injuries of the liver unless haemostasis cannot be controlled by other means . If there has been direct damage to the hepatic artery , it can be tied o ff . Damage to the portal vein must be repaired, as tying o ff the portal vein carries a greater than 50% mortality rate. If it is not technically feasible to repair the vein at the time of surgery , it should be shunted and the patient referred to a specialist centre. A drainage system must be left in situ following hepatic surgery . Finally , the liver can be definitively packed, restoring the anatomy as closely as possible. Placing omentum into cracks in the liver is not recommended. Arthur Hendley Blakemore , 1897–1970, Associate Professor of Surgery , Summary box 29.6 Liver trauma /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF

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Planned emergency thoracotomy

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Planned emergency thoracotomy implies an emergency thora cotomy performed as a planned procedure in the operating theatre, directed at the management of a specific injury . As such, the approach c hosen is dependent on the indication for surgery and the organ injured (Table 29.5). Some organs are best approached through a median sternotomy . Otherwise the thoracotomy may be right or left sided, and these may be joined, producing the so-called ‘clamshell incision’. This gives excellent exposure for any surgeon who is not routinely entering the chest. Posterolateral thoracotomy is not used in the emergency situation because of the di ffi culties in positioning of the patient, except for specific access to certain posterior media stinal organs. /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF Patients who have su ff ered abdominal trauma can generally be classified into the following categories based on their physio - logical condition after initial resuscitation: /uni25CF physiologically ‘normal’ – investigation can be completed before treatment is planned; /uni25CF physiologically ‘non-compromised’ – investigation is more limited; it is aimed at establishing whether the patient can be managed non-operatively , whether angioembolisation can be used or whether surgery is required; /uni25CF physiologically ‘compromised’ – investigations need to be suspended as immediate surgical correction of the bleed - ing is required. A trauma laparotomy is the final step in the pathway to delineate intra-abdominal injury . Occasionally it is di ffi cult to determine the source of bleeding in the shocked, multiple injured patient. If doubt still e xists, especially in the presence of other injuries, a laparotomy may still be the safest option. - The key is to make a decision, as indecision leads to delay in - definitive control. - The patient’s physiology must be assessed constantly; if there is an indication that the patient is still actively bleeding, the source must be identified unless the patient is unstable and requires immediate surgery . Blood loss into the abdomen can be subtle and there may be no clear clinical signs. Blood - is not an irritant and does not initially cause any abdominal pain. Distension is subjective, and a drop in the blood pressure may be a very late sign in a young fit patient. Examination in compromised patients should take place either in the emergency department or in the operating theatre if the patient is deteriorating rapidly .

TABLE 29.5 Different approaches to the contents of the chest cavity. Approach Best for Left anterolateral Left lung and lung hilum thoracotomy Thoracic aorta Origin of left subclavian artery Left side of heart Lower oesophagus Right anterolateral Right lung and lung hilum thoracotomy Azygos veins Superior vena cava Infracardiac inferior vena cava Upper oesophagus Thoracic trachea Median sternotomy Anterior aspect of heart Anterior mediastinum Ascending aorta and arch of aorta Pulmonary arteries Carina of the trachea

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Potentially life-threatening injuries

Potentially life-threatening injuries

Thoracic aortic disruption Traumatic aortic rupture is a common cause of sudden death after a vehicle collision or fall from a great height. The vessel is relatively fixed distal to the ligamentum arteriosum, just distal to the origin of the left subclavian artery . The shear forces from a sudden impact disrupt the intima and media. If the adventitia is intact, the patient may remain physiologically non-compromised. Thoracic aortic injury should be clinically suspected in patients with gross asymmetry in systolic blood pressure (between the two upper limbs, or between upper and lower limbs), widened pulse pressure and chest wall contusion. Erect c hest radiography can also suggest thoracic aortic disruption, the most common radiological finding being a widened media stinum (Figure 29.4). The diagnosis is confirmed by a CT scan of the mediastinum (Figure 29.5). In the hypotensive patient, widening of the mediastinum and aortic injury is not the cause of the hypotension. Inv ariably , these patients have other inju ries causing hypotension as patients with complete aortic dis ruption rarely , if ever, survive to reach hospital. In the presence of thoracic aortic injury , initial manage ment consists of control of the systolic arterial blood pres sure (to less than 120 /uni00A0 mmHg). Thereafter, an endovascular intra-aortic stent (Figure 29.6) can be placed, or the tear can be operatively repaired by direct repair or by excision and grafting using a Dacron g raft. Tracheobronchial injuries Severe subcutaneous emphysema with respiratory compromise can suggest tracheobronchial disruption. A chest drain placed on the a ff ected side will reveal a large air leak and the collapsed lung may fail to re-expand. Bronchoscopy is diagnostic. Treat ment involves intubation of the una ff ected bronchus followed by operative repair. Referral to a trauma centre is advised. - - - - - -

Figure 29.5 Computed tomography scan showing aortic disruption (courtesy of Dr Elizabeth Dick, Consultant Radiologist, Imperial College Healthcare NHS Trust, London, UK). (a) (b) Figure 29.6 (a) Aortic tear showing the presence of a prein /f_l ation stent and test run. (b) Aortic tear post in /f_l ation of the stent and test run (courtesy of Dr Elizabeth Dick, Consultant Radiologist, Imperial College Healthcare NHS Trust, London, UK).

Significant blunt cardiac injury that causes haemodynamic and physiological instability is rare. Blunt myocardial injury should be suspected in any patient sustaining blunt trauma who develops early electrocardiogram abnormalities. Transthoracic echocardiography may show wall motion abnormalities. A transoesophageal echocardiogram may also be helpful. There is very little evidence that enzyme estima tions have any place in diagnosis . All patients with myocardial contusion diagnosed with con duction abnormalities are at risk of developing sudden dys rhythmias and should be closely monitored. Diaphragmatic injuries Any penetrating injury below the fifth intercostal space should raise suspicion of diaphragmatic penetration and, therefore, injury to abdominal contents. Blunt injury to the diaphragm is usually caused by a com pressive force applied to the torso. The diaphragmatic rupture is usually large, with herniation of the abdominal contents into the chest. Diagnosis of diaphragmatic rupture can easily be missed in the acute phase, and may only be discovered at oper ation or thr ough the presentation of complications. Most diaphragmatic injuries are silent and the presenting features are those of injury to the surrounding organs. There is no single standard investig ation. Historically and in limited resource environments, chest radiography after placement of a nasogastric tube may be helpful (as this may show the stomach herniated into the chest). CT scan and ultrasound scan all lack positive or negative predictive value. The most accurate evalu ation is by video-assisted thoracoscopy or laparoscopy , the lat ter o ff ering the advantage of allowing the surgeon to proceed to a repair and additional evaluation of the abdominal organs. The thorax is at negative pressure and the abdomen is a positive pressure. A complication of a breach of the diaphragm is herniation of abdominal contents into the chest. This may present m uch later, and strangulation of any of the contents can then occur, with a high mortality rate. Operative repair is recommended in all cases. All penetrating diaphragmatic injury must be repaired via the abdomen – and not the chest – to rule out penetrating hollow viscus injury . Oesophageal injury Most oesophageal injuries result from penetrating trauma; blunt injury is rare but should be suspected in patients exposed to barotrauma. A high index of suspicion is required. The patient can present with odynophagia (pain on swallowing saliva, foods or fluids), subcutaneous or mediastinal emphy sema, pleural e ff usion, air in the perioesophageal space and unexplained fever. Mediastinal and deep cervical emphysema are evidence of an aerodigestive injury until proven otherwise. T he mortality rate rises exponentially if treatment is delayed. A combination of CT with oral contrast and oesoph agoscopy confirms the diagnosis in the great majority of cases. The treatment is operativ e repair of any defect and drainage. Pulmonary contusion Pulmonary contusion occurs more frequently following blunt trauma, and is usually associated with a flail segment injury and the major cause of hypoxaemia after blunt trauma. Following gunshot wounds, there is an area of contusion from the shock wave of the b ullet. The natural progression of pulmonary contusion is worsen - ing hypoxaemia for the first 24–48 hours. Chest radiographic findings may be typically delayed. Contrast CT scanning can be confirmatory . Haemoptysis or blood in the endotracheal - tube is a sign of pulmonary contusion. In mild contusion, the treatment is oxy gen administration, pulmonary toilet and ade - - quate analgesia. In more severe cases mechanical ventilation is - necessary . Normovolaemia is critical for adequate tissue perfu - sion and fluid restriction is not advised. Potentially life-threatening injuries

Thoracic aortic disruption Traumatic aortic rupture is a common cause of sudden death after a vehicle collision or fall from a great height. The vessel is relatively fixed distal to the ligamentum arteriosum, just distal to the origin of the left subclavian artery . The shear forces from a sudden impact disrupt the intima and media. If the adventitia is intact, the patient may remain physiologically non-compromised. Thoracic aortic injury should be clinically suspected in patients with gross asymmetry in systolic blood pressure (between the two upper limbs, or between upper and lower limbs), widened pulse pressure and chest wall contusion. Erect c hest radiography can also suggest thoracic aortic disruption, the most common radiological finding being a widened media stinum (Figure 29.4). The diagnosis is confirmed by a CT scan of the mediastinum (Figure 29.5). In the hypotensive patient, widening of the mediastinum and aortic injury is not the cause of the hypotension. Inv ariably , these patients have other inju ries causing hypotension as patients with complete aortic dis ruption rarely , if ever, survive to reach hospital. In the presence of thoracic aortic injury , initial manage ment consists of control of the systolic arterial blood pres sure (to less than 120 /uni00A0 mmHg). Thereafter, an endovascular intra-aortic stent (Figure 29.6) can be placed, or the tear can be operatively repaired by direct repair or by excision and grafting using a Dacron g raft. Tracheobronchial injuries Severe subcutaneous emphysema with respiratory compromise can suggest tracheobronchial disruption. A chest drain placed on the a ff ected side will reveal a large air leak and the collapsed lung may fail to re-expand. Bronchoscopy is diagnostic. Treat ment involves intubation of the una ff ected bronchus followed by operative repair. Referral to a trauma centre is advised. - - - - - -

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Rectum

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Renal and urological tract injury

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In physiologically non-compromised patients, CT scanning with contrast is the investigation of choice. For assessment of bladder injury a cystogram should be performed at the time of CT . A minimum of 300 /uni00A0 mL of contrast is instilled into the bladder via a urethral catheter. The large volume is essential because a small volume may not distend the bladder enough to produce a leak from a small bladder injury , once the cystic muscle is contracted. Generally , renal injury is managed non-operatively unless the patient is physiologically compromised. The kidney can be angioembolised if required. Henri Albert Charles Antoine Hartmann , 1860–1952, Professor of Clinical Surgery , Faculty of Medicine, University of Paris, Paris, France. - Ureteric injury is rare and is generally due to penetrating trauma. Most ureters can be repaired or diverted if necessary , or may even be ligated as part of damage control procedures. Intraperitoneal rupture of the bladder, usually from direct blunt injury , will require surgical repair. Extraperitoneal rup - ture is usually associated with a fracture of the pelvis and will heal with adequate urine drainage via the transurethral route . Suprapubic drainage is reserved for when this is not possible. - Summary box 29.7 Injuries to structures in the abdomen /uni25CF - /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF

2 2 3 Figure 29.10 The zones of the retroperitoneum. Zone 1, central; zone 2, lateral; zone 3, pelvic. In children, splenic injury can be managed non-operatively in most cases, but not if physiologically compromised Duodenal injuries are often associated with pancreatic trauma Bowel injuries need urgent de /f_i nitive repair, or isolation using resection or by stapling Rectal injuries are managed depending on whether intra- or extraperitoneal Kidney and urinary tract injuries are best diagnosed with contrast CT scanning Intraperitoneal bladder tears need formal repair and drainage

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Retroperitoneum

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Injury to the retroperitoneum is often di ffi cult to diagnose, especially in the presence of other injury , when the signs may be masked. Diagnostic tests (such as ultrasound and DPL) may be negative. The best diagnostic modality is CT , but this requires a physiologically stable patient. The retroperitoneum is divided into three zones (Figure 29.10) for the purposes of intraoperative management in blunt trauma: explored, once proximal and distal vascular control has been obtained. /uni25CF Zone 2 (lateral): lateral haematomas should only be ex plored if they are expanding or pulsatile or penetrating injury is present. They are usually renal in origin and can be managed non-operatively , although they may some times require angioembolisation. /uni25CF Zone 3 (pelvic): as with zone 2, these should only be explored if they are expanding or pulsatile or penetrating injury is present. Pelvic haematomas are exceptionally di ffi cult to control and, whenever possible, should not be opened; they are best controlled with compression or extraperitoneal packing, or, if the bleeding is arterial in origin, with angioembolisation.

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Small bowel

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- The small bowel is frequently injured as a result of blunt trauma. - The individual loops may be trapped, causing high-pressure rupture of a loop or tearing of the mesentery . Penetrating trauma is also a common cause of injury . control takes priority and these wounds can be temporarily controlled with simple sutures. In blunt trauma with mesenteric vessel damage, the bowel ischaemia that results will dictate the extent of a resection. Resections should be carefully planned to limit the loss of viable small bowel, but should be weighed against an excessive number of repairs or anastomoses. Haematomas in the small bowel mesenteric border need to be explored to rule out perforation. With low-energy wounds, primary repair can be performed, whereas more destructive wounds associated with military-type weapons require resection and anastomosis. Damage control ‘clip and drop’ of damaged or resected bowel may be necessary . Small bowel
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Spleen

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Splenic injury occurs from direct blunt trauma. Most isolated splenic injuries, especially in children, can be managed non-operatively . However, in adults, especially in the presence of other injury or physiological compromise, laparotomy should be considered. The spleen can be theoretically packed, repaired or placed in a mesh bag. However, in reality , splenec tomy is the safer option, especially in the compromised patient with multiple potential sites of bleeding. In certain situations, selective angioembolisation of the spleen can play a role. Following splenectomy there are significant, though tran sient, changes to blood physiology . The platelet and white count rise and may mimic sepsis. Inoculation against Pneumo coccus is advisable within 2–3 weeks, by which time the patient’s immune system has recovered. Allen Oldfather Whipple , 1881–1963, V alentine Mott Professor of Surgery , The College of Physicians and Surgeons, Columbia University , New Y ork, NY , USA. Most pancreatic injury occurs as a result of blunt trauma. The major problem is that of diagnosis because the pancreas is a retroperitoneal organ. CT remains the mainstay of accurate diagnosis. Amylase or lipase estimation is insensitive. In pene - trating trauma, injury may only be detected during laparotomy . Classically the pancreas should be treated with conser - vative surgery and closed, low-suction drainage. Injuries are treated according to the ISS system of the AAST . Injuries to the pancreatic body to the left of the superior mesenteric ves - sels and to the tail are treated by closed drainage alone, with distal pancreatectomy if the duct is involved. Proximal injuries (to the right of the superior mesenteric artery) are treated as conservativ ely as possible, although partial pancreatectomy may be necessary . The role of pyloric exclusion remains con - troversial and remains surgeon dependent. A Whipple’s proce - dure (pancreaticoduodenectomy) is rarely needed and should not be performed in the emergency situation because of the very high associated mortality rate . A damage control proce - dure with packing and drainage should be performed and the patient referred for definitive surgery once stabilised. Spleen

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Stomach

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Most stomach injuries are caused by penetrating trauma. Blood presence is diagnostic if found in the nasogastric tube, in the absence of bleeding from other sources. Surgical repair is required but great care must be taken to examine the stomach fully , as an injury to the front of the stomach can be expected to have an ‘exit’ wound elsewhere on the organ. Stomach

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