Investigation of the acute abdomen

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Abstract

The 'acute abdomen' is a common general surgery emergency resulting from conditions that range from serious life-threatening surgical pathologies to benign, gynaecological and even medical conditions. Accurate diagnosis depends on a structured systematic approach including a careful detailed history, a thorough clinical examination and appropriate investigations. Appropriate investigations are essential to confirm the correct diagnosis quickly, without delaying treatment and worsening outcome. The aim of any investigation is to:

- establish a diagnosis from a list of differentials
- provide information on the patient's fitness for surgery
- guide surgical or non-surgical management e.g. open or endovascular repair of a ruptured aneurysm.

This article will focus on the types of investigation commonly available and the potential beneficial use in achieving these aims.

Keywords Abdominal pain; acute abdomen; biochemical tests; computed tomography; diagnosis; haematology; investigation; ultrasound

Introduction

The assessment of the acute abdomen, which accounts for up to 50% of non-traumatic emergency admissions, is a main requirement of the Intercollegiate Surgical Curriculum (www. iscp.co.uk): General Surgery (2010). It states that for the acute abdomen stated trainees should be able to:

"...assess and provide the early care of a patient presenting with acute abdominal symptoms and signs. This should include localised and generalised peritonitis (acute cholecystitis, acute diverticulitis, acute pancreatitis, visceral perforation, acute appendicitis and acute gynaecological conditions), obstruction (small and large bowel — obstructed herniae, adhesions, colonic carcinoma) and localised abdominal pain (biliary colic, non-specific abdominal pain)."

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Dileep N Lobo DM FRCS FACS is Professor of Gastrointestinal Surgery at the Division of Gastrointestinal Surgery, Nottingham Digestive Diseases Centre NIHR Biomedical Research Unit, Nottingham University Hospitals, Queen's Medical Centre, Nottingham, UK. Conflicts of interest: none declared. Appropriate investigation forms a key component of assessment of the patient and providing further care. Investigations are chosen based on a list of possible differential diagnoses which have been derived from a careful history and examination of the patient. However this can be a challenging process in an emergency setting due to the patients' physiology (e.g. age, pregnancy, immunological status) and availability of an adequate history. A structured but adaptable approach is necessary to ensure effective and timely management of patients.

Anatomy and physiology

Pain is one of the most important symptoms that drive patients to visit the A&E department or be referred by their GP. It can be difficult to interpret and a good understanding of the abdominal developmental and anatomy is essential to help understand the possible aetiology of pain. Pain can be classified into three types:

Visceral pain

This is often diffuse and difficult to localize. The patient may indicate pain in the midline in cutaneous dermatomes which correspond to the level at which the visceral nerves enter the spinal cord, i.e. viscera-somatic convergence. Examples include obstruction or infarction of the small bowel pain presenting as T10 level peri-umbilical pain, or early appendicitis presenting as peri-umbilical pain. Autonomic reflexes related to visceral pain can result in nausea and vomiting, even if no gastrointestinal obstruction is present.

Somatic pain

This sharp, intense pain is often accurately localized by the patient over the area of pathology. It occurs when the abdominal wall or parietal peritoneum is involved in the pathology or has been irritated by e.g. inflammatory mediators. A good example include is acute appendicitis, where the pain classically moves from the peri-umbilical region (visceral inflammation) to the right iliac fossa (visceral and peritoneal inflammation).

Referred pain

Referred pain occurs when irritation of an abdominal viscus is not felt within the anatomical location of the organ, but at a cutaneous site which may be some distance away. This pain occurs because the convergence of visceral and somatic nerves in the spinal cord depends on the embryological origin of the abdominal viscus, which in some cases is initially distant from the abdominal cavity. For example, shoulder tip pain, which can indicate a diaphragmatic problem as both areas are innervated by C4/5 nerves.

Important exceptions

When assessing the abdomen of patients, it is also important to appreciate that the location and severity of pain can be altered in different physiological states.

Pregnancy: in pregnancy the gravid uterus can displace pelvic and lower abdominal viscera, resulting in alteration of pain location in some pathologies^{1,2} e.g. somatic pain in acute appendicitis can be located within the upper abdomen.

Elderly: the acute abdomen is common in elderly population, but diagnosis can be challenging and many suffer high morbidity and mortality.^{3–6} This is because of decreasing immune function, increasing co-morbidities (e.g. ischaemic heart disease, diabetes, chronic obstructive pulmonary disease), medications (e.g. non-steroidal anti-inflammatory drugs, steroids) and increasing incidence of malignancy, diverticular disease, infections, abdominal aortic aneurysm or mesenteric ischaemia. They also tend to wait longer before seeking medical attention and present with vague symptoms. Peritonitis may also not present with classical guarding, rigidity or rebound tenderness.⁵ White blood cells and C-reactive protein may also not be raised as much as in younger populations.

Immunocompromised patients: they (e.g. Transplant recipients, chemotherapy recipients, haematological and other malignant conditions, HIV sufferers) may also not give a good history of pain or the signs and symptoms may be reduced due to a diminished production of inflammatory mediators and decreased peritoneal irritation leading to a reduction in localized pain.⁷ The medications some of these patients are taking can also lead to their own abdominal complications.⁷ A high index of suspicion and an appreciation for the lack of clinical signs and/or positive laboratory results are required for this group.⁷

Alteration of normal anatomy: previous surgery or embryological anatomical variations, e.g. mal-rotation, sinus-invertus, can also alter the presentation and differential diagnosis of abdominal pain. (For a review regarding investigation of abdominal pain after gastric bypass, see Greenstein and O'Rourke.⁸)

The acute abdomen following trauma has been discussed elsewhere in this journal (*Surgery* 2009: **27(6)**: 266–271). Patient factors should always be appreciated when generating a list of differential diagnosis and organizing timely investigations.

Generating a differentials list

Causes of an acute abdomen

Common causes of acute abdominal pain according to organ of origin, location and pathology as well as the extra-abdominal or systemic causes of acute abdominal pain are listed in Figure 1.

Pathophysiology of the acute abdomen

Common pathological sequences in different viscera can result in an acute abdomen. These include:

Luminal obstruction (see also *Surgery* 2011; 29(1): 33–38): any hollow viscera can become obstructed e.g. gastrointestinal tract, genitourinary system or biliary tree. These can be divided into luminal, mural and extramural. If intestinal obstruction is suspected, it is important to inquire about a history of previous surgery or symptoms suggestive of gastro-intestinal malignancy. On examination it is important to check the hernial orifices and for abdominal tenderness. Increasing tenderness in intestinal obstruction can be a sign of imminent or actual perforation of a viscus. If untreated, adynamic ileus, strangulation and perforation can occur.

Common presenting features of obstruction include:

• Colicky pain: this is classically intermittent gripping pain which is referred to the dermatomes supplying the part of the luminal structure proximal to the obstruction. The frequency and duration of the pain is related to the rate of peristalsis of the blocked structure. However this can develop into continuous pain if inflammatory mediators or ischaemia develop. It is also important to note that in biliary colic, the contraction of the gallbladder can be prolonged resulting in continuous pain which can last several hours.

- Vomiting: this is a prominent feature of upper gastrointestinal obstruction, for example gastric outlet or small bowel obstruction. Large bowel obstruction often results in constipation being an early feature, while vomiting tends to occur later if the obstruction is not resolved. If the ileocaecal valve is competent, patients with large bowel obstruction may not vomit but have an increased risk of perforation.
- Abdominal distension: this is a more prominent feature of lower gastrointestinal obstruction, for example large bowel obstruction. It is often associated with absolute constipation (no passage of wind).

It is important to recognize that patients with high obstruction may continue to pass stool, as the gastrointestinal tract distal to the obstruction continues to empty. Conversely those with large bowel obstruction commonly develop early constipation with vomiting as a late feature. Therefore passing faeces does not rule out obstruction, as this can still occur with partial obstruction.

Inflammation: any intra-abdominal organ can become inflamed. In most instances this is caused by infection (with or without luminal obstruction) or ischaemia. In some instances this can be self-limiting and treated with antibiotics, for example diverticulitis, cholecystitis. However, in some cases if left untreated gangrene and perforation may occur. This can lead to peritonitis.

Peritonitis: guarding, rigidity and rebound tenderness are often present. The patient will often keep still and be reluctant to be examined. The gastrointestinal tract may cease peristalsis resulting in abdominal distension and absent bowel sounds as the condition progresses. Importantly in the elderly or immuno-suppressed patients (e.g. those taking steroids or having chemotherapy) these symptoms and signs may be reduced and so a high index of suspicion is required in these patients.

Causes of peritonitis are listed in Figure 1. Any perforated viscus may release contents that can irritate the peritoneum, for example bowel contents, bile, urine, pus and blood, and lead to peritonitis. Patients with peritonitis are often septic (Table 1) with or without shock (end organ hypoperfusion and/or hypotension (septic shock)). It is essential to resuscitate these patients at the same time as diagnose and treat the underlying cause. Input from other specialities, for example critical care, is important. If possible a diagnosis of the underlying cause of peritonitis should be made to help plan surgery. However this should not delay definitive treatment.

Ischaemia and infarction: arterial or venous infarction can occur. Causes can be again divided into intra (e.g. emboli or thrombosis) or extra luminal (e.g. volvulus, intussusception, hernia, tumours and aortic dissection). These differential diagnoses should be suspected in patients with vascular disease and atrial fibrillation.

Hiatus hernia/reflux

1. Oesophagus (T5-6)

Causes: Oesophagitis

Spasm

. Rupture⁺

Sites and common causes of acute abdominal pain

1. Liver (T7-9)

+/- Referred to tip of shoulder. **Causes:** Active hepatitis Liver abscess Bleed into cyst/tumour Infarction Congestive cardiac failure

2. Biliary Tract (T7-9)

+/- Radiates along rib cage. **Causes:** Biliary colic Cholecystitis Mucocele/empyema Gangrenous/perforation* Biliary tract obstruction Ascending cholangitis

1. Kidney (T10-L1)

+/- May radiate to testis/labia **Causes:** Calculi Pylonephritis Bleed into cyst/tumour Tumours Obstruction

1. Appendix

+/- Moves to RIF or becomes generalized Causes: Appendicitis Abscess Perforation* Tumour

1. Large bowel (T11-L2)

+/- may localize to inflamed area or become generalized. **Causes:** Infection, e.g. Salmonella Inflammatory bowel disease Diverticulitis Constipation Obstruction*/perforation* Ischaemia/infarction

1. Urinary (T11–12) Causes: Cystitis Acute retention Obstruction (stone/tumour)

1. Male reproductive organs (T10-11) +/- Radiate to hypogastrium, right and left lower quadrants Causes: Epididymo-orchitis Torsion Trauma Tumours

1. Pancreas (T6-10)

+/- Radiates to back and eased by sitting forwards. Causes: Acute pancreatitis Acute on chronic pancreatitis Pancreatic cancer Pancreatic obstruction

2. Stomach (T6-10)

Causes: Gastritis Gastric ulcer Gastric cancer Perforation*/obstruction

3. Duodenum

Causes: Duodenal ulcer Perforation*/obstruction

1. Spleen (T6–10)

Causes: Splenomegaly Infarction Sickle cell crisis Infection, e.g. Epstein--Barr virus Rupture/haematoma*

1. Aorta

+/- Radiates to flank/back or becomes generalized **Causes:** Rupture/dissection

1. Small bowel (T9-10)

+/- may localize to inflamed area or become generalized. **Causes:** Gastroenteritis Irritable bowel syndrome Mesenteric adenitis Meckel's diverticulitis Crohn's disease Obstruction* Ischaemia/infarction Perforation*

1. Female reproductive organs (T12-L1)

+/- may be referred to inner thighs or become generalized. **Causes:** Ectopic pregnancy Endometriosis Mittelschmerz Dysmenorrhoea Ovarian cyst/torsion Pelvic inflammatory disease

Other causes:

Abdominal wall: Hernia, Haematoma, Abscess, Neuropathy, Herpes Zoster.

Extra-abdominal: Pneumonia, Pulmonary embolism, Myocardial infarction, Congestive cardiac failure, Myocarditis, Diabetic ketoacidosis, Adrenal insufficiency, Porphyrias, Systemic lupus erythematosus, Henloch-Schnlein purpura, Lead poisoning, **Post-operative:** Intra-abdominal bleeding or collection, Anastomotic leak/dehiscence, Abdominal compartment syndrome.

Key

(T) Segmental innervation of viscera.

 * Perforation may be localized or generalized: NB Rebound pain, Guarding, Rigid abdomen +/- absent bowel sounds.
 * Causes of bowel obstruction: (a) Luminal: Foreign body, Bezoars, Gallstone ileus (b) Mural: Tumours, Intussusception, Benign strictures e.g. diverticula/Crohn's/ischaemic, (c) Extra-Mural: Adhesions, Hernia, Volvulus, Abdominal aortic aneurysm.

Definitions of systemic inflammatory response syndrome (SIRS) and sepsis

SIRS	Two or more of:			
	• Tachycardia (>90 bpm)			
	 Temperature (>38 or <36°C) 			
	 Respiratory rate >20 or pCO₂ <4.3 kPa 			
	• White blood cell count >12 or $<4 \times 10^{9}/$			
	litre or $>10\%$ immature cells			
Sepsis	SIRS with known source of infection			
Severe sepsis	Evidence of end organ hypo-perfusion, e.g.			
	altered renal function (raised urea and			
	creatinine), respiratory failure, disseminated			
	intravascular coagulation			
Septic shock	Hypotension (systolic BP $<$ 90) after fluid			
	resuscitation.			
	Required inotropes to maintain blood			
	pressure			

Table 1

Visceral ischaemia and infarction can be difficult to diagnose, but delay can prove fatal. Pain can vary in intensity, site and character and may be out of proportion to physical findings. Anorexia, nausea, vomiting, diarrhoea or bleed can also occur. The production of pro-inflammatory cytokines, bacterial translocation and anaerobic metabolites entering the circulation can make the patient acutely unwell or develop septic shock. Resuscitation and prompt laparotomy is often required. Arterial lactate concentration can be greater than 2 mmol/litre and CT features, such as pneumatosis cystoides intestinalis, can be helpful in diagnosis.⁹

Non-specific abdominal pain: this is a diagnosis of exclusion and often requires patients to be admitted to hospital for 24–48 hours to allow observation and investigation. Occasionally these patients are re-admitted with recurrent abdominal pain. Each patient should be investigated thoroughly. Causes which can sometimes be labelled as 'non-specific abdominal pain' can include:

- infections (e.g. viral parasitic infestations, gastroenteritis, mesenteric adenitis)
- physiological pain (e.g. ovulatory pain, period pain)
- functional gastrointestinal conditions (e.g. irritable bowel syndrome, dyspepsia)
- other causes, such as domestic violence (with abdominal trauma not disclosed), torsion of the appendices epiploicae of the colon (rare).

Often the pain will settle, but investigation by CT, US (perabdominal and trans-vaginal) and even laparoscopy may be required.

In some (rare) cases patients seek admission to hospital without genuine abdominal symptoms. Munchausen's syndrome patients can present with a dramatic history of an acute abdomen and simulate the necessary physical signs. They often appear to be in a great deal of distress. Many of these patients may be admitted for observation for several days before the true diagnosis is revealed. It is useful to investigate the background by contacting doctors who have treated the patient in the past. These patients usually leave the hospital without informing the staff, once this process of enquiry starts or when they fail to obtain the treatment sought. However, even patients with established Munchausen's syndrome may sometimes present with real pathology.

Management of the acute abdomen

Resuscitation of the patient with effective investigation of the underlying causes and prompt treatment often have to occur simultaneously. In all cases the patient's pre-morbid state and comorbidities should be considered.

Initial management

Initial management and assessment follows advanced trauma life support (ATLS) and care of the critically ill surgical patient (CCrISP[®]) principles. As many patients will require surgery, they should be kept nil by mouth and intravenous (IV) access sought through two large-bore cannulae.

History

Detailed histories from the patient, relatives and pre-hospital and other hospital staff (if necessary) are important for diagnosis. Important questions to ask when assessing an acute abdomen are listed in Box 1. As decisions in resuscitation and operative treatment are assisted by past medical history, co-morbidities and pre-morbid physical state, it is important not to miss these questions by being too focused on the abdominal history.

Clinical examination

Examination should follow a systematic approach. It is important to assess all emergency patients using the ATLS and CCrISP principles. It is important to document the vital signs, including pulse rate and rhythm, blood pressure, respiratory rate,

Questions to ask when taking the history of a patient with acute abdomen

- Where did the pain start?
- Was the onset sudden?
- What brought the pain on?
- Are there any aggravating or relieving factors?
- Where is it now?
 - Does it radiate elsewhere?
- What is the character of the pain and how severe is it?
- Are there any associated symptoms? (e.g. distension, nausea, vomiting, fever, diarrhoea, absolute constipation, rectal bleeding, anorexia, jaundice, prutitus, gastrointestinal bleeding, dysuria, oliguria, chest pain)
- Was there a similar episode in the past?
- When was your last period and is there any chance of being pregnant?
- History of alcohol intake
- Drug history
- History of previous surgery and pre-existing disease
- History of travel, especially foreign travel
- Family history

saturations, temperature and the Glasgow coma score. As all patients potentially need surgical management, cardiovascular and respiratory examinations are important, to exclude underlying pathology. A careful and thorough examination of the main system affected, for example the abdomen, and other relevant systems should occur. Per rectum, genital and vascular examinations should be performed, as it is easy to miss associated signs in these areas. All signs must be interpreted in conjunction with the patient's history and the general condition, age, gender, and potential risk factors.

Resuscitation and immediate management

In patients who require resuscitation, assistance from anaesthetic and intensive care unit (ITU) staff may be required. Resuscitation can be performed with IV crystalloids or colloids. Urine output can be monitored with a catheter and guide resuscitation. A central line may aid fluid resuscitation in patients where fluid resuscitation is difficult to assess, such as cardiac failure, sepsis (+/- shock), severe acute pancreatitis with third space losses. In bleeding patients (e.g. those with aortic aneurysm rupture), blood may be required as part of immediate resuscitation (see ATLS guidelines). It is important to contact seniors, anaesthetic and critical care staff early if a patient is acutely unwell, for example hypovolaemic or in septic shock (Table 1), and they are likely to require critical care or emergency surgery. The indications for immediate surgery are shown in Table 2.

In vomiting patients, a nasogastric tube can help monitor gut losses and provide symptomatic relief. Analgesia should be offered to patients in pain as it will not mask abdominal signs or the ability to make a diagnosis, and aids patient comfort.¹⁰

Indications for emergency surgery				
NCEPOD Time delay Examples				
1	Immediate	Life threatening: often needs resuscitation simultaneously with surgery Ruptured abdominal aortic aneurysm Ruptured spleen Internal bleeding		
1a	Within 6 hours	Major trauma Life threatening but not immediate. Often needs resuscitation prior to theatre Perforations Large bowel obstruction (esp. closed loop or tenderness) Ischaemic bowel		
2	Within 24 hours	Toxic megacolon Septic patients with NCEPOD two indications Urgent: deterioration of condition threatens life Appendicitis		

NCEPOD, National confidential enquiry into peri-operative deaths score. Score 3 (expedited) and 4 (elective) not shown.

Table 2

Morphine can be effective and can be administered by the IV or subcutaneous (SC) route. In renal colic, non-steroidal antiinflammatory drugs (NSAIDs) as well as opioids can be very effective.¹¹ In those with sepsis, antibiotics can be commenced after appropriate samples, such as blood culture and mid-stream urine, have been taken. Microbiological advice should be sought if there is doubt over the diagnosis or organisms involved. This is especially the case in people who have had previous infections with antibiotic-resistant organisms or who are immunocompromised. It is also important to note that some antibiotics are contra-indicated in pregnancy and advice should be sought in these incidences.

Investigations

Blood and non-radiological investigations: Table 3 lists common investigations and their indications.

X-rays: radiological investigations should be requested once the patient has been stabilized.

The usual initial radiological investigations of the acute abdomen are:

Erect chest – free gas can be seen in approximately 70–80% of bowel perforations (Figure 2). Care should also be taken not to misinterpret a loop of large bowel positioned between the hemidiaphragm and liver or spleen, as free gas. This is a normal variant and is called Chilaiditi's syndrome with haustra often seen to aid the diagnosis (Figure 3). Pneumonias, pleural effusions, pulmonary metastasis, raised hemi-diaphragms (e.g. subphrenic collections – which can have gas/fluid levels), and widened mediastinum (e.g. aortic dissections) can all be visualized and aid diagnosis. Signs of co-morbidities such as cardiac and respiratory disease may also be identified.

Supine abdominal X-ray – the Royal College of Radiology has produced guidelines for the use of plain abdominal X-rays in the acute abdomen.^{12,13} These can be useful in:⁹

Bowel obstruction: dilated loops of bowel indicating small and large bowel obstruction may be seen. But a normal X-ray does not exclude the diagnosis if a good history of obstruction is obtained,¹³ as fluid-filled loops of dilated bowel may not be visible on the X-ray. Dilated small bowel can be recognized by valvulae conniventes, which cross the full diameter of the bowel (Figure 4). In the large bowel, the haustra cross only half the diameter (Figure 5). Plain X-rays can also demonstrate classic signs associated with some specific pathologies, such as sigmoid or caecal volvulus (Figure 6). Gallstone ileus is a rare cause of small and large bowel obstruction with two additional classical features: (a) air within the biliary tree (pneumobilia), which stands out against the dense liver parenchyma (b) calcified gallstone – only visible in 10%. However, a CT scan is usually more sensitive in identifying this (Figure 7). Opacity of one of the obturator foramen, which can be seen on plain abdominal Xrays, can indicate a rare obturator hernia.

Perforations: although an erect chest X-ray is the first line radiological investigation for suspected perforation,¹³ Rigler's sign may be identified, indicating intra-abdominal free gas. Rigler's sign is when both sides of the bowel wall can be observed, when usually only one side (luminal) is seen. Historically a left lateral decubitus film was used in patients who are unable to sit up for an erect chest X-ray. However a CT may

Common investigations and their indications

Investigation	Significance			
Full blood count	Haemoglobin Leukocytes	 ↓ acute or chronic blood loss ↑ dehydration or intravascular depletion e.g. third space loss ↓ or ↑ can be found in inflammation/Infection or infarction 		
	Platelets	 ↑ in inflammation e.g. inflammatory bowel disease ↓ can occur in overwhelming sepsis 		
Urea and electrolytes	$\downarrow \mathbf{Na^+} \downarrow \mathbf{K^+} \downarrow \mathbf{Cl^-}$ can be due to profuse vomiting			
	\downarrow Na ⁺ \uparrow K ⁺ can indicate an addisc	onian crisis		
	\uparrow urea & \uparrow creatinine can be found in dehydration or end organ failure			
Glucose	Aid diagnosis of diabetic ketoacidosis (DKA)			
Amylase (and lipase)	↑> four upper limit of normal suggests pancreatitis ^a			
	↑in perforation and bowel infarction			
Liver function tests	↑in biliary tract obstruction or liver injury ^{b,d}			
Pregnancy test (βhCG)	Important to exclude ectopic pregnancies in women of child-bearing age $^{\mathrm{c}}$ Urine or blood			
Group and save (G&S) or	G&S should be performed in all patients going to theatre			
cross-match	Cross-match blood should be requested if bleeding is suspected, e.g. abdominal aortic aneurysm			
Arterial blood gas	$\downarrow pH \downarrow BE \uparrow lactate$ can indicate metabolic acidosis from severe sepsis, pancreatitis or ischaemic bowel			
	Can be useful is assessing respiratory function in patients with co-morbidities			
Urine	Blood may be infections, trauma, calculi or a ruptured aortic aneurysm			
	n of DKA			
	Leucocytes and nitrites often indicate urinary infection			
	Leukocytes can be found in appen	dicitis or diverticulitis		
	Samples should be sent for micros	scopy, culture and sensitivity (M/S/C)		
Electrocardiography	Changes can occur in myocardial infarction, myocarditis or pericarditis and aortic dissections			
	Indicated in anyone >50 years pri-	or to surgery		
^a NB normal for 72 hours after onset and in chronic pancreatitis.				

^b See investigations into obstructive jaundice (Ref X).

^c See gynaecological causes of pain (Ref X2).

^d Jaundice, right upper quadrant pain, fever and rigors (Charcot's triad) suggest ascending cholangitis.

Table 3

provide a more accurate diagnosis of localize perforations and obstructions as well as underlying pathology.¹³

Other pathology: calcifications in chronic pancreatitis and aortic aneurysms, renal tract stones (90%) and even gallstones (10%) may be observed. Thumb printing or intra-mural gas can be a sign of necrotizing enterocolitis or intestinal ischaemia.

It is important to recognize that a normal X-ray does not exclude intra-abdominal pathology. All investigations should be interpreted with the clinical history and examination findings. In most patients conventional radiography needs to be supplemented with US or CT, which have an overall higher sensitivity (CT: 96% vs X-ray; 30%).^{9,14}

Ultrasonography: this cheap, widely available investigation is excellent in demonstrating abnormalities in fluid and solid structures. It can also aid identification of structures over areas of maximum tenderness and does not involve radiation, so can be used in pregnancy. It is still the modality of choice in suspected biliary colic or cholecystits, but can provide useful information in suspected liver, renal and female reproductive system pathology. Obesity, bowel gas and pneumo-peritoneum can obscure the views and detailed views of retroperitoneal structures such as the pancreas can be difficult. US is also operator dependent. The experience of the operator can affect the sensitivity and accuracy of diagnosis. US can be used in confirming appendicitis and is now routinely used in trauma as the FAST assessment (focused assessment using ultrasonography in trauma) to identify free fluid and AAA.

US and colour Doppler now allows observation of flow within the vasculature, and can be used in assessing patients with venous and arterial pathology. Ultrasound can also be used in treatment. Guided drainage of intra-abdominal abscess may avoid operations, especially in unfit patients. Emergency drainage of obstructed hydronephrosis or pyonephrosis can prevent imminent renal loss and allow definitive surgery to be planned.

CT: CT scans provide accurate, detailed cross-sectional images and even three-dimensional reconstructions in a wide variety of conditions.⁹ It is widely available and increasingly used in the emergency setting for diagnosis, especially in challenging patient groups, such as the elderly^{15,16} or the immunocompromised.^{7,17}



Figure 2 Patient with a perforated duodenal ulcer. (a) Pneumoperitoneum on erect CXR – arrow shows subtle gas under diaphragm. (b) Pneumoperitoneum on CT – arrow shows extra-luminal gas. (c) Pneumoperitoneum on a different patient with a perforated ulcer – obvious gas under both domes of the diaphragm (arrows).



Figure 3 Chilaiditi's syndrome. (a) Erect chest X-ray — arrow points to the transverse colon, not pneumoperitoneum. (b) Computed tomography of same patient — arrow points to the transverse colon anterior to the liver.

It is more sensitive than US (89% vs. 70% p < 0.001)⁹ and is not affected by the factors which limit US.¹⁸ Intravenous and oral contrast agents can improve accuracy of diagnosis in some cases.⁹ However IV contrast must be used with care in patients who are taking metformin and may be contraindicated in patients with renal insufficiency.

CT is useful in providing or excluding diagnoses in acutely ill patients and can provide vital information to allow planning of surgical procedures. In haemodynamically stable patients with aortic aneurysms, CT provides anatomical data that can identify those suitable for endovascular repair. The causes of large bowel obstruction may be identified allowing appropriate surgery (see Figure 5). A loop colostomy or endoscopic stent may be suitable in some patients for palliation in wide spread malignancy or as a bridge to definitive elective surgery.¹⁹ This may be more appropriate than a laparotomy in some cases, which may delay chemotherapy or other medical management. A CT scan is often helpful in the diagnosis of intestinal obstruction due to rare hernias such as a Richter's hernia. CT is also often used to categorize palpable masses in the abdomen prior to planning surgical management.



Figure 4 Adhesive small bowel obstruction. (a) Small bowel obstruction on abdominal X-ray – distended small bowel loops. (b) CT of the same patient – arrow showing transition point between obstructed and collapsed small bowel.

However the radiation dose of CT is much greater than conventional X-ray (X-ray approximately 0.1–1.0 mSv vs. CT approximately 10 mSv). It is estimated that giving this dose of radiation to a 25 year-old will cause one cancer in 900 individuals and a fatal cancer in one in 18,000 individuals.²⁰ It is contraindicated in pregnancy for these reasons. However for older individuals these risks are much lower.⁹ In all cases the risks of future malignancy versus the clinical benefit should be weighed up.

Magnetic resonance imaging (MRI): although MRI is not widely available or used in investigation of the acute abdomen, it is useful in patient groups who cannot be exposed to radiation (e.g. pregnancy).² Its excellent tissue resolution also means that IV contrast medium is not required.⁹ It has been demonstrated to be accurate in the diagnosis of appendicitis and diverticulitis.^{2,21} It



Figure 5 Large bowel obstruction secondary to obstructing sigmoid cancer. (a) Abdominal X-ray showing large and small bowel dilatation. (b) Computed tomography abdomen of the same patient with an obstructing sigmoid cancer (arrow).

has also been shown to be more accurate than CT in the diagnosis of cholecystitis and bile duct stones.²² However there have been limited studies into its general use in abdominal pain.⁹

Interventional radiology:

Visceral angiography – although intestinal ischaemia and haemorrhage is most commonly diagnosed with CT angiography,²³ interventional angiography can provide further information about intestinal ischaemia and gastrointestinal haemorrhage as well as allow embolization of vessels.⁹ This may prevent the need to operate on patients with gastrointestinal or pelvic bleeding. However it requires specialist radiological input which may not be available in all hospitals.

Other investigations:

Endoscopy - in cases of rectal bleeding or volvulus, rigid sigmoidoscopy can be utilized. This may sometimes identify the source of bleeding (e.g. a malignancy), or indicate if it is



Figure 6 Caecal volvulus on abdominal X-ray. Note - coffee-bean sign arising out of left iliac fossa.



Figure 7 Gallstone ileus. (**a**) Pneumobilia (arrow) on abdominal CT, (**b**) Gallstone obstructing the duodenum (arrow) in the same patient.

proximal to the rectum. In volvulus a flatus tube may be passed under direct vision to untwist the bowel and relieve the obstruction.

Flexible sigmoidoscopy and colonoscopy can aid diagnosis of several causes of the acute abdomen, including inflammatory bowel disease and malignancy. Colonic stent insertion at endoscopy may relieve large bowel obstruction, and is an alternative to stoma formation.

Gastroscopy can confirm the presence of gastric and duodenal ulcers, malignancy, gastritis and coeliac disease. Endoscopic retrograde cholangiopancreatography (ERCP) can also be therapeutic in relieving biliary obstruction, especially in ascending cholangitis.

Water-soluble gastrointestinal contrast studies – these can be useful in the diagnosis of mechanical large bowel and pseudoobstruction, although CT is used more frequently and can provide additional information of the pathology involved.⁹ In pseudo-obstruction, contrast studies can sometimes be therapeutic. In postoperative patients they are also useful in identifying anastomotic leaks. Small bowel follow-through examinations are also helpful for identifying rarer causes of mechanical small bowel obstruction (e.g. tumours), which can be difficult to diagnose.

Laparoscopy/**laparotomy** – laparoscopy is useful in patients in whom the exact diagnosis is unclear despite appropriate noninvasive investigation, especially if appendicitis, cholecystitis, perforated peptic ulcer or pelvic inflammatory disease are suspected.²⁴ Early laparoscopy can provide a higher diagnostic accuracy and allow treatment in patients with acute abdominal pain of uncertain aetiology.²⁵

Conclusion

Investigations are essential to allow accurate and timely patient assessment and diagnosis. However these should not take the place of good history taking and clinical examination. It is essential to be aware of the limitations and potential complications when requesting investigations, to make sure they are appropriate for the patient and the suspected diagnoses.

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