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Jan O Jansen, Steven R Yule and Malcolm A Loudon

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Jan O Jansen,[1] Steven R Yule,[2] Malcolm A Loudon[1]

[1]Department of Surgery, Aberdeen Royal Infirmary, Aberdeen AB25 2ZN

[2]Department of Radiology, Aberdeen Royal Infirmary

Correspondence to: J Jansen
jan.jansen@nhs.net

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Concealed haemorrhage is the second most common cause of death after trauma,[1] and missed abdominal injuries are a frequent cause of morbidity and late mortality in patients who survive the early period after injury. Appropriate and expeditious investigation facilitates definitive management and minimises the risk of complications, so it is crucially important.

Several high quality prospective and retrospective studies have shown non-operative management of solid organ injury to be safe and effective, and this strategy is now accepted into mainstream practice.[2-4] In parallel, a paradigm shift has occurred in imaging algorithms, with greater emphasis being put on the detection of specific findings, rather than the mere detection of intraperitoneal fluid, which does not predict the need for intervention.[5] The greater availability of computed tomography and ultrasound in emergency departments has contributed to changes in practice, but it has also created new controversies—diagnostic peritoneal lavage is now rarely performed, but the diagnosis of hollow viscus injury by imaging alone remains contentious.

The selection of appropriate investigations is therefore of key importance. The initial management of major trauma, and consequently the choice of investigations, still often falls to non-specialist or junior doctors with limited experience in this field,[6] and this article aims to provide a structured evidence based approach to the investigation of blunt abdominal trauma in adults.

Why investigate blunt abdominal trauma?

Unlike penetrating abdominal trauma, where management is largely determined clinically, the diagnosis of blunt abdominal injury by clinical examination is unreliable, particularly in patients with a decreased level of consciousness.[6-9] Confirmation of the presence or absence of injury therefore relies largely on the use of diagnostic adjuncts. Late diagnosis and missed injuries are associated with poor outcome. A large prospective observational study of patients with blunt polytrauma but no clinical signs of injury—which found radiological evidence of abdominal injury in almost 10% of patients—and a recent consensus guideline suggest that the threshold for investigation of blunt abdominal trauma should be low.[10 11] Accurate imaging facilitates selection for non-operative management, where appropriate, and reduces non-therapeutic laparotomy rates.[4] The main first line investigations are ultrasound, diagnostic peritoneal lavage, and computed tomography. These tests are complementary rather than interchangeable, and their usefulness depends on the clinical context.

How useful is plain abdominal radiography?

Plain abdominal radiography has no role in the assessment of blunt abdominal trauma, although some authorities continue to advocate its use.[5 12] Little evidence exists to support such a recommendation, and it is difficult to justify conceptually—plain abdominal radiography does not visualise abdominal viscera or detect free fluid, so it cannot provide direct evidence of organ injury or indirect evidence of haemorrhage. Abdominal radiography may provide indirect evidence of hollow viscus injury by showing air or gas in the peritoneum, but it lacks sensitivity and specificity. Chest and pelvic radiography continue to be important adjuncts to the primary survey. The results may suggest haemorrhage in adjacent cavities, but they cannot rule out intra-abdominal bleeding or visceral injury.

What is the role of diagnostic peritoneal lavage?

Diagnostic peritoneal lavage was first described in 1965 and rapidly became the standard of care. It involves accessing the peritoneal cavity, either through an "open" approach, similar to the Hassan technique for inserting a laparoscopic port, or using a percutaneous Seldinger-type set. Once the catheter has been placed in the peritoneal cavity, any fluid present is aspirated. More than 10 ml of blood or the presence of gastrointestinal content is considered a frankly positive result and mandates laparotomy. In the absence of

Tips for non-specialists

Signs of blood loss and hollow viscus injury may initially be subtle

A normal ultrasound scan (focused abdominal sonography for trauma or formal) does not exclude injury

The diagnosis or exclusion of hollow viscus injuries can be problematic

these findings, one litre of warmed normal saline is infused into the peritoneal cavity and then drained. A sample of the effluent is examined in the laboratory. The presence of >100 000 red blood cells/mm^3 indicates a clinically relevant haemoperitoneum, whereas the presence of >500 white blood cells/mm^3 or vegetable matter signifies a hollow viscus injury. The presence of any of these parameters is regarded as an indication for laparotomy.

A large well conducted prospective study showed diagnostic peritoneal lavage to be a highly accurate (sensitivity 95%, specificity 99%) test for intraperitoneal blood.[13] Diagnostic peritoneal lavage is more sensitive than computed tomography or ultrasound for the detection of hollow viscus injuries,[10] but does not exclude retroperitoneal injury. Unlike ultrasound or computed tomography, diagnostic peritoneal lavage is an invasive procedure and carries with it a small risk of visceral injury (0.6%).[13] Although in principle this procedure is easy and quick to perform, this is not always the case—particularly in inexperienced hands, in uncooperative or obese patients, and in those who have had previous abdominal surgery—and the need for microscopic analysis can delay further management. The infusion of lavage fluid, which is never completely removed, may also interfere with the interpretation of subsequent imaging.

Not all patients with a haemoperitoneum need laparotomy, and the biggest drawback of diagnostic peritoneal lavage is the resulting high non-therapeutic laparotomy rate of up to 36%.[14] Ultrasound has therefore replaced diagnostic peritoneal lavage in Europe and North America as the investigation of choice in haemodynamically unstable patients.[12 15 16] When resources are constrained, however, diagnostic peritoneal lavage is a good way to determine the presence of intraperitoneal blood, and it continues to have a role as a second line investigation in the diagnosis of hollow viscus injuries.

How reliable is ultrasound?

Abdominal ultrasound can be used to look for organ injury and free intra-abdominal fluid, which after trauma is assumed to be blood or gastrointestinal content, and provides indirect evidence of injury. Ultrasound is non-invasive, does not use ionising radiation, is repeatable, and can be performed in the emergency department, concurrently with other aspects of resuscitation. Focused abdominal sonography for trauma (FAST) is an abbreviated, protocolised form of ultrasound that seeks only to demonstrate intraperitoneal and pericardial fluid. With appropriate training—usually a taught course followed by a period of supervised practice—focused abdominal sonography for trauma can be performed by non-radiologists.[15] Several well conducted prospective observational studies found this technique to be sensitive (79-100%) and specific (95.6-100%), particularly in haemodynamically compromised patients.[17-20]

A formal abdominal ultrasound examination, usually performed by a radiologist, looks for organ injury and free fluid. A recent review combining the results of eight major published series reported a sensitivity of 74% for organ injury.[5] The resulting consensus guideline concluded that ultrasound is not a satisfactory imaging modality for haemodynamically stable patients, because up to a quarter of hepatic and splenic injuries; most renal injuries; and almost all pancreatic, mesenteric, bladder, and gut injuries may be missed.[5] A separate meta-analysis reached similar conclusions,[21] and a Cochrane review analysing the use of treatment algorithms based on ultrasound—albeit marred by heterogeneity—found no evidence in favour of ultrasonography in blunt trauma.[22] A negative ultrasound does not rule out injury, and if ultrasound is used as the sole imaging modality, patients should be admitted for observation and possibly repeat examination.[5 7] When injuries are diagnosed, ultrasound does not predict the need for surgery.[5]

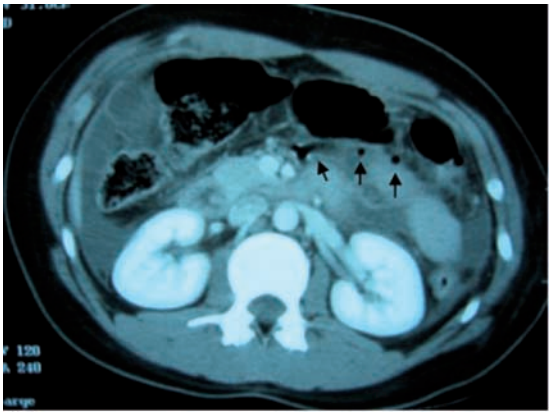

Fig 1 | Gas in small bowel mesentery (arrowed) from a tear at the duodenojejunal flexure

How useful is computed tomography?

Computed tomography is the imaging modality of choice for evaluating haemodynamically stable patients.[5 10 12] It is sensitive (92-97.6%) and specific (98.7%).[10] Its main advantage is the ability to detect arterial contrast extravasation,[23] uncontained or as a

SOURCES AND SELECTION CRITERIA

We searched the Medline database for reviews and clinical trials using the terms "blunt abdominal trauma", "blunt abdominal injury", "investigation", "computed tomography", "ultrasound", "FAST", and "diagnostic peritoneal lavage". Search results were individually reviewed and manually cross referenced. We also searched the Cochrane Library and Clinical Evidence databases, reviewed guidelines from the American College of Radiology and the Royal College of Radiologists, and used references from our personal collections. The literature is dominated by non-randomised studies, and few systematic reviews and meta-analyses are available. Most of the evidence is level II-IV.

Unanswered questions

Can hollow viscus injury be diagnosed or excluded using non-invasive techniques of investigation?

What is the role of interventional radiology, in particular embolisation, in managing abdominal solid organ injury and pelvic fractures?

What is the best modality to diagnose injury to the diaphragm after blunt trauma?

Can patients be safely discharged on the basis of a normal computed tomography scan?

pseudoaneurysm, which predicts the need for surgery or angioembolisation. Computed tomography also accurately evaluates the retroperitoneum, but it is less sensitive for detecting hollow viscus injuries,[5] although detection rates are improving with increasing experience (fig 1).[24] Computed tomography is also the modality of choice for diagnosing injuries to the diaphragm,[5] which may result in major morbidity and mortality if undetected and may not present until many years after the event.

Computed tomography does, however, involve exposure to ionising radiation and intravenous contrast media. Also, in most hospitals, the patient has to be moved away from the resuscitation area, so this technique is not appropriate in haemodynamically compromised patients. Nevertheless, turnaround times are decreasing as a result of the trend towards locating scanners in or close to emergency departments and the proliferation of new generation multidetector helical scanners with faster image acquisition times.[25]

A practical approach

The following algorithm, summarised in fig 2, is widely accepted and applicable in hospitals with access to ultrasonography and computed tomography.[5]

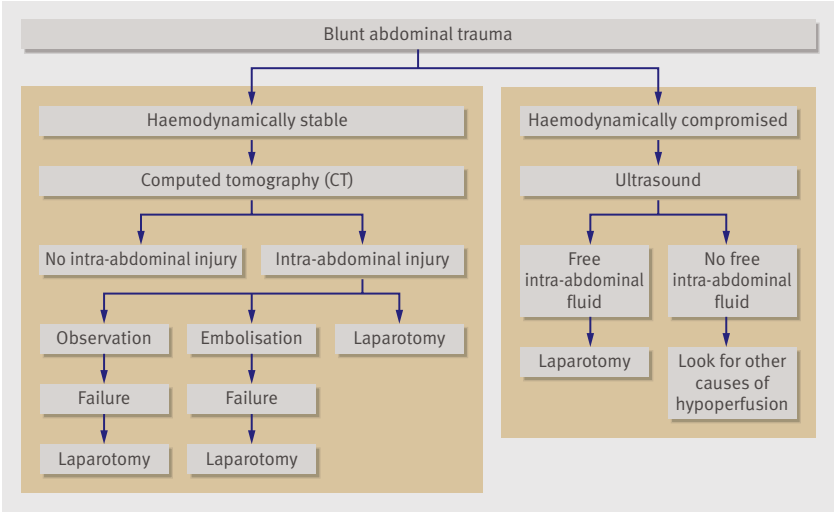

Fig 2 | Algorithm for the investigation of blunt abdominal trauma

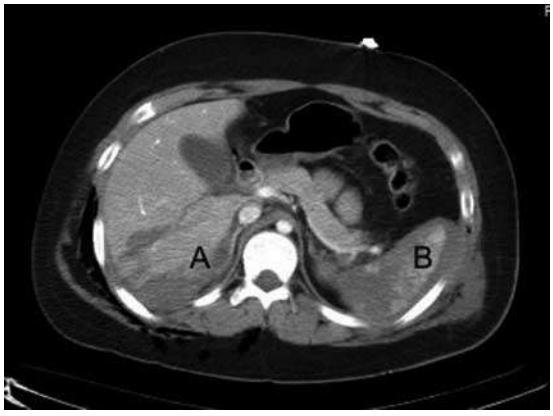

Fig 3 | Computed tomography image of a grade III liver haematoma (A) and grade IV splenic haematoma (B), with minimal free fluid.[26] The patient was managed without surgery

How should I investigate haemodynamically unstable patients?

The main aim in haemodynamically unstable patients with blunt trauma is to stop the bleeding. This will usually require laparotomy if the source of the haemorrhage is intra-abdominal, and investigation will serve just to localise the site of haemorrhage to the abdomen.[9] The investigation of choice is ultrasound,[5 12] which can be performed quickly and without moving the patient from the resuscitation area. If free fluid is detected, the patient should proceed to laparotomy (fig 2).[9 10 15]

How should I investigate haemodynamically stable patients?

The aims of investigation in haemodynamically stable patients are to demonstrate or exclude intra-abdominal injury. This requires a test that is sensitive and specific. The decision to operate does not depend solely on the presence or absence of injury, because many injuries to solid organs can be managed non-operatively. Focused abdominal sonography for trauma will miss injuries not associated with intra-abdominal fluid and is therefore not useful in haemodynamically stable patients,[7] and even formal abdominal ultrasonography lacks the sensitivity and specificity needed in this context.[5] Computed tomography is therefore the investigation of choice in haemodynamically stable patients (figs 2 and 3).[5 12]

How should I manage a stable patient with isolated free fluid on computed tomography?

Free intra-abdominal fluid without solid organ injury is a concern, particularly in neurologically compromised patients, and must be placed in the clinical context with regard to injury patterns and signs of high risk, such as abdominal seat belt marks. In most cases, the fluid is blood and of no further consequence, but occasionally it may be gastrointestinal content from an undetected hollow viscus injury. Such patients should be managed by a surgeon. A recent systematic review reported that

SUMMARY POINTS

- The diagnosis of abdominal injury by clinical examination is unreliable
- Blunt abdominal trauma requires decisive investigation and management
- Ultrasound is the investigation of choice in haemodynamically unstable patients
- Computed tomography is the investigation of choice in haemodynamically stable patients
- Solid organ injury in haemodynamically stable patients can often be managed without surgery

only 27% of these patients will need a therapeutic laparotomy and recommended that awake patients should be managed according to findings of the clinical examination, whereas neurologically compromised patients should undergo diagnostic peritoneal lavage to clarify the nature of the fluid.[27]

Does a normal computed tomography scan rule out abdominal injury?

Patients without discernible injuries despite a major mechanism of injury are usually admitted to hospital for observation. A systematic review confirmed that a normal ultrasound scan does not exclude injury and should be followed by a period of observation or further investigation.[5 9 21] In contrast, a large prospective multicentre study showed that a normal abdominal computed tomography scan has a high negative predictive value (99.63%), and it concluded that admission for observation may not be necessary.[8] Such a strategy has obvious health economic appeal but requires further study.

What should I do if an initially unstable patient becomes "stable" during ultrasound?

Some initially unstable patients may respond to resuscitation during the time taken to complete the ultrasound scan. If no other indication for immediate laparotomy exists, such patients should then undergo computed tomography. Patients who transiently respond to resuscitation should be managed as unstable patients. The decision to obtain a computed tomography scan in such patients should be made only by experienced staff, after careful appraisal of the risks and potential benefits, and only if the results are likely to alter management.

Does the initial investigation of patients with major pelvic fractures differ?

The management of patients with pelvic fractures, particularly in the face of haemodynamic instability, is controversial, and a detailed discussion is outside the scope of this article. In broad terms, investigation should proceed along similar lines to other patients with major blunt abdominal trauma, albeit with attention to stabilisation of the pelvis.[28 29] Despite limitations, a recent systematic review identified focused abdominal sonography for trauma as the initial investigation of choice in haemodynamically compromised patients.[28 29] Diagnostic peritoneal lavage in the presence of a pelvic fracture is associated with a high false positive rate.[10] Haemodynamically stable patients with pelvic fractures should be evaluated by computed tomography.

Conclusion

The investigation of blunt abdominal trauma is a challenging and contentious subject with a limited evidence base. The algorithm proposed here is widely accepted and should help doctors in emergency departments decide on the most appropriate form of investigation pending the arrival of a specialist.

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Additional educational resources

Resources for healthcare professionals

American College of Radiology (ACR) (www.acr.org/SecondaryMainMenuCategories/quality_safety/app_criteria/pdf/ExpertPanelonGastrointestinalImaging.aspx)—Appropriateness criteria for blunt abdominal trauma

Eastern Association for the Surgery of Trauma (www.east.org/tpg.asp)—Trauma practice guidelines for evaluating blunt abdominal trauma

The Cochrane Collaboration (www.cochrane.org/reviews/en/ab004446.html)—Emergency ultrasound based algorithms for diagnosing blunt abdominal trauma

Resources for patients

Patient UK (www.patient.co.uk/showdoc/40002004)—Provides an explanation of the trauma assessment process

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