

## The role of interventional radiology in trauma

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Most preventable deaths from trauma are caused by unrecognised and therefore untreated haemorrhage, particularly in the abdomen. Haemorrhage causes early deaths, and the associated hypovolaemic shock leads to secondary brain injury and contributes to late death from multiorgan failure.<sup>1</sup> Early management is focused on resuscitation and the diagnosis and treatment of life threatening bleeding to prevent the lethal metabolic disturbance triad of acidosis, hypothermia, and coagulopathy.<sup>2</sup>

Many aspects of immediate trauma care suffer from a lack of high quality prospective research. This review is based predominantly on evidence from retrospective cohort series and is subject to the limitations inherent in this type of level 2 research.<sup>3</sup> There are no prospective randomised controlled trials of interventional radiology in major trauma. Although the volume of level 2 evidence is substantial and contains few contradictory findings, no robust level 1 evidence yet exists. This review aims to summarise the evidence supporting the use of interventional radiological techniques in the management of haemorrhage caused by blunt abdominal trauma.

### What is the role of interventional radiology in abdominal trauma?

Interventional radiology uses minimally invasive endovascular techniques to stem haemorrhage. Endovascular haemostatic techniques are established in non-trauma clinical scenarios. In trauma, the main application is to control endovascular haemorrhage by blocking bleeding vessels (transcatheter arterial embolisation (fig 1) or relining them (stent grafting) (fig 2). The objective is to stop the bleeding without the physiological stress of surgery.

Transcatheter arterial embolisation is now an accepted adjunct to non-operative and surgical management protocols in trauma. This parallels its increasing use in other settings of life threatening haemorrhage, such as gastrointestinal and postpartum haemorrhage.<sup>4,5</sup> Insertion of a stent graft is a well established technique in the management of traumatic rupture of the thoracic aorta.<sup>6</sup>

### What injuries are sustained in blunt abdominal trauma?

The frequency of injury to different structures varies among studies. A recent prospective series in which 224 patients with sustained blunt abdominal trauma had computed tomography regardless of their haemodynamic status provides an illustration of patterns of injury (table).<sup>7</sup>

### How does interventional radiology compare with surgery for control of haemorrhage after abdominal trauma?

The key question is: what evidence indicates the clinical scenarios in which interventional radiology for stopping haemorrhage is as good as or better than surgery in terms of morbidity and mortality? The evidence base is relatively poor. For transparency, we usually state the type of study and sample size—for example: (a) the evidence that saving a damaged spleen by using embolisation to avoid splenectomy is weak as it is based only on a study of 17 subjects, and (b) single centres reporting their own outcomes may choose to present them in a positive light.

### Spleen

Splenectomy used to be the standard treatment for a damaged spleen. However, asplenic patients have impaired short

Distribution of injuries by site among 224 patients with blunt abdominal injury in whom the injury was identified on computed tomography

Site	Percentage of patients with identified injury	
	All patients	Haemodynamically unstable subgroup
Spleen	35	53
Liver	24	44
Kidney	13	15
Pancreas	12	0
Bowel perforation	9	6
Pelvic fracture	22	15

### SUMMARY POINTS

Interventional radiological techniques to stop bleeding are a minimally invasive alternative to surgery in blunt abdominal trauma

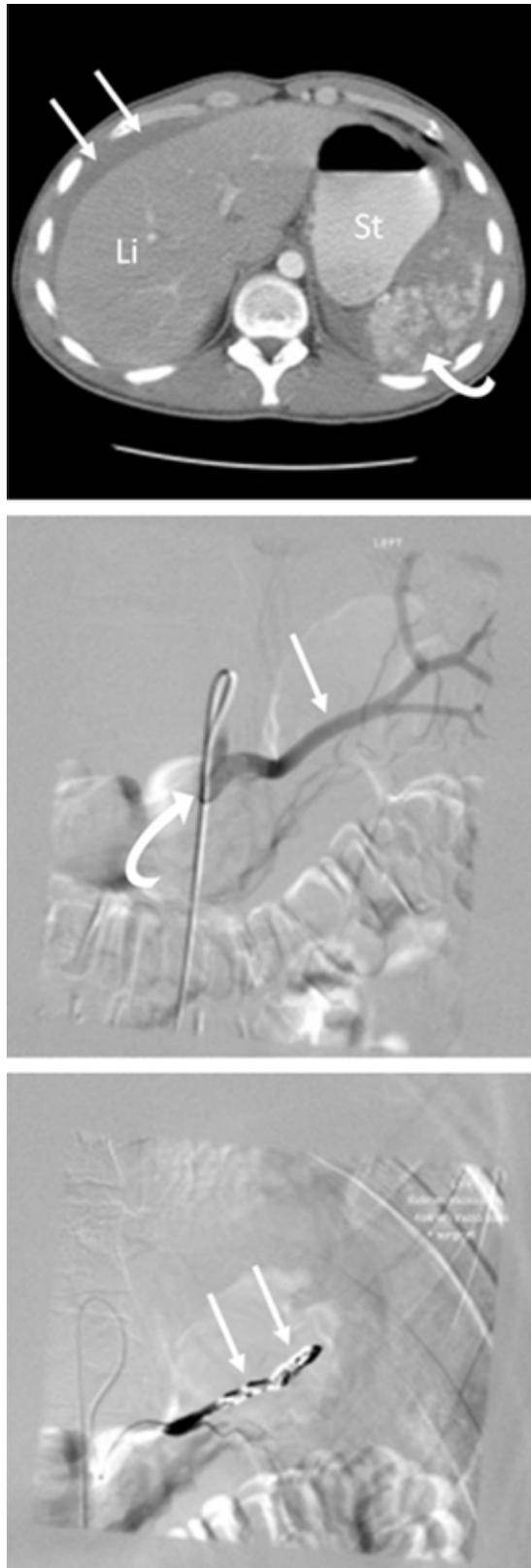
In haemodynamically stable patients with trauma, interventional radiology has an established role in the management of solid organ injuries

In haemodynamically unstable patients with trauma, interventional radiology is effective in stemming haemorrhage from pelvic fractures

Recent series suggest that in a wider range of haemodynamically unstable patients interventional radiological techniques may further reduce the number of patients needing surgery

The overall quality of the evidence for interventional radiological and surgical interventions in trauma is poor

**Fig 1 | Top:** Axial computed tomogram through the abdomen showing free intraperitoneal blood (straight arrows) and shattered spleen fragments (curved arrow); Li=liver, St=stomach. **Centre:** Angiogram showing catheter tip in origin of the splenic artery (curved arrow) and main splenic artery opacified with contrast material (straight arrow). **Bottom:** Angiogram showing complete occlusion of the main splenic artery after insertion of multiple metal coils (arrows) and gelatin slurry via the catheter. Temporary embolisation agents such as biodegradable gelatin are profoundly thrombogenic. The commonest permanent agents are metal coils incorporating microscopic filaments that encourage thrombosis



and long term immunity. Unplanned splenectomy for iatrogenic surgical injury carries a twofold to 10-fold increase in the incidence of postoperative infection and double the risk of mortality.<sup>8</sup> A retrospective review of 196 patients with trauma injury found that splenectomy carried a 50% increased risk of postoperative infections.<sup>9</sup>

Several studies suggest that in haemodynamically stable

#### SOURCES AND SELECTION CRITERIA

We searched PubMed and Google using a variety of search terms including “trauma”, “angiography”, “embolisation”, “computed tomography”, and “endovascular”. We extracted further sources from our personal and colleagues’ archives of references. We used the term “trauma” to search *Clinical Evidence* and the *Cochrane Database of Systematic Reviews*. Other sources included governmental and UK royal college reports. We also used selected references from identified articles

patients embolisation achieves the same survival and reduces the need for splenectomy. A series of 154 patients found that the survival rate of 85% with embolisation was closely similar to the 82% survival in historical controls who had had splenectomy.<sup>10</sup> A Norwegian centre reported outcomes for 133 patients with splenic injuries before and after the introduction of embolisation to the trauma service.<sup>11</sup> The change in practice reduced the laparotomy rate from 55% to 30% and increased the rate of spleen salvage from 57% to 70%. The overall survival rate was stable at 85-89%; the survival rate in the United Kingdom for comparable patients is 78%.<sup>1</sup>

Importantly, embolisation does not obliterate the spleen. A prospective study of 17 patients found that half the splenic bulk was preserved<sup>12</sup> and that serological measures of immune function were normal. Embolisation may preserve splenic function, avoiding the short and long term risks of splenectomy.

Complications in a retrospective series of 140 patients included recurrent haemorrhage in 11%, symptomatic infarct leading to splenectomy in 2%, and abscess in 4%.<sup>13</sup> Two smaller series with a total of 36 patients describe similar outcomes and also report fever in 56% and left pleural effusion in 31%<sup>14,15</sup>—a form of mild post-embolisation syndrome similar to that seen after tumour embolisation and attributed to tissue infarction.

#### Liver

For haemodynamically unstable patients with liver injuries the standard approach is rapid “damage control” surgery with extensive packing of liver injuries.<sup>16</sup> Bleeding from central hepatic or portal veins also requires surgical repair, even in haemodynamically stable patients.<sup>17</sup> In this setting embolisation is a potentially attractive adjunctive therapy for patients with ongoing haemorrhage. In one retrospective series seven patients with liver injuries had angiography after damage control surgery; six of these had ongoing bleeding, and embolisation was successful in all seven patients, with no late rebleeds.<sup>18</sup>

The potential impact of interventional radiology is shown in a review of outcomes for 114 patients with liver injuries before and after the introduction of embolisation to a trauma service in Norway.<sup>19</sup> In haemodynamically unstable patients, angiography and embolisation were performed immediately after damage control surgery. In haemodynamically stable patients with high grade injuries, angiography was performed immediately if there was clinical or computed tomography evidence of ongoing bleeding. The change in practice reduced the laparotomy rate from 58% to 34% and lowered the complication rate by 40% (including abscess, biloma, and bile leak). The survival rate was stable at 89-90%; the survival rate in the UK for comparable patients is 78%.<sup>1</sup>

High grade liver injuries cause extensive vascular and biliary disruption that may be exacerbated by treatment. Focal necrosis of devitalised liver tissue is seen after embolisation, especially with extensive injuries; subsequent abscess formation may require percutaneous drainage or surgical intervention.<sup>20,21</sup> A retrospective study of 71 patients receiving embolisation for hepatic trauma found that complications occurred in 61% (major hepatic necrosis in 42%, abscess in 17%, gallbladder necrosis in 7%, and bile leak in 20%).<sup>20</sup> Surprisingly, mortality in patients with major hepatic necrosis was lower than in those without (7% v 20%, P for difference=0.1).

**Kidney**

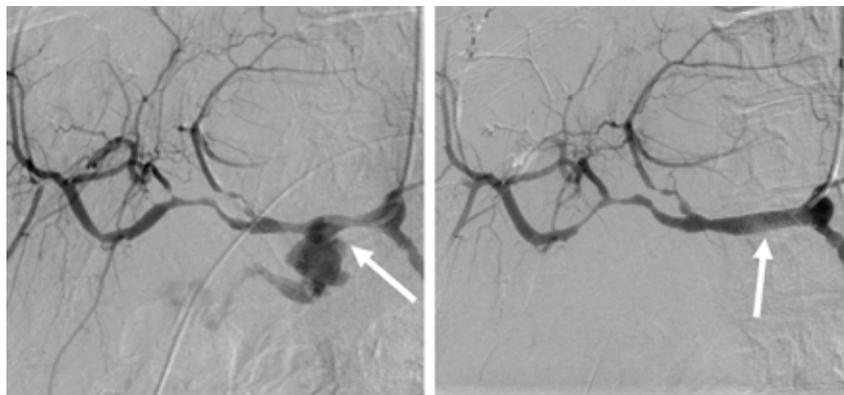
Injuries involving the renal arteries usually occur in conjunction with other solid organ injuries, and require intervention.<sup>22</sup> Embolisation is performed as selectively as possible to maximise preservation of viable, perfused renal tissue. Surgical treatment of similar injuries will often involve nephrectomy.

Recent reports indicate that embolisation is an effective haemostatic technique for these injuries. Initial haemostasis was achieved in all 43 patients reported in three retrospective series.<sup>22-24</sup> Rebleeding occurred in three patients (two of whom were treated with further embolisation), and abscess occurred in one patient. Ultimately, delayed nephrectomy was performed in five of the 43 patients but there were no deaths.<sup>22-24</sup>

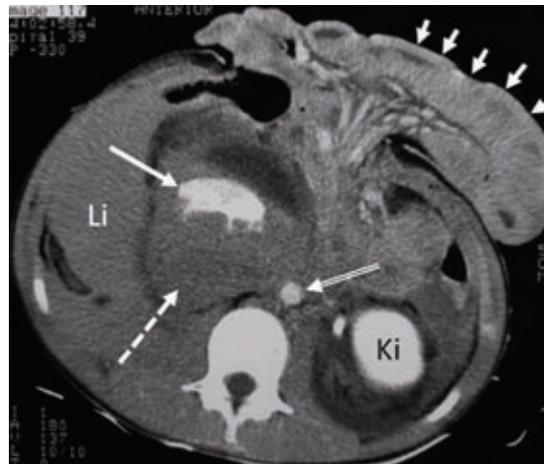
**Pelvic fracture**

Bleeding from pelvic fractures may originate from bone, muscle, and large vessels. This adversely influences the prognosis for the severely injured patient (mortality can exceed 25%),<sup>25</sup> so prompt effective management is essential. Pelvic fractures are often associated with other abdominal injuries, emphasising the importance of computed tomography in planning effective treatment.<sup>26</sup>

Surgical exploration and control of pelvic bleeding is technically challenging<sup>25</sup> and may disrupt the useful tamponade effect of existing haematoma (fig 3). Endovascular treatment for bleeding pelvic fracture has become an established and reliable technique.<sup>27</sup> In one retrospective study, angiography identified pelvic arterial bleeding in 19 of 26 haemodynamically unstable patients; it also identified that fitting surgical external fixator devices led to avoidable delays to angiogra-



**Fig 2** | Left: Angiogram showing haemorrhage (arrow) from the hepatic artery. Right: Angiogram showing relining of the hepatic artery by insertion of a stent graft (arrow), which has stopped the haemorrhage while maintaining arterial blood flow to the liver



**Fig 3** | Axial computed tomogram through the abdomen of a haemodynamically unstable patient after surgical exploration had failed to identify a source of bleeding. Laparotomy released the abdominal tamponade on a retroperitoneal haematoma (dashed arrow), prompting further haemorrhage from the injured right kidney. Extravasation of intravenous contrast (white material, solid arrow) indicates rapid active bleeding. Expansion of the haematoma during surgery prevented reinsertion of the bowel (short arrows) into the abdomen. The liver (Li), normal left kidney (Ki), and constricted “shock” aorta (hollow arrow) are also labelled. The bleeding vessels were successfully treated with embolisation, but the patient died of multiorgan failure caused by the preceding prolonged hypovolaemic shock

phy and haemostasis.<sup>28</sup> Pelvic fractures may instead be temporarily immobilised with sheet-wrap techniques to facilitate prompt assessment with computed tomography and subsequent angiography.

Complications of embolisation may be difficult to distinguish from the consequences of the injury itself. A retrospective series of 31 patients reported gluteal necrosis in three patients, all of whom had sustained degloving injuries of the buttock, although the embolisation may have contributed.<sup>29</sup> Another retrospective series—of 100 patients with pelvic fracture of whom 67 received embolisation—found a similar incidence of early complications (skin necrosis, perineal infection, nerve injury) in patients with and without embolisation.<sup>30</sup> Long term complications such as claudication, skin ulceration, and regional pain were also similar across treatment groups, although regional paraesthesia was more common after embolisation.<sup>30</sup>

**Might interventional radiology be beneficial for the most severely injured patients?**

Although interventional radiology for pelvic bleeding in haemodynamically unstable patients is gaining acceptance, the standard approach to other organ injuries in these patients remains surgery, without prior computed tomography.

The most widely adopted guidelines for management of haemodynamically unstable patients with blunt abdominal trauma advocate laparotomy without computed tomography or attempted endovascular management.<sup>31</sup> Similarly, 97% of trauma surgeons in the United States consider haemodynamic instability to be an indication for immediate splenectomy in blunt splenic injury.<sup>32</sup> The concept that haemodynamically unstable patients should not have computed tomography

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- Current management of clubfoot (2010;340:c355)
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- Managing comorbid disease in patients with psoriasis (2010;340:b5666)

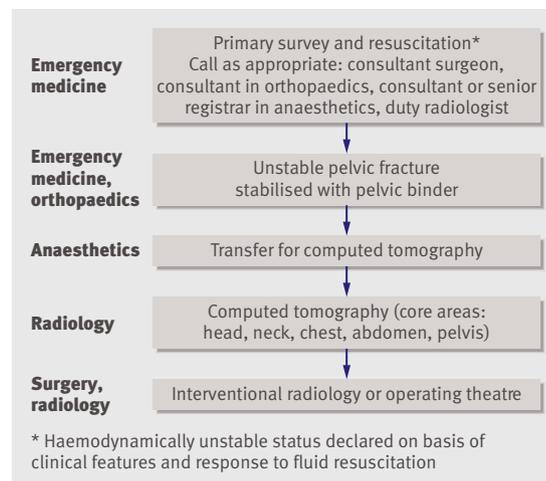
but should instead proceed direct to laparotomy is widely accepted but not based on any evidence.<sup>1</sup>

However, this philosophy of care is challenged by the speed and clinical utility of modern multidetector computed tomography scanners. Laparotomy allows review and repair of injuries to solid organs and hollow viscera, but assessment of some commonly injured areas such as the retroperitoneum and pelvis is limited.<sup>25</sup> Some patients have bleeding in these regions identified on computed tomography only after surgery has failed, resulting in delayed diagnosis and delayed effective treatment.

### What are the barriers to progress in interventional radiology in the United Kingdom?

Despite numerous technological advances in traumatology, surgery, anaesthesia, and radiology the mortality from major trauma has not changed over the past 30 years and is particularly poor in the United Kingdom.<sup>33</sup> Incorporation of interventional radiological techniques into the management of severe injury is intuitively desirable as the additional trauma of surgery is avoided. The use of interventional radiology may increase the number of patients who are successfully managed non-operatively or act as a bridge to definitive surgery in initially unstable patients.<sup>34</sup>

The main barrier to progress is the absence of good evidence. Use of interventional radiology to treat ruptured berry aneurysms is well proved because prospective study designs have several hours' leeway in which to make treatment decisions after the initial subarachnoid haemorrhage. In major trauma, treatment decisions have to be made immediately so study designs must allow this. Further, in contrast to subarachnoid or myocardial infarction, major trauma is not a discrete diagnosis with straightforward diagnostic criteria. Past research studies into thrombolysis for acute management of myocardial infarction were reasonably easy to organise because the treatment was simple to deliver and could be done by relatively junior medical staff at all times of the day and night. But the numerous possible injury combinations in major trauma require the collaboration of experienced staff from several disciplines (traumatology, anaesthesia, surgery, orthopaedics, radiology) to deliver high quality care.<sup>1</sup> Securing agreement among all members of these teams at several institutions for good recruitment into prospective randomised trials poses a substantial challenge that has not yet been overcome. In addition, serious problems exist regarding consent for research in hyperacute clinical scenarios where patients are usually attending without next of kin. Only after all these challenges have been overcome will it be possible to develop reliable triage tools to decide on early surgery, early



**Fig 4 | Management pathway used at authors' institution for treating haemodynamically unstable patients who have blunt abdominal trauma. Pathway shows decision making on key events, with each responsible specialty (senior level) indicated on the left**

endovascular treatment, or conservative management for individual patients.

In the United Kingdom administrative and cultural obstacles are also present. A review of trauma services in the 2007 NCEPOD report described very poor availability of senior clinicians and poor access to immediate computed tomography and interventional radiology.<sup>1</sup> Review of the records of 795 trauma patients found that surgery had been performed in 110 cases but embolisation in only one; perhaps limited awareness accompanies limited availability. The report recommended substantial changes to the organisation of trauma care in the UK and consideration of centralisation of relevant skills and resources to optimise patient care in the future.<sup>1</sup> If these recommendations are met this reorganisation would facilitate future high quality UK research into many of the management areas of major trauma, including clarifying the role of interventional radiology alongside fluid resuscitation and surgery.

Figure 4 illustrates the management pathway used at our institution for treating haemodynamically unstable patients who have blunt abdominal trauma. At any time the senior surgeon involved can divert the patient direct to the operating theatre. The target time from admission to computed tomography is one hour. Resuscitation continues during transfers and scanning; radiology rooms have piped gases and anaesthetic trolleys.

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**Competing interests:** All authors have completed the Unified Competing Interest form at [www.icmje.org/coi\\_disclosure.pdf](http://www.icmje.org/coi_disclosure.pdf) (available on request from the corresponding author) and declare (1) no financial support for the submitted work from anyone other than their employer; (2) no financial relationships with commercial entities that might have an interest in the submitted work; (3) their spouses, partners, or children have no relationships with commercial entities that might have an interest in the submitted work; (4) no non-financial interests that may be relevant to the submitted work.

**Provenance and peer review:** Commissioned; externally peer reviewed.

**Patient consent** not required (patient anonymised, dead, or hypothetical).

### AREAS FOR FUTURE RESEARCH

- Development and execution of study designs that prospectively randomise trauma patients to treatment arms (rather than retrospective series)
- Evaluation of the impact of immediate computed tomography for all patients with blunt abdominal trauma followed by non-operative management, interventional radiology, or damage control surgery, compared with traditional management algorithms
- For patients with blunt abdominal trauma who are in hypovolaemic shock, determination of the potential for interventional radiology to replace surgery by randomising patients either to (a) traditional immediate surgery or to (b) immediate computed tomography followed by embolisation with or without subsequent surgery, or surgery with or without subsequent embolisation

ADDITIONAL EDUCATIONAL RESOURCES

- National Confidential Enquiry into Patient Outcome and Death. *Trauma: who cares?* 2007. [www.ncepod.org.uk/2007report2/Downloads/SIP\\_report.pdf](http://www.ncepod.org.uk/2007report2/Downloads/SIP_report.pdf). The report is free with no registration required.
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ANSWERS TO ENDGAMES, p 371. For long answers go to the Education channel on [bmj.com](http://bmj.com)

CASE REPORT

Refeeding syndrome in a patient with anorexia nervosa

- Hypophosphataemia, hypomagnesaemia, gastric dilation, congestive cardiac failure, severe oedema, confusion, coma, and death are classic complications of refeeding syndrome.
- Hepatic fatty change associated with refeeding is the most likely cause of the deranged liver function tests.
- Very gradual refeeding, either orally or enterally can help prevent refeeding syndrome. In general, if nutrition is given enterally, patients should be given 21-42 kJ/kg/day (5-10 kcal/kg/day) initially, and this should be gradually increased. Assume that the patient has thiamine deficiency and treat it. Monitor daily, with treatment as needed, for hypophosphataemia, hypomagnesaemia, hypokalaemia, and other electrolyte disturbances. Patients are likely to have other important micronutrient and vitamin deficiencies. You may need to consider using the Mental Health Act if refeeding is refused.
- Hypoglycaemia, hypothermia, osteoporosis, renal failure, arrhythmias, pancreatitis, neutropenia, immunosuppression, and anaemia are other important physical risks in severe anorexia nervosa.
- The psychiatric management of anorexia nervosa should focus on forming a good therapeutic alliance; working on motivational factors; providing information on the effects of the illness and its treatments, both physical and psychological; working with families and carers; and if appropriate, treating comorbidities such as depression, anxiety, and obsessive compulsive disorder.

PICTURE QUIZ

Painless non-itching yellow-white spots on genital mucosa

- The most likely diagnosis is Fordyce's spots (also known as Tyson's glands or ectopic sebaceous glands).
- The skin lesions are caused by sebaceous glands that are not linked to hair follicles.
- Treatment is unnecessary.
- Differential diagnoses include pearly penile papules, milia, flat warts, condylomata acuminata, and planar xanthomas.

STATISTICAL QUESTION

Generalisation and extrapolation  
The conclusions a, b, c, and d cannot be drawn.