The principles of trauma radiology

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Introduction

Individuals who have sustained major trauma require a well led, efficient and cohesive multi-disciplinary team to best manage their injuries. Having early and accurate knowledge of the injuries sustained allows correct and prompt management. Radiology, specifically multi-detector computed tomography (MDCT), is now fundamental in managing almost all major trauma patients; it has been shown to reduce both mortality and morbidity and improves the probability of survival in polytrauma patients.1

The role of radiology in managing trauma patients is to provide a fast and accurate diagnosis of life or limb threatening injuries, identify sources of active bleeding, identify or exclude spinal injuries and identify the need for thoracic, abdominal or pelvic surgery. Imaging can also aid the difficult decision of when not to operate.

Trauma radiology

When the trauma patient arrives in the emergency department (ED) it is a busy time for all involved. This time is critical to stabilise and resuscitate the patient while the primary survey is performed. Positive and salient negative findings should be conveyed to the team leader as they are identified. It is the team leader who is ultimately responsible for the care of the patient during this initial period and they must decide if MDCT is necessary and when it should be undertaken.5

Plain film radiology is a useful adjunct during the primary survey.5 Digital radiology (DR) allows immediate viewing of the radiographs. Commonly, frontal chest and pelvic radiographs are performed to identify haemo/pneumothoraces or pelvic ring disruption. These injuries may require prompt treatment prior to transfer to CT. It is important that performing these images and other extremity radiographs does not delay transfer of the patient to have the definitive MDCT scan.2 The aim should be an urgent transfer of all adult trauma patients for CT to determine the extent of injuries and allow lifesaving surgery to be planned and performed. The exception to this would be those patients who are the most haemodynamically unstable.

CT is still of value in managing the most haemodynamically unstable patients. These are patients who require damage control surgery to gain proximal control of the blood loss either in the ED or in theatre immediately after the primary assessment. CT can be performed in the post surgery period to assess the extent of injuries and to assess the success of surgery.3

The use of focused abdominal sonography in trauma (FAST) should not delay transfer to CT if the decision already has been made to proceed to CT. FAST should also not be used as a screening tool to determine the need of CT. The latest NICE trauma guidance states that FAST should not be used if there is access to CT.

Ideally a major trauma centre that regularly receives trauma patients would have an MDCT scanner in the trauma bay or immediately adjacent to it, with a spacious and direct transit route. EDs and radiology departments are often in buildings that have been adapted to fit their current clinical purpose and are therefore a compromise. This compromise often requires transferring acutely unwell patients hundreds of meters along busy corridors and even over multiple floors. Trauma patient transfers can be a dangerous but necessary business and keeping the distance and time away from a well-staffed and well equipped clinical area should be kept to a minimum. Transfer routes and contingency plans must be clearly defined and practised.5,6

CT trauma protocol

CT technology and equipment has undergone a paradigm shift since its conception by the former Royal Air Force reservist Sir Godfrey Hounsfield in the 1970s. Sir Hounsfield joined the RAF as a volunteer reservist before the start of World War 2 where he learned to operate radar and other electronic equipment. After WW2 Sir Godfrey attended the Faraday House Electrical Engineering College in London where he graduated with a diploma.6 He went on to work for EMI in Middlesex in 1951 and it was here where he was fundamental in designing and constructing the first CT scanners.

With new technologies come new possibilities and the current third generation MDCT scanners can perform a continuously acquired contrast enhanced scan from the vertex to mid-thigh in less than two minutes (including the time of contrast administration);7 fortunately this is ideal for imaging trauma patients and a trauma CT can be undertaken immediately after the clinical primary survey. Essentially the success of CT is because it has become faster, more detailed and more available in the acute trauma care setting. It is highly accurate for a wide range of injuries8-10 and when correctly interpreted has a low missed diagnosis rate.10

The use of MDCT scanners early in the management of trauma patients allows fast and only necessary surgeries to be performed.3 It also allows safe transfer of patients who are known not to have internal injuries without the use of negative exploratory surgical procedures which have a significant mortality and morbidity.11

CT protocol

The use of the ‘traumagram’ or ‘pan CT’ is now commonplace in major trauma centres in the UK. This may have local variations; however it is based on the principles of a split contrast bolus which allows best visualisation of both the arterial and venous systems combined with a single image acquisition that has a significantly lower radiation dose than multiple acquisitions to image different phases of contrast opacification.12
A pan-CT should include a non-contrast CT head prior to the injection of intravenous contrast (if clinically indicated) followed by a contrast enhanced CT from the Circle of Willis (CoW) to the lesser trochanters. Contrast should be administered on an estimated weight criteria using 2ml per kilo of iodinated low osmolar contrast solution 300mg/ml. There should be continuous administration of intravenous contrast which should be split so that two thirds of the bolus is delivered slowly and the last third is delivered at twice the rate of the first with acquisition being initiated at 70 seconds at the CoW (figure 1). The images can be viewed as they are acquired and CT primary assessment should be made available to the trauma team leader within five minutes, with a more detailed secondary trauma report being issued within one hour of image acquisition.

Pros and cons of a split bolus technique

Using the split bolus contrast technique described above has many advantages; vitally it reduces the time the patient must remain in the scanner and reduces the radiation dose to the patient by negating the need to re-irradiate the same volume of tissue to obtain different contrast phases. It reduces the need for multiple injections of potentially nephrotoxic intravenous contrast to shocked and hypovolaemic patients. Triggering the scan at 70 seconds after the IV contrast has started to be injected allows both good portal venous and angiographic phases to be obtained in one pass of the CT gantry. Good contrast enhancement of the solid organs assists in diagnosing lacerations and penetrating injuries as well as bowel injuries. The angiographic phase allows the reporting radiologist to comment on injuries to the great vessels and identify active bleeding points in the form of contrast blushes. Serendipitously, some patients have good opacification of their systemic veins and occasionally a deep vein thrombosis can be diagnosed in the deep pelvic veins which can create unexpected management dilemmas, especially if the patient is actively bleeding elsewhere.

A split contrast bolus is a compromise but more often than not it is an acceptable compromise and allows the clinical question to be answered with certainly. It does not always produce perfect images due to both technical factors and patient factors, however its limitations are understood and, when ambiguity exists about the images obtained, dedicated imaging of that body part can be performed to answer the specific question at a later date.

Some trauma scans have been chosen (figures 2-5) which highlight the effectiveness of the split bolus MDCT and instances where it has been particularly useful and have been included in the text.

Radiation

The medical professional who justifies the use of MDCT to investigate the trauma patient must consider the radiation dose that the patient will receive and the potential harm it may cause. The use of radiation should be kept as low as reasonably practicable (ALARP).2 It is difficult to quantify the risk of a pan CT scan, however, there is thought to be a 1 in 20 risk of fatal solid organ tumour associated with an effective dose of 1 Sievert.6,15 The effective dose of a trauma CT varies due to a machine’s technical factors including age of equipment, detector type, pitch, mA modulation, and the shape and size of the patient. Trauma CT scans often have doses of greater than 20mSv1,6,15 and are considered high exposure examinations. Radiation risks are theoretical and there is much debate around how the risk models have been calculated, however the principle of ALARP should be followed.

Technology is advancing and with better scanners and continued progression in the processing software, the radiation dose will continue to fall and the radiation burden will reduce which will undoubtedly see an increase in demand for the investigation. Radiation risks may cause fatal cancers in the future, however abdominal or pelvic injuries sustained from trauma may kill the patient in the short-term and often the benefit outweighs the risk.

Paediatrics

CT is not the first line investigation in children presenting with trauma, except in head trauma where, if the NICE guidelines have been met, CT head is the first line investigation.2,13 Clinical examination, plain films and ultrasound are the first line investigation for trauma below the base of skull. Children’s mechanism of injuries, body structures and thus their injury patterns are different to adults and they should not be thought of as small adults. The risk of radiation-induced cancer from CT in childhood is real, significant and higher when performed at younger ages. In certain circumstances CT is necessary when specific low dose paediatric protocols should be used.2,11

Mass casualties

In the event of a mass casualty scenario, the ED will receive multiple patients in a short time period and may be overwhelmed. A well-rehearsed plan should come into effect. A senior radiologist and radiographer should coordinate the imaging response with the ED team leader. Ultrasound can be used to prioritise patients for CT or theatre. CT scanners should be made available and both radiographers and radiologists stood up to scan and report patients in a timely fashion. It should also be remembered that with a localised PACS network, reporting the scans could be performed remotely.

Conclusion

Early use of MDCT to manage trauma patients allows clear and definitive management plans to be formulated early and thus improves morbidity and mortality. It allows damage control surgery to be focused and prompt and negates the need for negative blind exploratory laparotomies prior to patient transfer or discharge from care. Current CT technology allows a contrast enhanced pan CT to be performed in less than two minutes which makes this an ideal test to perform on all but the most haemodynamically unstable patients. As radiation dose is reduced with improving technologies and purchasing cost reduced, the use of MDCT scans will increase. MDCT is an excellent and appropriate investigation when managing trauma patients.

References


Figure 1
Bastion Contrast Calculator giving the volume and rates of contrast to be administered for a biphasic contrast with single phase acquisition in adults and children.13

Figure 2
Case A. Complex head trauma demonstrating:

Figure 3
Bastion Contrast Calculator giving the volume and rates of contrast to be administered for a biphasic contrast with single phase acquisition in adults and children.13

Figure 4
Case C. 1. Extensive liver laceration. 2. A small splenic laceration. No active bleeding was demonstrated; this can be excluded when a dual phase CT is performed correctly.

Figure 5
Case D. A complex and unstable pelvic fracture showing: 1. A vertical fracture through the right sacrum. 2. Comminuted fractures through both pubic rami. Note the pelvic binder compressing the pelvis tamponading any damaged vessels.