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Pictorial Review

Emergency computed tomography for acute pelvic trauma: Where is the bleeder?

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Contrast medium extravasation at computed tomography (CT) is an accurate indicator of active haemorrhage in pelvic trauma. When this is present, potentially lifesaving surgical or endovascular treatment should be considered. Identification of the site or territory of haemorrhage is helpful for the interventional radiologist as it allows for focused angiographic evaluation and expedites haemostatic angio-embolisation. Even with thin-section arterial phase CT, tracing the bleeding vessel is not always possible and is often time consuming. We introduce a technique for predicting the bleeding vessel based on knowledge of the cross-sectional anatomical territory of the vessel as an alternative to tracing the vessel's course. Several case examples with digital subtraction angiography (DSA) correlation will be provided.

Introduction

Active haemorrhage occurs in up to 40% of patients with pelvic fractures and is a significant cause of morbidity and mortality in acute pelvic trauma (APT).[1] Vascular injuries were historically assessed using digital subtraction angiography (DSA). However, the development of multidetector computed tomography (MDCT) now enables rapid, non-invasive assessment of vascular injuries in APT, with DSA reserved for further evaluation of suspected arterial haemorrhage and potential angio-embolisation.[2]

Active pelvic haemorrhage may result from injury to the iliac arterial and venous branches, pelvic venous plexuses, and/or fractured bone. In patients with pelvic fractures and ongoing hypotension, extravasation of contrast medium at CT is the most reliable indicator of significant arterial bleeding seen on subsequent DSA.[3–7] The site of contrast medium extravasation at CT also enables the interventional radiologist to target specific vessels at high risk of injury.

In this article, we describe the concept of finding the bleeding vessel based on pelvic vascular territories, using case examples with DSA correlation. The specific topics discussed include the evidence for the utilisation of MDCT in detecting haemorrhage in APT, MDCT compared to DSA to detect haemorrhage in APT, MDCT protocol and decision making in APT, pelvic arterial anatomy, pelvic vascular territories combined with case examples, and potential pitfalls.

MDCT for detecting haemorrhage in APT

In the initial studies of CT in trauma performed in the late 1980s and early 1990s, the classic pattern of active extravasation was described as an administered contrast agent that has escaped from injured arteries, veins, or the urinary tract.[8] These studies were performed using a single portal venous phase protocol on a single-detector CT system with limitations regarding acquisition times. With the advent of MDCT with dual or triphasic capabilities, active vascular extravasation could be further characterized as a jet or focal

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area of hyperattenuation within a haematoma that fades into an enlarged, enhanced haematoma on delayed images.[9] This finding was found in several studies to indicate significant bleeding, and prompted the use of potentially lifesaving surgical or angio-embolic intervention.[10,11]

Other vascular injuries that can be detected using multiphasic MDCT include pseudoaneurysms, which unlike active arterial or venous extravasation remain stable in size and show "wash-out" in the delayed phase images.[10] Other important information available using MDCT includes the location of vessel injury, lack of vascular enhancement (caused by occlusion or spasm), vessel irregularity, size change (such as occurs with pseudoaneurysms and active arterial or venous extravasation), and intimal flaps signifying arterial dissection.[10] Table 1 lists the characteristics of various types of injury at contrast-enhanced CT.

MDCT compared to DSA to detect haemorrhage in APT

MDCT has excellent correlation with DSA for the detection of arterial haemorrhage in APT with a high sensitivity of >90% noted in several studies.[8,12] A large study by Maturen et al.[8] examined MDCT in chest, abdominal, and pelvic trauma for the detection of active haemorrhage compared to DSA. A standard trauma CT protocol was used without CT angiography. Forty-eight patients underwent CT and subsequent DSA for suspected haemorrhage. The sensitivity and negative predictive values for detection of haemorrhage and secondary need for intervention were 94.1%/97.6% and 92.6%/91.2%, respectively.[8]

Another study by Anderson et al.[9] utilised 64-section MDCT including arterial, portal venous, and delayed phases for detection of vascular injuries in blunt pelvic trauma. Twenty-one of 53 patients had vascular injuries at CT and of these, 15 patients had suspected arterial extravasation, with 11 out of the 15 undergoing subsequent DSA. Ongoing arterial haemorrhage was identified in seven patients with angio-embolisation required in all. Importantly, all 32 of 53 patients without haemorrhage at MDCT were successfully treated conservatively.

These studies indicate that MDCT findings correlate strongly with DSA findings, though sensitivity remains imperfect. However, given that the CT findings are combined with clinical parameters, particularly haemodynamic instability, clinicians are increasingly reserving emergent DSA for confirmation of suspected haemorrhage and possible embolisation.

Table 1
Contrast-enhanced computed tomography (CT) characteristics of vascular versus non-vascular injuries.

Injury	Contrast enhanced CT characteristics
Arterial bleeding	Focal area of hyper attenuation within a haematoma on arterial phase images that fades into an enlarged, enhancing hematoma on delayed images.
Venous bleeding	Focal area of hyper attenuation within a on portal venous phase images that fades into an enlarged, enhancing on delayed images.
Arterial pseudoaneurysm	Focal area of hyper attenuation that appears in the arterial phase, remains stable in size and shows "wash-out" in the delayed phase.
Urinary injury	Focal area of hyper attenuation on delayed phase images adjacent to the urinary tract.
Bone fragments	Adjacent to fracture site and remain stable in appearance on all phases. Optimally seen on bone windows.

MDCT protocol and decision making in APT

In APT, information from a primary MDCT study indicates two potential outcomes. A negative MDCT study, with no vascular injury or active extravasation of contrast medium enables the consideration of conservative non-operative management, which has become increasingly common in the trauma setting. In turn, a positive MDCT study enables the consideration of angio-embolisation instead of initial surgical management.

Initial studies of trauma CT utilised a single portal venous phase. However, it is becoming increasingly common for multiphasic acquisitions including a delayed phase and/or CT angiography to be performed. Currently, no standard CT trauma protocol exists.

The Royal College of Radiologists (UK) provide guidance on trauma CT protocols. For haemodynamically unstable patients with a high risk of vascular injury a triphasic trauma CT protocol is advised utilising an arterial, portal venous, and delayed phase. This protocol is aimed at detecting foci of active bleeding with potential differentiation between arterial and venous haemorrhage.[13]

The specific protocol for abdominopelvic trauma at Tan Tock Seng Hospital utilises a portal venous phase (70 s delay) on a 64-section CT system (SOMATOM Sensation, Siemens Healthcare, Erlangen, Germany) using a collimation of 0.625 mm with a reconstructed section thickness of 3 mm. Finer 1 mm reconstructions are often obtained as necessary from the raw data at the time of review by the radiologist. An additional delayed phase of the abdomen and/or pelvis is performed after a 5 min delay, if there are suspected underlying vascular injuries, e.g., visceral lacerations, pelvic fractures and haematomas. All patients receive a single intravenous bolus of 100 ml non-ionic iodinated contrast medium (iohexol, 350 mg iodine/ml; Omnipaque 350, Nycomed Imaging AS, Oslo, Norway), which is injected at a rate of 3 ml/s using a dual-syringe power injector. Parameters for the delayed phase imaging are identical to those for the portal venous phase imaging. CT angiography is not typically performed unless specifically requested by the trauma surgeon or interventional radiologist in patients with a high likelihood of haemorrhage, e.g., displaced pelvic fractures on the initial