Seminars in
ROENTGENOLOGY

Recent Advances in Abdominal Trauma Computed Tomography

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Introduction

Computed tomography (CT) has evolved considerably since the introduction of this groundbreaking technology, with the initial research on the use of CT imaging of the brain, chest, and abdomen published in 1975.[1-4] Its potential role in imaging the emergency and trauma patient was first published in 1978.[5] Since the introduction of multi-detector CT (MDCT), it has emerged as the main imaging modality for the evaluation of the poly-trauma patient.[6] As the technology continues to evolve, protocols have been developed which can optimize visualization of the most critical injuries, which in turn determines if a patient requires conservative or surgical management. Emerging technologies, particularly dual-energy CT, have potential roles for standard trauma imaging in the near future, and are being used routinely or selectively at some trauma centers. Other advances in research include evaluating the types of patients who may potentially benefit from follow-up imaging, as well as investigating CT triaging algorithms for patients with blunt abdominal or pelvic trauma (Figures 1-6).

Protocols

With advances in technology and increasing speed of MDCT scanners, and due to the wealth of diagnostic information it provides, MDCT has become a critical tool that is being routinely used in evaluating the trauma patient. Initially, MDCT was used in the trauma setting selectively, with imaging performed by body part; that is, imaging of the head, cervical spine, chest, abdomen, pelvis, and extremities. Linsenmaier et al[7] published their initial work with whole-body computed tomography (WBCT) in the poly-trauma patient in 2002; their protocol included CT of the head, chest, and abdomen. Since then, there has been a gradual but steady incorporation of WBCT protocols at many trauma centers, given the shorter scanner times with the newest, available scanners. Most WBCT protocols now incorporate imaging of the head, or cervical spine, chest, abdomen, and pelvis.

In the trauma setting, CT can be performed selectively vs used with a WBCT protocol.[8,9] CT of the abdomen and pelvis, whether performed selectively or as part of a WBCT protocol, is most commonly performed in the arterial phase and/or portal venous phase.[10,11] Some centers will also selectively image the chest, most often performed in the arterial phase, followed by imaging of the abdomen and pelvis in the portal venous phase. Selective CT protocols of the abdomen and pelvis vary by institution, which can also be tailored to the specific mechanism of trauma and the specific type of injury suspected. Imaging of the abdomen and pelvis is often performed through the arterial phase to assess for vascular injuries, and/or in the relatively early portal venous phase to best assess for parenchymal injuries.[12] Performing both the arterial and portal venous phases of CT increases the level of confidence of the interpreting radiologist, and increases the detection of active bleeding and its source(s), as well as revealing other vascular injuries and parenchymal injuries, although at the “cost” of increased radiation exposure to the patient. Single-phase imaging is often performed in either the arterial or portal venous phases, with some institutions adopting a “late” arterial phase to incorporate elements of both the late arterial and early portal venous phases on a single-phase acquisition.

Some radiology practices use a split-bolus technique of administering intravenous (IV) contrast at 2 points in time, followed by the acquisition of a single set of acquired images. The split-bolus injection protocol can be performed with an initial bolus of IV contrast, followed by a second bolus of contrast. The patient is then scanned only once, with contrast simultaneously present in the arterial and portal venous phases. Therefore, the split-bolus technique decreases radiation exposure, and decreases the number of images that have to be interpreted, compared with imaging the patient in the

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Figure 1 A 26-year-old man was thrown off a ladder by the tree branch he was cutting, and fell from a height of 6 ft. He presented with a large pancreatic parenchymal contusion on IV contrast-enhanced abdominal CT. (A) Axial image shows extensive contusion of the pancreatic body (arrow), with intraparenchymal hematoma and edges of normally enhancing parenchyma at the neck and tail (arrowheads).

arterial phase followed by the portal venous phase. In a recent study by Hakim et al,[13] radiologists scored image quality of the split-bolus technique as comparable to image quality of conventional MDCT performed during both the arterial and portal venous phases.

Given that CT is the main imaging modality in the assessment of the trauma patient, in addition to its increasing usage, there has been considerable recent research in dose reduction techniques. Loewenhardt et al,[14] retrospectively analyzed 100 trauma patients who underwent WBCT, and reported dose reductions of 16%-22% when WBCT was performed with the patient's arms raised above their heads, compared to WBCT performed with the patient's arms positioned on their abdomens. These results are concordant with other reported studies demonstrating lower effective WBCT radiation dose when a patient's arms are positioned above the head, compared to with the arms overlying the thorax or abdomen.[15-17]

There have been several recent studies investigating the dose savings as a result of implementing CT protocols with iterative reconstruction compared to filtered back projection (FBP) in abdominal and pelvic CT, with reported reductions in dose of 23%-66%.[18-20] A recent retrospective study of 152 WBCT scans by Geyer et al[21] reported radiation dose reductions of 10%-34% in WBCTs performed on a 64-row multi-detector CT with the implementation of adaptive statistical iterative reconstruction (ASIR) using a gemstone-based scintillator, vs WBCTs performed on a 64-row multi-detector CT with FBP. A study of 122 patients with multiple trauma performed by Kahn et al[22] reported a similar dose reduction of 23% in the WBCT ASIR protocol group compared to the WBCT FBP protocol group, without any loss of image quality, as qualitatively assessed by 2 observers. A more recent study by Alagic et al[23] compared 109 poly-trauma patients who had a low-dose multiphase WBCT with adaptive statistical iterative reconstruction V (ASIR-V), which consisted of noncontrast imaging of the skull, mid-face, and cervical spine, followed by WBCT angiography and an abdominal scan in the venous phase, with 110 poly-trauma patients who had a single-phase trauma CT. The authors reported dose reductions of 13.0% in the low-dose multiphase WBCT group, with improved diagnostic accuracy for trauma-related arterial injuries.[23]

As previously discussed, the split-bolus technique is one way of reducing radiation dose by incorporating 2 or more phases of contrast on a single set of acquired images. Leung et al[24] compared a 2-phase trauma CT protocol consisting of CT of the chest, abdomen, and pelvis in the arterial phase, followed by the venous phase of the abdomen and pelvis, to a trauma split-bolus protocol from the circle of Willis to the pubic symphysis, and found the split-bolus protocol resulted in a 43.5% reduction in the mean dose length product (DLP) compared to the two-phase CT protocol.

Triaging Algorithm

Given the increased availability of CT, especially in the emergency department (ED) and trauma setting where most level-1 trauma centers have dedicated CT scanners nearby or

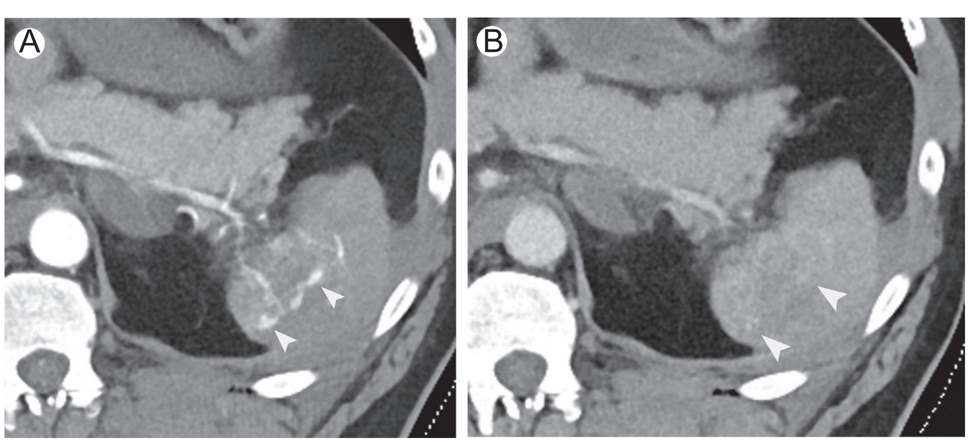

Figure 2 A 49-year-old man who was thrown into rocks following a boating accident, with a resultant intraparenchymal splenic pseudoaneurysms. (A) Axial arterial-phase CT image shows multiple foci of contrast enhancement (arrowheads), similar in attenuation to arterial contrast, and perisplenic hematoma. (B) Axial portal venous-phase image shows contrast washout (arrowheads).