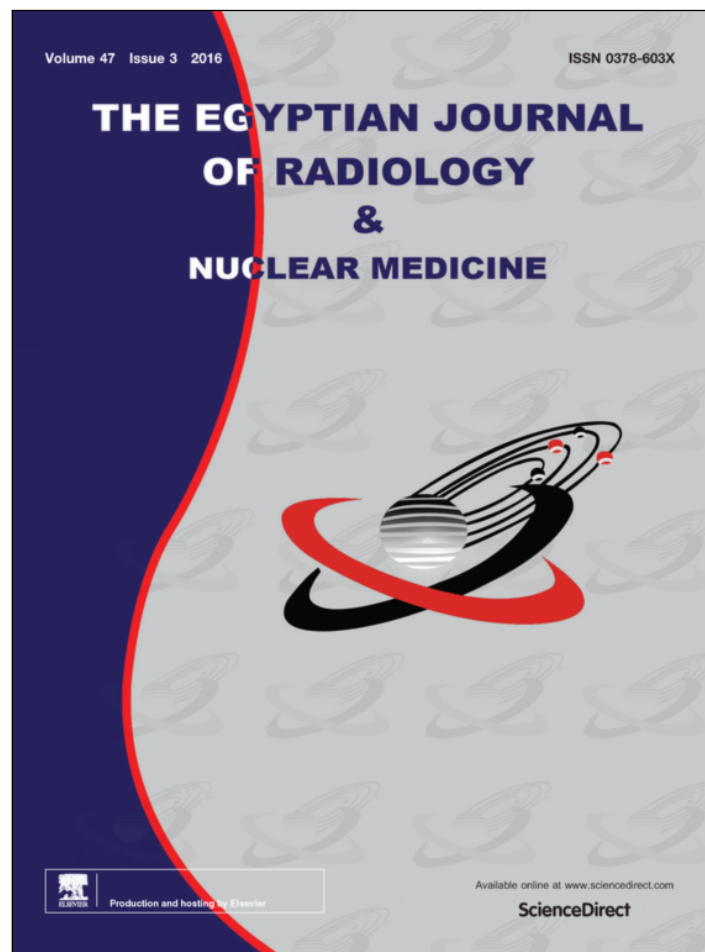


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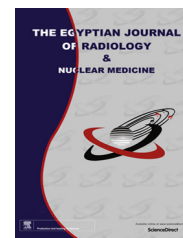
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ORIGINAL ARTICLE

Role of multislice computed tomography in assessment of non-solid organ injury in patients with blunt abdominal trauma



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KEYWORDS

Multislice CT;
 Abdominal trauma;
 Blunt;
 Contrast

Abstract Objective: Blunt abdominal trauma is a leading cause of morbidity and mortality. Multidetector computed tomography (MDCT) scanning with intravenous contrast is the gold standard diagnostic modality in hemodynamically stable patients. The aim of this work was to highlight the role of MDCT in patients with blunt abdominal trauma for diagnosis and staging of non-solid organ injury.

Materials and methods: Thirty injured patients were enrolled into the study, including 28 males and 2 females, with a mean age of 38. They were referred from the surgical department after stabilization of their general condition. Multi-detector CT was conducted including non-contrast MDCT of the abdomen and pelvis followed by contrast enhanced MDCT.

Results: Five patients had diaphragmatic rupture, five patients were diagnosed bowel perforation, and two patients were diagnosed traumatic rectovesical fistula. Three patients were diagnosed by MDCT had mesenteric injury. Four had vascular injury diagnosed by MDCT. Five patients had traumatic urinary bladder injury. Four patients had spine injury. Two patients had rectus sheath hematoma.

Conclusions: CT is the imaging modality of choice to evaluate non-solid organ injury in patients with blunt abdominal trauma.

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1. Introduction

Blunt abdominal trauma is a leading cause of morbidity and mortality among all age groups. It is one of the most challeng-

ing conditions in emergency department that physicians encounter because of varied presentations (1).

Blunt abdominal trauma usually results from motor vehicle collisions, recreational accidents, or falls. Men tend to be affected slightly more often than women. The most commonly injured organs are the spleen, liver, retro peritoneum, small bowel, kidneys, bladder, colorectal, diaphragm, and pancreas (2).

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The management of blunt abdominal injury has changed considerably (3). Computed tomography (CT) is currently a widely available imaging technique in clinical practice (4). Currently, multidetector computed tomography (MDCT) scanning with intravenous contrast is the gold standard diagnostic modality in hemodynamically stable patients with intra-abdominal fluid. MDCT scanning with intravenous contrast has numerous advantages. First, the detection of injuries related to solid organs can be reliably determined, with a sensitivity of 90–100%. Second, active bleeding (a contrast blush), can be diagnosed, and the MDCT scan plays a decisive part in the order of treatment if more than one injury is present (3).

MDCT readily detects direct and indirect features of bowel and/or mesenteric injury an important advance given that unrecognized bowel and mesenteric injuries may result in high morbidity and mortality (5).

Multidetector CT offers significantly faster scanning times and improved image resolution due to thinner collimation and reduced partial volume and motion artifacts (6).

The ability of CT to perform and produce fast-processing images, such as multiplanar reconstruction (MPR), is important for accurate interpretation of abnormalities (7).

The aim of this study was to highlight the role of MDCT in patients with blunt abdominal trauma for diagnosis and staging of non-solid organ injury.

2. Materials and methods

2.1. Patients

Thirty critically injured patients were enrolled into the study, including 28 males and 2 females, aged 2–74, with a mean age of 38. They were referred from the surgical department. There was a detailed trauma request, emphasizing the type of injury, indication of the study to tailor the imaging protocol. Patients were referred after stabilization of their general condition. All patients were subjected to portable Plain X-ray and portable ultrasound before requesting CT scan.

16 patients were managed conservatively and 14 patients managed operatively. The operated patients were correlated with the CT findings, and most of the conservative patients were followed up before hospital discharge. The patients were evaluated with Multidetector Computed Tomography and various injuries were graded according to American Association for the Surgery of Trauma (AAST). This study was approved by the ethics committee of our institution.

2.2. Patients' handling and preparation

The patients were handled with care, immobilized in a vacuum mattress which rendered moderate artifact; patients with injured cervical spine were immobilized in a collar.

Oral contrast was given only if an adequate visualization of gastrointestinal tract was required, 500–600 ml of diluted (2–5%) water-soluble oral contrast material administered orally or through a nasogastric tube. The urinary bladder catheter was clamped prior to leaving emergency department (ED) especially if there is pelvic trauma. Serum creatinine was checked for all patients. The radio-opaque objects were removed.

An expert radiologist, expert radiographer and nursing staff were available.

2.3. MDCT imaging protocol

All examinations were performed with a GE Light Speed VCT 16 slice combined with Advantage Workstation 4.4; parameters included a tube voltage of 120 kV, a tube current of 300 mA, FOV large/36 cm, pitch/speed 0.984:1/ 39.37, and a rotation time (s), 0.4 gantry tilt: 0, slice thickness 5 mm at 5 mm interval, patient position: supine, patient orientation: feet first. And the scan range extends from lower chest domes of the diaphragm to the iliac crests.

The patients were scanned in the supine position with the arms elevated whenever possible above his head. Patient orientation was feet first. Patient motion should be avoided during study.

Multi-detector CT including non-contrast MDCT of the abdomen and pelvis to exclude hemorrhage and plan for the contrast study, contrast enhanced MDCT of the abdomen (arterial, portal venous phases), delayed phase in selected cases.

Nonionic contrast was injected intravenous through 18 or 20-gauge cannula in an antecubital vein. All patients received a single bolus of contrast calculated according to the body weight 1 ml/1 kg especially in children. Patients were injected at the rate of 3–4 mL/s. followed by 30 ml of 0.9% saline solution at the same rate. The contrast-enhanced scans were obtained in arterial phase by smart prep. Portal venous phase was acquired 70 s after the onset of contrast material injection. Delayed Images after 5–10 min were acquired in selected cases according to the radiologist opinion. The radiologist read the examination on the monitor, immediately conveying the results to the trauma surgeon.

2.4. Images interpretation

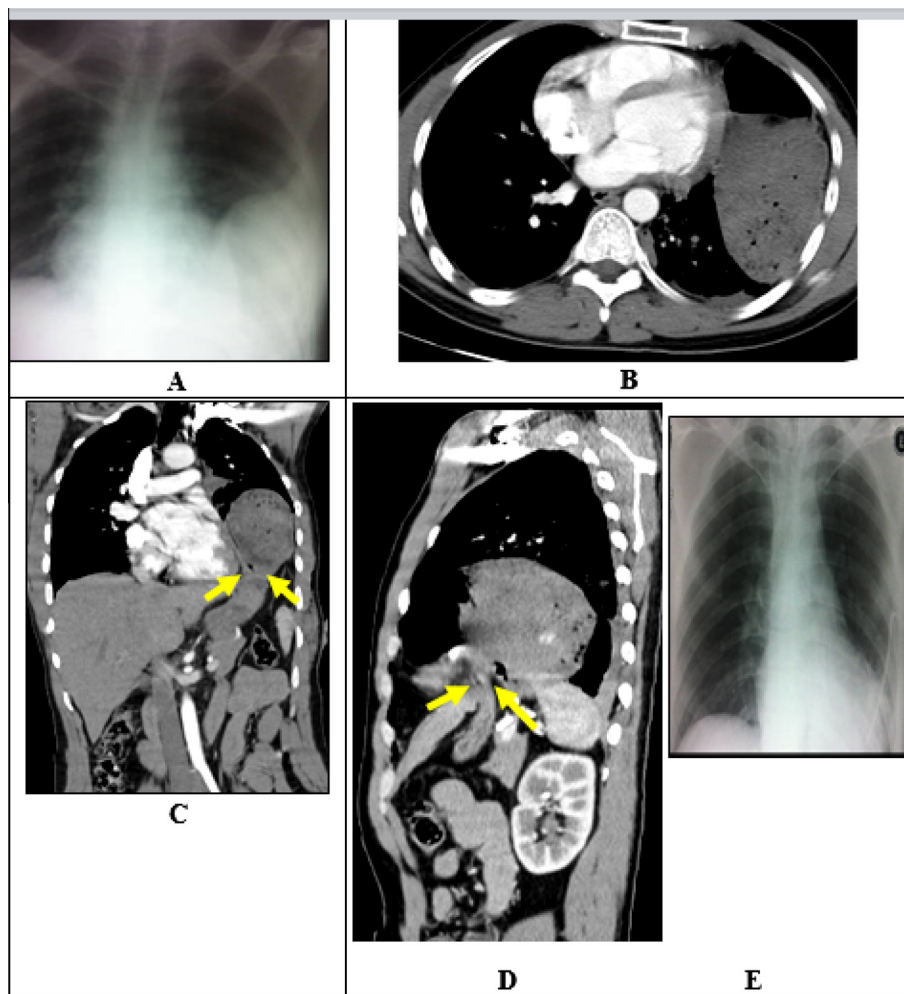
Axial images in all phases were reviewed and analyzed; high quality post-processing 2D coronal and sagittal reformatted images with thin cuts 1.25 mm thickness were routinely obtained using the multiplanar reconstruction (MPR) technique from volumetric and isotropic axial CT data. Images obtained were sent to the work station. The Maximum Intensity Projection (MIP) and 3-D volume reconstruction could be obtained as needed.

The abdomen and pelvis were scanned in lung window for the detection of free intraperitoneal air, air adjacent to bowel loops, and retroperitoneal air. Soft tissue window was used to detect hemoperitoneum, retroperitoneal hematoma or extra peritoneal fluid, searching for arterial extravasations (contrast blush) and localizing the anatomical sites of injury. Assessment of diaphragm integrity, muscle injury and bone fractures was done via bone window.

3. Results

A total of 30 patients with blunt abdominal and pelvic trauma were submitted for Multidetector CT examination.

28 males and 2 females were included, aged 2–74, with a mean age of 38. Five (16.6%) patients had diaphragmatic rup-



Case 1 33-year old man who had respiratory compromise following fall from height. Chest X-ray depicts elevation and apparently disruption of the left hemidiaphragmatic contour. No air under diaphragm. (B) MDCT contrast axial image, and (C) coronal and (D) sagittal reformation MDCT images showing herniation of the stomach (fundus and body) across the left hemidiaphragm with abrupt narrowing at the level of diaphragmatic tear causing waist like constriction of the herniated viscous. “The collar sign” (arrows). Pleural effusion and lung base atelectasis are associated findings. Follow-up (E) X-ray post-exploratory laparotomy shows reduction in the abdominal content denoting hernia repair.

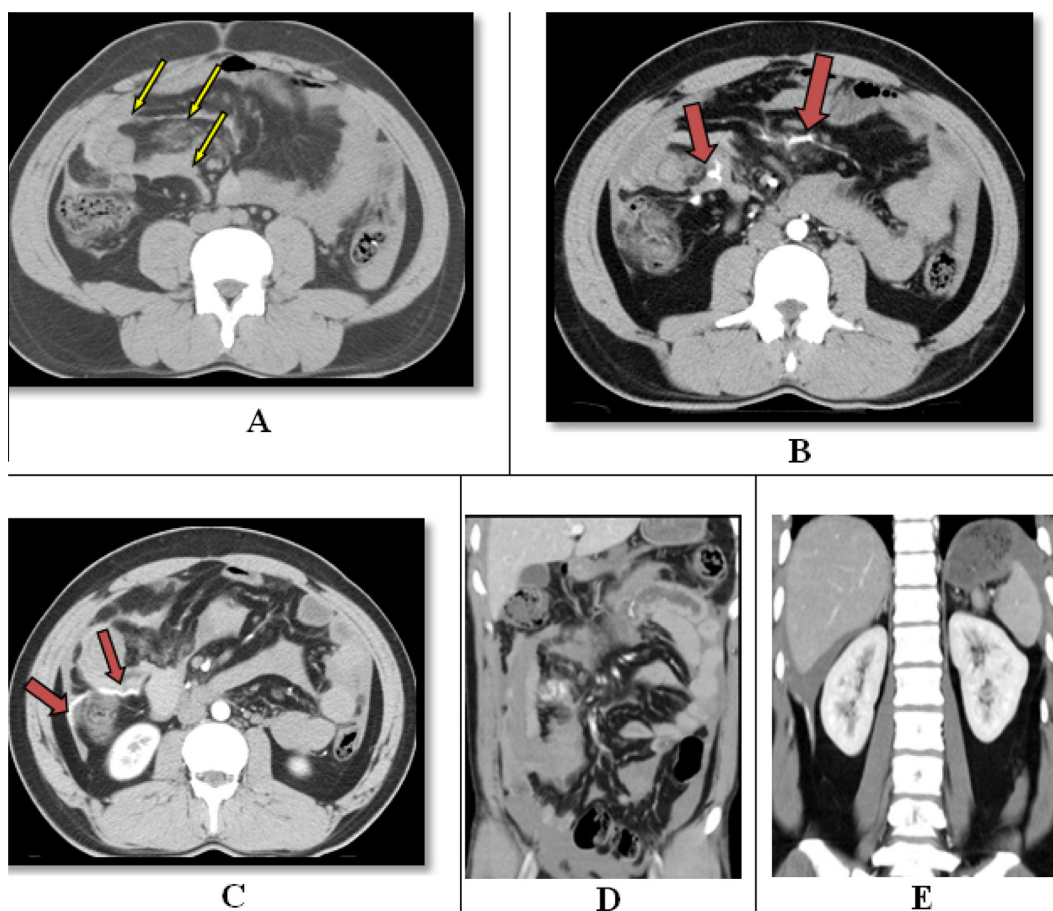
Table 1 Site of bowel injury documented by MDCT.

| Patient's number | CT findings |
|------------------|--|
| 2 | Cecal perforation |
| 1 | Descending colon perforation |
| 2 | Rectal injury associated with bladder injury |

ture diagnosed by MDCT (Case 1); they showed intrathoracic herniation of the abdominal viscera. Five (16.6%) patients were diagnosed by MDCT bowel perforation (Table 1) (Cases 2 and 3), and two patients (6.6%) were diagnosed traumatic rectovesical fistula. Three patients (10%) were diagnosed by MDCT had mesenteric injury (Table 2). Four patients (13.3%) had vascular injury diagnosed by MDCT (Table 3) (Case 4). Five (16.6%) patients had traumatic urinary bladder

injury diagnosed by MDCT (Table 4). Four (13.3%) patients out of 30 had spine injury and 2 patients (6.6%) of them had unstable spine injury proved by MDCT. The four patients showed associated solid organ injury. One patient had been subjected to MRI for evaluation of the spinal cord. Two (6.6%) patients had rectus sheath hematoma, proved by CT (Case 5).

According to statistical analysis of the study results, the most common affected non-solid organs are the bowel, urinary bladder and the diaphragm; each structure accounts for 16.6% of the injury findings in the study population. The second most prevalent injury is the vascular and spine lesions in which each accounts for 13.3%, followed by mesenteric injury 10% and finally rectus sheath and rectovesical fistula; each accounts for 6.6% of the study population. The prevalence and distribution of organ injury are illustrated in Chart 1.



Case 2 A 30 year-old man admitted after road traffic accident. (A) US study done on admission time shows free intraperitoneal fluid. No organ injury. CT (A) Axial non-contrast MDCT image demonstrates focal increase in bowel wall thickness, consistent with focal small bowel contusion with mesenteric fat standing and the characteristic triangular shape of mesenteric hematoma (yellow arrows) associated with free intraperitoneal fluid. (B and C) Axial arterial phase shows extravasation of the intravenous contrast at the region of mesenteric stranding (brown arrows) indicative of active mesenteric bleeding, with tracking of the IV contrast to the paracolic gutter. (D and E) Coronal, reformate images show the previous findings. Exploratory laparotomy with resection anastomosis of small bowel was done.

4. Discussion

Currently, Multidetector computed tomography (MDCT) scanning with intravenous contrast is the gold standard diagnostic modality in hemodynamically stable patient (3).

With the advent of multidetector CT (MDCT), scanning times have progressively decreased while image resolution has increased owing to thinner collimation and reduced partial volume and motion artifacts. This high quality image data can be processed further into multiplanar reformatted (MPR) or maximum intensity projection (MIP) images and three-dimensional volumetric (3-D) images, which often aid in the diagnosis of complex injuries in trauma patient (8).

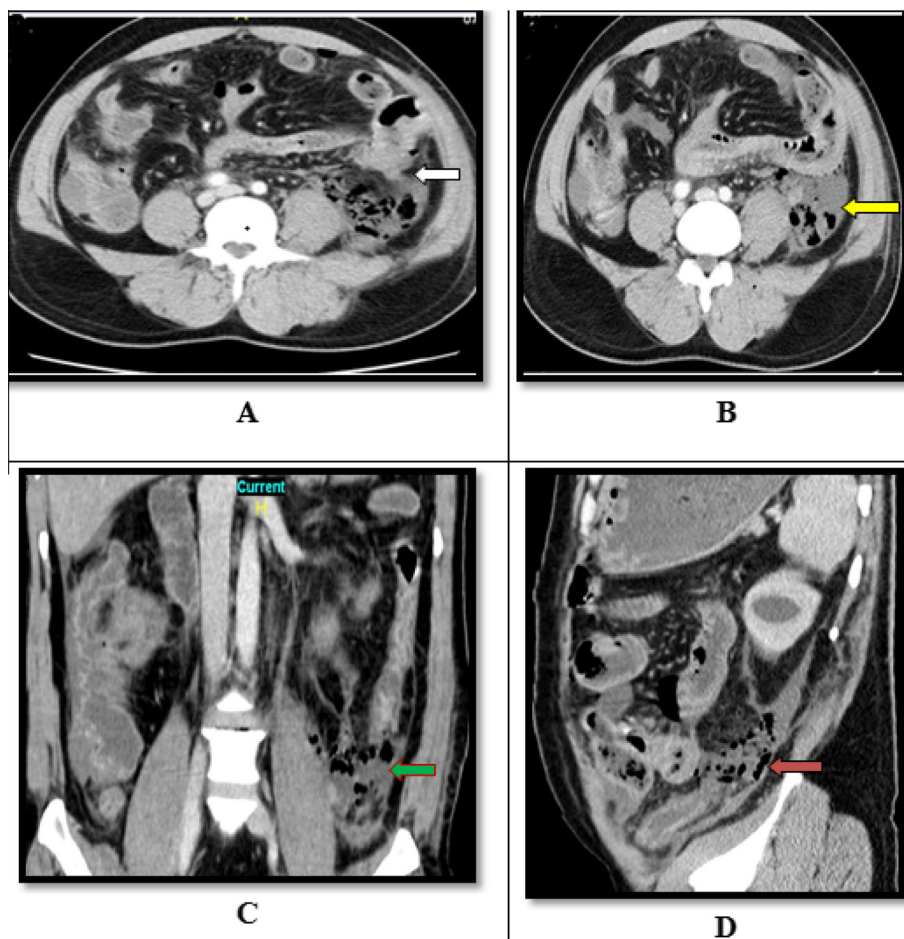
It was observed that no age group was exempted from traumatic injury of abdomen. But that was more common in the second to third decade of life; this indicates that young adult were more common to abdominal trauma probably because of more exposure to day to day hazards. It was also evident from this study that male affection was more common (93.3%). According to Awe et al. (9) in 2013, in their 5 year

work, that abdominal injury predominantly affects young male patients reaching the peak in twenty to fifty age groups and the incidence of male patients was 86.9% to female patients was 13.1%.

CT scan has advantage over ultrasound, less operator-dependant and is not limited by the abdominal wall, subcutaneous emphysema, obesity, intestinal distension (10). Moreover Van et al. (3) in 2011, reported other limitation of US study was the retroperitoneal accuracy and does not accurately detect the extent (grade) or the exact site of injury. Hence ultrasound scanning still served as an appropriate investigation, correctly detecting the presence of intra-abdominal injury, but was poor at localizing the injury to specific viscera.

From this study experience the most important answer for the surgeon was that it is or it is not active blood extravasations, and major vascular injuries, and these findings are all readily identified on well-performed CT examinations.

In this study, the reconstructions added fine details that would be difficult to evaluate using axial reconstructions alone, adding diagnostic capabilities such as cases of diaphragmatic rupture, bony injuries, bowel perforation and renal vein avul-



Case 3 A 43-year old male admitted one day after being involved in blunt abdominal trauma. Axial contrast venous phase (A and B) showing disruption, discontinuity at the distal portion of the descending colon (white arrow), with localized extra-luminal air and free fluid at the site of perforation (yellow arrow). (C) Coronal reformatted image demonstrates the entire descending colon and is helpful in better understanding the location and extent of injury (green arrow). (D) Sagittal reformates image proves the extraluminal air and fluid (brown arrow). Laparotomy done confirmed the diagnosis with transection to the perforated segment.

Table 2 MDCT findings of mesenteric injury.

| Patient's number | CT findings |
|------------------|--|
| 1 | Mesenteric injury associated with bowel injury |
| 1 | Blunt mesenteric contusion |
| 1 | Vascular extravastion |

Table 3 MDCT findings of vascular injury.

| Patient's number | CT findings |
|------------------|------------------------------------|
| 2 | Renal vein avulsion and IVC injury |
| 1 | IVC injury |

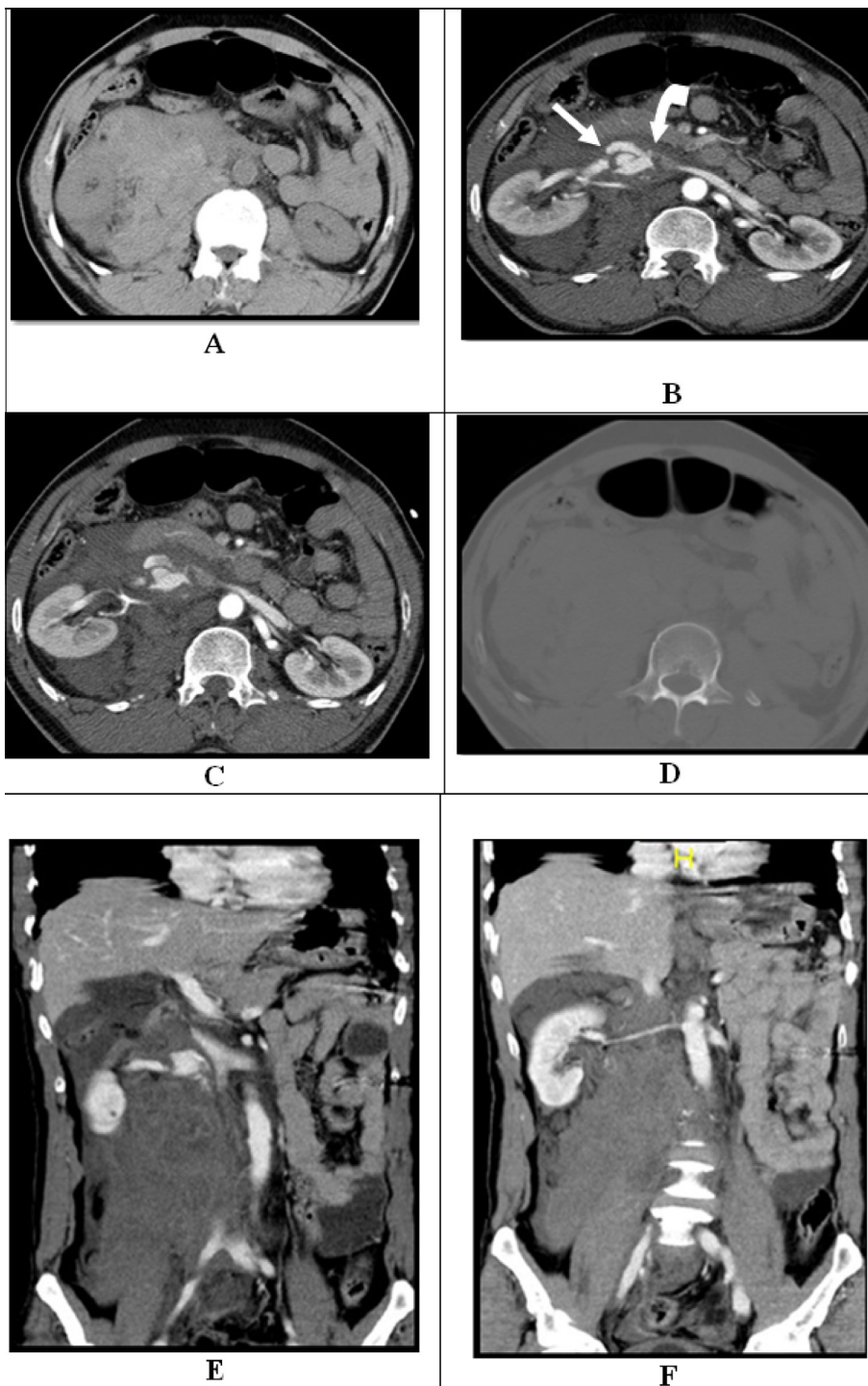
sion. The MIP images provide an excellent vessel depiction and amazing detail provided in one coronal plane. According to Perandini et al. in (8) 2010, MIP can follow the complete course of the structures even if they are tortuous.

In many trauma case studies, the CT scans were acquired during the portal venous phase (without arterial phase) approximately 70–80 s after the contrast injections such as studies carried out by Hassan et al. (7) in 2010, and Drasin et al. (11) in 2008, compared to other study carried out by Steenburg et al. (12) in 2013, and the author found that the addition of arterial phase images enabled the radiologist to better detect and characterize traumatic vascular injuries which include bleeding and non-bleeding entities, compared

with portal venous imaging alone. In this work arterial phase was routinely done where active bleeding was seen in the MDCT imaging as an irregularly shaped, curved or linear hyper density seen in arterial phase that displays similar density to the aorta. During the portal venous phase images, the focus of blood will maintain its hyperdensity and size increase.

In this study the diaphragm, bowel and urinary bladder were the most commonly injured structures.

A study reported by Hassan et al. (7) in 2010, carried out on 92 patients, reported that the spleen is the most frequently injured abdominal organ during blunt abdominal trauma accounts for up 45% of all visceral injuries. The liver is the second most frequently injured. The pancreatic injury is encountered in only 3–12% of all abdominal injury while renal injury



Case 4 A 28-year old male patient who experienced severe blunt abdominal trauma. (A) Axial Image shows a large retroperitoneal hematoma causing displacement of the kidney antero-laterally. (B and C) Axial contrast venous phase displays the discontinuity of the right renal vein (*white arrow*) with contrast extravasation at the junction between right renal vein and IVC (*bent curved arrow*). The kidney, IVC, and duodenum are displaced anteriorly by the large retroperitoneal hematoma. (D) Axial image bone window shows fracture left transverse process at L3 V. Other transverse fractures not demonstrated seen from L1 to L5. Note decrease in parenchymal contrast enhancement of right kidney compared to the left. (E) Coronal reformate image shows right renal vein avulsion and extensive retroperitoneal hematoma. (F) Coronal image demonstrates stretched right renal artery. The patient was managed with exploratory laparotomy and right nephrectomy. Intraoperative findings are significant large retroperitoneal hematoma with an avulsed renal vein and laceration of the renal artery.

Table 4 MDCT findings of the urinary injury.

| Patient's number | CT findings |
|------------------|---|
| 3 | Extravastion of contrast from the urinary bladder + fractured pelvis + perivesical hematoma |
| 2 | Traumatic rectovesical fistula + air accumulation in urinary bladder + thickened urinary bladder wall |

was about 10%, while a study done by Desir et al. (13) in 2012 estimated that diaphragmatic injuries occur in 0.8% to 8% of patients with blunt abdominal trauma. A similar incidence found by Dwari et al. (14) in 2013, reported that, the incidence of diaphragmatic rupture is between 0.8 and 1.6% of blunt abdominal trauma and most of them are in the third decade of life. Another study done by Hamidi et al. (15) in 2007, reported that the most commonly injured organs are the spleen, liver, retroperitoneum, small bowel, bladder, colorectal, diaphragm and pancreas.

Another similar study done by Kumar et al. (16) was carried out on two hundred and ten patients with blunt abdominal trauma in which various organ injuries were graded and the management was decided based on the CT findings, and the author concluded in his study that CT organ injury grading

is helpful in guiding the surgeon toward patient management. CT is accurate and safe, and has all the attributes to make it an initial investigation of choice in hemodynamically stable patients of blunt abdominal trauma.

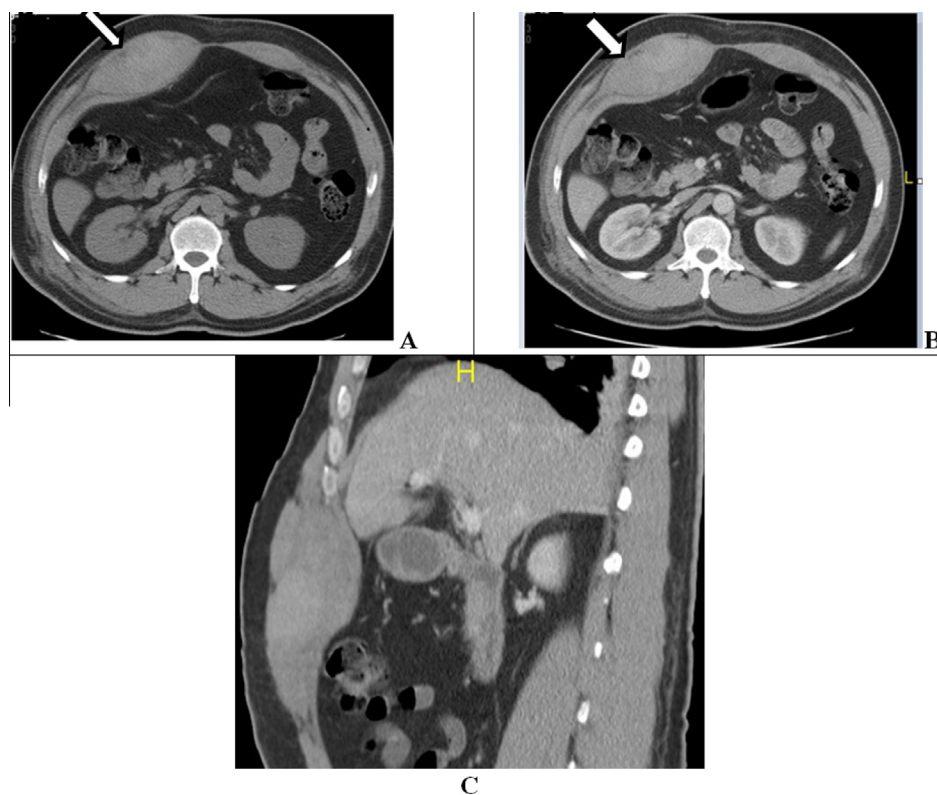
Daly et al. (6) in 2008 reported that multidetector CT plays an important role in accurate radiologic characterization of injury and can help in selecting patients who need urgent surgical intervention, as opposed to those in whom non-operative management is possible, particularly since the morbidity rate for unnecessary laparotomy is between 8.6% and 25.9%.

In this work the MDCT had shown high sensitivity in diagnosis of injuries in the abdomen and pelvis involving non-solid organs reaching 100%.

Compared to a study done by Van et al. (3) in 2011, who reported that MDCT scanning with intravenous contrast has a sensitivity of 90–100%, another study done by Salimi et al. (17) in 2009 over a period of two years reported CT scan had the highest sensitivity for detecting the injuries to the liver (100%), followed by detection of spleen injuries (86.6%).

5. Conclusion

CT is an excellent imaging modality to evaluate non-solid organ injury in patients with blunt abdominal trauma, being reliable, safe and non-invasive study that can guide in the management and follow-up of cases with blunt abdominal and pel-



Case 5 A 50-year old male after one week of blunt abdominal trauma (blow), patient had experienced moderate abdominal pain. Axial images (A) non-contrast phase shows fusiform increase and enlargement of right rectus muscle by the diffusely increased density representing rectus sheath hematoma (arrow). The hematoma is unilateral and does not dissect along the facial planes. (B) Venous phase no enhancement seen, and (C) sagittal reformate image shows the extension of the lesion. The patient successfully managed conservatively.

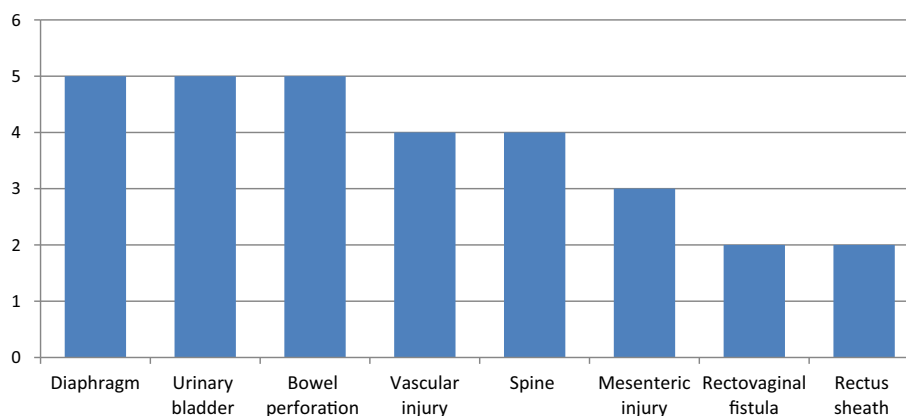


Chart 1 Number of individual injury by CT in the study.

vic trauma but require stable vital signs. MDCT decreases the unnecessary exploration and increases patients' survival.

Conflicts of interest

None declared.

Disclosure of funding

Nothing to disclose.

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