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# Multi-detector computed tomography in traumatic abdominal lesions: value and radiation control

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## Abstract

**Background, The context:** A prospective study was conducted involving 81 patients (mean age, 20.79 years) with abdominal trauma who underwent ultrasonography and post-contrast CT on MDCT scanner. The total DLP for each patient was reviewed, and the effective dose was calculated. Purpose of the study to: explore the role of MDCT in assessing traumatic abdominal lesions, demonstrate radiation dose delivered by MDCT, and describe specific CT technical features to minimize radiation.

**Results:** The spleen was the most commonly injured organ (49.4%) followed by liver (39.5%) and kidney (24.7%). Pancreatic injury occurred in seven patients, whereas only two patients had intestinal injuries. One patient had adrenal injury. Minimal, mild and moderate free intra-peritoneal fluid collection was detected in 21 (25.9%), 47 (58%) and 10 (12.3%) patients, respectively. Only three (3.7%) patients had no collection. One patient had active uncontrolled bleeding and died. Radiation dose was below the detrimental level (calculated effective dose), with optimal image quality.

**Conclusions:** MDCT is sensitive to all types of traumatic abdominal lesions. Not only in determining the injury, but also in its grading. MDCT has affected the treatment directions, spotting a focus on conservative treatment by raising the diagnostic confidence. FAST cannot be the sole imaging modality. The individual radiation risk is small but real. Advancements in medical imaging reduce radiation risk.

**Keywords:** MDCT, Abdominal trauma, FAST, Contrast media, Radiation risk

## Background

Trauma is a major cause of death in developing countries where abdominal trauma accounts for approximately 10% of all deaths and 45% of morbidity [1]. Abdominal trauma can present with various organ injuries, depending on pattern of trauma (i.e., blunt or penetrating). Rapid and accurate investigations are essential for definitive management [2–6].

The abdomen is a diagnostic black box. Usually, radiological assessment is required as clinical examination is

unreliable and non-specific [2, 5–7]. Focused Assessment with Sonography for Trauma (FAST) has multiple advantages in abdominal trauma evaluation, including easy performance, noninvasiveness, low cost, portability and vital importance in observing patients in conservative management. However, FAST has significant shortcomings, such as its limited capability of evaluating the retroperitoneal region. Additionally, it cannot differentiate blood from other body fluids, for example, extravasated urine [6–9].

Multi-detector computed tomography (MDCT) provides supreme anatomical and physiological information that can differentiate trivial injuries from those requiring intervention. Moreover, MDCT with multiplanar capability and three-dimensional (3D) reformatted images

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offers fine details regarding retroperitoneal organs [10–16].

The use of CT is increasing faster than the industry that regulates it. Considering the CT radiation dose, several CT examinations today have an effective dose that is less than the yearly background radiation exposure [17–22]. There is a huge benefit when we decrease the radiation dose, especially in children. Children are more radiosensitive than adults: as the risk of radiation-induced cancer is related to rapidly dividing cells. Additionally, children have a longer expected lifetime. Thus, radiation-induced cancers can become manifest, and the radiation risk is cumulative over a lifetime [21–26].

Radiation dose metrics include CT dose index volume (CTDIvol), dose length product (DLP), conversion K-factor, and effective dose. CTDIvol represents scanner radiation output. DLP (mGy.cm) is CTDI (mGy) multiplied by the Scan length (cm). Both (CTDIvol) and DLP do not represent the actual patient dose. DLP measures the quantity of ionizing radiation exposure during image acquisition. The international unit for measuring radiation exposure is the Sievert (Sv)[17–20, 23].

The effective dose is measured in Sieverts (Sv) and is used to evaluate the risk of radiation exposure. To convert DLP to effective dose, a conversion factor (k-factor) must be used. The effective dose is the product of the tissue-weighting factor (k-Factor) multiplied by the absorbed dose (DLP). k-Factors differ among various tissues, depending on the estimated sensitivity to radiation of each tissue. Additionally, k-factors are age dependent as radiation impacts are higher in children. These k-factors (Table 1A) are defined by the International Commission on Radiological protection (ICRP) [23–29].

In a CT dose report, the CT scanners will output both the CTDI and the DLP. For example, an abdominal and pelvic CT scan with technical Parameters leads to a CTDI of 10 mGy and a scan length of 45 cm. Thus, DLP is 450 mGy.cm. If the input is 450 mGy.cm for the DLP and scanning the abdomen and pelvis of an adult patient, the result will be an effective dose of  $450 \times 0.015 = 6.75$  mSv. The cumulative radiation dose is the effect of repeated exposures to low-dose ionizing radiation of the same region, i.e., no “safe” dose. Nowadays, no established

**Table 1** (A) k-Factors in various tissues. (B) Calculation of effective dose in each exam

| <b>(A)</b>            |          |                    |                    |                     |              |
|-----------------------|----------|--------------------|--------------------|---------------------|--------------|
| <b>Region of Body</b> | <b>0</b> | <b>1 years old</b> | <b>5 years old</b> | <b>10 years old</b> | <b>Adult</b> |
| Head and Neck         | 0.013    | 0.0085             | 0.0057             | 0.0042              | 0.0031       |
| Head                  | 0.011    | 0.0067             | 0.0040             | 0.0032              | 0.0021       |
| Neck                  | 0.017    | 0.012              | 0.011              | 0.0079              | 0.0059       |
| Chest                 | 0.039    | 0.026              | 0.018              | 0.013               | 0.014        |
| Abdomen and Pelvis    | 0.049    | 0.030              | 0.020              | 0.015               | 0.015        |
| Trunk                 | 0.044    | 0.028              | 0.019              | 0.014               | 0.015        |

| <b>(B)</b>                                       |                     |                          |                             |
|--|---------------------|--------------------------|-----------------------------|
| <b>Conversion of total DLP to effective dose</b> |                     |                          |                             |
| <b>Patient age</b>                               | <b>Type of exam</b> | <b>Total DLP (mgycm)</b> | <b>Effective dose (msv)</b> |
| 5 years  | Monophasic          | 82.4                     | 1.6                         |
| 9 years  | Monophasic          | 119                      | 2.4                         |
| 17 years   | Triphasic           | 347                      | 5.2                         |
| 17 years   | Biphasic            | 327                      | 4.9                         |
| 18 years   | Biphasic            | 308.3                    | 4.6                         |
| 20 years   | Triphasic           | 692.9                    | 10.4                        |
| 25 years   | Triphasic           | 668                      | 10.02                       |
| 25 years   | Triphasic           | 666                      | 10                          |
| 27 years   | Biphasic + enema    | 1350                     | 20.3                        |
| 34 years   | Triphasic           | 855                      | 12.8                        |
| 42 years   | Biphasic            | 439.6                    | 6.6                         |
| 53 years   | Triphasic           | 1103                     | 16.6                        |

NB. Table 1B shows representative group of our patients, conversion of Total DLP to Effective dose, through multiplication by K-factors tissue weighting considering age (according to Table 1A)

method is available to track cumulative patient radiation dose [22–29].

Several studies have discussed the role of CT in abdominal trauma assessment [2–5]. The uniqueness of this study is that it focused on radiation debates from CT scans not to avoid imaging for fear of radiation in trauma critical situations. Additionally, this study discussed various technical aspects to decrease radiation and the limits of dose reduction.

This study aimed at: exploring the role of MDCT in assessing traumatic abdominal lesions also demonstrating radiation dose delivered by MDCT, and describing specific CT technical features to minimize radiation with hints on future developments.

## Methods

### Study design

This Prospective diagnostic accuracy study was conducted at a tertiary care hospital in Upper Egypt from May 2018 to May 2020.

### Ethics approval and consent to participate

Institutional Review Board approved this study, and an informed written consent was obtained from all patients who were included in the study.

### Study population

The study involved 81 patients. Of the 103 trauma cases, 81 patients were enrolled in this study with confirmed abdominal trauma, including 55 males (67.9%) and 26 females (32.1%). The age of the patients ranged between 4 and 53 years, with a mean age of  $20.79 \pm 14.21$  years. The inclusion criterion was patients presenting with a rigid abdomen after abdominal trauma (Table 2). The exclusion criterion was patients who were hemodynamically unstable.

### Patient assessment

All enrolled patients were subjected to the following interventions:

**Table 2** Demographic data of studied patients

|            | <b>N= 81</b>  |
|------------|---------------|
| Age (year) | 20.79 ± 14.21 |
| Range      | 4–53          |
| Age group  |               |
| ≤ 16 year  | 38 (46.9%)    |
| > 16 year  | 43 (53.1%)    |
| Sex        |               |
| Male       | 55 (67.9%)    |
| Female     | 26 (32.1%)    |

Data were expressed in form of frequency (percentage), mean (SD), range

- A. Detailed clinical examination and history was documented according to hospital trauma protocol.
- B. FAST examination was performed for all patients with special attention to free intraperitoneal fluid, lesions in solid organs and any local hematoma. Ultrasound examination was performed using GE Logiq P7 (GE Healthcare Systems, Korea) and Philips HD 11XE (Philips Medical systems, Holland) duplex ultrasound machines with bandwidth frequency transducers 3.5–5 MHz curved probe and 5–13 MHz linear probe. FAST scans were obtained at three interfaces: hepatorenal, splenorenal, and pelvis interfaces.
- C. For MDCT, pre-contrast and contrast-enhanced CT were performed using a 160-slice MDCT (Aquilion Prime Model, TSX-303A CGGT-032A, Toshiba, Canon Medical Systems, Japan).

### MDCT technique

For adult cases, a dual-phase study was performed as routine. All adult patients received a bolus of intravenous (IV) contrast medium (CM), typically 100–150 mL (1–1.5 mL/Kg) low-/iso-osmolar nonionic iodinated CM (*Iohexol = Omnipaque 350/Iodixanol = Visipaque or Isovist 320*) injected at a rate of 3–5 mL/s through an 18–20-gauge cannula. An automatic power injector was used, followed by 30–50 mL of saline solution as a chasing bolus, also at a rate of 3–5 mL/s. Arterial phase series (25–30 after injection) of the abdomen and/or pelvis was done for all patients [15, 16, 30–34]. Portal venous phase images of the abdomen and pelvis were acquired 75–80 s, after the start of IV CM administration. Delayed phase (5–10 min after start of IV CM administration) was optional. (Performed as a necessary step in adults with renal injuries, lesions were noted preliminary on portal venous images.) A radiologist was available to review the portal venous phase images at a CT workstation, while patients were still on the table of CT scanner.

For the pediatric group, only Portal venous phase (approximately 75–80 s) was obtained, that is, monophasic study [22, 23, 27–29, 33]. Typically, using IV CM with a dose of 1.8 mL/kg, iso-/low-osmolar nonionic iodinated injected using a power injector at 2.5 mL/s followed by 15–20 mL of saline flush. The scanned region was from the diaphragm to the symphysis pubis.

### Rectal CM

Instant barium enema was performed for suspicious patients (penetrating injury due to stab wound = three patients) using diluted 5% Omnipaque 350 mgI/mL

(iodine-based low-osmolar CM) as substitute for diluted diatrizoate meglumine (Gastrografin, i.e., high-osmolar CM) [35, 36]. Oral CM was not used routinely in this study, due to time constraints, and its exclusion did not affect patient outcomes. We used it in three cases of penetrating injury (triple CM) and seven cases of pancreatic injury (according to clinical suspicions, FAST and laboratory findings). Axial cuts were acquired, and post-processing reformates on coronal and sagittal planes were obtained. Imaging findings were correlated with the ultrasound findings, and results were tabulated and analyzed with special attention to the grades of injury of the spleen, liver and kidney. Additionally, CTDIvol and DLP values were reviewed for each CT examination and then the effective dose was calculated to assess the radiation risk.

**Image analysis**

Two senior radiologists with 15 and 20 years’ (A and B) experience in emergency radiology reviewed CT data independently for the presence of hemoperitoneum, vascular injuries and organ injuries (i.e., contusions, lacerations, hematomas, hollow viscus injury, contrast extravasation and pneumo-peritoneum).

The final diagnosis was based on: (1) clinical follow-up and serial imaging ( $n=75$ ) (patient stability and

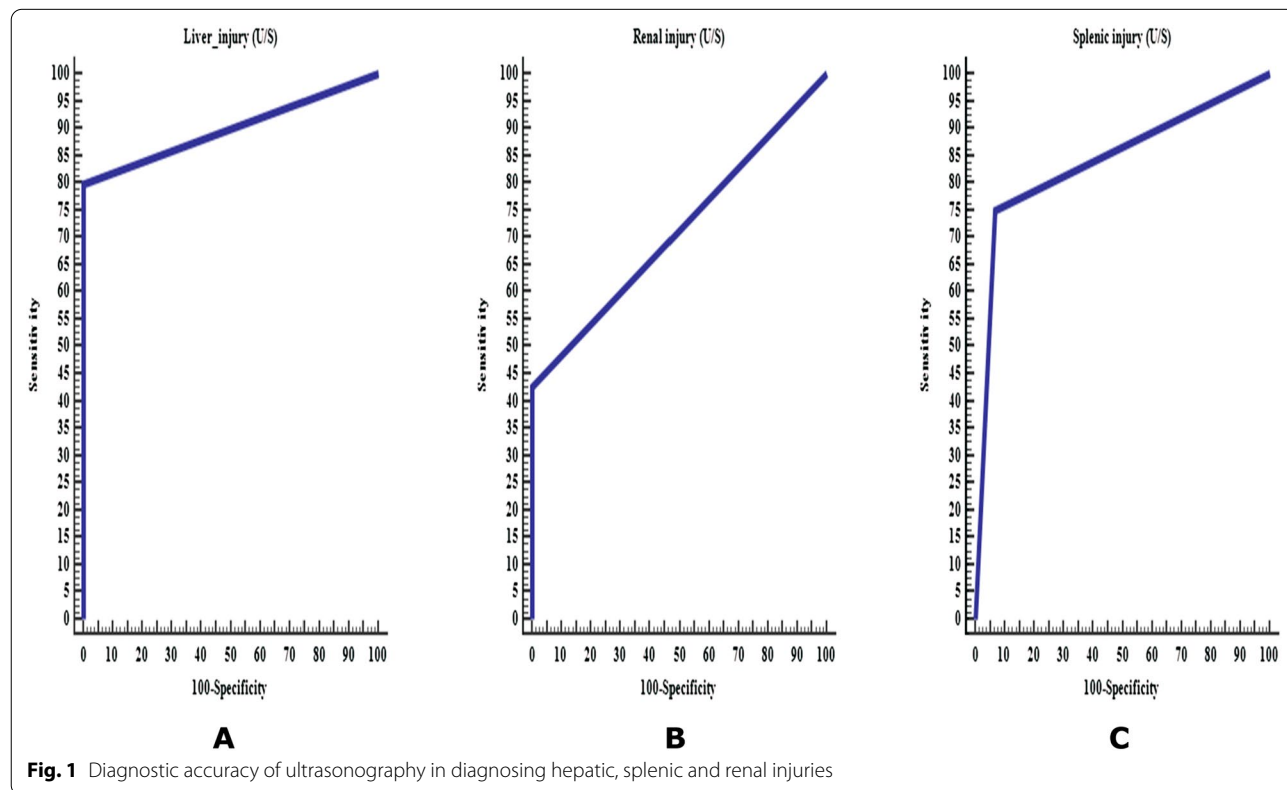
improvement indicate proper diagnosis and an appropriate conservative line of management) and (2) Surgical findings ( $n=5$ ).

**Statistical analysis**

Data were collected and analyzed using Statistical Package for the Social Sciences (SPSS, version 20: IBM Corp., Armonk, New York, USA). Continuous data were expressed as mean  $\pm$  standard deviation and range, whereas nominal data were expressed as frequency (percentage). Diagnostic accuracy of abdominal ultrasound was determined using receiver operator characteristic (ROC) curves (Fig. 1). The degree of agreement between two observers (A and B) regarding CT findings was determined by inter-observer agreement and K degree. The level of confidence was kept at 95%, and hence,  $p$  values of less than 0.05 were used to denote statistical significance (Table 9).

**Results**

Demographic data of studied patients are summarized in Table 2. Patients with blunt trauma outnumbered those with penetrating trauma. Motor vehicle accidents accounted for 58% of all cases, followed by falling from height, accounting for 32.1% of all cases (Table 3). Splenic



injuries accounted for 49.4% of all cases, followed by hepatic injuries (39.5%) and renal injuries (24.7%). Seven patients (8.6%) had pancreatic injury. Only two patients (2.5%) had intestinal injuries, and one patient had adrenal injury (1.2%) (Table 4). Of the 40 patients with splenic injury, eight (20%), 23 (57.5%) and nine (22.5%) patients had grade II, III, and IV splenic injuries, respectively (Table 5). Of the 32 patients with liver injury, 15 (46.9%), 14 (43.8%), and three (9.4%) patients had grade II, III, and IV liver injuries, respectively (Table 5). Ultrasound had 80% sensitivity and 100% specificity for liver injuries, 75% sensitivity and 93.3% specificity for splenic injuries and 43% sensitivity and 100% specificity for renal injuries (Table 6).

Moreover, 36 (44.4%) patients had chest injuries. Of them, 24 (66.7%), 27 (75%), 21 (58.3%), and 18 (5.0%) patients had pneumothorax, pleural collection, lung contusion, and rib fracture, respectively (Table 7).

At time of admission, majority of patients (55.6%) were hemodynamically unstable, whereas 36 patients (44.4%) were stable. Conservation and strict follow-up were the main line of management in 75 patients (92.59%). Splenectomy was performed in three patients, and surgical repair was performed in two patients with intestinal injury. Eighty patients (98.8%) improved. The condition of only one patient deteriorated, and the patient died. The Management and outcomes of studied patients are shown in Table 8.

Inter-observer agreement between observers A and B for the different MDCT findings are shown in Table 9. Additionally, both observers noticed an excellent subjective image quality for anatomical landmarks, soft tissues, and vascular structures. No significant subjective image noise or artifacts were observed. The same note was recorded using low kilo-voltage imaging (80–100 kV), in smaller patients (i.e., children and young adults).

Both observers (A and B) had 100% agreement with a K degree was 1 in cases of detecting renal, intestinal, adrenal, and chest injuries including (e.g., pneumothorax, pleural collection, lung contusion, and rib fracture). For diagnosing liver injuries, both observers had 93.8% agreement with a K degree was 0.91. In diagnosing splenic and pancreatic injuries both observers had 92.5% and 85.7% agreement, respectively, with K degrees of 0.89 and 0.60, respectively (Figs. 2, 3 and 4).

Sample of all patients is shown in Table 1B. The TDLP was presented in mgy.cm, Conversion to the effective dose in mSv was performed by multiplying the TDLP by the tissue-weighting factor (k-factor) (Table 1A). The TDLP is the absorbed dose through the entire examination (cumulative: topogram plus all phases in addition to complementary examination of the same region).

## Discussion

Abdominal trauma presents variably. MDCT is the “gold standard” technique for assessing and managing abdominal trauma due to its sensitivity and specificity. The most widely used methods for categorizing traumatic injuries are the American Association for Surgery of Trauma (AAST) injury scoring scales [12–15, 37–39].

Medical imaging is the cornerstone of medical care. The proper use of imaging procedure makes potential benefits outweigh the risks. Appropriate CT imaging standards are targeted to improve patient safety by minimizing the radiation dose without sacrificing diagnostic quality. To the best of our knowledge, our study is *unique* in reviewing and calculating radiation doses, as it tracked radiation exposure in a cumulative manner for critical trauma patient [20–23].

In this study, radiation doses were reviewed simply using the total DLP value (the only figure you should check) in the dose sheet provided by the machine at the end of an examination (e.g., the dose sheet shown in Fig. 5G, H). Then, the effective dose for each patient was calculated by multiplying the TDLP by the tissue-weighting factor (K-factor) (Table 1A).

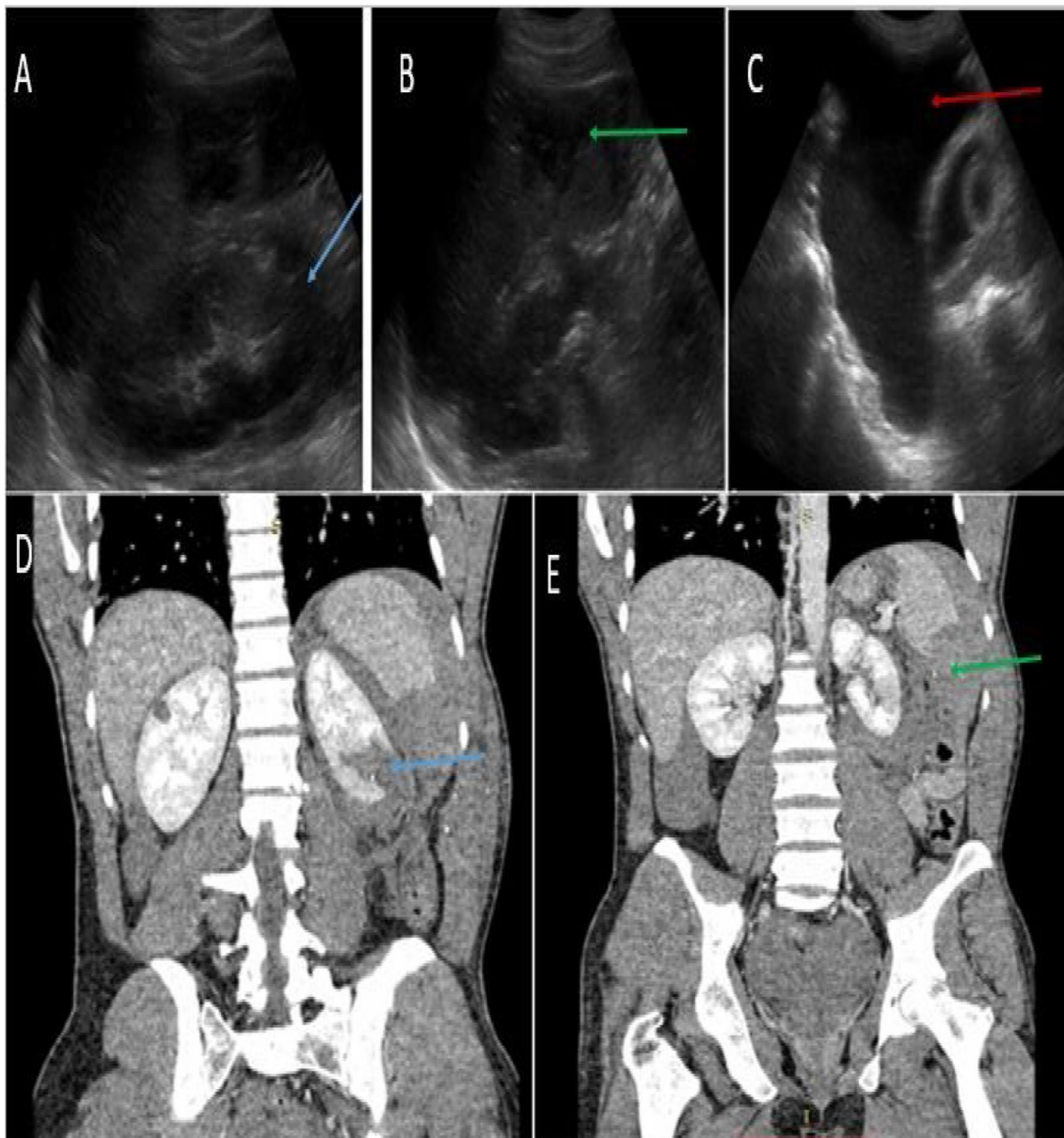
The TDLP includes the summation doses from all scans performed for the same region plus the topogram. In the entire series (with variable techniques, and multiphase examinations), the effective dose was below the detrimental level, that is, 50 mSv for a single procedure. A representative sample of all patients is shown in Table 1B. The TDLP was presented in mgy/cm, and the effective dose was presented in mSv.

However, adhering to the “as low as reasonably achievable” “ALARA” principle is wise [18–20], as trauma patients usually need repeated/follow-up imaging procedures over a short period. In present study, we explored the role of MDCT in diagnosing different traumatic abdominal injuries to assess its validity comparing to clinical follow-up, serial imaging and surgical findings as reference standards.

In trauma settings, techniques differ from institution to another according to facilities, indications, and guidelines. CT protocols should be tailored to match the need of each individual patient. Optimizing the CT technique is a real target to get the best diagnostic accuracy and radiation control; this is achieved by a) properly using CM, b) acquiring an adequate number of phases (multiphase study if needed), and c) minimizing the radiation dose while preserving the image quality (diagnostic performance) [13, 31–36].

CT with only IV CM can be performed more quickly, with a similar level of efficacy (to that implemented with enteric CM). The portal phase is essential in a CT trauma protocol [30–35].



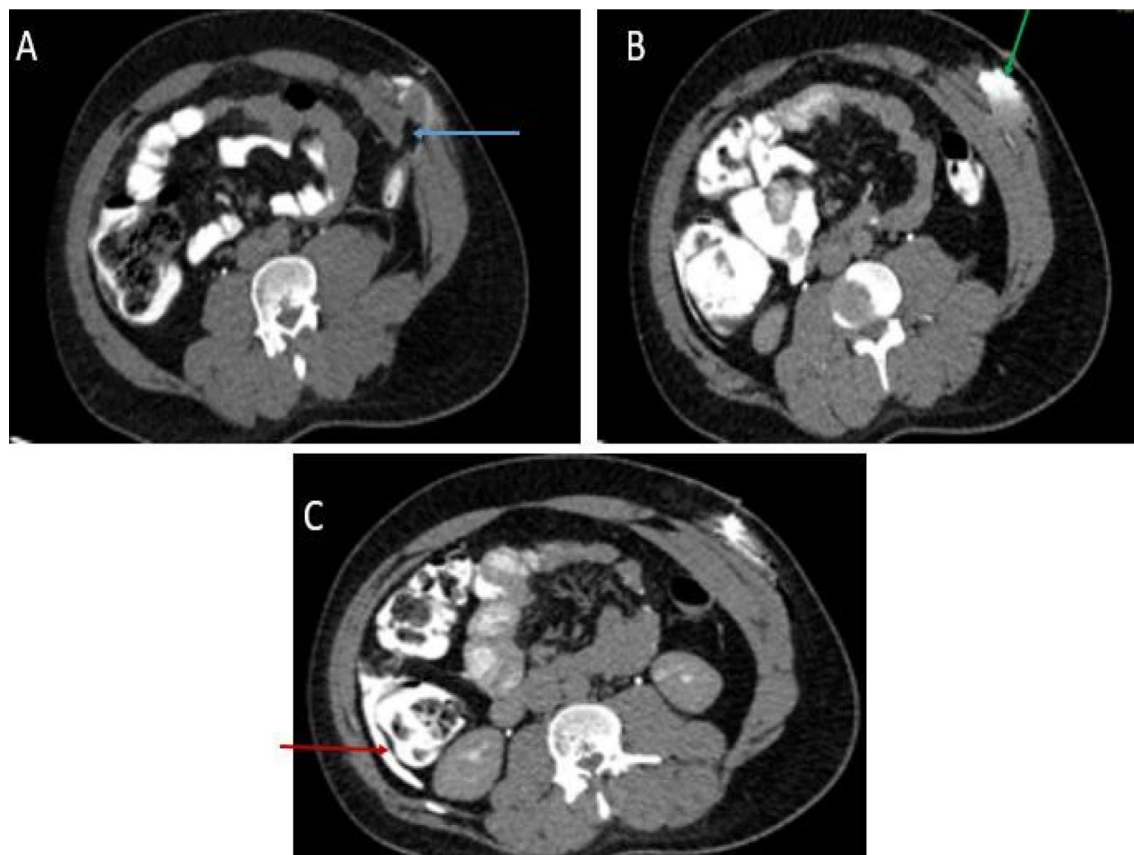


**Fig. 2** A 25-year-old male patient presented with firearm injury. FAST examination. **A** Lower pole of the left kidney shows hyperechoic area with irregular border (blue arrow)... *left renal contusion*. **B** The lower pole of the spleen shows a heterogeneous area (green arrow)... *parenchymal hematoma*. **C** Mild pelvic Intra peritoneal fluid (red arrow). Contrast-enhanced MDCT. **D** Coronal reformatted image: an area of decreased enhancement at the lower pole of the left kidney (blue arrow) with perinephric hematoma; renal contusion with perinephric hematoma (grade II renal injury). **E** Coronal reformatted image: a hypodense non-enhanced area lower pole of the spleen measuring approximately 5; intra-parenchymal splenic hematoma (green arrow) with peri-splenic hematoma (Grade III splenic injury). Management, surgical intervention (splenectomy)

#### Technical varieties include the following:

1. A *simple typical* blunt abdominal trauma protocol includes the portal venous phase (monophasic). A delayed excretory scan is performed 3–5 min later if urinary tract injury is detected on the initial scan;
2. *Triple phase imaging* is more accurate than the dual phase due to the diagnostic performance of all three CT phases [11–14, 30–34].

that is, multiphasic imaging is optional to limit the amount of radiation delivered.



**Fig. 3** A 27-year-old male patient presented with a stab wound. Contrast-enhanced MDCT: **A** Axial image of the site as well as the orientation of the stab wound (blue arrow). **B** Axial image of CT after enema demonstrates leakage of contrast into the site of the stab wound (green arrow) denoting perforated colon. **C** Axial image of CT after enema demonstrate leakage of contrast into the site of the stab retroperitoneal space (red arrow)

3. *Whole body CT (WBCT) or pan scan* is an increasingly used technique after significant trauma. Triphasic single-bolus pass contrast CT of the chest, abdomen, and pelvis with the speed of MDCT scanners (64-detector and more), is easily involved into protocols. This is for patients with severe polytrauma, fall from height of more than 2 m, and abnormal FAST. However, the use of WBCT in trauma is a debated issue in the emergency department (ED). With the availability of higher resolution CT scanners and their proximity to the trauma room, WBCT has become widely used in trauma protocols [40–44].

By requesting WBCT, a) more incidental findings are noted (approximately 40% of cases), which require further workup. b) Additionally, CT overuse results in increased radiation exposure and risk of malignancy. This is vital in trauma patients, as they are mostly young and in need for serial CT imaging [45]. A statistically

significant difference in radiation exposure between the WBCT and selective CT groups was noted by Siernk et al., 2016 [40].

In the selective CT group, patients had a lower radiation exposure by approximately 20 mSv dose than those from a WBCT group. Therefore, clinicians should select which CT is indicated. Therefore, we must resist the “one-size-fits-all” approach, which had made WBCT widely used in blunt trauma. A selective imaging strategy is ideal for high-volume trauma centers. WBCT is required in high-mechanism, polytrauma patients [40–45].

For the pediatric group, the portal venous phase is equivalent for diagnosing acute trauma; monophasic study all what is needed. Acute hemorrhages are excluded in younger patients (through FAST). One long scan results in a lower radiation than multiple regional scans (multiphasic). This simplified CT protocol is associated with a radiation dose reduction of 61%. In small children (3 years old or younger), the CM is manually injected [11, 22, 23, 27–29, 33].

**Table 3** Mode of trauma in the current study

| Mode of trauma     | N=81       |            |
|--------------------|------------|------------|
| Blunt trauma       |            | 73 (90.1%) |
| Motor car accident | 47 (58%)   |            |
| Fall from height   | 26 (32.1%) |            |
| Penetrating trauma |            | 8 (9.9%)   |
| Firearm injury     | 5 (6.2%)   |            |
| Stab wound injury  | 3 (3.7%)   |            |
| Total              | 81 (100%)  |            |

Data were expressed in form of frequency (percentage)

**Table 4** Findings in abdominal computed tomography of studied patients

| Findings                   | N=81       |
|----------------------------|------------|
| Splenic injury             | 40 (49.4%) |
| Liver injury               | 32 (39.5%) |
| Renal injury               | 20 (24.7%) |
| Pancreatic injury          | 7 (8.6%)   |
| Intestinal injury          | 2 (2.5%)   |
| Adrenal injury             | 1 (1.2%)   |
| Intraperitoneal collection |            |
| None                       | 3 (3.7%)   |
| Minimal                    | 21 (25.9%) |
| Mild                       | 47 (58%)   |
| Moderate                   | 10 (12.3%) |

Data were expressed in form of frequency (percentage)

In this study, CT examination was tailored according to preliminary findings from FAST. We followed a biphasic protocol in all adult cases. The addition of the arterial phase was performed, in agreement with several recent studies, which enhances the role of the arterial phase in trauma. The arterial phase facilitates the detection of foci of active arterial extravasation, trauma to major vessels, and vascular injuries of the solid organs [15, 16, 30–33]. The portal phase with a longer delay (80 s) was implemented as our CT scanner 80 detector/double-slice technology [30–32]. The delayed phase was optional and performed in 20 patients with renal injuries. In this series, the aforementioned monophasic protocol was applied for pediatric cases. Additionally, an automated injector was used for all cases as the lower age limit was more than 3 years.

In the 81 patients included in this study, (90.1%) had blunt abdominal trauma. Meanwhile, only 9.9% of patients had penetrating trauma. El-Menyar et al. [46] have reported the same pattern with 79.16% of their patients having blunt trauma and 20.83% of their patients having penetrating trauma. Most patients with

penetrating trauma had flank injuries, so the risk of bowel perforation is great. If there is no reason for immediate surgery on the initial scan, those patients should undergo an additional scan after enteric contrast administration. Enteric contrast is not given at the start of the examination, as it may cause confusion, whether the contrast deposition is due to active bleeding or bowel perforation. So, the bleeding could be missed [35, 47, 48].

In this study, instant barium enema was performed for suspicious patients, ( $n=3$  (3.7%); stab injury in the flank); positive findings were noted in two patients (2.4%). In cases of firearm injuries, no enteric CM was used (as in a hurry for surgery); that is, the use of enteric CM is not routine. The exclusion of enteric contrast had been heavily studied in blunt abdominal trauma. Oral CM should not be used routinely in abdominal CT in the emergency department because oral CM administration results in a marginal increase in radiation dose, the need for nasogastric tube placement, possible aspiration pneumonia, increased time to diagnosis, and long stay in the ED. Also, it can delay the time to the operating room and time to discharge. Abdominal CT with IV CM without oral CM has a 95% sensitivity and 99% specificity [5, 13, 28, 34–36, 47–49].

Hemodynamic instability is an absolute contraindication for enteric CM, as it would delay lifesaving care, for example, urgent laparotomy [47, 48]. Of our 81 patients included in this study, enteric CM was used in nine patients, of whom seven (8.6%) had pancreatic injuries (oral CM) and two had bowel injuries (oral and enema, i.e., triple CM). Rajpal et al., Detwiler et al., and Bonatti et al. [10, 50, 51] have reported that active hemorrhage originating from various organs, including liver, spleen, pancreas, kidneys, bowel, mesentery, and abdominal soft tissues, can be detected on CT. They have observed that identification of massive active hemorrhage is of utmost importance, because this indicates a life-threatening condition and has a great impact on emergency management. In this study, only one patient had splenic and hepatic injuries associated with active bleeding and lost life. Moreover, 78 patients (96.3%) were associated with hemoperitoneum and three patients (3.7%) did not presented with hemoperitoneum. Of the positive group, 21(25.9%), 47(58%), 10(12.3%) showed minimal, mild, and moderate amounts, respectively. Our findings were similar to Kharbanda et al. [13] who reported, hem peritoneum with visceral injury (solid organ, hollow viscus, and mesentery) were detected by CT in 81.7% of similar cases. Kharbanda [13] and other authors [15, 49–55] mentioned that: small pockets of low attenuation fluid can be found in 3%–5% of male patients with BAT; in the absence of any hollow and solid organ injury, those patients require close clinical observations and



**Table 5** Characteristics and grades of different injuries in the current study

| Injury             | Frequency (%) | Mean age      | M/F   | Grades     |               |               |              |
|--------------------|---------------|---------------|-------|------------|---------------|---------------|--------------|
|                    |               |               |       | I          | II            | III           | IV           |
| Splenic injury     | 40/81 (49.4%) | 23.58 ± 14.78 | 23/17 | 0          | 8/40 (20%)    | 23/40 (57.5%) | 9/40 (22.5%) |
| Hepatic injury     | 32/81 (39.5%) | 19.22 ± 16.53 | 20/12 | 0          | 15/32 (46.9%) | 14/32 (43.8%) | 3/32 (9.4%)  |
| Renal injury       | 20/81 (24.7%) | 17.40 ± 11.65 | 17/3  | 2/20 (10%) | 7/20 (35%)    | 5/20 (25%)    | 6/20 (30%)   |
| Pancreatic injury  | 7/81 (8.6%)   | 31.29 ± 12.55 | 7/0   | 0          | 6/7 (85.7%)   | 1/7 (14.3%)   | 0            |
| Intestinal injury  | 2/81 (2.5%)   | 27            | 2/0   |            |               |               |              |
| Adrenal injury     | 1/81 (1.2%)   | 45            | 1/0   |            |               |               |              |
| Pneumothorax       | 24/81 (29.6%) | 30.50 ± 16.26 | 15/9  |            |               |               |              |
| Pleural collection | 27/81 (33.3%) | 29.67 ± 17.01 | 18/9  |            |               |               |              |
| Lung contusion     | 21/81 (25.9%) | 27.43 ± 19.23 | 9/12  |            |               |               |              |
| Rib fracture       | 18/81 (22.2%) | 40.67 ± 7.67  | 15/3  |            |               |               |              |

Data were expressed in form of frequency (percentage), mean (age). M/F: male/female

**Table 6** Accuracy of U/S in diagnosing liver, splenic and renal injuries

|                           | Liver injury | Splenic injury | Renal injury |
|---------------------------|--------------|----------------|--------------|
| Sensitivity               | 80%          | 75%            | 43%          |
| Specificity               | 100%         | 93.3%          | 100%         |
| Positive predictive value | 100%         | 90%            | 100%         |
| Negative predictive value | 90%          | 82.4%          | 83.3%        |
| Accuracy                  | 92.5%        | 83.4%          | 85.2%        |
| Area under curve          | 0.90         | 0.84           | 0.71         |

**Table 7** Associated chest injury in the current study

| Injury             | N = 36     |
|--------------------|------------|
| Pneumothorax       | 24 (66.7%) |
| Pleural collection | 27 (75%)   |
| Lung contusion     | 21 (58.3%) |
| Rib fracture       | 18 (50%)   |

Data were expressed in form of frequency (percentage)

follow-up. In female patients of reproductive age group, isolated free fluid can be explained by normal menstrual cycle. In current series, all female patients were children (not menstruating yet).

Chaurasia IC et al. [56] have reported that using FAST, of 300 patients with blunt abdominal trauma who had road traffic accident came to the ED, 85.2% (255 patients) were diagnosed with hemoperitoneum and 14.7%(45 patients) did not have intra-peritoneal collection.

Ravinder Nath and Reddy et al. [57] have identified hemoperitoneum in their 56 patients (100%) using CT,

**Table 8** Outcome and management of studied patients in the current study

| Patient status and management   | N = 81      |
|---------------------------------|-------------|
| Stability of patients           |             |
| Stable                          | 36 (44.4%)  |
| Unstable                        | 45 (55.6%)  |
| Management conservative surgery | 75 (92.59%) |
| Splenectomy                     | 3 (3.7%)    |
| Surgical repair                 | 2 (2.5%)    |
| Follow-up and outcome           |             |
| Alive                           | 80 (98.8%)  |
| Died                            | 1 (1.2%)    |

Data were expressed in form of frequency (percentage)

whereas they identified hemoperitoneum only in 47 cases (83.9%) using FAST. Changole et al. and Samer et al. [58, 59] have concluded that FAST has a sensitivity of 85.26% for detecting free intraperitoneal fluid in blunt abdominal trauma cases. The required Clinical observation time following abdominal trauma is controversial, which ranges from 8 to 24 h.

Naveen et al. and Faruque et al. [7, 8] have observed that FAST had sensitivity of 96.8%, specificity of 100%, and negative predictive value of 57% in diagnosing solid organ injuries. Up to 29% of abdominal injuries may be missed if trauma victims are evaluated using FAST as the sole diagnostic modality [7–14, 55–58]. In this study, Ultrasound had sensitivity of 80% and specificity of 100% for diagnosing liver injuries, a sensitivity of 75% and specificity of 93.3% for diagnosing splenic injuries while sensitivity of 43% and specificity of 100% for renal injuries. Along with close clinical monitoring, CT is reliable in the evaluating of BAT, that is, CT reduces the risk of

**Table 9** Inter-observer agreement between observer A and B for findings in CT

| Findings           | Observer |    | K degree (95%CI) | p value | Percentage |
|--------------------|----------|----|------------------|---------|------------|
|                    | A        | B  |                  |         |            |
| Liver injury       |          |    |                  |         |            |
| Grade II           | 15       | 14 | 0.91 (0.79–1)    | <0.001  | 93.8%      |
| Grade III          | 14       | 14 |                  |         |            |
| Grade IV           | 3        | 4  |                  |         |            |
| Splenic injury     |          |    |                  |         |            |
| Grade II           | 8        | 7  | 0.89 (0.78–1)    | <0.001  | 92.5%      |
| Grade III          | 23       | 23 |                  |         |            |
| Grade IV           | 9        | 9  |                  |         |            |
| Grade V            | 0        | 1  |                  |         |            |
| Renal injury       |          |    |                  |         |            |
| Grade I            | 2        | 2  | 1 (1–1)          | <0.001  | 100%       |
| Grade II           | 7        | 7  |                  |         |            |
| Grade III          | 5        | 5  |                  |         |            |
| Grade IV           | 6        | 6  |                  |         |            |
| Pancreatic injury  |          |    |                  |         |            |
| Grade II           | 6        | 5  | 0.60 (0.09–1)    | 0.03    | 85.7%      |
| Grade III          | 1        | 2  |                  |         |            |
| Intestinal injury  | 2        | 2  | 1 (1–1)          | <0.001  | 100%       |
| Adrenal injury     | 1        | 1  | 1 (1–1)          | <0.001  | 100%       |
| Pneumothorax       | 24       | 24 | 1 (1–1)          | <0.001  | 100%       |
| Pleural collection | 27       | 27 | 1 (1–1)          | <0.001  | 100%       |
| Lung contusion     | 21       | 21 | 1 (1–1)          | <0.001  | 100%       |
| Rib fracture       | 18       | 18 | 1 (1–1)          | <0.001  | 100%       |

Inter-observer agreement: Inter-observer agreement between 2 emergency radiologists on the interpretation of images was measured using the kappa statistic

Kappa values: <0 = no agreement, 0.0–0.20 = slight agreement, 0.21–0.40 = fair agreement, 0.41–0.60 = moderate agreement, 0.61–0.80 = good agreement, and 0.81–1.00 = very good agreement

CI confidence interval

missed injury with negative results by FAST [34–37, 53, 54].

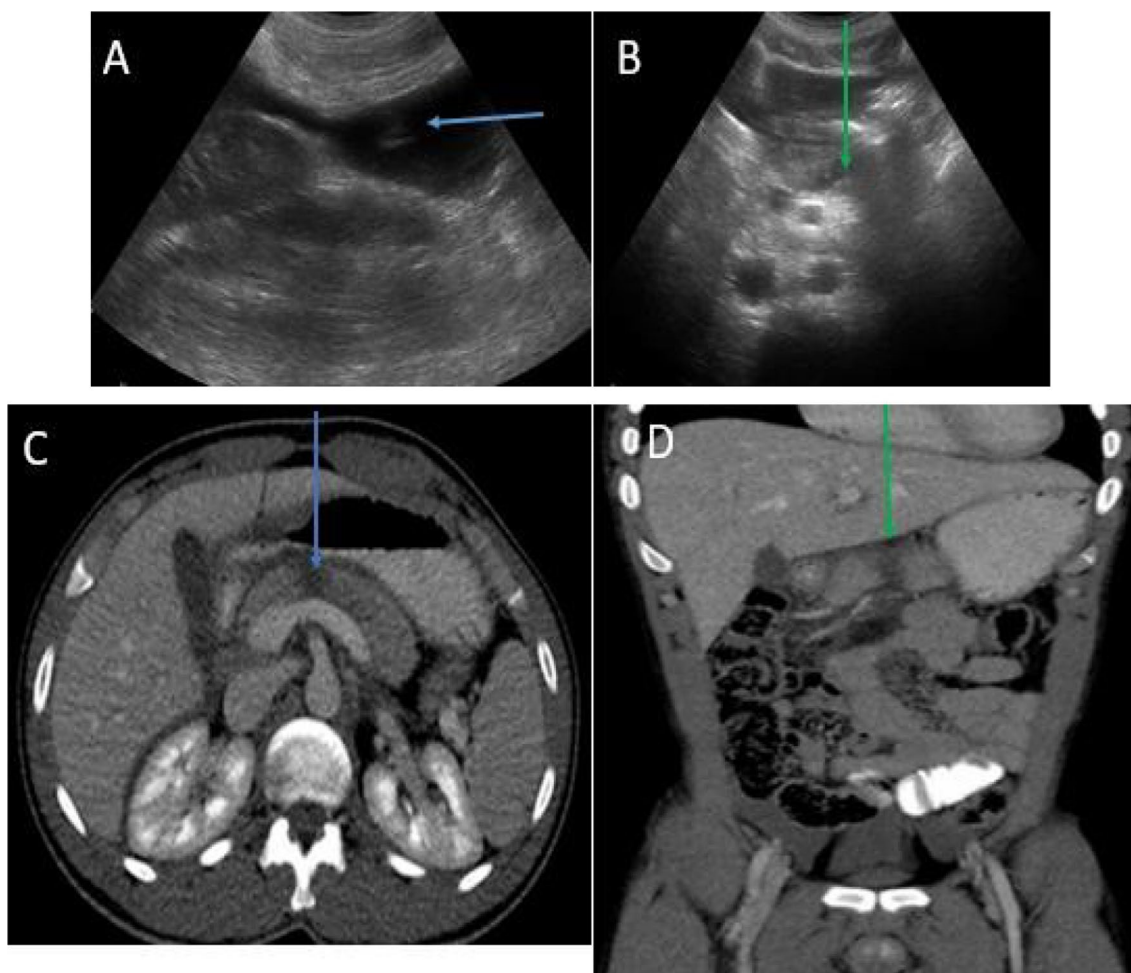
In this study, two false negative cases were noted using FAST. Twenty-seven and 30-year-old male patients presented to the trauma department with a stab wound at the flank. Initially, FAST showed: no abnormality, Re-evaluation using CT with enteric CM (enema) revealed air foci opposite site of the stab. In addition, extravasation of luminal bowel contrasts into the peritoneum and within the wound. Both patients underwent surgical intervention (bowel repair). Those findings agreed with many authors [52–54] whom have reported that the detection of bowel and mesenteric injuries using FAST is extremely difficult, as the volume of hemorrhage and extravasated bowel contents are usually minimal immediately after time of injury.

The most common injured organ in abdominal trauma is the spleen, followed by the liver and kidneys. The Frequency of organ injuries is 50% in the spleen, 36% in the liver, 20% in the kidneys and 5% in the pancreas. Both blunt and penetrating abdominal traumas can lead to the rare pancreatic injuries, which can be missed easily by initial FAST examination [10–14]. In this study, the most frequent injuries were splenic (49.4%) and hepatic (39.5%) injuries followed by renal injuries (24.7%). Pancreatic injuries were observed in seven patients (8.6%). Two patients had intestinal injury (2.5%) and only one patient had adrenal injury (1.2%). Saavedra et al.[15] examined 110 patients with splenic injuries. Most patients (n = 71, (65%), belonged to grade III and IV. Our results were similar to those of Saavedra et al. [15] as most patients (n = 32, 80%) with splenic injuries in this study belonged to grade III and IV splenic injuries.

In the study performed by Saksobhavit et al.[39] 171 patients with splenic injuries underwent MDCT. Treatment decisions were taken, and the patients received either observation [50%] or splenic surgical intervention [11%] or splenic angiography and embolization [39%]. No patient who was observed required splenectomy. Meanwhile, in the studies by Kharbanda et al. and Selim et al. [13, 60] the main line of management was conservation. In our study, 37 of 40 (92.5%) patients presented with splenic injury, were observed and did not need surgery. Only three patients (7.5%) underwent splenectomy.

Sener et al. and Miele et al. [22, 61] have reported that the most commonly injured solid organ was the liver, which was observed in 57.3% of abdominal trauma cases, and it was the first one among children. El Wakeel et al. [12] have reported that the liver was the most frequently injured organ in children and young adults, representing 65% of patients with liver injuries, whereas the spleen was the most frequent injured in adults, representing 53.7% of patients with abdominal traumatic injuries. In this study, the liver was the most commonly injured organ in children, representing 58% of patients with blunt abdominal trauma.

El-Wakeel et al. and Miele et al.[12, 22] have reported that grade II hepatic injury was the most common, accounting for grade 65% of patients with hepatic injuries. Similar to our results, 46.9% of the patients with hepatic injuries had grade II hepatic injuries, 43.8% had grade III injuries and 9.4% had grade VI. Jalli et al.[62] have examined 164 patients using FAST and CT; renal injuries were detected in 103 patients (63%) using CT. In 14 patients (13.5%), bilateral renal injuries were identified. The overall sensitivity and specificity of ultrasonography in detecting renal injuries were 48% and 96%, respectively. In this study, the sensitivity of ultrasonography



**Fig. 4** A 40-year-old male patient presented with a fall from height with epigastric pain. **A** FAST examination: mild Intra peritoneal fluid (blue arrow) with no definite solid organ injury. **B** Serial FAST of the same patient: hypo-dense line traversing the body of pancreas (green arrow). Contrast-enhanced MDCT: **C** axial portal phase image showing a hypo-dense line traversing the body of pancreas with involvement of the pancreatic duct and sparing of the pancreatic head (grade IV laceration, blue arrow). **D** Coronal portal phase image: showing a hypodense line traversing the body of pancreas (green arrow)

in detecting renal injuries was the lowest compared with those in detecting hepatic and splenic injuries.

Heller, Schnor and Bonatti et al. [38, 51] have reported that most renal injuries are of the minor types, which include contusion, sub-capsular or peri-nephric hematoma and superficial laceration. Fischer et al. [63] have found that urinary leaks were identified in 96% of patients on delayed excretory phase CT. In this study, most patients (60% with renal injuries were of grade II and grade III injuries. Of the 20 patients with renal injuries, six (30%) had extravasation of CM at the excretory phase (grade IV).

Traumatic deep renal laceration in pediatric population is rare in addition to originally rare occurrence of blunt renal injury in children. In this study, only 2 cases

of 20 patients with renal injuries were of pediatric age, and both had grade I injuries, that is, Parenchymal contusion. The renal insult clearly appeared in the standard monophasic protocol. So, further phases are not needed. However, as in adults, if deep lacerations were noticed or suspected according to portal phase findings or clinical suspicion (i.e., Gross hematuria or involvement of a renal collecting system). A delayed scan will be decided; that is; the examination is tailored according to preliminary findings. Multiphasic examination is reduced to a few selected cases in children (Radiation control). Worldwide, this protocol is accepted [64, 65].

Traumatic pancreatic injuries are rare but life-threatening events and often difficult to diagnose due to non-specific clinical signs, association with multiple injuries,

and subtle imaging findings. Clinical suspicion and awareness of trauma mechanism are important. CT is the initial imaging modality of choice, although it underestimates pancreatic trauma and is inaccurate in detecting main pancreatic duct (MPD) injuries. Complications are higher with the disruption of the MPD. CT findings can suggest pancreatic duct injury but, MRCP/ERCP help in directly assessing the MPD [66, 67].

In a study by Stewart et al. [68] the sensitivity of MDCT for detecting traumatic injuries of the pancreas was low 47% to 60%, because edema, inflammation, and fluid associated with these injuries take time to evolve. The pancreas appears normal in 20–40% of patients with acute pancreatic injuries scanned within the first 12 h after the trauma. In this study, seven adult male patients (8.6%) had pancreatic injuries detected using MDCT after FAST examination, which revealed intra peritoneal fluid collection. Moreover, 85.7% of patients with pancreatic injuries had grade II injuries, and 14.3% had grade III injuries. Inter-observer agreement was the lowest among all abdominal injuries with Kappa value of 0.6.

Regarding adrenal trauma, Addeo et al. [69] have reported that the suprarenal glands are rarely affected by trauma due to its small size, and deep retroperitoneal position in the upper part of the abdomen with the presence of full fat surrounding the gland; the possibilities of traumatic suprarenal injuries were scarce (0.03% to 4.95% of all abdominal blunt or penetrating trauma cases). However, when adrenal injuries occur, they are more likely to be associated with major trauma and multiple other organ injuries. Although adrenal trauma can usually be treated non-operatively, bilateral adrenal damage can cause adrenal insufficiency. In this study, only one patient had adrenal hematoma, which was associated with other injuries, including ipsilateral kidney, lung and ribs injuries. FAST examination only detected right perinephric hematoma; other findings were diagnosed using MDCT with IV CM.

A study by Panchal et al. [3] has observed that, isolated abdominal trauma without any other systemic trauma was found in 46% of their patients. Also, they have noted that abdominal trauma is commonly associated with thoracic injury in 38% of patients and orthopedic injuries in 34%. In other study, by Culp and Silverstein in 2015 [70],

thoracic injury was associated with abdominal trauma in 27% of patients. In our study, isolated abdominal trauma without any other thoracic injuries was found in 55.6% ( $n = 45$ ) of the patients, and 36 (44.4%) patients had associated chest injuries. Of patients with chest injury; 24 (66.7%), 27 (75%), 21 (58.3%), and 18 (50%) had pneumothorax, pleural collection, lung contusion and rib fracture, respectively. Thus, every patient with abdominal trauma should be evaluated for thoracic injuries regardless of the presence or absence of any overt sign of thoracic trauma.

The use of MDCT to assess abdominal trauma has affected the directions of treatment, spotting a large focus on conservative treatment. Surgical intervention decision was essentially depend on clinical signs instead of imaging findings. CT scan information raises the diagnostic confidence and reduces unnecessary surgeries [71–73]. In this study, conservation and strict follow-up were the main line of management in 75 (92.59%) patients. Splenectomy was performed in only three patients, and surgical repair was performed in two patients with intestinal injury. The condition of 80(98.8%) patients improved. One patient (1.2%) had severe injuries, and his condition deteriorated and the patient died.

Therefore, CT is an extremely important diagnostic tool for trauma patients. The multi-detector technology had accentuated the evaluation of trauma patients due to: speed and diagnostic capability. However, since the development of CT, manufacturers are facing a true challenge concerning radiation hazards as large doses of radiation from CT scans, will translate statistically, into additional cancers [17–21, 74].

In the absence of a dose-tracking program, the best effort is to monitor radiation dose in each performed examination. All recent CT machines save CT dose page showing CTDIvol and DLP. So, all CT scanners should be accredited to include all CT dose levels, accidental overdoses, and annual assessment of the dose in every protocol [23–29, 74].

To assess lifetime attributable risks for cancer incidence Schmidt et al. and Wortman et al. [75, 76] have reported that the average scan DLP for Single Energy CT (SECT) is  $681.5 \pm 339.3$  mGy.cm in routine imaging of the abdomen and pelvis. In this study, *for adults, in a tri-phasic*

(See figure on next page.)

**Fig. 5** **A** Ultrasonographic examination: large right perinephric hematoma (blue arrow). **B** Axial CT image showing surgical emphysema (yellow arrow), pneumothorax (green arrow). **C** CT axial image showing thickening within the right crus of the diaphragm (red arrow). **D** CT coronal reformatted image showing bulky right adrenal gland which appears isodense to hyperdense (blue arrow)...Right adrenal hematoma. **E** Sagittal CT image showing: non-enhanced hypodense linear area at the middle pole of the right kidney (blue arrow)... Grade III renal injury. **F** Coronal reformatted image showing large right perinephric hematoma (green arrow). Management: conservative treatment and follow-up. **G, H** Example of a dose sheet (dose summary) provided by our accredited machine at the end of an examination. Simply, TDLP (red circle) is the only needed figure to check. The TDLP includes all absorbed radiation during the examination (topogram, pre-contrast scan + sure start + post-contrast scan involving three phases)



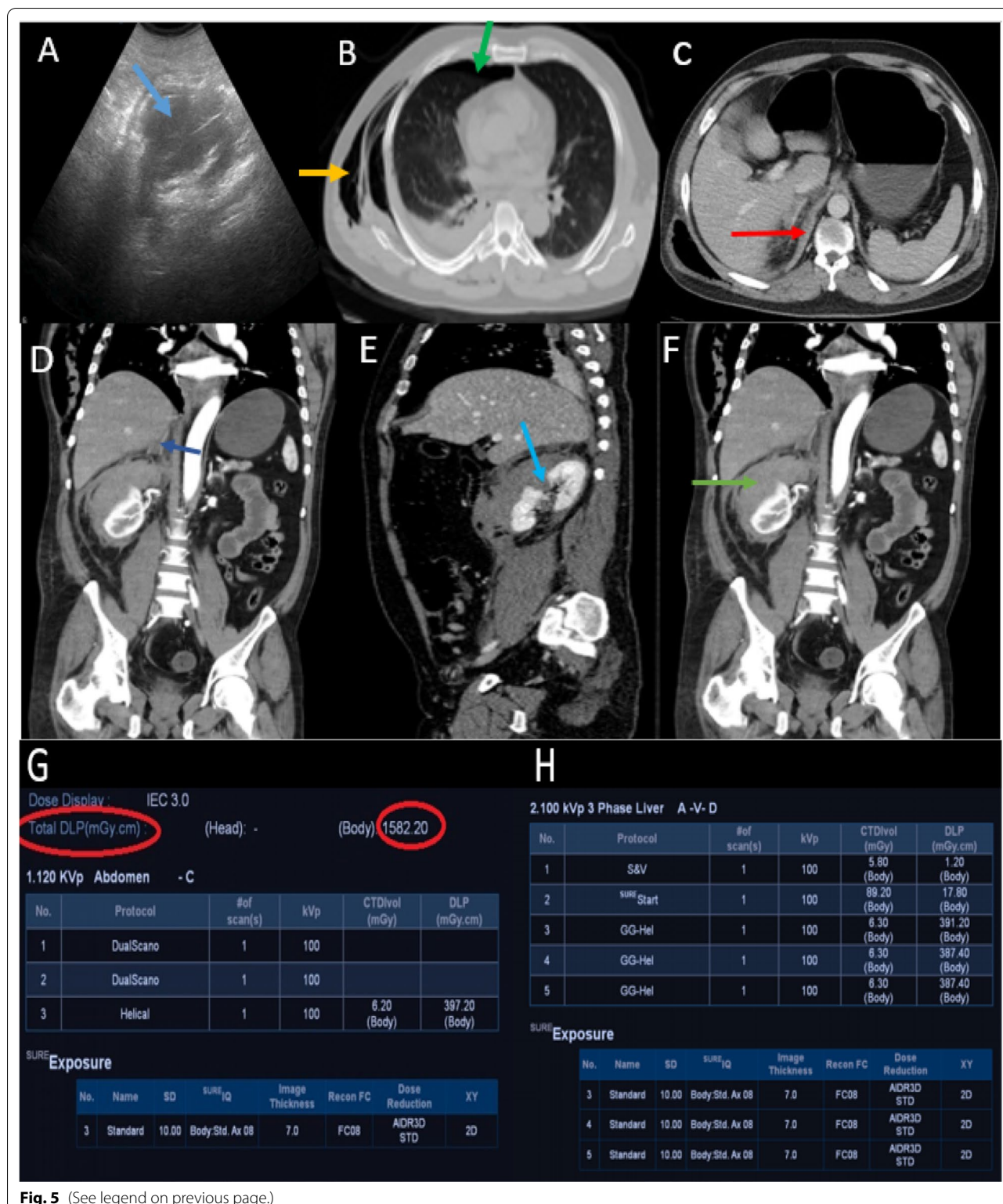


Fig. 5 (See legend on previous page.)

study the average scan DLP was  $725 \pm 378$  mGy.cm, whereas in a biphasic study, the average DLP was  $378 \pm 70.5$  mGy.cm. For children, in a monophasic study,

the average scan DLP was  $100.5 \pm 18.5$  mGy.cm, that is DLP was significantly lower (due to feature of adaptive iterative reduction technology “ADIR” in our CT

scanner). In this series, radiation doses were reviewed simply using the total DLP values, then the effective dose for each patient was calculated by multiplying Total DLP by the tissue-weighting factor (Table 1B). In the entire present series, the effective dose was below the detrimental level.

In trauma settings, dual energy CT (DECT) is a recent application for abdominal trauma. According to a few available studies on DECT, the CTDIvol for DECT was  $10.9 \pm 3.8$  mGy and the average scan DLP was 534.8 mGy cm ( $\pm 201.9$ ). Both the average scan CTDIvol and DLP values are lower using DECT than those using SECT; however this advantage was achieved on the expense of image quality, that is, liable for artifacts (e.g., beam hardening and noise). Currently, there is a much smaller literature about the application of DECT in trauma. Some Authors are encouraging the use of DECT in trauma patients. However, image artifacts are a weak point of DECT. The risk of missing injuries in trauma critical situations is a vital issue [75–78]. Wortman et al. [77] have mentioned that even with a lower image quality, the diagnostic quality using DECT remains sufficient.

In this study (multi-detector SECT machine was used), the machine could display the delivered radiation dose as CTDI volume and DLP values. The only number that we really need to know is the total DLP. The TDLP is the total dose added from the scan plus the topogram. If more than one scan of the same body region is performed (e.g., contrast and non-contrast scans) all are added into the Total DLP [17–21, 23–27].

The American Association of Physicists in Medicine states: “Risks of medical imaging at effective doses of less than 50 mSv for single procedure or 100 mSv for multiple procedures over a short period are too low or non-existent. So, it is essential that imaging diagnostic studies should not be avoided for fear of radiation, especially in trauma situations.

Regarding the fetus, radiation dose of less than 50 mSv is considered safe and of no harm. Updated MDCT delivers radiation doses below detrimental levels and may be the appropriate examination during pregnancy [20, 21, 25, 26].

The main issue with dose reduction efforts is preserving the diagnostic capability, that is, image quality, as there are limits for decreasing radiation dose against missing diagnosis due to artifacts associated with lower radiation. Recently, new inventions, such as SECT with Iterative CT Reconstruction Techniques (IR), e.g., AIDR (Adaptive Iterative Dose Reduction) technology which is available on our machine and used in this study. Also, DECT significantly decreases the radiation dose. Our MDCT scanner is (SECT) but double slice technology with AIDR technology addition. It is a key feature

through it; iterative reconstruction algorithm (IR) is applied to improve the spatial resolution without dose penalty. IR techniques allow radiation dose reduction (by approximately 20%). IR algorithms preserve lesion detectability with radiation dose reduction [21, 81, 82].

#### Other specific technical modifications to decrease radiation

Acquisition/machine parameters, can be manipulated as they have a direct influence on the radiation dose: (1) Optimal combination of exposure factors (kVp, mA in seconds) along with to pitch related to the patient’s size (i.e., size-based scanning), to achieve low radiation doses, while maintaining diagnostic image quality. (2) Gantry rotation time (i.e., exposure time), section thickness (collimation), pitch (table distance in 360° gantry rotation). (3) Right centering the patient in the gantry (Proper centering decreases the dose by 11–15%). (4) The extent of the scout to be limited to the area of concern and changing its orientation from AP to PA in a supine patient, this reduces the dose to male gonads. (5) Automatic Exposure Control (AEC) Technique: It is one of the most important methods to reduce doses mainly in children (by 30–50%). The system calculates the size of the patient and automatically uses the lowest possible dose to obtain the desired image quality, i.e., adapting the CT tube current to the patient/patient size-specific protocol; depending on the CT manufacturer, for example, Toshiba Medical Systems (machine used in this study) calls its system Sure Exposure, e.g., Sure kV [Canon Medical Systems]. This tool selects the tube potential based on patient size (localizer) and type of examination. (6) Fewer CT phases. (7) Noise reduction filters (upcoming technique). (8) scanner-independent radiation dose saving methods: e.g., bismuth shielding to protect sensitive organs. (9) Personal and area dose monitors including thermos luminescent dosimeters and optically stimulated luminescence dosimeters. (10) Calculation and reporting of radiation dose: recent scanners calculate radiation exposure, which can be saved in the patient’s clinical record. This will facilitate tracking radiation exposure to patients [79, 83–88].

In this study, the first six items from this list were applied for significant radiation dose reduction. Further technological improvements will continue to reduce radiation dose. Thus, scanning patients in a safer way occurs. Precautions should be used to maintain image quality and diagnostic confidence.

#### Future directions

(1) The clinical use of DECT in trauma is beneficial and may precede other applications. The recent

development of noise reduction techniques may remove negative effects on image quality. (2) The development of a high-pitch (up to 3.4) dual-source CT and new types of tube current modulation. Moreover, automated scan protocols based on the clinical indication are evolving. (3) The ACR suggested the development of a dose index to track the radiation dose amount over a lifetime [23, 25–27, 29, 77–88].

#### Limitation of this study

At our locality, no DECT was available to perform examinations to assess the image quality with lower radiation doses.

#### Conclusions

Abdominal trauma can present differently. MDCT is sensitive to all types of traumatic abdominal lesions; the detection of hemorrhage, which is a life-threatening condition; the evaluation of retroperitoneal region; and the determination of organ injury and its grading which has great impact on the choice of management line. FAST cannot be the sole imaging modality. MDCT has affected the treatment directions; and highlights conservative treatment as it raises the diagnostic confidence, subsequently reducing unnecessary surgical interventions. Optimizing the CT technique through patient-tailored protocols is a must.

Radiation from CT scans creates debates within the scientific community. The individual radiation risks are small but real. Thus, practitioners must be aware about radiation doses delivered by different CT scanners and possible health Hazards. The increased radiation awareness leads to the development of recent radiation-sparing techniques and innovation of dose-saving tools. The benefit of clinically justified CT scans, by far outweighs the risks.

#### Abbreviations

AAST: American Association for the surgery of trauma; ACR: American College of Radiology; AIDR: Adaptive Iterative Dose Reduction; ALARA: As low As Reasonably Achievable; BAT: Blunt Abdominal Trauma; CM: Contrast Media; CT: Computed Tomography; CTDI Vol: Computed Tomography Dose Index Volume; DLP: Dose Length Product; DECT: Dual Energy CT; ED: Emergency department; ERCP: Endoscopic Retrograde Cholangio-Pancreatography; FAST: Focused Assessment with Sonography for Trauma; FDA: Food and Drug Administration; HOCCM: High-osmolar contrast media; ICRP: International Commission for Radiation Protection; IR CT: Iterative Reconstruction CT; I.V. CM: Intra-Venous Contrast Media; LOCM: Low-osmolar contrast media; MDCT: Multi Detector Computed Tomography; MPD: Main pancreatic duct (MPD); MRCP: MR Cholangio-Pancreatography; mGy: Mille Gray; Msv: Mille Sieverts; SECT: Single Energy CT; SSDE: Size-specific dose estimate; WBCT: Whole Body Computed Tomography.

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#### Authors' contributions

AHM is the guarantor of integrity of the entire study. AHM and RA contributed to the study concepts and design; SAE contributed to the literature research. AHM and RA contributed to the clinical and experimental studies. BM and AHM contributed to the data analysis. RA and SAE contributed to the statistical analysis. AHM, RA and SAE all contributed to clinical correlation and follow-up outcome. All authors have read and approved the manuscript.

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#### Availability of data and materials

The corresponding author is responsible for sending the used data and materials upon request.

#### Declarations

##### Ethics approval and consent to participate

The study was approved by the ethical committee of the Radiology and the General surgery Departments of an academic highly specialized multidisciplinary hospital, and an informed written consent was taken from all patients/or relatives (if patient is unconscious) that were included in the study. The ethics committee's reference number is: Ref.No.aswu /246/5/18.

##### Consent for publication

All patients included in this research were legible. They gave written informed consent to publish the data contained within this study. For patients less than 16 years old, decreased or unconscious: written informed consent for publication was given by their parents or legal guardians.

##### Competing interests

The authors declare that they have no competing interests.

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