Original Article

JHSMR Journal of Health Science and Medical Research

Contrast-enhanced Computed Tomography Versus Contrast and Non-contrast Enhanced Computed Tomography for Detecting Blunt Abdominal Injury

Kornkanok Naraweerawut, M.D., Kamonwon Cattapan, M.D., Panjai Choochuen, M.D., Khanin Khanungwanitkul, M.D.

Department of Radiology, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.

Received 3 May 2023 ● Revised 27 July 2023 ● Accepted 29 July 2023 ● Published 31 October 2023

Abstract:

Objective: This study aimed to compare the diagnostic ability of contrast-enhanced computed tomography (CECT) and CECT combined with non-contrast computed tomography (NCT) for intraabdominal organ injury in patients with blunt abdominal injury.

Material and Methods: Overall, 195 adult patients having had blunt abdominal trauma underwent CT at this institution; from 2016 and 2021. All CT images were retrospectively reviewed by two radiologists. The efficacy of detection of organ injuries and the degree of intra-abdominal injury were recorded. The radiologists scored their diagnostic confidence for each CT image dataset on a five-point scale: inter-observer agreement was also calculated.

Results: All included patients underwent CT for blunt abdominal trauma. The most common cause of injury was motorcycle accident (59.5%), with patients being predominantly male: the mean patient age was 44 years. Hemoperitoneum was the most common CT finding, with a significantly higher detection rate on CECT combined with NCT than on CECT alone. There was no statistically significant difference in the diagnostic efficacy of the detected organ injury nor other types of organ injuries between CECT alone and CECT combined with NCT. Nevertheless, the accuracy of CECT in detecting hemoperitoneum may diminish in patients with severe fatty liver disease; especially in the perihepatic region.

Conclusion: CECT alone is a potential tool for detecting abdominal injuries in patients with blunt trauma. NCT provides no additional benefits in detecting organ injury; except in cases of severe fatty liver disease. NCT is recommended as an optional protocol; particularly for patients with obesity.

Contact: Khanin Khanungwanitkul, M.D.
Department of Radiology, Faculty of Medicine, Prince of Songkla University,
Hat Yai, Songkhla 90110, Thailand.
E-mail: khanin14@gmail.com

J Health Sci Med Res ....
doi: 10.31584/jhsmr.20231003
www.jhsmr.org

Keywords: blunt abdominal trauma, computed tomography, contrast-enhanced computed tomography, non-contrast computed tomography, radiation exposure

Introduction

Trauma patients, from both traffic and non-traffic injuries, are common in emergency departments. According to the data from a level 1 trauma center in Southern Thailand, there are over 20,000 patients each year admitted to the emergency departments[1]. Blunt abdominal trauma is a common health issue in emergency departments, which can cause morbidity and mortality. Individuals with blunt abdominal trauma present with nonspecific abdominal tenderness, which is not predictive of a definite abdominal injury[2]. It is difficult to diagnose abdominal injury based solely on clinical presentation and physical examination; especially in cases of low-risk mechanisms of injury and inadequate clinical signs; such as unstable vital signs or loss of consciousness[2-4]. Computed tomography (CT) of the abdomen and pelvis with IV contrast is the modality of choice for hemodynamically stable patients in the evaluation of abdominal organ injury[5]. However, there is still disadvantages of CT scanning; such as the risk of ionizing radiation; especially in young individuals; wherein, high radiation doses could cause radiation-induced cancer[6,7].

Contrast-enhanced computed tomography (CECT) studies can be tailored into multiple phases, based on the time after contrast injection[8]. Each CECT phase has a clear benefit for detecting different organ injuries. The arterial phase is useful for evaluating vascular injury, and identifying active bleeding, pseudoaneurysms, and arteriovenous fistulas that require treatment[9,10]. The portal-venous or nephrographic phase, which is used in routine studies, is the most suitable phase for evaluating the visceral parenchyma in solid organ injury, while the excretory phase is critical for evaluating the pelvicalyceal system[10-12].

Non-contrast CT (NCT) is another phase used in cases of trauma. NCT promotes detection and differentiation between contrast extravasation and hyperdense lesions; such as hematoma, foreign bodies, and small bony fragments[13]. On the other hand, NCT has some drawbacks owing to increased radiation exposure, which increases the risk of cancer, and increased scanning time, resulting in delayed treatment. At our institution, CT is used with non-contrast and contrast-enhanced arterial and portal-venous phase images as a standard protocol in cases of trauma. Excretory phase CT is optional for patients clinically suspected to have a urinary tract injury; such as hematuria. However, the role of NCT in the diagnosis of trauma remains controversial.

This study aimed to evaluate the benefits of NCT in the diagnosis of abdominal injury in patients with blunt trauma, and to compare the diagnostic ability of CECT alone with that of CECT combined with NCT.

Material and Methods

Study population

The institutional Human Ethics Research Committee approved the study design. The data of 574 patients aged ≥15 years, who visited the emergency department due to trauma or suspected abdominal injury, were retrieved from the trauma registry and checked against records in the hospital information system. All patients had undergone abdominal CT for blunt traumatic injuries between June 2016 and August 2021. The medical records included information on baseline patient characteristics (age and gender), duration from accident to start of CT scan, mechanism of injury (motorcycle accident, car accident, body assault, falling from height, blast injury, and others), injury severity score (minor, ≤14; severe, 15-24; critical, >24), and Glasgow Coma Scale (GCS) scores (mild, 13-15; moderate, 9-12; severe, 3-8).

All patients met at least one criterion of the reference standard according to the American Association for the

Surgery of Trauma grading system, in which solid organ injury was evaluated based on imaging, operative, and pathologic criteria[14,15]. In this study, the reference standards included operative or angiographic findings, follow-up CT findings, and clinical follow up. A total of 379 patients with a history of procedures involving the peritoneal cavity; such as exploration laparotomy for diagnostic peritoneal lavage, or abdominal surgery, were excluded. The remaining 195 patients were included in the CT analysis.

CT protocol

All patients with blunt abdominal trauma underwent abdominal CT using a standard protocol at our institution, with a 160-slice multidetector CT scanner (Toshiba, Aquilion Prime) and a 512-slice single-source CT scanner having a single detector layer (Revolution CT 1.0; GE Healthcare, Milwaukee, Wis, USA). The CT parameters included a tube voltage of 100–120 kV peak (kVp), and an automatic tube current with a collimation of 0.5 mm. Optimization of the CT protocol permitted the acquisition of a non-contrast phase with a scan length from the basal lungs to the pubic symphysis, followed by a late arterial phase with a scan length from the basal lungs to the bilateral kidneys, and an extended scan length to the pubic symphysis in cases of suspected pelvic trauma in addition to a portal-venous phase with a scan length from the basal lungs to the pubic symphysis. An excretory phase was optionally requested if urinary tract trauma was suspected. No oral contrast material or rectal contrast enema was administered. Intravenous administration of 1.5 mL/kg iohexol (350 mg iodine/mL), iopromide (370 mg iodine/mL, or iodixanol (320 iodine/mL) was achieved through power injection at 4 mL/s. The region of interest (ROI) was located in the descending aorta at the level of the dome of the diaphragm. The late arterial phase was performed 18 s after the trigger threshold reached approximately 150 Hounsfield units (HU), followed by a portal-venous phase of 90-100 s after contrast material injection. The time to obtained portal-venous phase images in our institution is a little delayed from usual portal-venous phase, which could be around 60-90 s; however, imaging from most of our cases fulfilled the criteria for portal-venous phase; including full enhancement of the portal veins, enhancement of the hepatic veins and bright hepatic parenchymal enhancement[17]. Delayed scanning at 8–10 min was performed in the excretory phase. The images were reconstructed with slice thickness of 3 mm, a reconstruction interval of 3 mm, and soft tissue kernel.

CT image interpretation

All CT images were retrospectively reviewed twice by two radiologists (K.K. and K.C., who have 5 and 7 years of experience, respectively) that were blinded to the study. First, each radiologist independently reviewed only the CECT images. At least 4 weeks later, each radiologist reviewed the CECT images combined with the NCT images. The images, phases and cases were reviewed in random order. Decisions were based on a consensus between the reviewers.

The efficacy of the detection of organ injuries was also recorded. To evaluate the degree of intra-abdominal organ injury, CT features were examined separately for each organ by location. Organ injury was classified as: liver, kidney, spleen, pancreas, adrenal glands, kidney, ureter, bladder, bowel, mesentery, hemoperitoneum, retroperitoneum or vascular injury. The severity of the organ injury was graded based on the Injury Severity Score (ISS)[18,19].

Both radiologists were asked to score their diagnostic confidence for each CT image dataset on a five-point scale (5=completely confident, 4=fairly confident, 3=somewhat confident, 2=slightly confident, and 1=not confident at all). Any discrepancies between the radiologists were resolved through discussion until a consensus was reached.

Statistical analysis

The data were recorded using EpiData version 3.1

(The EpiData Association, Odense, Denmark). All statistical data were analyzed using R version 4.1.2 (R Foundation for Statistical Computing, Vienna, Austria). Quantitative data are described as mean±standard deviation for normally distributed continuous variables and as median±interquartile range for non-normally distributed data. Categorical variables are expressed as frequencies and percentages.

The diagnostic ability is represented as sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). These were compared using a proportion test. The area under the curve (AUC) with 95% confidence interval was used to compare the diagnostic ability of the modalities. A bootstrap test was performed to compare the area under the curve (AUC) between CECT alone and CECT combined with NCT.

The confidence level between CECT and CECT combined with NCT of each radiologist was compared using the Wilcoxon rank sum test. The agreement between the two radiologists was described using Cohen's kappa statistics; the following scale was used for interpretation: slight agreement, 0-0.20; fair agreement, 0.21-0.40; moderate agreement, 0.41-0.60; substantial agreement, 0.61-0.80; and almost perfect agreement, 0.81-1.00[19]. Statistical significance was set at p-value<0.05.

Results

The patients' demographic data are presented in Table 1. Of the 195 patients, 69.2% were men, and the mean age of the patients was 44±18.9 years. The median time between accident onset and the start of CT scanning was approximately 2.5 hour. Motorcycle accidents were the most common cause of injury (59.5%), followed by car accidents (14.9%), then falling from height (12.3%). The recorded ISSs indicated mild injury in 51.3% of patients, moderate injury in 27.2%, and severe injury in 21.5%. Most patients had clinical follow-up (79%), followed by underwent operative and angiogram treatment (12.3%) and CT follow-up (8.7%).

Table 2 shows the prevalence of intra-abdominal organ injury. Of the 195 patients, only 70 (35.9%) showed positive results for abdominal organ injuries, which were classified into 163 locations. The most common CT finding was hemoperitoneum (18.5%). The most commonly affected solid organ was the liver (15.4%), followed by the kidneys (10.3%), and spleen (8.7%). No ureteric injuries were observed.

Table 1 Baseline characteristics of the patients

Characteristic	Value (n=195)
Age (years)†	44±18.9 (16-91)
Gender	
Male	135 (69.2)
Female	60 (30.8)
Time to computed tomography (hour)§	2.5 (1.5,4)
Mechanism of injury	
Motorcycle accident	116 (59.5)
Car accident	29 (14.9)
Body assault	1 (0.5)
Falling from height	24 (12.3)
Blast	3 (1.5)
Others	22 (11.3)
Injury severity score	
Minor (≤14)	100 (51.3)
Severe (15-24)	53 (27.2)
Critical (>24)	42 (21.5)
Glasgow Coma Scale scores	
Mild (13-15)	148 (75.9)
Moderate (9-12)	25 (12.8)
Severe (3-8)	22 (11.3)

Data are presented as numbers, with percentages in parentheses.
†Data are presented as the mean with standard deviation and range in parentheses
§Data are presented as the median with interquartile range in parentheses

There was no significant difference in the diagnostic efficacy of CECT combined with NCT and CECT alone for the detection of abdominal organ injury. For the detection of hemoperitoneum, CECT combined with NCT showed slightly higher sensitivity (83% vs. 74%), specificity (94% vs. 92%), PPV (75% vs. 68%), and NPV (96% vs. 94%)

than CECT alone (p-value=0.04), together with a higher AUC value (0.88 vs. 0.83) having statistical significance. Subgroup analysis for the detection of each solid organ injury showed no statistically significant differences between CECT combined with NCT and CECT alone. The sensitivity, specificity, PPV, NPV, and AUC with p-values for the two groups are presented in Table 3.

Table 2 Distribution of organ injuries

Variable	Value (n=195)
Detection of the organ injury	70 (35.9)
Organ injury	
Liver	30 (15.4)
Spleen	17 (8.7)
Pancreas	5 (2.6)
Adrenal glands	11 (5.6)
Kidneys	20 (10.3)
Ureters	0 (0.0)
Bladder	2 (1.0)
Bowel	12 (6.2)
Mesentery	7 (3.6)
Hemoperitoneum	36 (18.5)
Retroperitoneum	15 (7.7)
Vessel	8 (4.1)

Data are presented as the number with percentage in parentheses

Diagnostic confidence scores are presented in Table 4. The detection of CT findings was significantly higher with CECT combined with NCT (median 5 for each reviewer) than with CECT alone (median 4 for the first reviewer and median 5 for the second reviewer) (p-value<0.001).

Overall, the individual κ values for the assessment of the detected organ injury between both readers were in near-perfect agreement (κ=0.83) for CECT combined with NCT and in substantial agreement (κ=0.80) for CECT alone. For each organ injury, perfect and substantial agreement was observed for injuries of the liver, spleen, pancreas, adrenal glands, kidneys, ureters, bowel and hemoperitoneum. The ability to detect liver injury had the highest interobserver agreement values among all other groups. These data are presented in Table 5.

Discussion

Abdominal trauma induced by blunt force is a common medical emergency. Prompt and accurate diagnosis is essential for early treatment. Hence, CT plays an important role in identifying the type of injury for informed decision-making. The CT protocol for blunt abdominal injuries varies according to organ-specific injury. However, the extensive use of abdominal and pelvic CT raises concerns regarding radiation exposure. Radiation hazards can be decreased through, the use of limited CT phases before image acquisition. This study aimed to determine the benefits of NCT in the diagnosis of abdominal injury in patients with blunt trauma and to compare the diagnostic ability of CECT alone and that of CECT combined with NCT.

In terms of the prevalence of organ injury, the most common CT finding in this study was hemoperitoneum. The detection rate of hemoperitoneum using CECT combined with NCT was slightly higher than that of using CECT alone. Further data was also collected on the identified hemoperitoneum lesions, as they are an indirect sign of injury to a visceral organ. NCT was expected to contribute significantly to diagnosis, as it supports the detection of hematoma or hemorrhage[13]. However, attenuation measurements on CT, which are presented as a value, are more reliable than the subjective interpretation of images by radiologists; as they do not require disturbance of the window settings[20]. Based on this study's measurements, CECT alone and CECT combined with NCT showed similar density values for the hemoperitoneum; ranging from approximately 33 to 74 HU on CECT and 25 to 71 HU on NCT. A previous study involving CT with protocols designed for oral and intravenous contrast media administration showed that free peritoneal blood had an attenuation coefficient of approximately 15 to 75 HU (average, 45 HU)[21]. Few CT signs of hemoperitoneum in trauma patients have been evaluated using CECT; such as sentinel clots or high attenuated fluid collection[22]. In some conditions; such as severe anemia and low attenuation of acute traumatic

Table 3 Diagnostic efficacy for organ injuries

CT findings (n=195)	CECT combined with NCT					CECT					P-value
	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC	
Detected Organ injury	93 (84–98)	94 (88–98)	90 (81–96)	96 (90–99)	0.93	94 (86–98)	93 (87–97)	89 (80–95)	96 (91–99)	0.94	0.72
Types of organinjury											
Liver	80 (61–92)	99 (97–100)	96 (80–100)	96 (92–99)	0.90	80 (61–92)	98 (95–100)	89 (71–98)	96 (92–99)	89	0.16
Spleen	65 (38–86)	98 (94–99)	73 (45–92)	97 (93–99)	0.81	65 (38–86)	97 (93–99)	65 (38–86)	97 (93–99)	0.81	0.16
Pancreas	80 (28–99)	99 (96–100)	67 (22–96)	99 (97–100)	0.90	60 (15–95)	99 (97–100)	75 (19–99)	99 (96–100)	0.80	0.28
Adrenal	91 (59–100)	95 (91–98)	53 (29–76)	99 (97–100)	0.93	90 (55–100)	94 (90–97)	47 (24–71)	99 (97–100)	0.92	0.57
Kidney	70 (46–88)	98 (95–100)	82 (57–96)	97 (93–99)	0.86	79 (54–94)	98 (94–99)	79 (54–94)	98 (94–99)	0.88	0.38
Bladder	50 (1–99)	99 (97–100)	50 (1–99)	99 (97–100)	0.75	50 (1–99)	100 (98–100)	100 (2–100)	99 (97–100)	0.75	0.30
Bowel	55 (23–83)	99 (97–100)	86 (42–100)	97 (94–99)	0.77	50 (21–79)	100 (98–100)	100 (54–100)	97 (93–99)	0.77	0.32
Mesentery	86 (42–100)	97 (94–99)	55 (23–83)	99 (97–100)	0.71	86 (42–100)	97 (93–99)	50 (21–79)	99 (97–100)	0.71	1.00
Hemo-peritoneum	83 (67–94)	94 (89–97)	75 (59–87)	96 (92–99)	0.88	74 (57–88)	92 (87–96)	68 (51–82)	94 (89–97)	0.83	0.04
Retro-peritoneum	73 (45–92)	96 (91–98)	58 (33–80)	98 (94–99)	0.84	67 (38–88)	96 (91–98)	56 (31–78)	97 (94–99)	0.81	0.30
Vessel	75 (35–97)	97 (93–99)	50 (21–79)	99 (96–100)	0.91	86 (42–100)	97 (94–99)	55 (23–83)	99 (97–100)	0.91	0.31

Data in parentheses are 95% confidence intervals, CT=computed tomography, CECT=contrast-enhanced computed tomography, NCT=non-contrast computed tomography, PPV=positive predictive value, NPV=negative predictive value, AUC=area under the curve

Table 4 Level of confidence in the detection of CT findings

Reviewers	CECT combined with NCT	CECT	p-value
1	5 (4,5)	4 (3,5)	<0.001
2	5 (5,5)	5 (4,5)	<0.001

Data are presented as the median with interquartile range in parentheses, CT=computed tomography, CECT=contrast-enhanced computed tomography, NCT=non-contrast computed tomography

Table 5 Interobserver agreement between reviewers 1 and 2 for the detection of organ injury in each CT group

CT findings	CECT combined with NCT	CECT
	Kappa	Kappa
Detected organ injury	0.83	0.80
Organ injury		
Liver	0.88	0.82
Spleen	0.70	0.68
Pancreas	0.76	0.66
Adrenal glands	0.82	0.73
Kidneys	0.71	0.66
Ureters	1.00	1.00
Bladder	0.66	1.00
Bowel	0.72	0.80
Mesentery	0.48	0.42
Hemoperitoneum	0.79	0.74
Retroperitoneum	0.50	0.57
Vessel	0.57	0.41

CT=computed tomography, CECT=contrast-enhanced computed tomography, NCT=non-contrast CT

hemoperitoneum on CT, the region with lysed red blood cells may be seen as low attenuated fluid content through NCT. This can cause an inability of separating clear fluid from the hemoperitoneum; thus, the role of NCT in detecting hemoperitoneum may be limited[23]. Therefore, it was inferred that NCT is only an optional tool for the detection of hemoperitoneum.

Conversely, it was found that in patients with severe fatty liver, the detection rate hemoperitoneum of CECT may be reduced; especially in the perihepatic region. The high density of the hemoperitoneum may be equal to the enhanced fatty liver, as shown in Figure 1. This result corresponds with that of Kelly et al., who observed that a hyperdense hematoma on NCT appeared iso-attenuated after IV contrast administration[13]. This may be attributable to fat deposition in the liver, resulting in decreased attenuation of the hepatic parenchymal background to a value similar to the hyperdense hemoperitoneum. Therefore, it can be inferred that NCT is superior for the detection of a hemoperitoneum in severe fatty livers; especially in the perihepatic space. Careful detection of liver parenchymal injury or perihepatic hemoperitoneum in obese patients is necessary during CT examination.

CECT combined with NCT and CECT alone showed efficacy in the detection of specific organ injury; as in Table 5. Although there is no statistical significance in the detection of specific organ injury, the results show differences in the values of sensitivity, specificity, PPV and

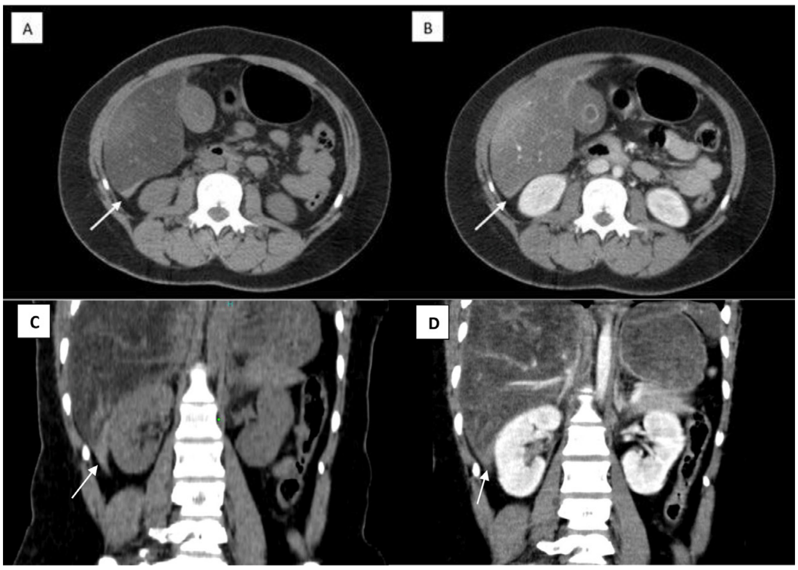

Figure 1 Hemoperitoneum (white arrow) in a case of severe fatty liver: Hyperdensity hemoperitoneum in non-contrast CT appearing isodensity to hepatic parenchyma after contrast-enhanced CT. (A) Non-contrast axial view. (B) Contrast-enhanced axial view. (C) Non-contrast-enhanced coronal view. (D) Contrast-enhanced coronal view

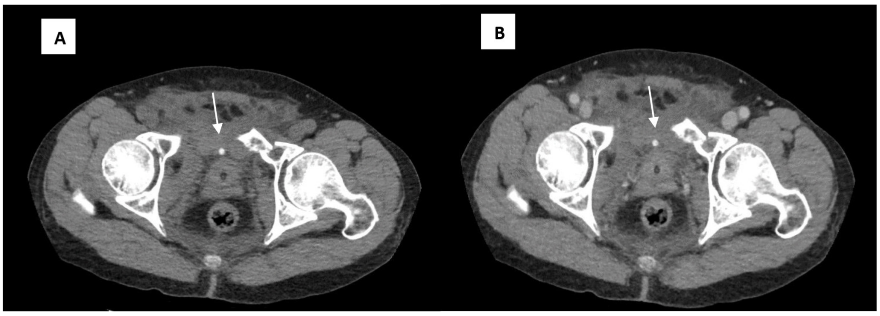

Figure 2 Bony fragment (white arrow) in a case of fracture pelvic bone, mimicking pseudoaneurysm in contrast-enhanced CT. However, the case was also interpreted as bony fragment in CECT alone, but with a less confident score. (A) Non-contrast axial view. (B) Contrast-enhanced axial view

NPV. The radiologists in this study reviewed CECT and CECT combined with NCT as two different tools. They reviewed each tool independently, with a gap of a period of at least 4 weeks. However, each time of imaging review may have some miss rates. depending on the tools, the results show no statistical significance. This could infer that CECT with NCT shows no difference in efficacy in the detection of specific organ injury.

There was no statistically significant difference in the diagnostic ability of CECT combined with NCT and CECT alone for the detection of overall organ injury as well as other specific organ injuries. This study showed similar results to previous retrospective studies, in that NCT did not improve the diagnostic performance for traumatic lesions of the liver, spleen, kidneys, adrenal glands or retroperitoneal effusion[24,25]. Naulet et al. also reported sensitivity of specific organs injury using CECT and CECT combined with NCT and showed no significance in the detection of each abdominal organ injury; for example, the sensitivity of detection for liver injury in CECT and CECT combined with CECT is 96% and 92%[24]. According to the ACR (American College of Radiology) guidelines, CECT is more suitable than NCT for hemodynamically stable patients[2]. The British Royal College of Radiologists has also indicated that NCT is not useful[26]. Nonetheless, a few previous reviews showed different results of using NCT in blunt abdominal trauma. Kelly et al. prospectively reviewed the utility of CECT combined with NCT and noted that it had higher sensitivity than CECT alone for detection of visceral injury; wherein, the sensitivity increased from 74% to 84%[13]. Miyakawa et al. also retrospectively reviewed 126 patients with blunt abdominal trauma and found that CECT was superior to NCT in the detection of organ injury. However, CECT in this review failed to detect a few patients with visceral hematoma, so they recommended CECT combined with NCT for blunt abdominal injury[27]. These studies were not conducted in the modern CT era, and the obtained image quality was not as good as that of the present day. In terms of the accuracy of diagnosis, the specificity and NPV were high for both CECT combined with NCT and CECT alone, indicating similar diagnostic ability. Therefore, there may be no additional advantages of performing NCT in cases of blunt abdominal trauma. This observation is based on this study's findings in regard to both detection and grading of the injuries. Limited CT phases, with the exclusion of NCT, would be more useful owing to the decreased radiation exposure and a significant reduction in examination time, which is relevant in emergency cases.

Both radiologists in this study reported higher diagnostic confidence in detecting organ injury with CECT combined with NCT than CECT alone. The example of the cases with higher confidence levels, having the addition of NCT, includes cases with adrenal hematoma and some cases with bony fragments. An example of a case with a bony fragment is shown in figure 2; wherein, small bony fragments may mimic pseudoaneurysm. Another reason affecting confidence score could be due to the familiarity with the CT protocol that was used; including routine NCT interpretation in blunt abdominal trauma and learning occurred with subsequent passes through imaging reviews. These results do not affect the diagnostic performance in terms of the ability to detect organs. In the future, more frequent use of CECT alone as a potential CT protocol in blunt abdominal trauma is suggested to gain relevant experience in imaging interpretation and to increase diagnostic confidence using CECT images alone.

This study's inter-observer agreement with CECT combined with NCT was significantly higher than that with CECT alone in detecting organ injury and hemoperitoneum, with perfect agreement and substantial agreement for almost all CT findings. In a study by Naulet et al. on peritoneal effusions, which was the same as in this study, the kappa coefficient showed substantial agreement at 0.71 and almost perfect agreement at 0.85 for CECT combined with NCT and CECT alone, respectively[24]. This indicates good reproducibility of the method for the detection of abdominal injury, with increased reliability for grading the severity of the injury.

Recent advances in CT have led to the development of new techniques to replace traditional NCT, with multiphase imaging to reduce the radiation dose, while maintaining imaging quality. Reconstructed virtual non-enhanced images from dual-energy CT or spectral CT have been used to replace true NCT scans[28]. Photon-counting CT is a novel modality for routine clinical use that provides CT data with higher imaging quality and a lower radiation dose[29]. However, the CT equipment required for these modalities is associated with a high cost and lack of availability for trauma patients in emergency departments; particularly in middle to low-income countries. Therefore, NCT is often used in many institutions as a routine CT protocol despite the increase in radiation dose. To the best of our knowledge, a multiphase abdomen and pelvic CT had a higher and more variable radiation dose than a single-phase CT of about 2 times (mean effective dose ranging from 12 to 20 mSv in a single-phase study and ranging from 24 to 45 mSv in a multiphase study)[30].

This study has a few limitations. The small sample size in this study may have reduced the statistical power and increased the margin of error of the findings. Most patients did not undergo surgical treatment, which is the gold standard. Finally, this was a retrospective study. In the future, prospective and randomized studies should be performed.

Conclusion

CECT alone is a potential standard protocol in cases of abdominal injury. Its diagnostic ability is similar to that of CECT combined with NCT for detecting abdominal organ injuries. NCT provides no additional benefits in detecting organ injury, except in cases of severe fatty liver disease; particularly in the perihepatic region. Therefore, patients with obesity may require NCT.

Acknowledgement

Ms. Jirawan Jayuphan for statistical consultation.

Conflict of interest

There are no potential conflicts of interest to declare.

References

1. Patcharee P, Thanom P, Janya N, Mayuree M, Walailuk J, Rassamee S. Epidemiological characteristics of traffic and non-traffic injuries and quality of emergency medical services in southern thailand. J Health Sci Med Res 2021;39:273-82.
2. Jones EL, Stovall RT, Jones TS, Bensard DD, Burlew CC, Johnson JL, et al. Intra-abdominal injury following blunt trauma becomes clinically apparent within 9 hours. J Trauma Acute Care Surg 2014;76:1020-3.
3. Ledrick D, Payvandi A, Murray AC, Leskovan JJ. Is there a need for abdominal CT scan in trauma patients with a low-risk mechanism of injury and normal vital signs? Cureus 2020;12:e11628.
4. Jansen JO, Yule SR, Loudon MA. Investigation of blunt abdominal trauma. BMJ 2008;336:938-42.
5. Shyu JY, Khurana B, Soto JA, Biffl WL, Camacho MA, Diercks DB, et al. ACR appropriateness criteria® major blunt trauma. J Am Coll Radiol 2020;17:S160-74.
6. Amy BG, Sarah D. Risk of cancer from diagnostic x-rays estimates for the UK and 14 other countries. Lancet 2004;363:345-51.
7. Hui CM, MacGregor JH, Tien HC, Kortbeek JB. Radiation dose from initial trauma assessment and resuscitation: review of the literature. Can J Surg 2009;52:147-52.
8. Stuhlfaut JW, Anderson SW, Soto JA. Blunt abdominal trauma: current imaging techniques and CT findings in patients with solid organ, bowel, and mesenteric injury. Semin Ultrasound CT MRI 2007;28:115-29.
9. Godt JC, Eken T, Schulz A, Øye K, Hagen T, Dormagen JB. Do we really need the arterial phase on CT in pelvic trauma patients? Emerg Radiol 2021;28:37-46.
10. Bonatti M, Lombardo F, Vezzali N, Zamboni G, Ferro F, Pernter P, et al. MDCT of blunt renal trauma: imaging findings and therapeutic implications. Insights Imaging 2015;6:261-72.
11. Hallinan JT, Tan CH, Pua U. The role of multidetector computed tomography versus digital subtraction angiography in triaging care and management in abdominopelvic trauma. Singapore Med J 2016;57:497-502.
12. Uyeda J, Anderson SW, Kertesz J, Soto JA. Pelvic CT angiography: application to blunt trauma using 64MDCT. Emerg Radiol 2010;17:131-7.
13. Kelly J, Raptopoulos V, Davidoff A, Waite R, Norton P. The value of non-contrast-enhanced CT in blunt abdominal trauma. AJR Am J Roentgenol 1989;152:41-8.
14. Moore EE, Cogbill TH, Malangoni MA, Jurkovich GJ, Champion HR. Scaling system for organ specific injuries [Monograph on the Internet]. Chicago: The American Association for the Surgery of Trauma; [cited 2022 Aug 22]. Available from: https://www.aast.org/Assets/56ef079d-229c-45f2-9b18-c3825e450e65/633867256925730000/injuryscoringtables-pdf
15. Kozar RA, Crandall M, Shanmuganathan K, Zarzaur BL, Coburn M, Cribari C, et al. Organ injury scaling 2018 update: Spleen, liver, and kidney. J Trauma Acute Care Surg 2018;85:1119-22.
16. Kulkarni NM, Fung A, Kambadakone AR, Yeh BM. Computed

tomography techniques, protocols, advancements, and future directions in liver diseases. Magn Reson Imaging Clin N Am 2021;29:305-20.

17. Javali RH, Krishnamoorthy, Patil A, Srinivasarangan M, Suraj, Sriharsha. comparison of injury severity score, new injury severity score, revised trauma score and trauma and injury severity score for mortality prediction in elderly trauma patients. Indian J Crit Care Med 2019;23:73-7.
18. Bolorunduro OB, Villegas C, Oyetunji TA, Haut ER, Stevens KA, Chang DC, et al. Validating the injury severity score (ISS) in different populations: ISS predicts mortality better among hispanics and females. J Surg Res 2011;166:40-4.
19. McHugh ML. Interrater reliability: the kappa statistic. Biochem Med (Zagreb) 2012;22:276-82.
20. Kim SW, Kim JH, Kwak S, Seo M, Ryoo C, Shin CI, et al. The feasibility of deep learning-based synthetic contrast-enhanced CT from nonenhanced CT in emergency department patients with acute abdominal pain. Sci Rep 2021;11:20390.
21. Federle MP, Jeffrey RB Jr. Hemoperitoneum studied by computed tomography. Radiology 1983;148:187-92.
22. Lubner M, Menias C, Rucker C, Bhalla S, Peterson CM, Wang L, et al. Blood in the belly: CT findings of hemoperitoneum. Radiographics 2007;27:109-25.
23. Levine CD, Patel UJ, Silverman PM, Wachsberg RH. Low attenuation of acute traumatic hemoperitoneum on CT scans. AJR Am J Roentgenol 1996;166:1089-93.
24. Naulet P, Wassel J, Gervaise A, Blum A. Evaluation of the value of abdominopelvic acquisition without contrast injection when performing a whole body CT scan in a patient who may have multiple trauma. Diagn Interv Imaging 2013;94:410-7.
25. Esposito AA, Zilocchi M, Fasani P, Giannitto C, Maccagnoni S, Maniglio M, et al. The value of precontrast thoraco-abdominopelvic CT in polytrauma patients. Eur J Radiol 2015;84:1212-8.
26. The Royal College of Radiologists. Standards of practice and guidance for trauma radiology in severely injured patients second edition [homepage on the Internet]. London: The Royal College of Radiologists; 2015 [cited 2022 Nov 13]. Available from: https://www.rcr.ac.uk/system/files/publication/field_publication_files/bfcr155_traumaradiol.pdf
27. Miyakawa K, Kaji T, Ashida H, Kuwabara M, Ishizuka K, Wakabayashi M, et al. Evaluation of non-contrast-enhanced CT in blunt abdominal trauma. Nihon Igaku Hoshasen Gakkai Zasshi 1992;52:300-7.
28. Holz JA, Alkadhi H, Laukamp KR, Lennartz S, Heneweer C, Püsken M, et al. Quantitative accuracy of virtual non-contrast images derived from spectral detector computed tomography: an abdominal phantom study. Sci Rep 2020;10:21575.
29. Willemink MJ, Persson M, Pourmorteza A, Pelc NJ, Fleischmann D. Photon-counting CT: Technical principles and clinical prospects. Radiology 2018;289:293-312.
30. Smith-Bindman R, Lipson J, Marcus R, Kim KP, Mahesh M, Gould R, et al. Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. Arch Intern Med. 2009;14:169:2078-86.