

The role of computed tomography in arterial injury evaluation in solid organ trauma

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Abstract

Background. Abdominal solid organ trauma accounts for 86.9% of all blunt abdominal trauma cases, among which 5%–25% of cases are associated with arterial injuries. Aim: In this study, we aimed to determine the characteristics and diagnostic functions of computed tomography (CT) scans during the diagnosis of arterial injuries, including active extravasation, pseudoaneurysm, and arteriovenous fistula associated with solid organ trauma compared with digital subtraction angiography (DSA).

Methods. From July 2019 to March 2020, a retrospective study was performed on 44 patients who presented with clinical manifestations of blunt abdominal injury and CT diagnosis of arterial injuries due to solid organ trauma, including active extravasation, pseudoaneurysm, and arteriovenous fistula, and later underwent DSA at Vietduc Hospital, in Hanoi, Vietnam. The features of arterial lesions on CT scan was described. Value of CT scan for the diagnosis of arterial injuries was analyzed compared to the DSA findings.

Results. There were 53 arterial lesions observed on CT scan including 15 active extravasations, 34 pseudoaneurysms, and 4 arteriovenous fistulas while 51 arterial lesions were observed on DSA including 15 active extravasations, 30 pseudoaneurysms, and 6 arteriovenous fistulas. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of active extravasation, pseudoaneurysm, and arteriovenous fistula on CT scan were 93.3%, 97.7%, 93.3%, 97.7% and 96.6%; 90%, 75%, 79.4%, 87.5% and 82.8%; and 66.7%, 100%, 100%, 96.3% and 96.6%, respectively.

Conclusions. Our study showed that CT scans had high sensitivity and specificity for the diagnosis of active extravasation; however, CT scans demonstrated low specificity for detecting pseudoaneurysm and low sensitivity for the diagnosis of arteriovenous fistula. *Clin Ter* 2020; 171 (6):e528-533. doi: 10.7417/CT.2020.2268

Key words: Arterial injuries, solid organ trauma, CT scan, active extravasation, pseudoaneurysm, arteriovenous fistula

Introduction

Abdominal solid organ trauma accounts for 86.9% of all blunt abdominal trauma cases, among which 5%–25% of cases are associated with arterial injuries (1,2). The mortality

rate associated with abdominal vascular trauma ranges from 20% to 60% (3). Therefore, the correct diagnosis of abdominal solid organ trauma, particularly when associated with arterial injuries, is essential, due to the high morbidity and mortality rates (4,5). Arterial injuries can include active extravasation, pseudoaneurysm, and arteriovenous fistula, although active extravasation and pseudoaneurysm are more common (6). Contrast-enhanced computed tomography (CT) is considered to be the first-line modality for the diagnosis of arterial injuries associated with blunt abdominal trauma, especially solid organ trauma (7). Contrast-enhanced CT is a non-invasive examination, with demonstrated sensitivities for the detection of active extravasation and pseudoaneurysm of 90% and 86.1%, respectively (8,9).

The value of CT scans for the evaluation of vascular injuries associated with blunt abdominal trauma, abdominopelvic trauma, and separate organ trauma (liver, spleen, and kidney) has been discussed in previous studies (10,11). However, the role of CT scans for the diagnosis of pseudoaneurysm and arteriovenous fistula has rarely been reported (9,12).

In this study, we aimed to determine the characteristics and diagnostic functions of CT scans during the diagnosis of arterial injuries, including active extravasation, pseudoaneurysm, and arteriovenous fistula associated with solid organ trauma compared with digital subtraction angiography (DSA).

Materials & methods

Study population

From July 2019 to March 2020, a retrospective study was performed on 44 patients (38 men and 6 women, aged 6–77 years old, with a median age of 32.45 years), who presented with clinical manifestations of blunt abdominal injury and CT diagnosis of arterial injuries due to solid organ trauma, including active extravasation, pseudoaneurysm, and arteriovenous fistula, and later underwent DSA at Vietduc Hospital, in Hanoi, Vietnam. Ethical clearance was obtained

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from the institute ethics committee (Ref: 362/QĐ-ĐHYHN dated 25 February 2020), with waived consent due to the retrospective nature of this study.

Imaging technique

The abdominal CT examination was conducted on a 16-detector row CT scan (Optima 2019, GE Healthcare System, Milwaukee, WI, USA). Patients were supine and scanned in a craniocaudal direction, at 350 mAs and 120 kVp. A multiphase CT scan, including non-contrast, arterial, and portal phases was performed from the diaphragm to the pubic symphysis, with 5-mm slice thickness. A reconstruction from the raw image data, set in axial, coronal, and sagittal planes, was produced, with a section thickness of 0.625 mm. An intravenous bolus of Xenetix 350 (Guerbet, France) was injected, at a dose of 1.5 mL/kg and a flow rate of 2.5–3 mL/s, using a power injector. The arterial phase was initiated at 25–30 s and the portal phase was operated 60–70 s after the start of contrast injection. Postprocessing images were transferred to a picture archiving and communication system (PACS) workstation (Carestream PACS; Carestream Health, Eemnes, Netherlands).

Imaging analysis

The abdominal CT scan images were independently analyzed by two radiologists (a second-year resident and a senior radiologist, with 15 years of body imaging experience), who were blinded to the DSA results. Any disagreements between them were resolved by consensus. The severity of solid organ injury (liver, spleen, kidney, and pancreas) was classified according to the American Association for the Surgery of Trauma (AAST) scales, revised in 2018 (13). Active extravasation was defined as high-density (> 80 Hounsfield units or HU), extravascular fluid, which could be focal or diffuse, in ill-defined, radial (linear or layering), or irregular rounded shapes in the arterial phase and that demonstrated altered morphology, size, and density in the portal phase (14) (Figure 1a and b). Pseudoaneurysm was defined as high-density (> 80 HU), extravascular, focal fluid collection that is well-defined, in round or oval shapes in the

arterial phase and that shows no alterations in morphology but displays modifications in size and density in the portal phase (4,14) (Figure 2a and b). Arteriovenous fistula was defined as any direct connection between arteries and veins, with dilated venous drainage in the arterial phase (15,16) (Figure 3a and b). The size of active extravasation and pseudoaneurysm was calculated by multiplying the two longest perpendicular axes that were measured on the axial plane at the same level in both the arterial and portal phases (17). The densities of active extravasations and pseudoaneurysms were measured at the center of the lesion in the arterial phase and compared with the densities of the aorta, on the axial plane at the same level (17,18).

DSA images were independently analyzed by a senior interventionist, with 10 years of experience in peripheral vascular intervention and who was blinded to the abdominal CT scan results. Active extravasation was defined as the appearance of extravasation in a jet shape or an ill-defined, focal, round shape (Figure 1c). Pseudoaneurysm was defined as the appearance of extravasation in a well-defined round, or oval shape (Figure 2c). Arteriovenous fistula was defined as the early filling of dilated venous drainage in the arterial phase (Figure 3c).

Statistical analysis

SPSS version 20.0 was used to analyze the data (IBM corp., New York, USA). Quantitative variables are described as the median and interquartile range (IQR). Categorical variables are described as numbers and percentages. The Mann-Whitney U test was used to determine differences in the sizes of active extravasations and pseudoaneurysms between the arterial and portal phases and differences in the densities of these lesions compared with those of the aorta.

The diagnostic function of CT scan for the diagnosis of active extravasation and pseudoaneurysm was determined by evaluating the sensitivity (Se), specificity (Sp), negative predictive value (NPV), positive predictive value (PPV), and accuracy (ACC) compared with DSA results, which are considered to be the gold standard. Chi-squared or Fisher's exact test was used to compare the differences between CT scans and DSA findings. Significance was set to $p < 0.05$.



Fig. 1. Active extravasation in grade IV liver trauma. Axial arterial phase image (a) shows a linear, ill-defined, active extravasation (arrow). Axial portal phase image (b) shows an alteration in the morphology, size, and density of the lesion (arrow). DSA image (c) shows an ill-defined, linear extravasation (arrow).

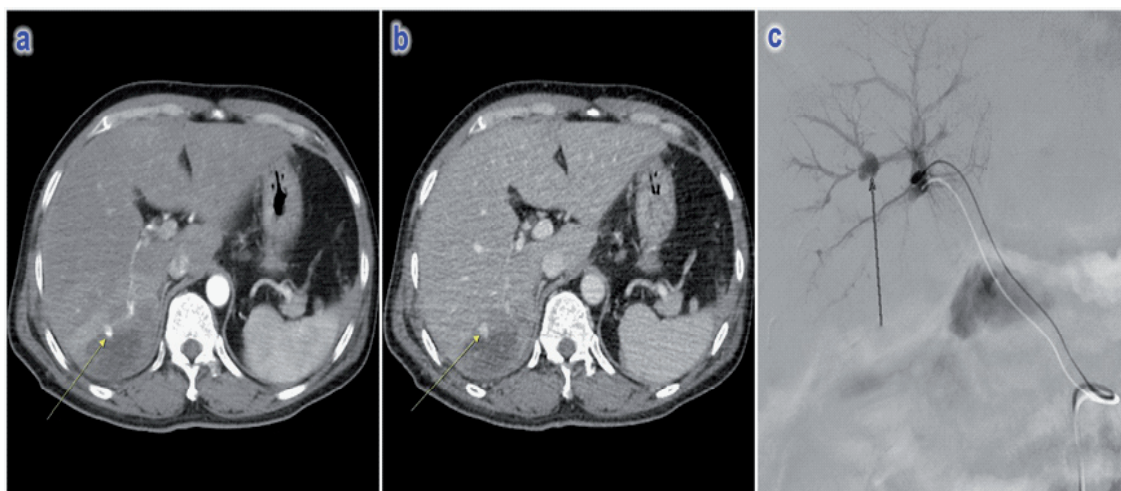


Fig. 2. Pseudoaneurysm in grade III liver trauma. Axial arterial phase image (a) shows a round-shaped, well-defined pseudoaneurysm (arrow). Axial portal phase image (b) shows a modification in the size and density of the lesion (arrow). DSA image (c) shows a well-defined, round-shaped extravasation (arrow).

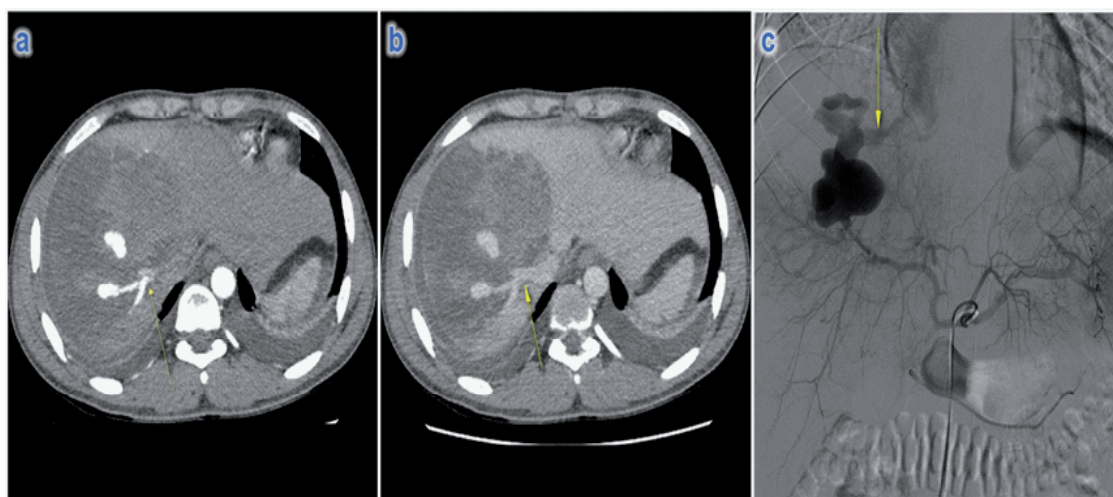


Fig. 3. Arteriovenous fistula in grade IV liver trauma. Axial arterial phase (a) and portal phase images (b) show a pseudoaneurysm, with a dilated venous drainage to the right hepatic vein (arrow). DSA image (c) shows the early filling of a dilated venous drainage into the hepatic vein (arrow).

Results

The characteristics of arterial injury associated with solid organ trauma on CT scan

The arterial injury distribution and severity of solid organ trauma, according to the AAST scales, are shown in Table 1. Arterial injury was most commonly observed in the liver (66%), followed by the spleen (22.7%), and kidney (11.3%), and these injuries were predominantly classified as grade III (40.9%) and grade IV (43.18%). Additionally, 6 cases of grade V splenic injury and 1 case of grade II liver injury were associated with arterial injury. No pancreatic injuries were identified in this study.

Table 1. Arterial injury distribution and solid organ trauma severity, according to AAST scales

Distribution	AAST scales				
	Grade I	Grade II	Grade III	Grade IV	Grade V
Spleen	0	0	10	12	6
Liver	0	1	7	4	0
Kidney	0	0	1	3	0
Total	0	1	18	19	6

AAST, American Association for the Surgery of Trauma

In CT images, 53 arterial lesions were observed, including 15 active extravasations, 34 pseudoaneurysms, and 4 arteriovenous fistulas. Among 37 round-shaped lesions, 34 were identified as pseudoaneurysms, whereas 3 were active extravasations. All 12 radial-shaped lesions were active extravasations. In DSA images, 51 arterial lesions were observed, including 15 active extravasations, 30 pseudoaneurysms, and 6 arteriovenous fistulas. All 7 lesions that were detected on CT scan but misdiagnosed on DSA were pseudoaneurysms, and the 5 lesions that were misdiagnosed on CT scan but were detected on DSA included 1 active extravasation, 2 pseudoaneurysms, and 2 arteriovenous fistulas.

The sizes of the active extravasations and pseudoaneurysms observed in the arterial and portal phases on CT scan are shown in Table 2. No significant differences in the sizes of the lesions in the arterial and portal phases were noticed between the positive and negative groups on DSA.

Data are presented as the median (IQR). CT, computed tomography; DSA, digital subtraction angiography; NA: not available

The median density of active extravasations and pseudoaneurysms was 289 HU (237.63–321.50), which was lower than the median density of 334.50 HU (284.25–354.50) for the aorta ($p < 0.05$).

Diagnostic function of CT scan for the diagnosis of active extravasation, pseudoaneurysm, and arteriovenous fistula.

Based on Table 3, the CT scan Se, Sp, PPV, NPV, and ACC values were 93.3%, 97.7%, 93.3%, 97.7%, and 96.6% for active extravasation, 90%, 75%, 79.4%, 87.5% and 82.8% for pseudoaneurysm, and 66.7%, 100%, 100%, 96.3% and 96.6% for arteriovenous fistula detection, respectively.

Discussion

Multidetector CT scans, with short acquisition times and thin slice thicknesses, can improve both temporal and spatial resolution and allows multiplanar reconstructions, which can play a crucial role in the diagnosis of blunt abdominal trauma, particularly for arterial injuries (6,10). The AAST scales, which were introduced in 1994 and revised in 2018, represent the most popular classification system used for the

grade IV kidney trauma cases in the study by *Vozianov et al* (20). *Ekeh et al* studied splenic trauma and identified only 1 grade II case associated with arterial injury (21). Our study showed identical results with previous studies, with arterial injuries predominantly detected in grade III (40.9%) and grade IV (43.18%) organ traumas (19–21).

The shape of the arterial lesion can influence the diagnosis. Jet-shaped arterial lesions can indicate high-pressure vascular lesions, caused by a marked difference between the intra and extravascular pressure levels, creating a high-flow-rate leak out of the vascular lumen (22). Our study showed that all 12 radial-shaped lesions were active extravasations, similar to the results reported in previous studies (18,23). In contrast, round-shaped arterial lesions have lower flow rates and are often associated with pseudoaneury-

Table 3. Diagnostic function of CT scan for the diagnosis of active extravasation, pseudoaneurysm, and arteriovenous fistula

Parameters	CT findings	DSA findings		
		+ (n)	– (n)	Total (n)
Active extravasation	+ (n)	14	1	15
	– (n)	1	42	43
Pseudoaneurysm	+ (n)	27	7	34
	– (n)	3	21	24
Arteriovenous fistula	+ (n)	4	0	4
	– (n)	2	52	54

CT, computed tomography; DSA, digital subtraction angiography.

assessment of solid organ trauma on CT scan (13). Arterial injuries have been commonly found in solid organ trauma, ranging from grade III to V, in previous studies. *Dabb et al* (19) examined liver trauma and showed that arterial injuries were detected in 22.5% of grade III, 62% of grade IV, and 15.5% of grade V liver trauma cases. Arterial injuries were noticed in 10% of grade II, 55% of grade III, and 35% of

Table 2. Sizes of the active extravasation and pseudoaneurysms observed in arterial and portal phases on CT scan

Parameters	CT phase	DSA (+)	DSA (–)	p-value
Active extravasation	Arterial phase	95.35 (47.92–220.08)	48.79	0.49
	Portal vein phase	136.13 (102.93–268.87)	160.04	0.81
Pseudoaneurysm	Arterial phase	77.46 (23.74–141.90)	44.02 (22.97–65.50)	0.15
	Portal vein phase	111.65 (33.49–213.93)	81.06 (26.49–129.55)	0.32

sms (22). In the current study, the observed arterial injuries were predominantly round-shaped (75.5%) and the 7 lesions that were detected on CT scan but misdiagnosed on DSA were round-shaped pseudoaneurysms. The misdiagnosis of DSA may be due to these 7 patients having no coagulopathy associated with the slow pseudoaneurysm flow rate, which can form blood clots obstructing the vascular breach. The lesions that were misdiagnosed on CT scan but detected on DSA including 1 active extravasation, 2 pseudoaneurysms, and 2 arteriovenous fistulas. This disagreement may be the result of different contrast flow pressures, which are low on CT scans and high on DSA. Moreover, the direct injection into the injured artery improves the capacity of detecting small arterial lesions on DSA (24).

In the current study, no significant differences in the sizes of arterial and portal phase lesions were observed between the positive and negative groups on DSA. This result is comparable with those reported by *Sims et al* (18). *Sims* stated that the size of the lesion varies in 3 dimensions; thus, although measurements performed in 2 dimensions can provide rapid calculations in case of emergency, they are inaccurate for determining the volume of a lesion. In contrast, the study performed by *Willmann et al* (23), which included a delay phase, showed a significant difference in the size of the lesions between the positive and negative groups on DSA. The lesion density can provide information regarding the original blood supply (6). However, differences in lesion densities depend on the distance between the largest artery and the injured artery at the same level. Our study revealed a significant difference between the density of arterial lesions and that of the aorta. This result is similar to the results reported by *Shanmuganathan et al* (25) and *Willmann et al* (23).

For the diagnostic function of CT scans during the detection of active extravasation, the studies reported by *Hallinan et al* (8) and *Marmery et al* (12) mentioned that the Se, Sp, PPV, and NPV values of CT scans for the diagnosis of active extravasation were 93.9%, 77.8%, 88.6%, and 87.5% and 76%, 90%, 87%, and 80%, respectively. These results for these variables in our study were 93.3%, 97.7%, 93.3%, and 97.7%, respectively. The divergence between studies may be due to variations in the study designs. Our study focused on solid organ trauma, whereas *Hallinan et al*'s study concentrated on abdominopelvic trauma, and *Marmery*'s study investigated splenic vascular injury. CT scans demonstrated a high Se value of 90% and a low Sp value of 75% for the diagnosis of pseudoaneurysm in the present study. This is identical with the result of *Dawoud et al* (9) who stated that Se and Sp of CT scan were 86.1% and 50% respectively. Our study showed that CT scans had a low Se value of 66.7% and a high Sp value of 100% for the diagnosis of arteriovenous fistula. The study reported by *Dawoud et al* (9) found that all 4 arteriovenous fistulas detected on DSA were misdiagnosed on CT scan. *Vignali et al* (26) performed a study of 15 patients after percutaneous renal procedures and noticed 2 arteriovenous fistulas, which were detected on both CT scans and DSA. Previous studies declared that DSA is the best modality for the diagnosis of arteriovenous fistula and artery injury (9,26,27).

Our study has some limitations. First, this study was retrospective and did not assess the findings of arterial injuries in the delay phase. Second, this study had a small

sample size and was conducted at a single center. Thus, an additional prospective study with a larger sample size and the addition of the delay phase to the CT protocol should be conducted.

Conclusions

Our study showed that CT scans can be useful for evaluating arterial injuries in solid organ trauma. This method had high sensitivity and specificity for the diagnosis of active extravasation; however, CT scans demonstrated low specificity for detecting pseudoaneurysm and low sensitivity for the diagnosis of arteriovenous fistula.

Ethical Statement

This retrospective study was approved by institutional review board (Ref: 362/QĐ-ĐHYHN dated 25 February 2020). Inform consent of patients was waived.

ICMJE Statement and Conflict of interest

The authors declare that there is no conflict of interest

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Author Contribution

NDH and NMD contributed equally to this article as first authorship. NDH and NMD gave a substantial contribution in acquisition, analysis, and data interpretation. NDH and NMD prepared, drafted, and revised manuscript critically for important intellectual content. Each author gave the final approval of the version to be published and agreed to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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