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Blunt Hollow Viscus and Mesenteric Injury: Still Underrecognized

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Abstract
Background Despite the availability of more accurate imaging modalities, specifically multidetector computed tomography (MDCT), the diagnosis of non-ischemic (NI-) and ischemic (I-) blunt hollow viscus and mesenteric injury (BHVMI) remains challenging. We hypothesized that BHVMI can be still missed with newer generations of MDCT and that patients with I-BHVMI have a poorer outcome than those with NI-BHVMI.
Methods We performed an eight-year retrospective review at a level 1 trauma center. Ischemic-BHVMI was defined as devascularization confirmed at laparotomy. Non-ischemic-BHVMI included perforation, laceration, and hematoma without devascularization. The sensitivity of each generation of MDCT for BHVMI was calculated. Potential predictors and outcomes of I-BHVMI were compared to the NI-BHVMI group.
Results Of 7,875 blunt trauma patients, 67 patients (0.8 %) were included in the BHVMI group; 13 patients did not have any CT findings suggestive of BHVMI (sensitivity 81 %), and 11 of them underwent surgical intervention without delay (<5 h). Newer generations of MDCT were not associated with higher sensitivity. Patients with I-BHVMI had a significantly higher rate of delayed laparotomy ≥12 h (23 % versus 2 %; $p = 0.01$) and a significantly longer length of hospital stay (median 14 versus 9 days; $p = 0.02$) than those with NI-BHVMI.
Conclusions Even using an advanced imaging technique, the diagnosis of I-BHVMI can be delayed, with significant negative impact on patient outcome.

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Introduction

Multidetector computed tomographic (MDCT) scanning has assumed a greater role in the diagnosis of injured patients, often replacing other imaging modalities [1–3]. For example, conventional angiography, long considered the "gold standard" in the diagnosis of traumatic vascular injury, has been progressively replaced by CT angiography [4–6]. Furthermore, many trauma management guidelines are now based on the findings of MDCT, such as those for the treatment of hemodynamically stable patients with solid organ injury [7, 8].

However, there are organ injuries for which the accuracy of MDCT diagnosis may still be questioned [9, 10]. Blunt hollow viscus and mesenteric injury (BHVMI) is one such condition. Before the era of MDCT scanning, a large retrospective multi-institutional study revealed that CT scan findings were entirely normal in up to 13.0 % of patients with blunt small bowel perforation [11]. The fairly high false negative rate of CT diagnosis of BHVMI resulted in the frequent use of diagnostic peritoneal lavage (DPL) as an adjunctive test, with imperfect accuracy [12].

With recent enthusiasm for the use of MDCT in the management of injured patients, an increasing body of literature has re-evaluated the efficacy of this newer modality for BHVMI [13–21]. This work is widely disparate, with some authors reporting an accuracy rate approaching 100 %, while others demonstrate that as many as 20 % of BHVMI can be missed by MDCT. The discrepancy in these results may be related to the lack of discrimination between ischemic (I-) and non-ischemic (NI-) BHVMI.

Devascularizing injury is categorized as the highest grade of BHVMI in the organ injury scale of the American Association for the Surgery of Trauma (AAST) [22]. Severe mesenteric injury compromising visceral blood flow can cause ischemia and delayed necrosis. Although most severe mesenteric injury should result in concomitant active bleeding that can be identified on CT scan by contrast extravasation or formation of a hematoma, initial imaging can also be entirely normal or demonstrate only subtle findings [13]. In such cases, the timing of therapeutic laparotomy can be delayed significantly, with impaired clinical outcomes.

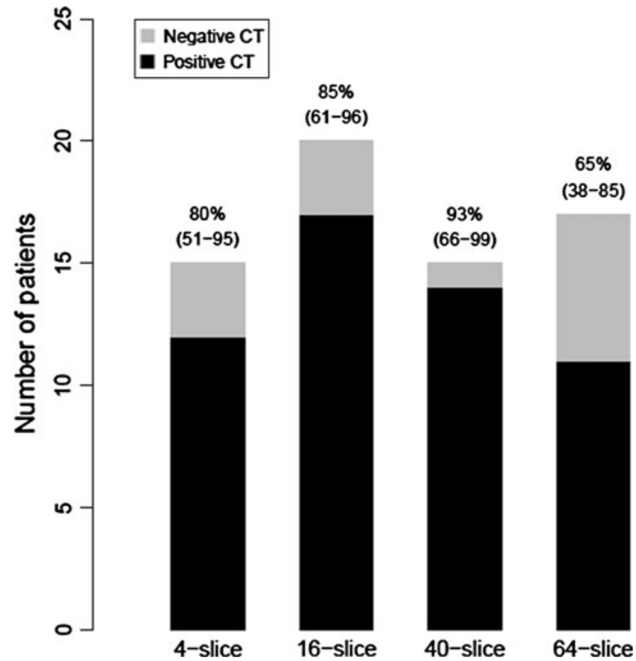

Fig. 1 Sensitivity (95 % confidence interval) of multidetector computer tomography (MDCT) for blunt hollow viscus and mesenteric injury (BHVMI) by generations of MDCT

Table 1 Patient demographics and CT scan findings of BHVMI cases

Patient demographics	
Median age (IQR)	38 (23–49)
Male gender	66 %
MVC as mechanism	73 %
Intubation at ED	16 %
Median ISS (IQR)	22 (14–34)
GCS ≤8	18 %
SBP <90	16 %
Abdominal tenderness	61 %
Abdominal rebound	9 %
Abdominal wall contusion	31 %
Initial WBC >10,000	85 %
Initial elevated amylase level	17 %
BHVMI CT scan findings	
Extraluminal gas	19 %
Active extravasation of IV contrast	13 %
Mesenteric stranding	30 %
Enhancement of bowel wall	15 %
Mesenteric hematoma	21 %
Bowel wall thickening	24 %
Isolated free fluid	57 %
Any positive BHVMI CT finding	81 %

BHVMI blunt hollow viscus and mesenteric injury; *IQR* inter-quartile range; *MVC* motor vehicle collision; *ISS* injury severity score; *GCS* Glasgow coma scale; *SBP* systolic blood pressure; *ED* emergency department; *WBC* white blood cell count; *CT* computed tomography; *IV* intravenous

The purpose of the present study was to evaluate the sensitivity of MDCT for the diagnosis of BHVMI. We also sought to investigate the outcome of I-BHVMI compared with NI-BHVMI. We hypothesized that the use of the newer generations of MDCT improves the diagnosis of BHVMI, but that definitive treatment can be still delayed in I-BHVMI patients whose clinical outcome is poorer than the outcomes recorded in NI-BHVMI.

Patients and methods

This study was approved by the institutional review board of Penn State College of Medicine. Penn State Milton S. Hershey Medical Center is a regional academic level 1 trauma center with a catchment area of approximately 1.2 million. Patient data were extracted from the institutional trauma database. Study data were collected from 2002 to 2009 based on the following injury codes: stomach, duodenum, small bowel, colon, rectum, and small bowel/colon mesentery. Patients who sustained penetrating injury or who were taken to the operating room (OR) immediately for exploratory laparotomy without a prior CT scan were excluded from this study.

The BHVMI group was defined as patients who had laparotomy-confirmed perforation, laceration, hematoma, or devascularization of the mesentery, stomach, small

Table 2 List of blunt hollow viscus and mesenteric injury cases without any findings for BHVMI

	Normal CT	MDCT generation	I-BHVMI	Abdominal wall contusion	Pelvic fracture	WBC >10,000	Indication for laparotomy	Time to laparotomy, min	LOS, days
1	No	4-slice	No	No	No	Yes	Splenic injury	25	22
2	No	4-slice	Yes	No	Yes	Yes	Bladder injury	232	23
3	No	16-slice	No	No	No	Yes	Splenic injury	103	9
4	No	16-slice	No	No	No	Yes	Liver, splenic injury	160	27
5	No	40-slice	No	Yes	No	Yes	Splenic injury	100	5
6	No	64-slice	No	Yes	Yes	No	Diaphragm injury	91	16
7	No	64-slice	No	No	No	Yes	Liver, splenic injury	62	23
8	No	64-slice	Yes	Yes	Yes	Yes	Splenic injury	112	69
9	No	64-slice	No	No	No	Yes	Splenic injury	105	8
10	Yes	4-slice	Yes	No	No	Yes	Peritonitis	40	7
11	Yes	64-slice	No	Yes	No	Yes	Peritonitis	92	10
12	Yes	16-slice	No	No	No	No	Worsening abdominal pain	1,260	7
13	Yes	64-slice	Yes	Yes	Yes	No	Worsening abdominal pain	2,880	24

I-BHVMI ischemic blunt hollow viscus and mesenteric injury

intestine, and large intestine. Patient baseline characteristics, clinically relevant data, and potential risk factors for BHVMI were collected from the database and hospital medical records. The decision of whether to obtain an abdominal CT scan was at the discretion of the attending trauma surgeon based on clinical judgment.

At the beginning of the study period in 2002, CT imaging was performed with a 4-slice MDCT scanner that was upgraded serially to a 16-slice scanner in 2005, a 40-slice scanner in 2007, and a 64-slice scanner (Siemens Medical Systems, Erlangen, Germany) in 2008. All CT images were obtained after administration of low osmolar intravenous contrast (Omnipaque, GE Healthcare, Little Chalfont, UK) without oral, nasogastric, or rectal contrast. The CT images were reviewed by a radiology resident and subsequently finalized by a board-certified attending radiologist. The radiology resident assigned to the emergency department reviewed the CT images at the time of study, and the findings were discussed with the senior trauma resident or attending trauma surgeon. Seven CT findings suggestive of possible BVHMI (BHVMI CT findings: mesenteric stranding, mesenteric hematoma, active mesenteric vessel extravasation, bowel wall thickening, extraluminal air, abnormal bowel wall enhancement, intraperitoneal free fluid in the absence of solid viscus injury) were evaluated for all patients [11, 15]. The overall sensitivity of MDCT for these seven BHVMI findings was calculated, along with the sensitivities for each generation of MDCT scanner.

We subsequently stratified the BHVMI patients into I-BHVMI and NI-BHVMI subgroups, and tested for associations between groups with patient characteristics, associated injuries, laboratory tests, and CT results [23, 24]. For this purpose, we used Wilcoxon tests to compare continuous variables and Fisher's exact tests to compare binary variables. The same tests were used to compare outcomes (mortality, major complication, and length of hospital stay) between groups. Because of the small sample size, no multivariate models were fitted.

Results

A total of 7,875 blunt-injured patients were identified during the study period from our institutional registry, 84 of whom had BHVMI. Seventeen cases were excluded from the analysis as these patients were taken to the operating room immediately for exploratory laparotomy based on clinical judgment without a CT scan. Therefore, 67 patients (0.8 %) were included.

Patient characteristics and BHVMI CT findings are shown in Table 1. Only 61 % of patients had a positive finding during the abdominal examination at admission. Initial WBC count was greater than 10,000 in the majority of patients, whereas the incidence of elevated amylase level was only 16 %. Isolated fluid collection without associated solid organ injury was the most common CT BHVMI finding. Overall sensitivity of MDCT for BHVMI was 81 %. Figure 1 shows the sensitivity of each generation of MDCT scanner for seven BHVMI findings. The highest sensitivity was for the 40-slice MDCT scanner (93 % sensitivity; 95 % CI 66 % to 99 %), the 64-slice scanner showed a sensitivity of only 65 % (95 % CI 38 % to 85 %).

Table 3 Comparison of patient characteristics and BHVMI CT scan findings (NI-BHVMI versus I-BHVMI)

	NI-BHVMI ($n = 41$)	I-BHVMI ($n = 26$)	p Value
Median age	34	41	0.42
(IQR)	(22–58)	(31–49)	
Male gender	61 %	73 %	0.43
MVC as mechanism	71 %	77 %	0.78
Median ISS	22	26	0.19
(IQR)	(17–29)	(14–41)	
Intubation at ED	15 %	19 %	0.74
GCS ≤8	15 %	23 %	0.52
SBP <90	17 %	15 %	1.00
Abdominal tenderness	63 %	58 %	0.80
Abdominal rebound	12 %	4 %	0.39
Abdominal wall contusion	29 %	35 %	0.79
Initial WBC >10,000	85 %	85 %	1.00
Initial elevated amylase level	28 %	0 %	0.002
Pelvic fracture	17 %	42 %	0.046
Lumbar spine fracture	17 %	23 %	0.55
BHVMI CT scan findings			
Extraluminal gas	27 %	8 %	0.06
Active extravasation of IV contrast	12 %	15 %	0.73
Mesenteric stranding	29 %	31 %	1.00
Enhancement of bowel wall	12 %	19 %	0.49
Mesenteric hematoma	20 %	23 %	0.77
Bowel wall thickening	27 %	19 %	0.57
Isolated free fluid	54 %	62 %	0.62
Any positive BHVMI CT finding	78 %	85 %	0.75

NI-BHVMI non-ischemic blunt hollow viscus and mesenteric injury

Table 4 Comparison of patient outcome (NI-BHVMI versus I-BHVMI)

	NI-BHVMI	I-BHVMI	p Value
Time to laparotomy ≥5 h	10 %	28 %	0.08
Time to laparotomy ≥12 h	2 %	23 %	0.011
Resection rate	20 %	96 %	<0.001
Diversion rate	2 %	8 %	0.55
Mortality rate	5 %	8 %	0.63
Median LOS (IQR)	9 (6–15)	14 (8–30)	0.018
Median ICU LOS (IQR)	2 (0–6)	5 (1–11)	0.05
Median vent days (IQR)	0 (0–2)	2 (0–6)	0.07
In-hospital complication	22 %	46 %	0.06

ICU intensive care unit

There were no positive BHVMI CT findings for 13 patients (Table 2), most of whom (11/13) were taken to the OR <5 h after arrival in the emergency department. In 9 patients, associated injuries requiring laparotomy were identified on the CT scan. The other 2 patients were taken to the OR emergently because of the development of early peritonitis. Two additional patients developed peritonitis over the course of admission and underwent laparotomy >12 h after presentation. There was no mortality identified in these 13 cases.

Among 67 BHVMI patients, 26 patients (39 %) were identified as having I-BHVMI. A comparison between the I-BHVMI and NI-BHVMI group is shown in Table 3. An elevated serum amylase level was found in 72 % of NI-BHVMI patients, whereas all I-BHVMI patients had a normal value ($p = 0.002$). The incidence of associated pelvic fracture was significantly higher in the I-BHVMI group (42 % versus 17 %; $p = 0.046$). Sensitivity of MDCT for any positive BHVMI CT findings were similar in the I-BHVMI and NI-BHVMI groups (85 % and 78 %; $p = 0.75$). Although extraluminal gas tended to be found more often in NI-BHVMI group, no CT scan findings were shown to be significant between I-BHVMI and NI-BHVMI.

Six patients (23 %) in the I-BHVMI group were taken to the OR ≥12 h after presentation compared to 1 patient (2 %) in the NI-BHVMI group ($p = 0.011$) (Tables 4 and 5). At laparotomy, the injury was identified in the ileocecal segment in 12 I-BHVMI cases (46 %). The most frequent site of injury in the NI-BHVMI group was jejunum (37 %). Five patients (12 %) had the injury in the ileocecal segment. Some 96 % of patients in the I-BHVMI group required surgical resection (versus 20 % in the NI- BHVMI group; $p < 0.001$). However, only 2 I-BHVMI patients (8 %) underwent a diversion procedure (versus 2 % in the NI-BBHVI group; $p = 0.56$). Two patients in each group died during the course of their hospitalization (8 % versus 5 %; $p = 0.64$). All deaths were due to associated injuries. Length of hospital stay was significantly longer in the I-BVHMI group (median 14 versus 9 days; $p = 0.018$). The major complication rate during hospital stay was higher in the I-BHVMI group, but the difference was not statistically significant (46 % versus 22.0 %; $p = 0.06$).

Discussion

The present study has demonstrated a lower incidence of delayed diagnosis of BHVMI than previous reports [11, 13]. Although the sensitivity of MDCT specifically for BHVMI findings was 81 %, only 6 % of patients had entirely normal CT results. We have also focused on the poorer outcome among I-BHVMI patients and to NI-BHVMI. The diagnosis of I-BHVMI was more likely delayed than NI-BHVMI.

Whereas CT scan, even before the era of MDCT, has been considered the gold standard for the diagnosis of intra-abdominal solid organ injury, its efficacy in the

Table 5 List of BHVMI cases with delayed laparotomy (>12 h)

	I-BHVMI	Age	ISS	Elevated amylase level	Positive BHVMI CT findings	Associated pelvic injury	Time to laparotomy	Indication for surgery	Injury site	Complication	LOS, days
1	No	36	29	No	0	No	1,260 min	Abdominal pain	Jejunum	None	7
2	Yes	47	50	No	1 (F)	Yes	12 days	Right flank abscess	Cecum	SSI, sepsis, ARF, ARDS	90
3	Yes	27	26	No	2 (MS, F)	Yes	6 days	Fever, succus from wound	Terminal ileum	SSI, sepsis	42
4	Yes	49	26	No	1 (MS)	No	6 days	Fever, abdominal pain	Ileum/A-colon	None	14
5	Yes	43	34	No	0	Yes	2,880 min	Abdominal pain, distension	A-colon	DVT	24
6	Yes	45	41	No	1 (MH)	Yes	1,260 min	Unreliable PEx with mesenteric hematoma	Jejunum	None	14
7	Yes	39	24	No	1 (F)	No	1,084 min	Repeat CT, abdominal pain	Terminal ileum	None	8

F isolated free fluid; *MS* mesenteric stranding; *MH* mesenteric hematoma; *NA* not applicable; *A-colon* ascending colon; *SSI* surgical site infection; *ARF* acute renal failure; *ARDS* acute respiratory distress syndrome; *DVT* deep vein thrombosis; *PEx* physical examination

diagnosis of BHVMI has not been established. Nonetheless, 77 % of respondents would use the CT scan as an initial diagnostic imaging for blunt small bowel injury in a nationwide survey performed in the late 1990s [25]. This number is undoubtedly even higher today because of the ready availability of MDCT.

Using logistic regression analysis, Elton and colleagues identified significant CT findings related to BHVMI [26]. Isolated free fluid, pneumoperitoneum, and bowel wall thickening were significantly associated with BHVMI in a 4-slice spiral CT scan. Since the introduction of MDCT, only a few articles have been published regarding BHVMI [13–19]. Brofman and colleagues reported various MDCT findings seen in patients with BHVMI [18]. Bowel wall discontinuity, extraluminal contrast material, and extraluminal air were considered specific for bowel injury. Mesenteric extravasation, mesenteric vascular beading, and termination of mesenteric vessels were considered specific for mesenteric injury. Their group also performed a case–control study using matched groups to determine the accuracy of MDCT for BHVMI requiring surgery [15]. The radiology resident and fellow radiologists successfully made the diagnosis of BHVMI in 36 of 38 cases (95 %). Tan and colleagues reviewed BHVMI patients who required laparotomy and underwent MDCT using a 4-slice or 64-slice scanner [14]. All cases demonstrated an abnormal preoperative CT scan. In contrast, Ekeh and colleagues showed a very high false negative CT rate (20 % with 4-slice MDCT, 17.6 % with 16-slice MDCT) [13]. Our results with ever newer generations of MDCT support their data.

To the best of our knowledge, this is the first study that has focused on the I-BHVMI. We found that I-BHVMI was significantly associated with pelvic fracture. Frick and colleagues reported that 22.9 % of their patients with BHVMI had associated pelvic fracture [24]. Shearing forces along the line of attachment of mesentery is believed to be the mechanism of mesenteric injury. Therefore, proximal jejunum and ileocecal mesentery are commonly injured. The most frequent site of I-BHVMI in our study was the ileocecal segment.

Although our study demonstrated a lower incidence of delayed diagnosis of BHVMI compared to previous literature [27, 28], 23 % of I-BHVMI patients still underwent operation ≥12 h after presentation. This was a significantly higher rate than for the NI-BHVMI group. The reason for this result remains unclear. None of the clinical data or BHVMI CT findings were more significantly associated with the I-BHVMI than with NI-BHVMI. Notably, the majority of the pelvic fractures in the I-BHVMI group required surgical fixation early in the hospital course. This would suggest that high grade pelvic fractures may be associated with I-BHVMI. Patients with delayed diagnosis of I-BHVMI frequently underwent pelvic fixation within 24 h of admission. In addition to the surgical procedure itself, postoperative pain could also have delayed the diagnosis of BHVMI in these cases.

The delay in diagnosis of BHVMI is well known to be significantly associated with poor outcome [29]. Classically, the delay in operative intervention beyond 24 h results in increased patient mortality and morbidity [29, 30]. This "cut-off" time for worsened outcome may be as short as 5–8 h [27, 28, 31]. While the mortality rate for I-BHVMI patients was similar to that for the NI-BHVMI group, LOS was significantly longer in the I-BHVMI group. This might be attributed to the difference in the type of procedure between the two groups. Recovery time from bowel resection, particularly advancing diet, is usually longer than simple repair of injury. Also, the in-hospital complication rate in I-BHVMI group tends to be higher than in the NI-BHVMI group. Nevertheless, we were unable to specify the type of complication that could create the increased LOS.

There are several potential limitations to our study. First, it was a retrospective single-institution study with a small sample size because of the low incidence of BHVMI. Second, the generation of MDCT scan was different between the beginning and the end of the study period because of the progressive evolution in technology. Ekeh and colleagues showed that there was no significant difference in the outcome of BHVMI patients between the 4-slice and the 16-slice MDCT technology [13]. Finally, patients with missed injuries could have presented at other institutions.

In conclusion, BHVMI can be missed with the newer generations of MDCT. Patients with I-BHVMI are at a greater risk of delayed diagnosis with poorer outcome than those with NI-BHVMI. A larger scale prospective study is needed to verify the accuracy of the current generation of MDCT scanners for the diagnosis of BHVMI.

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