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Defining an intra-operative blunt mesenteric injury grading system and its use as a tool for surgical-decision making

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ABSTRACT

Background: The mesentery may be injured in trauma and few grading systems describe mesenteric injury severity. We aimed to develop and validate an intra-operative mesenteric injury grading system.
Methods: A modified Delphi technique was used to generate an intraoperative grading system for blunt mesenteric injury called the mesenteric injury score (MIS). We performed a retrospective review (2010–2016) of patients >15 years old with blunt abdominal trauma. Patient demographics, injury severity score (ISS) and mechanism, clinical, operative, and outcome data were abstracted. The intraoperative grading system was used to describe patient outcomes including duration of stay and management approach. We compared the correlation of abdominal abbreviated injury score, Blunt Injury Prediction Score (BIPS) and the MIS with clinical outcomes using Spearman's rho.
Results: There were fifty-one patients of which 86% were male. Injury mechanisms included motor vehicle accidents (n = 37, 73%), pedestrian vehicle accidents (n = 7, 13%), assaults (n = 4, 8%), falls (n = 2, 4%), and a single airplane crash (2%). Median [IQR] ISS was 16 [10–25] and GCS at hospital admission was 15 [15–15]. The median [IQR] international normalized ratio was 1.2 [1.1–1.5], lactate was 2.7 [1.7–4.9], and hemoglobin was 11.4 [8.6–12.2]. The distributions of MIS included Grade I (3, 5%), Grade II (10, 20%), Grade III (10, 20%), Grade IV, 5 (10%), and Grade V (23, 45%). Increasing mesenteric injury grade was associated with longer duration of stay, need for bowel resection, and damage control laparotomy.
Conclusions: We developed an intra-operative mesenteric injury grading system (MIS) and provided an initial retrospective validation using a series of patients with blunt abdominal trauma. The proposed MIS corresponded with both the AIS and the BIPS. Future study comparing cross sectional imaging and operative findings based on MIS criteria is needed.

Background

Blunt abdominal trauma can cause injuries to both solid and hollow intra-abdominal viscera. Although solid visceral injuries are more common, hollow visceral injuries are associated with delays in diagnosis and intervention [1–7]. This can result in increased patient morbidity and mortality [2–7]. The mechanism of hollow visceral injuries is also poorly understood. Broadly there are two. Firstly, a segment of bowel can be caught between two solid structures and a subsequent increase in intra-luminal pressure may result in a blowout type injury. The second putative mechanism is associated with acute acceleration/deceleration which results in a mesenteric tear and may disrupt the blood supply to the affected bowel. If this injury remains undetected, it may progress to full thickness bowel necrosis.

Recently, mesenteric injuries have begun to be classified and subjected to detailed study. The Blunt Injury Prediction Score (BIPS) uses both clinical and computed tomography (CT) criteria to predict the presence of a hollow viscus or mesenteric injury after blunt abdominal trauma [8–10]. The following criteria are used: presence or absence of abdominal tenderness, white blood cell (WBC) count and the CT grade of mesenteric or bowel injury. The BIPS imaging grading criteria is shown in Table 1. BIPS is a

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Table 1
Blunt Injury Prediction Score computed tomography grades and definitions.

Grade	CT Grading of SBI as used in BIPS
1	Isolated mesenteric contusion without associated bowel wall thickening or adjacent interloop fluid collection
2	Mesenteric hematoma <5 cm without associated bowel wall thickening or adjacent interloop fluid collection
3	Mesenteric hematoma >5 cm without associated bowel wall thickening or adjacent interloop fluid collection
4	Mesenteric contusion or hematoma (any size) with associated bowel wall thickening or adjacent interloop fluid collection
5	Active vascular or oral contrast extravasation, bowel transection or pneumoperitoneum

pre-operative grading system and does not measure the severity of injury found at the time of operation. Currently, there is no intra-operative grading system to assist with surgical-decision making for mesenteric injuries [8–10]. This is a deficit especially given the increasing utilization of laparoscopy in stable, traumatically injured patients where diagnostic and clinical uncertainty is possible [11]. In light of this, we developed a mesenteric injury score (MIS) consisting of five levels which correspond with increasing injury severity, Table 2. We aimed to validate the proposed MIS in a set of patients with blunt abdominal trauma and mesenteric injury utilizing patients from two diverse institutions namely, the Mayo Clinic in Rochester Minnesota, USA and the Pietermaritzburg Metropolitan Trauma Service in Pietermaritzburg, South Africa. We hypothesized that the MIS would correspond to patient outcomes.

Methods

This study was a review of historical data from adult patients (>15 years old) and included patients that sustained blunt abdominal trauma and were diagnosed with mesenteric injury during 2010-2016. Patients that presented to either the Mayo Clinic in Rochester, USA and Pietermaritzburg Metropolitan Trauma Service in Pietermaritzburg, South Africa were included. Patients who were aged <15 years, presented with penetrating traumatic injury, or who expired prior to operative intervention were excluded. Institutional review board approval was obtained prior to data collection and consent was waived.

Developing an operative grading system for mesenteric injury

In order to develop an intra-operative mesenteric injury score (MIS), a modified Delphi type approach was utilized. Through an iterative process, repeated rounds of voting were used to generate the proposed MIS grading system criteria. The criteria were determined by expert group consensus, Table 2. Existing grading systems, namely the AAST [American Association for the Surgery of Trauma] abbreviated injury scale for trauma and the AAST EGS (emergency general surgery) were used as templates. We used the following approach for the modified Delphi Technique: The facilitator was the senior author on this paper. All the authors on the paper served as panel experts. The problem was defined as developing a grading system to classify mesenteric injury. The first round of questions was sent out via email to the entire group. These general questions were designed to obtain expert input regarding the scope of the problem and methods wherein a proposed intra-operative grading system might improve surgical-decision making. The primary and senior author collated and summarized the responses to identify areas of consensus. Following this, subsequent rounds of questions were sent out via email based on previous responses. These were again collated and summarized by the first and the senior author. Once the grading system had been generated, photographs of mesenteric injuries were collected and graded according to the proposed system by each of the panel members. Similarly, an artist's impressions were sent to the expert panel for grading. The proposed grading system is shown in Table 2 and Fig. 1.

There were three components of the system: the extent of hemorrhage from the injured mesentery, the anatomical extent of the mesenteric injury and the condition of the affected bowel. Grade I injuries consist of a contained hematoma in the bowel mesentery. There is intact bowel and mesenteric peritoneum, no exposed mesenteric vessels and no free intra-abdominal hemorrhage. Grade II injuries consist of a tear into the peritoneum covering the mesentery with exposed vessels and gaping mesenteric fat. Grade III injuries involve a tear in the peritoneum with concomitant gaping mesenteric fat and exposed vessels which are bleeding. Grade IV injuries represent a complete tear through the mesentery, bleeding or thrombosed vasculature with questionable bowel viability. Grade V injuries were defined as a non-viable injury wherein the mesentery is completely avulsed from its corresponding bowel and active bleeding or clot may be present.

Assignment of mesenteric injury score (MIS)

We queried operative reports for intra-operative anatomic injury descriptions as well as management approach. Operative and injury findings were then categorized according the MIS into one of the five grades (I–V). Grades were assigned by two authors (MCH, WB) and two senior authors (DLC, VYK) adjudicated any disputes. Intra-operative photographs of injuries were categorized by MIS.

Blunt injury prediction score (BIPS)

The BIPS was retrospectively calculated for all patients included in this study. A BIPS total score was generated by assigning points

Table 2
Proposed intraoperative mesenteric injury score (MIS).

Criteria			
Grade	Hemorrhage	Injury Extent	Bowel Viability
I	Hematoma / contusion	Intact peritoneum	Viable
II	Exposed vessels	<1 cm peritoneal tear	Viable
III	Active bleeding	Tear into mesenteric substance as evidenced by gaping mesenteric fat	Viable
IV	Bleed/thrombus	Mesenteric injury with resulting defect through which daylight is clearly visible.	Questionable
V	Bleed/thrombus	Avulsion injury	Non-viable

Non-viable bowel would be grade V irrespective of the grade mesenteric injury.

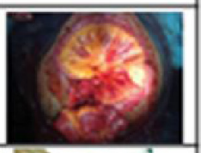
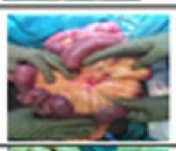
Grading	Hemmorhage	Injury Extent	Bowel Viability	Illustration	Picture
Grade 1	Hematoma / Contusion	Intact peritoneum	Viable		
Grade 2	Exposed vessels	Tear into mesenteric substance as evident by gaping mesenteric fat	Viable		
Grade 3	Active bleeding	Tear into mesenteric substance as evident by gaping mesenteric fat	Viable		
Grade 4	Any	Mesenteric injury with resulting defect through which daylight is clearly visible	Questionable		
Grade 5	Bleeding / Thrombus	Avulsion injury/Any	Non-viable		

Fig. 1. Mesenteric Injury Grading.

for the following: one point was given for WBC counts of >17 G/l, one point for the presence of abdominal tenderness and one point for a CT grade of >4, respectively. The computed tomography criteria for injuries were utilized and are reported in Table 1. Patients with a BIPS score of >2 have a high likelihood of a blunt abdominal injury.

Data collection and statistical analysis

The following were abstracted from the electronic medical record: injury mechanism, age, sex, Injury Severity Score (ISS), Glasgow Coma Scale (GCS), abdominal abbreviated injury score (AIS), laboratory and physiologic characteristics, cross-sectional imaging findings, operative management approach, relaparotomy, damage control laparotomy use, mortality, and duration of hospital stay.

All continuous data were described using medians with interquartile ranges [IQR]. Analyses were performed comparing patient clinical, laboratory, management approaches and outcomes with the MIS using Spearman's rho. Two-tailed p values were considered significant at ($\alpha < 0.05$).

Results

In this study, there were fifty-one patients that were reviewed, of which the majority (n = 44, 86%) were male. Mechanisms of injury included motor vehicle accidents (n = 37, 73%), pedestrian vehicle accidents (PVA) (n = 7, 13%), assaulst (n = 4, 8%), falls (n = 2, 4%), and an airplane crash (n = 1, 2%). Patients demonstrated severe overall injury patterns and the median [IQR] ISS was 16 [10–25]. At admission, the median [IQR] GCS was 15 [15–15], indicating that injuries predominantly did not involve the head or neck. The median [IQR] international normalized ratio was 1.2 [1.1–1.5] and this suggested that a quarter of patients had some degree of clinical coagulopathy. At admission patients were also acidotic and displayed acute anemia, lactate (mmol/dL) 2.7 [1.7–4.9] and hemoglobin (mg/dL) 11.4 [8.6–12.2] respectively. The majority of patients demonstrated a reduction in mean arterial pressure [median [IQR] 85 [76–90] and most patients displayed tachycardia, median heart rate 107 [89–123] beats per minute. In Table 3, computed tomography findings are shown.

There were 37 isolated small bowel mesenteric injuries, 3 isolated large bowel mesenteric injuries and 11 combined small and large bowel mesenteric injuries. The associated injuries in this patient cohort are summarized in Table 4. The distributions of MIS included Grade I (3, 6%), Grade II (10, 20%), Grade III (10, 20%), Grade IV (5, 9%), and Grade V (23, 45%). The interrater reliability between MIS grades was moderate-high with the kappa coefficient (0.83 95%CI 0.79–0.88, p = 0.03). In Table 5, patient median abdominal AIS and ISS are shown after stratification using the MIS grading system. There was a moderate positive correlation found between the MIS and the ISS and abdominal AIS scores which was statistically significant (p = 0.004 and 0.0004 respectively). However, there was no correlation between MIS and BIPS ($\rho = 0.11$, p = 0.43). Describing mesenteric injury using MIS criteria demonstrated a stronger correlation with the need for small bowel resection compared to using the abdominal AIS ($\rho = 0.6$ $p < 0.0001$ and $\rho = 0.39$ p = 0.01 respectively). BIPS did not correlate with the need for bowel resection. There was a moderate correlation between MIS and the need for DCL (r = 0.48; p = 0.0003). The correlation between MIS and mortality was not statistically significantly different. Table 6 shows the correlation between MIS, BIPS AIS and the following outcomes: mortality, and the need for relaparotomy, damage control laparotomy and the need for bowel resection. Comparison of the MIS and the abdominal AIS with patient outcomes were similar with respect to correlation (Fig. 2). Conversely, the MIS criteria were more positively correlated with patient outcomes in comparison to the BIPS.

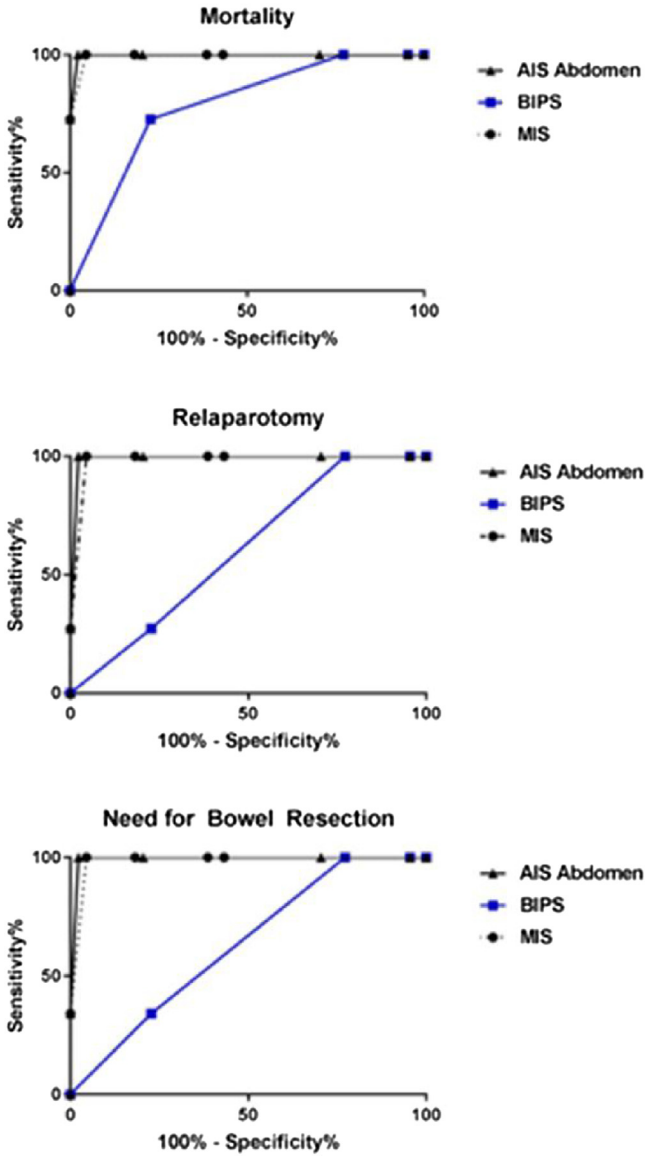


Fig. 2. Pairwise comparison abbreviated injury score (abdomen), blunt injury prediction score, and mesenteric injury score for selected outcomes.

Table 3
BIPS cross sectional imaging findings.

CT findings	N = 9
Haemoperitoneum	5
Free fluid and thickened bowel loops	1
Pneumatosis intestinalis	1
Free fluid and fat stranding	1
Bowel perforation	1

Discussion

In the present analysis, we set out to generate an intra-operative mesenteric injury score (MIS). We determined that utilizing a five-level grade based on well-defined criteria for intra-operative mesenteric injury findings; it was possible to describe clinical outcomes. Overall this study contributes to the understanding of mesenteric injury and the need for an intra-operative assessment to better guide management. These observations extend the use of the MIS to determine the extent of intra-operative visceral injury and subsequent management. Specifically, as the MIS severity increased there was an association with increased utilization of damage control laparotomy, bowel resection, relaparotomy, mortality, and this resulted in increased patient duration of stay. Finally, we have generated an initial validation of the MIS which supports the role of assessing mesenteric injury severity as an intra-abdominal organ in relation to other organs which may be critically injured as well.

Table 4
Concomitant injuries.

Associated Injury	N
Splenic injury	20
Bladder injury	4
Intra-abdominal vascular trauma	3
Intra-cerebral vascular injury	3
Lower limb fracture	8
Maxillo-facial injury	3
Thoracic injury	8

Blunt abdominal trauma continues to be associated with both morbidity and mortality due to delayed recognition of hollow visceral injury [2–7]. Even with early and focused cross-sectional imaging there is still a potential to miss these injuries. In response, several authors have attempted to better quantify this insidious injury [8–10]. The most studied method to identify blunt visceral injuries is the BIPS system which attempts to predict the presence of a mesenteric or bowel injury using imaging, laboratory, and patient symptoms. While this method is used to determine the likelihood of hollow visceral injury, it does not quantify injury severity and therefore does not provide guidance for intra-operative surgical decision-making. BIPS was originally reported to have a sensitivity and specificity for blunt hollow visceral and mesenteric injury of 86% and 76% respectively, with a positive predictive value (PPV) of 71% and a negative predictive value (NPV) of 89% [8–10]. The BIPS clinical component (abdominal pain) is non-specific and in this cohort only 20% of patients demonstrated CT findings suggestive of mesenteric or hollow visceral injury. This is in line with reported experiences that incorporate computed tomography findings in the diagnosis of this condition [12–15].

A potential approach to identifying patients earlier with these types of injuries includes the use of laparoscopy to assess blunt abdominal traumatic injuries [11]. A validated MIS may well be useful in this setting. While this study was not powered to evaluate the capability of laparoscopy to diagnose and ascertain the extent of mesenteric or hollow viscera injury, the generation of the MIS grading system provides an opportunity to expand the use of laparoscopy in stable patients with blunt abdominal trauma. The present study suggests that the proposed MIS correlates well with patient outcomes, specifically bowel resection. This is an important finding as diagnostic laparoscopy is expanded for other traumatic indications, defining operative criteria for mesenteric injuries are critically needed. Future work assessing the utility of these criteria in patients with blunt abdominal trauma should focus on intra-abdominal injury diagnosis utilizing laparoscopy.

The present study provided an initial audit of the MIS and comparison with the abdominal AIS and BIPS scores. The correlation of the MIS with several patient clinical outcomes and management approaches supports the early validity of the proposed MIS. The MIS is based on the extent of injury, similar to the organ injury scale which is a well-validated method to assess trauma injury severity. The data confirmed that an increasing MIS correlated with several operative and post-operative outcomes. Moreover, the MIS appears to discriminate need for bowel resection, reflecting the important role that the mesentery has in maintaining bowel viability after injury. The MIS appeared to

Table 5
Comparison of patient characteristics and outcomes after stratification by the mesenteric injury score (MIS).

Mesenteric Injury Score							
	Grade I N = 3	Grade II N = 10	Grade III N = 10	Grade IV N = 5	Grade V N = 23	ρ	P value
Age (years)	34 [28–61]	43 [32–56]	30 [25–43]	30 [27–45]	32 [24–44]	−.26	.06
Male sex (n, %)	2, 67	9, 90	10, 100	3, 60	20, 87	0.002	.98
Injury Severity Score	13 [9–16]	13 [10–15]	17 [16–18]	17 [9–25]	21 [16–27]	.38	.004
Abdominal AIS	3 [2–4]	3 [2,3]	3 [2–4]	3 [3,4]	4 [3–5]	.47	.0004
BIPS	1 [1,1]	0 [0–1]	1 [1,1]	1 [1,2]	1 [1,2]	.02	.84
Systolic blood pressure (mmHg)	102 [76–129]	121 [114–128]	120 [95–121]	128 [121–135]	116 [104–125]	.01	.93
Heart rate (beats per minute)	130 [126–133]	114 [86–130]	106 [99–114]	105 [92–119]	104 [90–135]	.11	.47
Lactate (mmol/L)	2.2 [2.2–2.9]	3.4 [3.3–3.5]	4.3 [1.8–5.5]	2 [1.7–2.2]	2.1 [1.4–2.9]	.20	.21
Hemoglobin (mg/dL)	11 [11–12.1]	7.9 [6–11.1]	11.6 [10–13.2]	12.1 [11.8–12.5]	11.9 [10–14]	.01	.57
Duration of Stay	6 [2–10]	11 [5–16]	14 [3–20]	15 [7–23]	23 [7–35]	.39	.007
Bowel resection (%)	0, 0	1, 10	3, 30	3, 60	18, 78	.60	<0.0001
Damage control laparotomy (%)	2, 67	1, 10	4, 40	1, 20	19, 83	.48	.0003
Relaparotomy (%)	1, 33	1, 10	6, 60	3, 60	19, 83	.51	.0001
Mortality (%)	0,0	1, 10	1, 10	1, 20	7, 30	.31	.06

Spearman's rho (ρ) was utilized; values were reported using medians with interquartile range.

Table 6
Comparison of the mesenteric injury score (MIS), abdominal abbreviated injury score (AIS), and the blunt injury prediction score (BIPS) with clinical outcomes.

	MIS		Abdominal AIS		BIPS	
	ρ	P value	ρ	P value	ρ	P value
Mortality	.26	.07	.41	.003	.22	.12
Relaparotomy	.51	.0001	.59	.0001	.03	.85
Bowel resection	.60	.0001	.39	.005	.19	.19
Damage Control Laparotomy	.48	.0003	.54	.0001	.01	.93
Duration of Stay	.39	.007	.20	.17	.09	.53

Spearman's rho (ρ) was utilized.

outperform the BIPS but was comparable to abdominal AIS. Future analysis comparing cross-sectional imaging or laparoscopic findings with MIS in a larger cohort is needed to demonstrate that preoperative injury severity may correlate with surgical approach. BIPS on the other hand appears to be a good screening tool but is poor at predicting grade or severity of mesenteric injury. The two scores need to be used in conjunction.

There are several limitations mostly due to the retrospective nature of the data. The retrospective assignment of scores is difficult and further assessment of this grading system requires prospective validation. Without a dedicated protocol for the radiologists to review and specifically comment on the bowel mesentery, the CT findings suggestive of these injuries may well be over looked. It is possible that operative notes did not fully estimate patient disease severity and the association of disease severity with clinical outcomes may have been underappreciated. In addition, low grade mesenteric injuries may not have been commented on in the operative notes or even operated upon. We utilized different patient populations which represent wholly different healthcare access, management, and post-operative care. Deriving a classification framework from only 51 subjects is difficult and this report will need to be substantiated by a larger prospective project using data from multiple international trauma units with a much larger sample. Despite these limitations it would appear that increasing disease severity as described by our proposed system did correlate with increased complexity of operative management and increased morbidity.

Conclusion

We have developed a MIS and provided an initial validation using a small cohort of patients. The MIS, which is based on the extent of injury, is similar to the organ injury scale and abbreviated injury scales, which are well validated methods to assess trauma organ injury severity. The study demonstrates that increasing MIS is associated with both operative and post-operative outcomes. Moreover, MIS was positively correlated with the need for bowel resection and subsequent laparotomy to assess bowel viability. Future analysis comparing cross-sectional imaging in a larger cohort is needed to demonstrate preoperative injury severity and correlate it with surgical approach and patient outcomes.

Conflicts of interest

The authors have no conflicts of interest for the generation of this work. No external or internal funding was utilized to generate this work.

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