Validation of the American Association for the Surgery of Trauma grading system for acute mesenteric ischemia—More than anatomic severity is needed to determine risk of mortality

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BACKGROUND: Acute mesenteric ischemia (AMI) is a highly morbid disease with a diverse etiology. The American Association for the Surgery of Trauma (AAST) proposed disease-specific grading scales intended to quantify severity based upon clinical, imaging, operative, and pathology findings. This grading scale has not been yet been validated for AMI. The goal of this study was to evaluate the correlation between the grading scale and complication severity.

METHODS: Patients for this single center retrospective chart review were identified using diagnosis codes for AMI (ICD10-K55.0, ICD9-557.0). Inpatients >17 years old from the years 2008 to 2015 were included. The AAST grades (1–5) were assigned after review of clinical, imaging (computed tomography), operative and pathology findings. Two raters applied the scales independently after dialog with consensus on a learning set of cases. Mortality and Clavien-Dindo complication severity were recorded.

RESULTS: A total of 221 patients were analyzed. Overall grade was only weakly correlated with Clavien-Dindo complication severity (rho = 0.27) and mortality (rho = 0.21). Computed tomography, pathology, and clinical grades did not correlate with mortality or outcome severity. There was poor interrater agreement between overall grade. A mortality prediction model of operative grade, use of vasopressors, preoperative serum creatinine and lactate levels showed excellent discrimination (c-index = 0.93).

CONCLUSION: In contrast to early application of other AAST disease severity scales, the AMI grading scale as published is not well correlated with outcome severity. The AAST operative grade, in conjunction with vasopressor use, creatinine, and lactate were strong predictors of mortality. (*J Trauma Acute Care Surg.* 2020;88: 671–676. Copyright © 2020 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic study, III.

KEY WORDS: Severity; scoring; emergency general surgery; acute mesenteric ischemia; American Association for the Surgery of Trauma.

Acute mesenteric ischemia (AMI) is a life-threatening condition that requires emergent surgical intervention. Injury to the bowel begins with ischemic damage to the mucosal layer and progresses to the serosa. The incidence of AMI is increasing, and mortality is reported at approximately 50% to 80%.[1,2] The risk of fatality increases as the diagnosis is delayed,[1–3] and the mortality of untreated mesenteric ischemia approaches 100%.[2] Causes of AMI include arterial embolism in 40% to 50% of cases,[1–3] arterial thrombus in 15% to 25%,[1–3] nonocclusive mesenteric ischemia in 10% to 20%,[2,3] and venous thrombus in 5% to 15%.[1–3] Clinical presentation is often vague diffuse abdominal pain and there is no pathognomonic screening test.[1,2] Some serologic markers have been found to be sensitive but none are specific enough to be used diagnostically.[4]

Acute mesenteric ischemia is considered an emergency general surgery (EGS) condition by the American Association for the Surgery of Trauma (AAST).[5] The EGS conditions impose a substantial and rising public health burden but have historically lacked a uniform, validated grading scale.[5,6] To improve disease severity assessment of EGS conditions, the AAST published 16 disease-specific grading scales in the format used for the Organ Injury Scale for trauma related diagnoses.[7] The authors' aim was to create a reliable scoring system that would aid in risk stratification and allow for comparison between outcomes, resource utilization, and quality improvement efforts.

The AAST grading has proven valuable in numerous clinical EGS diagnoses. Grades for acute colonic diverticulitis are independently associated with clinical outcomes and resource use.[8,9] Increasing AAST appendicitis grade correlates with patient outcomes including increased risk and severity of complications,[10,11] operative duration, and cost.[12] Discrimination of disease severity using the AAST grading system outperforms the Tokyo Guidelines for key clinical outcomes in acute cholecystitis.[13] The AAST grades for acute small bowel obstruction can be assigned with ease at any surgical facility using operative or imaging findings and has predictive validity for important clinical outcomes.[14] The AAST EGS grade for skin and soft tissue infection corresponds with outcomes.[15] In acute pancreatitis, the AAST EGS grade positively correlates with longer hospital and ICU stays and increased rates of readmission.[16]

The disease-specific grading scale for AMI has not yet been validated. Our hypothesis is that the AAST AMI grading scale will correlate well with outcomes as measured by Clavien-Dindo (CD) complication severity classification, hospital length of stay (LOS), direct hospital costs, and in-hospital mortality.

METHODS

Patients for this single-center retrospective chart review were identified using International Classification of Disease (ICD) codes for AMI (ICD10-K55.0, ICD9–557.0). These ICD codes apply to all acute or unspecified vascular insufficiency of the intestine, including ischemic colitis. In accordance with the EGS disease definitions set by the AAST Committee on Severity Assessment and Patient Outcomes, all etiologies of AMI are included.[5] Inpatients older than 17 years admitted between the years 2008 to 2015 were included; patients were excluded when they were treated in an outpatient setting only or when the diagnosis of AMI did not apply. The AAST grades (1–5) were assigned after review of clinical, computed tomography (CT) imaging, operative, and pathology findings. After discussing a set of learning cases, two raters applied the scales independently to 18 cases to assess interrater reliability. In categories where clinical grade descriptions were identical (4 and 5), grade was maximized (grade = 5). In the AAST system, a grade 2 lesion on CT imaging is described as “edema/mesenteric vessel occlusion.” For the purposes of this study, CT imaging grade 2 was interpreted as having either edema or mesenteric vessel occlusion. When documentation was unavailable, that subcategory was

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graded as n/a. In the categories of clinical examination, CT imaging, and pathology, if findings were normal, a grade of 0 was given.

The primary outcomes recorded were hospital LOS, Clavien-Dindo complication severity and total direct hospital costs. Clavien-Dindo grade provides a reliable and validated means to classify complication severity based on the intervention used to treat the complication.[17] Scores range from level 0: no complications to level 5: inpatient mortality. We calculated the CD score by grading each postoperative complication individually and using the overall highest grade assigned. Direct hospital costs were obtained from the hospital cost-accounting system (EPSi; Allscripts Healthcare, LLC, Chicago, IL). Given the lethality of AMI in this cohort, a secondary analysis was conducted focusing on in-hospital mortality. In-hospital mortality was defined as death before discharge from the primary encounter.

Patient risk factors recorded included age, Charlson Comorbidity Index (CCI), the use of vasopressors, and selected laboratory values (hemoglobin, platelets, lactate level, creatinine level) closest to admission. Vascular intervention was recorded and defined as mesenteric arterial bypass, stenting or thrombectomy/embolectomy. Pharmacologic venous or arterial thrombolysis was not included as vascular interventions.

Values are reported as mean (SD) if normally distributed and median (25th–75th, interquartile range) if not normally distributed. Relationships between the AAST AMI scale, subscales, patient risk factors and outcomes were assessed using Spearman's rho correlations. Significance levels were set at $p < 0.05$. Interrater agreement was assessed using the kappa statistic with the following assessment of results: 0 to 0.20, poor; 0.21 to 0.40, fair; 0.41 to 60, moderate; 0.61 to 0.80, good; and 0.80 or greater, very good.[18] Univariate analyses of the area under receiver operating characteristic curves (AUCs) of the individual scales were performed with the following assessment of results: AUC < 0.50, no discrimination of the outcome; 0.51 to 0.70, weak; 0.71 to 0.80, acceptable; and 0.80 to 0.90, excellent.[19] A backward multivariable logistic regression ($p > 0.10$ for exit, <0.05 for reentry) of the scales and patient risk factors relative to inpatient mortality was performed. Missing laboratory values were imputed with the mean of available values for the multivariable regression. The AUC of the resulting multivariable model estimates relative to mortality was compared with those of the individual scales. Statistical analyses were performed using SPSS® version 25 (IBM, Armonk, NY).

RESULTS

A total of 221 cases were included from December 2007 to September 2015. The mean patient age was 61.9 (13.9) years. Of the 221 patients, 71 (32.1%) used vasopressors and 51 (23.1%) had vascular surgery. The mean of several recorded laboratory values fell outside of the reference ranges, including hemoglobin (12.5 [2.6] g/dL), creatinine (1.47 [1.39] mg/dL), and serum lactate (3.04 [2.88] mmol/L) (Table 1).

The mean maximum grade of the four subcomponents was 3.7 (1.1), and the most commonly assigned maximum grade was 3. The clinical grade (3.5, SD = 1.3) was often higher than the imaging grade (2.3, SD = 1.1), operative grade (2.9, SD = 1.1), and pathology grade (2.8, SD = 0.9). The most common clinical, operative, and pathology grade assigned was 3, while the most common imaging grade assigned was 2 (Table 2).

TABLE 1. Patient Characteristics

Variables	n, % or Mean (SD) or Median [IQR]
No. patients	221
Age, y	61.9 (13.9)
CCI	
≤0	55, 24.9%
1	42, 19.0%
2–3	59, 26.7%
4–5	31, 14.0%
≥6	34, 15.4%
Use of vasopressors	71, 32.1%
Hemoglobin	12.5 (2.6)
Platelets	251 (129)
Creatinine	1.47 (1.39)
Lactate	3.04 (2.88)
Had vascular surgery	51, 23.1%
Hospital LOS, median d	9 [5–18]
Total direct hospital costs, $000	17.5 [8.2–37.6]

IQR, interquartile range.

Eighteen cases were graded independently by a second reviewer to assess reproducibility of the grading scales. The concordance between reviewers was poor for the clinical grade (K = 0.09) and only fair for the imaging (K = 0.27) and pathology grades (K = 0.22). The operative grade had very good concordance between reviewers (K = 0.81). The concordance for overall grade was fair (K = 0.30).

All grade subcategories showed a significant positive correlation with maximum grade. Maximum grade most closely correlated with the clinical grade (rho = 0.84, $p < 0.001$) and poorly correlated with imaging (0.32, $p < 0.001$), operative (0.45, $p < 0.001$), and pathology grades (0.23, $p < 0.01$). The two individual subcategories with the most closely correlated grades were operative and pathology (0.50, $p < 0.001$). The individual criteria with the most poorly correlated grades were clinical and imaging (0.17, $p < 0.05$) and clinical and pathology (0.16, $p > 0.05$) (Table 3).

Clavien-Dindo complication grade showed a bimodal distribution. The most commonly assigned maximum CD grade was 0 (no complications), followed by 5 (in-hospital mortality) (Fig. 1). The mortality rate for the entire cohort was 25%. The AAST clinical grade did not correlate with CD grade (rho = 0.11, $p = 0.121$). Imaging, pathology and maximum grades correlated modestly with CD grade (rho = 0.25, 0.22, and 0.27, respectively, Table 4). Operative grade correlated best with CD (rho = 0.41). Given the bimodal distribution of the CD score, the prevalence of death in this patient population, and the modest performance of the AAST grade relative to the CD score, an additional analysis focusing on prediction of mortality was performed.

Predictors of Mortality

The clinical and imaging grades were not significant predictors of death (AUCs, 0.51; 95% confidence interval [95% CI], 0.41–0.62 and 0.57; 95% CI, 0.46–0.67, respectively),

TABLE 2. Grading Frequencies

Grade	Clinical Grade	CT Imaging Grade	Operative Grade	Pathology Grade	Maximum Grade
0	1	10	0	4	0
1	18	30	33	9	2
2	6	74	14	13	18
3	105	51	103	105	110
4	0	15	12	6	13
5	71	5	20	4	78
n/a	20	36	39	80	0
Mean (SD)	3.5 (1.3)	2.3 (1.1)	2.9 (1.1)	2.8 (0.9)	3.7 (1.1)

while the pathology, total and operative grades were weak to acceptable predictors[19] (AUCs: 0.61 [0.51–0.72], 0.63 [95% CI 0.54–0.71], and 0.75 [0.66–0.83] respectively). Backwards regression of all grades and patient factors demonstrated creatinine, use of vasopressors, operative grade (especially grade 5) and lactate as independent predictors of death. Age and CCI were not independent predictors of death. This final model showed outstanding discrimination of mortality (AUC, 0.93; 95% CI, 0.89–0.96; Table 5), significantly better than the AAST operative grade alone (AUC, 0.75; 95% CI, 0.66–0.83; $p < 0.05$ for difference) (Table 5).

DISCUSSION

The AAST EGS grading scales were written to stratify and quantify the severity of these EGS conditions based on anatomic progression. A validated and easily reproducible grading scale would allow for registry data collection as well as the facilitation of clinical care, outcomes predictions, teaching, and quality improvement across all patients with a given diagnosis. When applied clinically, a grading scale can also allow providers to quickly and easily communicate information about severity and disease progression. Many of the AAST EGS grading scales have achieved these goals, but unlike these previously validated scales AAST overall grade in AMI did not correlate well with mortality, complications, and LOS.

These patients showed an interesting bimodal distribution of complication severity. Death was the most common maximum CD score, and overall mortality for AMI is high.[1,2] The distribution of CD scores shows that most patients either experience no complications or successive complications progressing to death. These findings directed us to consider mortality as the primary outcome. Patients with AMI die as the result of a wide variety of complications that result in sepsis and multi organ failure.

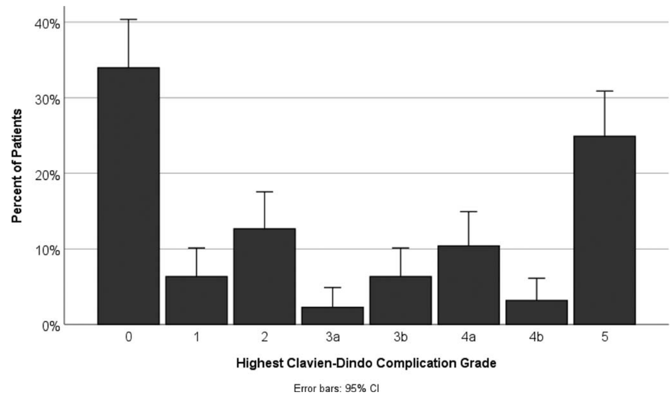

Figure 1. Distribution of maximum CD complication grade.

Hernandez et al. demonstrated that anastomotic complications and use of vasopressors were associated with higher mortality in a population including all EGS conditions requiring a bowel resection. In that study, anastomosis-specific complications were not associated with higher AAST grade.[20] This evidence supports our findings that overall AAST grade may not be an accurate assessment of a patient's likelihood of surviving the condition.

We then examined alternative criteria as predictors of mortality. Previously, Murphy et al.[21] identified vascular surgery as a predictor of increased survival in patients diagnosed with AMI who underwent a laparotomy. Our data did not show any association between vascular surgery and risk of death. Our study examined patients treated both operatively and non-operatively, including patients with reversible vascular insufficiency that were treated with medical thrombolytics and/or vascular surgery. It is most likely the reversibility of the arterial insufficiency that determined survivability, rather than the method of revascularization. The relationship between pathophysiology (arterial thrombus, venous thrombus, arterial emboli, nonocclusive mesenteric ischemia) and mortality should be further explored.

Despite the lack of correlation between overall AAST grade and mortality, AAST operative grade for AMI may help identify patients at high risk of mortality. Operative grade was determined to correlate with mortality. The operative grade also showed higher reproducibility than the overall grade, based on the results of the interrater agreement. The remaining AAST subcategory grades based on clinical, imaging and pathology criteria did not show this correlation with mortality.

The correlation between AAST operative grade and mortality can be explained by examining the anatomical and histological basis of the grading criteria. Patients with an AAST operative grade less than 3 lack full thickness necrosis and have a

TABLE 3. Correlations Between Grades (the Number of Pairs Varies Between 165 and 201)

Grade	Clinical Grade	CT Imaging Grade	Operative Grade	Pathology Grade	Maximum Grade
Clinical grade	1.00	0.17*	0.22**	0.16	0.84†
CT imaging grade	0.17*	1.00	0.35***	0.20*	0.32†
Operative grade	0.22**	0.35†	1.00	0.50†	0.45†
Pathology grade	0.16	0.20*	0.50†	1.00	0.23**
Maximum grade	0.84†	0.32†	0.45†	0.23**	1.00

* Spearman's rank correlation $p < 0.05$; ** $p < 0.01$; † $p < 0.001$.

TABLE 4. Correlations With Outcomes

	CD Complication Grade	LOS	Total Direct Costs
AAST grades			
Clinical	0.11	−0.04	0.04
CT imaging	*0.25	**0.16	*0.20
Operative	†0.41	−0.01	0.12
Pathology	*0.22	−0.01	0.15
AAST Overall Maximum Grade	†0.27	−0.01	**0.14
Patient risk factors			
Age	**0.19	0.07	0.13
Use of vasopressors	†0.65	*0.22	†0.45
Vascular intervention	*0.21	†0.25	†0.39
Lactate mmol/L (closest to admission)	†0.41	0.02	*0.21
Hemoglobin g/dL (closest to admission)	−0.11	0.01	−0.04
Creatinine mg/dL	†0.22	−0.03	0.06

* $p < 0.05$; ** $p < 0.01$; † $p < 0.001$.

much lower risk of mortality. Severe segmental ischemia (AAST operative grade 4—tissue necrosis progressed to perforation) is rare and not as strongly correlated with outcomes as is diffuse ischemia (AAST operative grade 5—panintestinal necrosis). We hypothesize that most patients are either successfully treated or expire prior to perforation. The AAST operative grade 5 is the only subcategory grade 5 that can be assigned in the absence of perforation. The inclusion of diffuse, earlier disease at the upper end of the grading scale contributed to the strong correlation between increasing operative grade and mortality. These results indicate that diffuse disease has a higher mortality than segmental, histologically advanced disease.

There may be an opportunity to improve the AAST AMI operative grade. The AAST operative grade 2 could only be assigned in cases that were diagnosed by either sigmoidoscopy, colonoscopy, or upper endoscopy as opposed to exploratory laparotomy. Intestinal mucosa is not routinely inspected during laparotomy. Very few patients underwent an endoscopy, making it difficult to assign an AAST operative grade 2. Since only a minority of cases allowed for the diagnosis of isolated mucosal injury, fewer conclusions can be drawn about operative grade of 2.

In addition to the AAST operative grade, we identified several other clinical parameters that correlated well with mortality. These included lactate level, creatinine level, and the use of vasopressors. While these clinical correlates are not specific or sensitive to the diagnosis of AMI,[1,2] they are useful adjuncts when determining disease severity. A mortality prediction model using these values was constructed to determine likelihood of death and was found to have excellent discrimination, particularly at higher operative grades. A mainstay of AMI treatment is planned relaparotomy,[1] therefore, an operative grade assigned during initial laparotomy can be useful in decision making regarding reexploration, anastomosis versus stoma construction, additional resection, and sequential abdominal closure. The AAST operative grade, in conjunction with vasopressor use, creatinine, and lactate could help determine which patients will survive relaparotomy or multiple bowel resections. This is the first attempt to combine anatomic severity with serologic markers of disease severity. The application of this mortality prediction model could inform decision making and discussion with surrogate decision makers, and potentially reduce the incidence of costly and futile operations. These cases are expected to be complex and very resource intensive. If such resource expenditure is unlikely to result in a favorable outcome or a treatment course consistent with the patient's wishes, early decision making may favorably impact the health care system.

LIMITATIONS

Acute mesenteric ischemia describes a complex set of diseases that vary significantly in both etiology and indicated interventions. In this study, all cases of AMI are included regardless of operative and non-operative management. The AAST grading scale is meant to apply to all cases of AMI, and therefore this study was designed to include all cases. While grouping these cases together allowed for a stronger analysis of the AAST grading system, it did reduce our ability to compare the effect of different types of interventions on mortality. There is emerging evidence that damage-control procedures and early revascularization can have a positive impact on mortality, but we are unable to comment on the effect these procedures in this cohort.

Although CCI has been shown to correlate with mortality in acutely hospitalized elderly patients,[22] and in the context of EGS,[23] CCI was not an independent predictor of mortality in our AMI patient population. This is likely due to the severity

TABLE 5. Independent Predictors of Hospital Death Based on Backwards Regression (p for Exit >0.10, for Reentry <0.05)

	p	Odds Ratio	95% CI	95% CI
Creatinine mg/dL (per unit change from the mean)	0.069	1.29	0.98	1.71
Use of Vasopressors	<0.001	18.05	6.86	47.46
Operative grade vs. 1				
Grade 2	0.296	0.29	0.03	2.97
Grade 3	0.943	0.96	0.34	2.76
Grade 4	0.834	1.22	0.19	7.76
Grade 5	0.002	48.13	4.34	533.83
Lactate mmol/L (per unit change from the mean)	0.004	1.36	1.10	1.66

N = 221 patients; 55 events; c-index was 0.93 (95% CI, 0.89–0.96).

of the condition; most patients die as a result of disease progression and not compounding comorbid conditions. Due to difficulties obtaining histories from very ill, elderly patients resulting in poor documentation, there is inadequate data to support this assumption. This hindered our ability to accurately assess and control for comorbidities when examining the mortality of this condition. There is a need to identify criteria that can be reliably obtained and can accurately assess disease severity to predict the risk of death in AMI.

In addition, deciding whether a patient has abdominal pain out of proportion to examination is highly subjective. It was difficult to determine when tenderness had progressed to peritonitis, resulting in some discrepancies between the graders. The clinical grade had the highest average grade, often making it the determinant of overall grade. This difficulty reproducing the clinical grade contributed to the low interrater reliability in both the clinical subcategory grade and in the overall grade. Similarly, the remaining subcategory criteria included language that was not routinely found in the medical record. Many cases fell anatomically between categories. The nuances of the AAST subcategory grades and opportunities to improve are the topic of future research. To mitigate the subjectivity of the grading scale when comparing with outcomes, the both graders reached a consensus on a learning set of cases. Afterward, 18 cases were completed independently and used for analysis, preventing the primary grader from being influenced by the results of the secondary grader. By collecting data in this way, the risk of inconsistent grading was minimized.

CONCLUSION

As it is currently written, the AAST grading scale for AMI is not well correlated with outcomes. Our hypothesis was not supported; therefore, we created an alternative predictor of death in AMI. The AAST operative grade, in conjunction with lactate level, creatinine level and use of vasopressors is a useful predictor of mortality.

AUTHORSHIP

M.S. conducted a literature search; contributed to study design; contributed to data collection, analysis and interpretation; contributed to the writing and critical revision of the article. D.D. contributed to the study design; conceived, designed and performed the data analysis; contributed to data interpretation, writing and critical revision of the article. P.W. contributed to the study design and data collection. A.B. created the study design; contributed to data interpretation; and contributed to the writing and critical revision of the article.

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DISCLOSURES

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