Acute appendicitis: A disease severity score for the acute care surgeon

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BACKGROUND: Analogous to organ injury scales developed for trauma, a scoring system is needed for acute care surgery. The purpose of this study was to develop a disease severity score (DSS) for acute appendicitis, the most common surgical emergency.

METHODS: A panel of acute care surgery experts reviewed the literature and developed a DSS for acute appendicitis as follows: grade 1, inflamed; Grade 2, gangrenous; Grade 3, perforated with localized free fluid; Grade 4, perforated with a regional abscess; and Grade 5, perforated with diffuse peritonitis. We applied the DSS to 1,000 consecutive patients undergoing appendectomy from 1999 to 2009 and examined its association with outcomes (mortality, length of hospital stay, incidence of in-hospital, and postdischarge complications). Of the 1,000 patients, 82 were excluded owing to negative or interval appendectomy or advanced end-stage renal disease.

RESULTS: Among 918 eligible patients, the DSS distribution was Grade 1 at 62.4%, Grade 2 at 13.0%, Grade 3 at 18.7%, Grade 4 at 4.4%, and Grade 5 at 1.5%. Statistical analyses indicated a stepwise risk increase in adverse outcomes with higher DSS grades (c statistics ≥ 0.75 for all outcomes). Covariates (age, sex, and type of surgical access) did not add to the predictive power of DSS.

CONCLUSION: Based on this single-institution study, the proposed appendicitis DSS seems to be a useful tool. This DSS can inform future, national efforts, which can build on the knowledge provided by the present investigation. This DSS may be useful for comparing therapeutic modalities, planning resource use, improving programs, and adjusting reimbursement (*J Trauma Acute Care Surg*. 2013;74: 32–36. Copyright © 2013 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Epidemiologic study, level III.

KEY WORDS: Appendicitis; appendectomy; postoperative complications; disease severity scoring; hospital costs.

Grading systems for the evaluation and description of injury was introduced in 1971 with the Abbreviated Injury Scale (AIS) score.[1] In 1987, the American Association for the Surgery of Trauma expanded these descriptors to create a comprehensive organ injury scale (OIS).[1,2] The development of the OIS in trauma surgery has proven to be useful in providing a common clinical nomenclature describing injury severity. This scoring system facilitates communication between clinicians and can be used to compare patient outcomes across institutions, over time, and after different treatments. It can also become a useful resource to estimate health care resource needs and do inform quality improvement efforts. Currently, OIS scales are in place for most major organs.[3–7] In brief, organ injuries are graded I to VI with Grade I representing the least severe injury and Grade VI representing a lethal injury. The OIS grading systems have been particularly useful in defining optimal care of specific injuries. For example, the OIS (or similar scales) for hepatic, splenic, and renal trauma have been used in studies comparing outcomes of operative and nonoperative management.[3–5,7] OISs have also been examined for their predictive power relating to morbidity and mortality. Using the National Trauma Data Bank, the OIS grading systems for the liver, kidney and spleen, have been validated, documenting that these scales of increasing severity were predictive of mortality, the need for operative intervention, increasing intensive care unit admission rates, increased length of stay (LOS), and increased hospital costs.[6,7]

As OIS grading systems have proven useful, a logical next step is to develop a similar grading system for acute illnesses of nontraumatic etiology in the relatively new area of acute care surgery (ACS). This creates a common nomenclature that can aid in clinical communication, patient management, outcome assessment, quality improvement and novel therapy development.[1] Thus, we developed and tested a disease severity score (DSS) for surgically treated acute appendicitis, the most common emergent operation performed in both adults and children. We hope that our proposed DSS can inform and assist national efforts to standardize disease descriptive systems across the country.

Current clinical scoring systems for appendicitis focus on cost-effective diagnosis (e.g., decreasing the need for computed tomography) and the identification of patients at risk for the disease.[8–10] However, to our knowledge there is no descriptive grading system for the severity of acute appendicitis once the diagnosis has been made. Thus, the purpose of this study was to propose a DSS for acute appendicitis and determine whether an association exists between the score and the occurrence of adverse outcomes such as postoperative complications and lengthy hospital stay. Our proposed DSS can inform future national efforts to devise such scoring systems that can then be revised and validated at the national level.

PATIENTS AND METHODS

Development of the DSS

A panel of six attending surgeons, led by one of the authors (E.E.M.), reviewed the literature on appendicitis but could find no previous description of a DSS. Existing scores, such as the Alavarado Score and the Pediatric Appendicitis Score[8–10] were designed to assist in the clinical determination of appendicitis. Consequently, we used a modified Delphi method to obtain a consensus driven 5-grade DSS system as follows: Grade 0, normal appearance; Grade 1, inflamed without perforation; Grade 2, gangrenous, without perforation; Grade 3, perforated with localized fluid (defined as fluid confined within a 10-cm radius around the appendix and directly contiguous to the appendix perforation); Grade 4, perforated with a regional abscess (defined as a collection of purulent material greater than 5 cm directly contiguous to the appendix perforation); and Grade 5, perforated with diffuse peritonitis.

A standardized form for medical record review was designed, and three medical students (MSs), led by the first author (G.C.G.), were trained to define the DSS based on three separate sources: (1) description dictated by the attending surgeon in the operative report, (2) description in brief operative note, and (3) final pathology report. The three MSs reviewed all medical records independently and defined a final grade based on the three sources. When discrepancies arose between the

MSs, the lead student (G.C.G.) took the reports to one of the authors (E.E.M.), who, blinded to the outcome and based solely on the three previously mentioned sources, adjudicated the discrepancy and defined a final grade. We report the proportion of discrepancies observed between the three MS reviewers as a measure of DSS interrater reliability.

We used the same process to define and collect data on complications associated with surgically treated acute appendicitis based on the National Surgery Quality Improvement Program criteria (available at http://nsqip.healthsoftonline.com/hsi/). Those included (1) wound infection, (2) abscess, (3) postdischarge small bowel obstruction, (4) hernia, (5) length of hospital stay of greater than 4 days, or (6) death.

Statistical Analyses

Normally distributed variables were reported as mean and SEM, while nonnormally distributed variables were reported as median and interquartile range. All tests were two-tailed with significance established at <0.05. To evaluate the proposed DSS, we report the morbidity rates (for all complications defined previously individually and also combined into a variable named adverse outcomes, defined as the occurrence of any of the following events: (1) wound infection, (2) abscess, (3) postdischarge small bowel obstruction, (4) hernia, (5) length of hospital stay of greater than 1 day, or (6) death for each of the DSS grades. The associations of DSS grades with complication and rates of adverse outcomes were tested using initially a χ^2 test for trend, followed by a logistic regression model to derive odds ratios and 95% confidence intervals. The reference group for the logistics regression models was the group of patients classified with DSS Grade I. Goodness of fit of logistic regression models was evaluated using the c statistic (area under the receiver operating characteristic curve).

The association of LOS, which is commonly right skewed and not normally distributed, with the DSS was initially assessed using the Kruskal-Wallis method (the nonparametric equivalent of analysis of variance). Subsequently, LOS was log transformed and its association with the DSS using a linear mixed model, which has been shown to produce reasonable estimators.[11]

We also examine the influence of important, predefined, covariates to include age, sex, type of surgical access (laparoscopy vs. open laparotomy) by including these variables in the previously described models. Finally, we report the proportion of discrepancies in assigning the DSS as a measure of interrater reliability.

RESULTS

Of the 1,000 consecutive patients from 1999 to 2009, 918 patients met inclusion criteria. The distribution of the DSS and the characteristics of patients classified in each grade are shown in Table 1. Grades distribution did not vary by year of operation within the study period (χ^2 for trend, $p = 0.34$), sex, and open laparotomy versus laparoscopic access (Table 1). Incidentally, of the 209 laparoscopic procedures, 18 (9%) required conversion to open laparotomy; of these, half were Grades 1 or 2, 8 (44%) were Grade 3, and 1 (6%) was Grade 4.

Higher DSS grades were significantly associated with higher rates of all documented complications and adverse outcomes (Table 1). Table 2 depicts the odds ratios of developing complications for each DSS grade. Higher DSS grades were significantly associated with higher odds ratios of developing complications for most of the variables, with two exceptions as follows: (1) small bowel obstruction, for which only grade 5 patients had a significantly higher risk than those classified as Grade 1 and (2) intra-abdominal abscess, for

TABLE 1. Characteristics, Complications, and Outcomes of 915 Surgically Treated Acute Appendicitis Cases Stratified by the DSS

	DSS Grade					*p*
	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	
n (%)	573 (62.4)	119 (13.0)	172 (18.7)	40 (4.4)	14 (1.5)	
Male sex, n (%)	216 (37.7)	33 (27.7)	59 (34.3)	12 (30)	4 (28.6)	0.1256*
Age, mean ± SEM, y	26.1 ± 0.5	26.1 ± 1.2	28.0 ± 1.4	29.4 ± 2.6	36.1 ± 5.5	0.0274†
Open vs. laparoscopy, n (%)‡	441 (77.0)	91 (76.5)	134 (78.0)	31 (77.0)	12 (85.7)	0.6156*
Complications, n (%)						
Intra-abdominal abscess	8 (1.4)	2 (1.7)	21 (12.2)	9 (22.5)	5 (35.7)	<0.0001*
Surgical site infection	21 (3.7)	20 (16.8)	55 (32.0)	21 (52.5)	6 (42.9)	<0.0001*
Postdischarge small bowel obstruction	3 (0.1)	2 (1.7)	3 (1.7)	3 (7.5)	2 (14.3)	<0.0001*
LOS > 4 d	12 (2.1)	12 (10.1)	76 (44.2)	32 (80)	10 (71.4)	<0.0001*
Outcomes						
Hospital days, median (IQR)*	1 (1–1)	2 (1–3)	4 (3–6)	6 (5–9)	9 (4–17)	<0.0001§
Adverse outcomes, n (%)‖	36 (6.3)	28 (23.5)	96 (55.8)	36 (90.0)	12 (86)	<0.0001*
Death, n (%)	0	0	0	0	1 (7)	0.001*

*χ^2 for trend.
†Analysis of variance.
‡Initial surgical procedure, see text for percentage of converts from laparoscopic to open.
§Kruskal-Wallis test.
‖Any of the following: (1) wound infection, (2) abscess, (3) postdischarge small bowel obstruction, (4) hernia, (5) hospital LOS of greater than 4 days, or (6) death.

TABLE 2. Odds Ratios of Developing Complications by DSS Grade

Adverse Outcomes*	Odds Ratios	95% Confidence Limits		*p*	c statistic
DSS Grade 2 vs. 1	4.59	2.671	7.888	<0.0001	0.84
DSS Grade 3 vs. 1	18.842	11.989	29.613	<0.0001	
DSS Grade 4 vs. 1	134.248	45.285	397.978	<0.0001	
DSS Grade 5 vs. 1	89.497	19.292	415.175	<0.0001	
Surgical site infection					
DSS Grade 2 vs. 1	5.31	2.776	10.158	0.0675	0.8
DSS Grade 3 vs. 1	12.356	7.194	21.222	0.0346	
DSS Grade 4 vs. 1	29.052	13.61	62.014	<0.0001	
DSS Grade 5 vs. 1	19.714	6.275	61.93	0.0483	
Intra-abdominal abscess					
DSS Grade 2 vs. 1	1.207	0.253	5.758	0.0055	0.8
DSS Grade 3 vs. 1	9.822	4.266	22.612	0.1063	
DSS Grade 4 vs. 1	20.504	7.403	56.786	0.0011	
DSS Grade 5 vs. 1	39.236	10.726	143.532	0.0001	
Postdischarge small bowel obstruction					
DSS Grade 2 vs. 1	3.248	0.537	19.653	0.3884	0.75
DSS Grade 3 vs. 1	3.373	0.675	16.865	0.351	
DSS Grade 4 vs. 1	15.406	3.005	78.981	0.0636	
DSS Grade 5 vs. 1	31.667	4.84	207.178	0.0084	
LOS > 4 d					
DSS Grade 2 vs. 1	5.243	2.294	11.981	<0.0001	0.89
DSS Grade 3 vs. 1	37.01	19.395	70.622	<0.0001	
DSS Grade 4 vs. 1	186.992	71.39	489.787	<0.0001	
DSS Grade 5 vs. 1	116.873	32.08	425.787	<0.0001	

*Any of the following: (1) wound infection, (2) abscess, (3) postdischarge small bowel obstruction, (4) hernia, (5) hospital LOS of greater than 4 days, or (6) death.

which we failed to detect a significant increased risk of Grade 3 compared with Grade 1 (but Grades 2, 4, and 5 were significantly associated with increased risk). The goodness of fit of these logistic regression models was mostly excellent with all but one of the c statistic values equal to or greater than 0.80. The exception was the model for small bowel obstruction, which had a c statistic value of 0.75.

Preestablished covariates were added to the logistic regression models (age, sex, open vs. laparoscopic access), but none emerged significant for any of the complications (all $p > 0.115$). The odds ratios associated with the DSS grades for all morbid complications remained essentially unchanged with the addition of these variables.

The linear mixed model testing the association of the DSS grades with the log-transformed LOS variables showed a significant positive relationship between these variables ($p < 0.0001$). Again, the addition of age, sex, and type of surgical access were not significant (all $p > 0.12$) and did not alter the association of LOS and DSS.

Regarding interrater reliability, initial disagreement in DSS assignment was observed in 195 cases (21%), most of these finally classified as Grade 1 (78 of 195, 40%) or Grade 2 (72 of 195, 37%). Grade 5 classification had no disagreement. Differences in classification occurred more often when the pathology report indicated a more severe disease than the operative dictation (121 of 195, 62%).

DISCUSSION

The goal of the present study was to standardize the description of operative treatment of acute appendicitis. We used a standardized process to devise the proposed DSS that can serve as a model for devising DSSs for other ACS conditions and as a building block for national efforts.

A descriptive scoring system must be associated with objective outcomes to provide a useful description of the disease severity that can be used across different institutions for a variety of purposes. Our proposed DSS seems to have achieved this goal. In particular, the cases with Grades 1 through 4 were consistently associated with increasing rates of postoperative complications, adverse outcomes, and lengthier hospital stay. In contrast, Grade 5 was not always associated with higher risk of complications than Grade 4; however, as expected, the number of patients classified as Grade 5 was small; thus, larger databases may be necessary to further refine this grade's definition.

The predictive power of the DSS in predicting postappendectomy complications seems to be very good with c statistics of 0.75 or greater for all models. Interestingly, age, sex and type of surgical access (open vs. laparoscopic access) did not add to the predictive power. This suggests that the DSS is valuable in predicting the level of postoperative management and the amount of time patients will need to recover and may provide valuable, additional information in determining reimbursements for the procedure. Currently, the Center for Medicare and Medicaid Services stratify appendectomy into incidental, indicated with other surgery, and ruptured,[12] as do many European health care systems that place patients into diagnosis-related groups.[13] Although we did not specifically address costs, the data on hospital stay suggest that care would be less expensive for patients having Grade 1 appendicitis compared with those presenting with Grade 5 who required longer stays. Further investigation is required to determine the full amount of resource use and absolute costs of care for patients from presentation to discharge.

This study has some limitations by its retrospective nature as well as the lack of assessing the impact of comorbidities and population selection from a single center. In addition, the reliability of the DSS, specifically regarding the Grades 1 and 2, was not ideal. Clearly, further investigation at multiple centers, coordinated at a national level, with a larger population and the assessment of intrareliability and interreliability rates are needed to validate this appendicitis DSS. We hope, however, that this experience can contribute to future efforts and provide the initial step to the process of developing additional DSSs for the emergent ACS field. These standard descriptions can facilitate clinical research, comparative effectiveness studies, and quality improvement programs as well as inform policies to establish appropriate reimbursement.

AUTHORSHIP

E.E.M. conceived of the study. E.E.M., C.C. Burlew, D.D.B., W.L.B., C.C Bartnett, and J.L.J. designed the study. G.C.G., M.N.B., and D.K.L. collected the data. G.C.G., E.E.M., and A.S. wrote the manuscript, which all authors reviewed and approved.

DISCLOSURE

The authors declare no conflicts of interest.

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