Prospective validation of the Emergency Surgery Score in emergency general surgery: An Eastern Association for the Surgery of Trauma multicenter study

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BACKGROUND: The Emergency Surgery Score (ESS) was recently developed and retrospectively validated as an accurate mortality risk calculator for emergency general surgery. We sought to prospectively validate ESS, specifically in the high-risk nontrauma emergency laparotomy (EL) patient.

METHODS: This is an Eastern Association for the Surgery of Trauma multicenter prospective observational study. Between April 2018 and June 2019, 19 centers enrolled all adults (aged >18 years) undergoing EL. Preoperative, intraoperative, and postoperative variables were prospectively and systematically collected. Emergency Surgery Score was calculated for each patient and validated using c-statistic methodology by correlating it with three postoperative outcomes: (1) 30-day mortality, (2) 30-day complications (e.g., respiratory/renal failure, infection), and (3) postoperative intensive care unit (ICU) admission.

RESULTS: A total of 1,649 patients were included. The mean age was 60.5 years, 50.3% were female, and 71.4% were white. The mean ESS was 6, and the most common indication for EL was hollow viscus perforation. The 30-day mortality and complication rates were 14.8% and 53.3%; 57.0% of patients required ICU admission. Emergency Surgery Score gradually and accurately predicted 30-day mortality; 3.5%, 50.0%, and 85.7% of patients with ESS of 3, 12, and 17 died after surgery, respectively, with a c-statistic of 0.84. Similarly, ESS gradually and accurately predicted complications; 21.0%, 57.1%, and 88.9% of patients with ESS of 1, 6, and 13 developed postoperative complications, with a c-statistic of 0.74. Emergency Surgery Score also accurately predicted which patients required intensive care unit admission (c-statistic, 0.80).

CONCLUSION: This is the first prospective multicenter study to validate ESS as an accurate predictor of outcome in the EL patient. Emergency Surgery Score can prove useful for (1) perioperative patient and family counseling, (2) triaging patients to the intensive care unit, and (3) benchmarking the quality of emergency general surgery care. (*J Trauma Acute Care Surg.* 2020;89: 118–124. Copyright © 2020 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic study, level III.

KEY WORDS: Emergency Surgery Score; postoperative mortality; postoperative complications; emergency surgery; quality benchmarking.

The burden of emergency general surgery (EGS) is considerable and steadily growing.[1,2] Using the Nationwide Inpatient Sample database from 2001 to 2010, Gale et al.[1] reported more than 27 million EGS admissions in the United States alone, accounting for 7% of all hospitalizations. In addition, compared with elective general surgery patients, those who undergo an EGS procedure have significantly higher rates of postoperative morbidity and mortality,[2–4] and often use more resources, such as the intensive care unit (ICU).[5] Predicting the perioperative outcomes of EGS patients is often challenging because of the complex interaction between the disease entity, comorbidities, and the concomitant acute physiologic derangements.

Havens et al.[6] recently reviewed all the risk stratification tools currently in use to predict the outcomes of EGS patients and concluded that the Emergency Surgery Score (ESS) and the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) risk calculator are the most applicable and most appropriate for this patient population.[6] Other studies have questioned the accuracy of the ACS-NSQIP risk calculator in EGS patients,[7–10] as the ACS-NSQIP calculator does not adequately account for the acuity of disease at presentation and it erroneously assumes that different risk factors affect EGS and non-EGS patients in a uniform fashion.[11]

Emergency Surgery Score is a preoperative risk scoring system derived from and for emergency surgery patients that takes into account patient demographics, comorbidities, and acuity of disease upon presentation (Table 1).[12] Emergency Surgery Score has already been retrospectively validated as an accurate tool to predict 30-day postoperative mortality, morbidity, and the need for postoperative critical care in the EGS patient.[12–16]

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TABLE 1. The ESS

Variable	Points
Demographics	
Age >60 y	2
White race	1
Transfer from outside emergency department	1
Transfer from an acute care hospital inpatient facility	1
Comorbidities	
Ascites	1
BMI <20 kg/m^2	1
Disseminated cancer	3
Dyspnea	1
Functional dependence	1
History of COPD	1
Hypertension	1
Steroid use	1
Ventilator requirement within 48 h preoperatively	3
Weight loss >10% in the preceding 6 months	1
Laboratory values	
Albumin <3.0 U/L	1
Alkaline phosphatase >125 U/L	1
Blood urea nitrogen >40 mg/dL	1
Creatinine >1.2 mg/dL	2
International normalized ration >1.5	1
Platelets <150 × 10^3/μL	1
SGOT >40 U/L	1
Sodium >145 mg/dL	1
WBC, ×10^3/μL	
<4.5	1
>15 and ≤25	1
>25	2
Maximum score	29

BMI, body mass index; COPD, chronic obstructive pulmonary disease; SGOT, serum glutamic-oxaloacetic transaminase; WBC, white blood cell.

In this multicenter study, we aimed to prospectively validate ESS and its ability to predict the postoperative risk of 30-day mortality, postoperative complications, and the need for postoperative ICU admission in the high-risk EGS population undergoing emergent laparotomy.

PATIENTS AND METHODS

This is a prospective, observational, multicenter study sponsored by the Eastern Association for the Surgery of Trauma. Study data were entered by each site and uploaded securely using the REDCap electronic data capture tools hosted at the study coordinating center (Vanderbilt University Medical Center, Nashville, TN).[17,18]

Patient Population

Between April 2018 and June 2019, all patients older than 18 years who underwent any emergent laparotomy at the participating institutions were enrolled. These included, but were not limited to, laparotomy for small bowel obstruction, mesenteric ischemia, complicated diverticulitis, and hollow viscus organ perforation. Emergency laparotomy was defined as any laparotomy that was performed as soon as possible following the patient diagnosis or after the onset of related preoperative symptomatology and where unnecessary delay could potentially jeopardize the patient's well-being and outcome.[19] Emergent trauma, vascular, and gynecological laparotomies, as well as laparoscopic procedures (e.g., appendectomy, cholecystectomy), inguinal hernia repairs, and soft tissue procedures were excluded.

Data Collection

All the preoperative (e.g., ESS components, admitting diagnosis), intraoperative (e.g., procedure performed), and postoperative variables were systematically collected using standard ACS-NSQIP definitions.[19] The postoperative variables collected included 30-day mortality, ICU admission, need for reoperation, length of hospital stay, and 30-day readmission, as well as 21 individual postoperative complications: superficial surgical site infection, deep surgical site infection, organ/space surgical site infection, abdominal wall dehiscence, pneumonia, unplanned intubation, pulmonary embolism, failure to wean off ventilator more than 48 hours after surgery, progression of baseline renal insufficiency

TABLE 2. Demographics, Comorbidities, and Laboratory Values

ESS Variables	Patients, n (%)
Total, N	1,649
Demographics	
Age >60 y	923 (55.97%)
White race	1,172 (71.46%)
Female	828 (50.21%)
Transfer from outside emergency department	244 (14.8%)
Transfer from an acute care hospital inpatient facility	257 (15.59%)
Transfer from nursing home, chronic care, intermediate care	44 (2.67%)
Comorbidities	
Ascites	369 (22.39%)
BMI <20 kg/m^2	167 (10.13%)
Disseminated cancer	143 (8.67%)
Dyspnea	287 (17.44%)
Functional dependence	304 (18.48%)
History of COPD	231 (14.03%)
Hypertension	933 (56.65%)
Steroid use	176 (10.69%)
Ventilator requirement within 48 h preoperatively	219 (13.28%)
Weight loss >10% in the preceding 6 months	197 (12.22%)
Laboratory values	
Albumin <3.0 U/L	483 (30.43%)
Alkaline phosphatase >125 U/L	317 (19.99%)
Blood urea nitrogen >40 mg/dL	271 (16.45%)
Creatinine >1.2 mg/dL	604 (36.63%)
International normalized ratio >1.5	253 (18.58%)
Platelets <150 × 10^3/μL	263 (15.97%)
SGOT >40 U/L	410 (25.80%)
Sodium >145 mg/dL	84 (5.11%)
WBC, ×10^3/μL	
<4.5	120 (7.28%)
≥4.5 and ≤15	1,012 (61.41%)
>15 and ≤25	403 (24.45%)
>25	113 (6.86%)

BMI, body mass index; COPD, chronic obstructive pulmonary disease; SGOT, serum glutamic-oxaloacetic transaminase WBC, white blood cell.

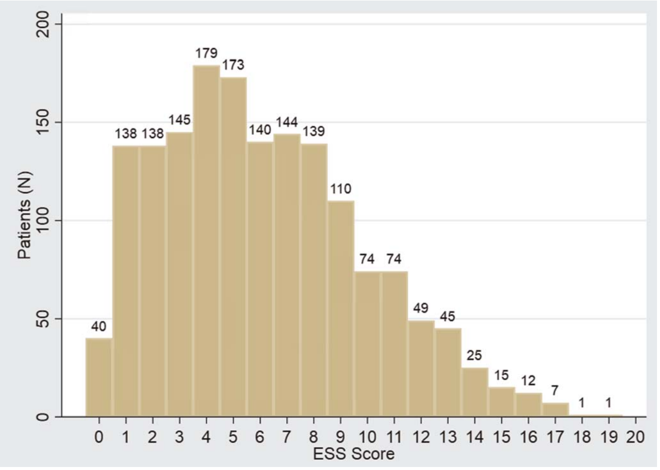


Figure 1. Emergency Surgery Score distribution.

with creatinine level of greater than 2 mg/dL, acute kidney injury requiring dialysis, urinary tract infection, cerebrovascular accident with neurological deficits, coma lasting more than 24 hours, cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, transfusion-requiring hemorrhage, deep venous thrombosis, sepsis, septic shock, peripheral nerve injury, and graft/prosthesis/flap failure.

Calculating ESS

Emergency Surgery Score was calculated using each patient's preoperative variables, including demographics (e.g., age, race), laboratory values (e.g., creatinine, white blood cell), comorbidities (e.g., hypertension, disseminated cancer), and acuity of disease (e.g., ventilator requirement within 48 hours preoperatively).[12] If a patient had a missing variable, it was treated as the default (i.e., no additional points assigned).

Outcomes

The correlation between ESS and each outcome of interest was evaluated using the area under the receiver operating characteristic (ROC) curve or c-statistic. The primary outcome of interest was 30-day mortality. The two main secondary outcomes were the occurrence of one or more postoperative complications and postoperative ICU admission.

Statistical Analysis

All data analyses were performed using STATA version 14.2 (StataCorp, College Station, TX), as described previously. All variables were presented as frequencies and percentages. The study was approved by the institutional review board at each participating site. Data User Agreements were signed between the coordinating center and all participating sites before data uploading. As a sensitivity analysis, we repeated all analyses with the subset of patients that had no missing data.

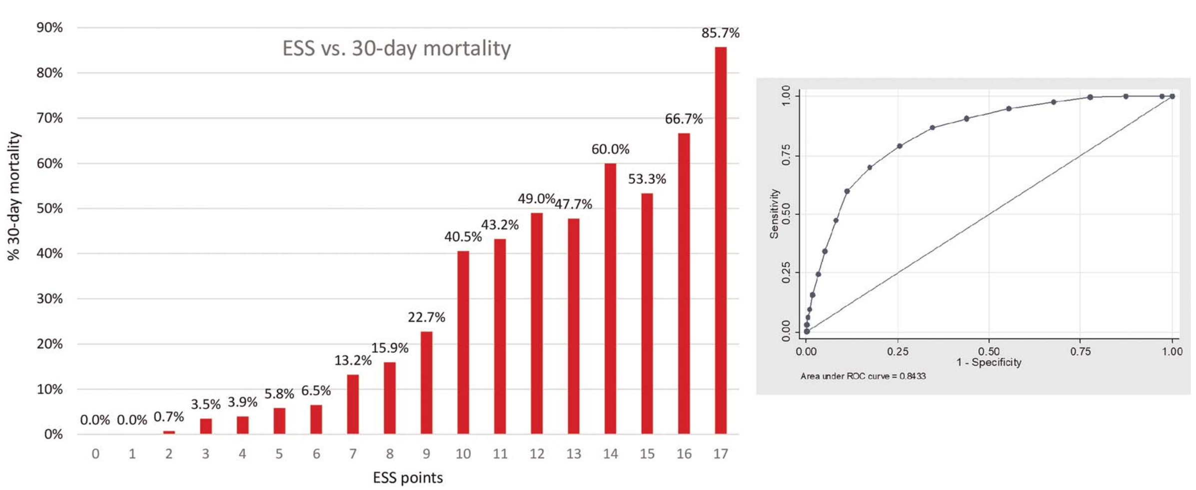
RESULTS

A total of 19 centers contributed data during the study period. A total of 1,649 patients who underwent EL were included. The mean age of the population was 60.5 years, half were female, and 71.5% were white. Table 2 demonstrates the demographics, comorbidities, and preoperative laboratory values of our patient population. In summary, 56.7% had hypertension, 18.5% were functionally dependent, and 13.3% had preoperative respiratory failure requiring ventilatory support. The median ESS was 6 (interquartile range [IQR], 3–9). The distribution of ESS was shown in Figure 1. The scores that represented the lowest, 50%, and 90% of each of the three outcomes were chosen in the results. The median hospital length of stay was 11 days (IQR, 7–20 days).

The most common diagnoses were hollow viscus organ perforation (29.5%), followed by small bowel obstruction (22.1%), strangulated or incarcerated hernia (13.0%), and bowel/mesenteric ischemia (12.3%).

ESS and 30-Day Mortality

The overall 30-day mortality rate was 14.8%. Emergency Surgery Score correlated well with 30-day mortality with a



ESS Points:
Age>60 years...**2** Albumin<3.0...**1** Alkaline phosphatase>125...**1** Ascites...**1** Body mass index<20...**1** BUN>40...**1** History of COPD...**1** Creatinine>1.2...**2** Disseminated cancer...**3** Dyspnea...**1** Functional dependence...**1** Hypertension...**1** INR>1.5...**1** Platelets<150...**1** SGOT>40...**1** Sodium>145...**1** Steroid use...**1** Transfer from outside ED or acute care hospital...**1** Ventilator requirement 48 hours pre-operatively...**3** WBC<4,500 or 15,000 -25,000...**1** WBC>25,000...**2** White race...**1** >10% weight loss in last 6 months...**1**

Figure 2. Emergency Surgery Score versus 30-day mortality; ROC, 0.84.

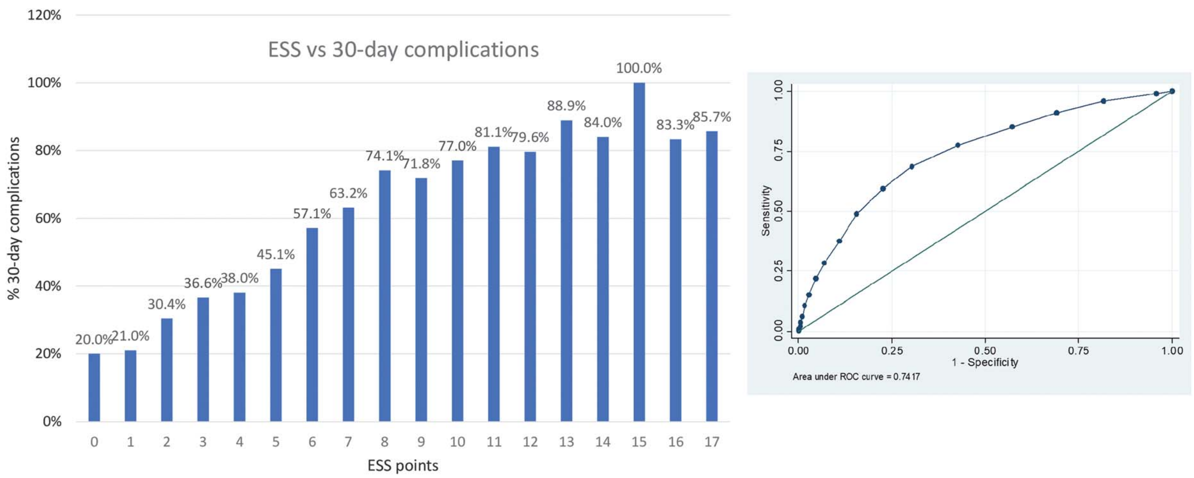


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Figure 3. Emergency Surgery Score versus 30-day postoperative complications; ROC, 0.74.

c-statistic of 0.84 (95% confidence interval [CI], 0.82–0.87). The observed mortality gradually increased from 3.5% to 50.0% to 85.7% at scores of 3, 12, and 17 points, respectively (Fig. 2).

ESS and 30-Day Complications

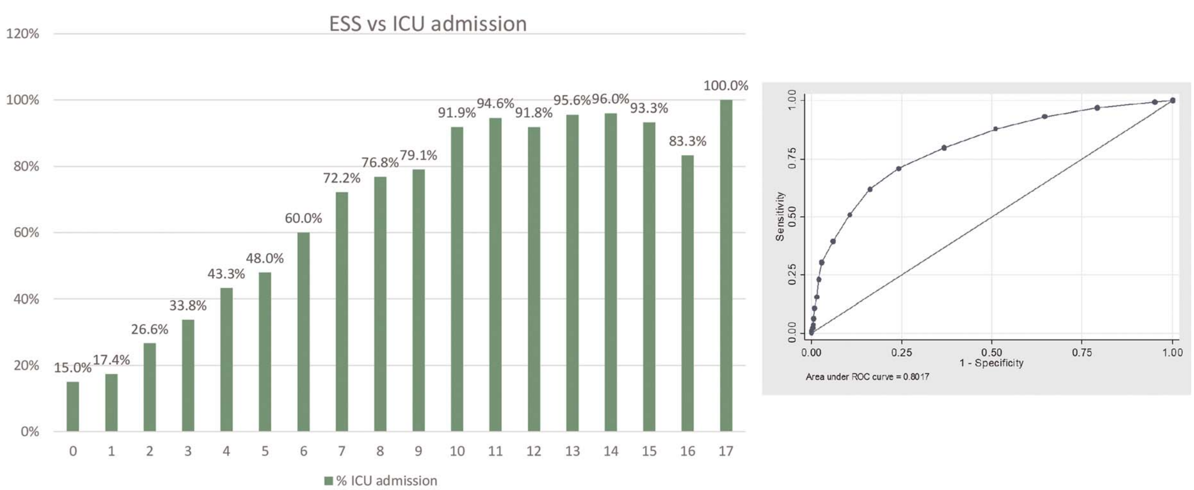
A total of 881 patients (53.4%) had at least one 30-day complication. One fourth of the patients failed to wean off ventilation within 48 hours after surgery, 15.3% had septic shock, and 15.2% experienced perioperative bleeding requiring transfusion. Emergency Surgery Score gradually predicted the risk of a 30-day complication, with scores of 1, 6, and 13 correlating with complication rates of 21.0%, 57.1% and 88.9%, respectively (Fig. 3). The c-statistic was 0.74 (95% CI, 0.72–0.77).

ESS and Postoperative ICU Admission

More than half of the patients (937 cases, 56.9%) required an ICU level of care postoperatively. The most common recorded indications for ICU admission were hemodynamic instability (50.0%), followed by the need for hemodynamic monitoring (38.3%), and septic shock (35.4%). The median length of ICU stay was 5 days (IQR, 2–11 days). Emergency Surgery Score gradually predicted which patients required postoperative ICU admission, with scores of 1, 6, and 13 correlating with ICU admission rates of 17.4%, 60.0%, and 95.6%, respectively (Fig. 4). The c-statistic was 0.80 (95% CI, 0.78–0.82).

Sensitivity Analysis

A total of 1,342 cases (81.4%) had complete ESS variables. The c-statistic analyses for this subset of patients were



ESS Points:
Age>60 years...**2** Albumin<3.0...**1** Alkaline phosphatase>125...**1** Ascites...**1** Body mass index<20...**1** BUN>40...**1** History of COPD...**1** Creatinine>1.2...**2** Disseminated cancer...**3** Dyspnea...**1** Functional dependence...**1** Hypertension...**1** INR>1.5...**1** Platelets<150...**1** SGOT>40...**1** Sodium>145...**1** Steroid use...**1** Transfer from outside ED or acute care hospital...**1** Ventilator requirement 48 hours pre-operatively...**3** WBC<4,500 or 15,000 -25,000...**1** WBC>25,000...**2** White race...**1** >10% weight loss in last 6 months...**1**

Figure 4. Emergency Surgery Score versus postoperative ICU admission; ROC, 0.80.

similar: ESS predicted mortality with a c-statistic of 0.83 (95% CI, 0.80–0.86), 30-day complications with a c-statistic of 0.75 (95% CI, 0.72–0.78), and postoperative ICU admission with a c-statistic of 0.81 (95% CI, 0.78–0.83).

DISCUSSION

In this prospective multicenter study, we demonstrate the ability of ESS to predict 30-day mortality, 30-day postoperative complications, and the requirement for postoperative critical care in the high risk EGS population undergoing EL. Emergency Surgery Score carries the premise of being (1) a useful bedside tool to help surgeons counsel their EGS patients and families regarding the perioperative risk of mortality and morbidity as well as the projected recovery trajectory, (2) a useful ICU triage tool in centers with limited critical care capacity, and (3) a valuable tool for benchmarking the quality of care of EGS patients.

Emergency general surgery patients present unique challenges because of their comorbidities and their acute physiological derangements related to the severity of their disease. Numerous studies have repeatedly shown that EGS is associated with higher mortality and postoperative complications, even after controlling for preoperative and perioperative confounders.[2,20–22] Compared with similar elective surgery, EGS has up to eight times higher postoperative mortality.[2] Moreover, Lissauer et al.[5] demonstrated that, compared with other surgical services, EGS patients had longer length of ICU stay and increased need for organ-supporting treatment, such as mechanical ventilation and renal replacement therapy.

As such, many experts have called for separation of the risk-stratification and benchmarking models of EGS and non-EGS.[6,23,24] At present, ESS is the only mortality and morbidity risk calculator created from and for EGS patients and the only one that accounts for the acuity of disease at presentation to the hospital. In addition, ESS is based on objective, well-defined variables, and its use is intended to be preoperative, before the intended surgical intervention. This study adds more prospective and multicenter supporting evidence for the accuracy and generalizability of ESS. We believe that the ability of ESS to predict postoperative mortality, morbidity, and critical care requirement is a key step in our efforts to adequately risk adjust and benchmark the quality of care for EGS patients. More specifically, it could prevent the unfair comparison of the quality of care provided by acute care surgeons with that provided in the elective general surgery setting. As the burden of EGS continues to increase, and in conjunction with the American Association for the Surgery of Trauma and Eastern Association for the Surgery of Trauma efforts to better define EGS, its scope, and its anatomical severity,[25,26] the importance of defining metrics specific to EGS to benchmark the quality of care cannot be overstated.

In the era of machine learning, our team is actively engaged in using artificial intelligence methodologies to improve the accuracies to predict the emergency surgery outcomes.[27] Artificial intelligence promises algorithms that can learn from their failures and, as such, continue to improve with a closed feedback loop. However, in the absence of better tools, ESS is still useful rather than simply relying on one surgeons' gestalt.

Our study has a few limitations. First, we did not use the American Association for the Surgery of Trauma definitions of EGS, and we only focused on laparotomies. Second, ESS applies only to EGS patients who underwent surgery. The quality of care of EGS patients managed nonoperatively was not assessed. Finally, while the data were collected prospectively from all 19 centers, we have not evaluated the bedside usefulness of ESS or its potential impact on decision-making in EGS patients.

CONCLUSIONS

In conclusion, this prospective multicenter study has demonstrated that ESS is an accurate outcome predictor in the EL patient. These findings suggest that ESS can be used as a valuable tool for (1) bedside perioperative patient and family counseling, (2) triaging patients to the ICU, and (3) benchmarking the quality of EGS care.

AUTHORSHIP

H.M.A.K. contributed in the study design, study leadership, data analysis, article writing, and article editing. N.K. contributed in the study design, data entry, data analysis, article writing, and article editing. G.C.V. contribute in the study design, article writing, and article editing. All authors contributed with patients and participated in the critical review of the article.

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DISCLOSURE

The authors declare no conflicts of interest.

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CRITIQUE

LINDA A. DULTZ, MD, MPH, FACS: This is, again, another thoughtful study from Dr. Kaafarani's group discussing the value of the emergency surgery scoring system for patients undergoing emergency general surgery.

In previous works, they have discussed the derivation and retrospective validation of the scoring system, and this is now a large, prospective validation of the ESS in patients undergoing emergency laparotomies. Once again, it performed very well in its accuracy in predicting post-operative mortality, morbidity, and the need for post-operative critical care in the EGS patient. I do have a few questions.

Number one, the ACS NSQIP risk calculator currently does have a section in it to differentiate between emergent and non-emergent cases, and so, knowing this, have you compared your scoring system directly with the ACS NSQIP calculator, to see how much variation there is between the two?

Number two, as you did point out in your manuscript, only patients undergoing emergent laparotomies were included in this study, and can you comment on the timeframe to undergo emergent laparotomy? For example, was it within twenty-four hours of admission, or, if a patient was admitted to the medical service, but then received a surgical consultation and underwent a laparotomy two weeks after initial admission, were they also included, and, if so, what pre-operative variables do you use, the admission ones or the ones just prior to laparotomy?

Number three, can you comment on why only patients undergoing laparotomy were included in this study and if there are plans to expand this to all EGS patients undergoing any type of surgeries?

Number four, do you think this calculator can also be used to predict discharge destination? This would be helpful when counseling a patient on the likelihood of being discharged to home versus a skilled nursing facility after the operation.

Once again, I would like to thank EAST for the opportunity to discuss this paper, and I would like to encourage everyone in this room to read this well-written paper, once published, and do what they can to implement this into their practice.