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ORIGINAL ARTICLE

Validation of the Emergency Surgery Score (ESS) in a Greek patient population: a prospective bi-institutional cohort study

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Abstract

Purpose The Emergency Surgery Score (ESS) is a reliable point-based score that predicts mortality and morbidity in emergency surgery patients. However, it has been validated only in the U.S. patients. We aimed to prospectively validate ESS in a Greek patient population.

Methods All patients who underwent an emergent laparotomy were prospectively included over a 15-month period. A systematic chart review was performed to collect relevant preoperative, intraoperative, and postoperative variables based on which the ESS was calculated for each patient. The relationship between ESS and 30-day mortality, morbidity (i.e., the occurrence of at least one complication), and the need for intensive care unit (ICU) admission was evaluated and compared between the Greek and U.S. patients using the *c*-statistics methodology. The study was registered on "Research Registry" with the unique identifying number 5901.

Results A total of 214 patients (102 Greek) were included. The mean age was 64 years, 44% were female, and the median ESS was 7. The most common indication for surgery was hollow viscus perforation (25%). The ESS reliably and incrementally predicted mortality (*c*-statistics = 0.79 [95% CI 0.67–0.90] and 0.83 [95% CI 0.74–0.92]), morbidity (*c*-statistics = 0.83 [95% CI 0.76–0.91] and 0.79 [95% CI 0.69–0.88]), and ICU admission (*c*-statistics = 0.88 [95% CI 0.81–0.96] and 0.84 [95% CI 0.77–0.91]) in both Greek and U.S. patients.

Conclusion The correlation between the ESS and the surgical outcomes was statistically significant in both Greek and U.S. patients undergoing emergency laparotomy. ESS could prove globally useful for preoperative patient counseling and quality-of-care benchmarking.

Keywords Emergency Surgery Score · Postoperative mortality · Postoperative morbidity · Emergency general surgery · Quality of care · Outcomes

Introduction

Emergency General Surgery (EGS) is associated with increased mortality and morbidity compared with elective surgery [1]. While EGS accounts for 7.1% of hospitalizations in the US, it disproportionally contributes to a large portion of overall perioperative mortality and morbidity [2–4]. Existing risk stratification calculators and decision-making tools such as the American College of Surgeons National Surgical Quality Improvement Program (ACS–NSQIP) risk calculator were not explicitly designed for EGS patients, and thus, do not account for the acuity of the disease while erroneously assume that the same risk factors impact EGS and non-EGS patients in a similar fashion [5, 6].

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The Emergency Surgery Score (ESS) was derived in 2016 as a novel preoperative risk assessment tool specifically designed for patients undergoing EGS [7, 8]. ESS was initially validated as a predictor of 30-day mortality. Since then, ESS has been consistently shown to predict not only mortality but also postoperative complications and the need for postoperative intensive care unit (ICU) admission [9–15]. More recently, an Eastern Association for the Surgery of Trauma (EAST) prospective multicenter study confirmed ESS as a reliable predictor of surgical outcomes, including 30-day postoperative mortality, morbidity, and the need for admission to the ICU [12].

As such, ESS is now being used in multiple institutions as a tool for bedside counseling of EGS patients and families, and its use as a benchmarking tool across hospitals is being evaluated [16–18]. However, ESS was originally derived from a United States (U.S.) national database and has been exclusively studied in the U.S. patient population. Its performance in non-U.S. patients remains unknown. We sought to prospectively study ESS's performance in a Greek patient population cohort compared to a similar U.S. patient population.

Materials and methods

Study design and patient selection

We conducted a prospective observational cohort study in two tertiary academic centers in Thessaloniki, Greece, and Boston, Massachusetts, USA. The Greek department is a public, academic, general surgery department in a tertiary (level I/II equivalency) hospital covering the emergencies of Thessaloniki and the surrounding areas. The US department is a private, academic, general surgery department in a tertiary, ACS level I trauma hospital covering the emergencies of Boston and the surrounding areas.

This study was conducted in accordance with STROCSS 2019 Guidelines [19] and was registered in "Research Registry," a publicly accessible database for studies involving human subjects with the unique identifying number 5901. Over a 15-month period (from 01/2019 until 03/2020 for the Greek department and from 04/2018 until 06/2019 for the US department), all adult patients who underwent emergency laparotomy in either hospital were included to capture a high-risk, severely ill cohort of patients. An emergency laparotomy was defined as one performed as soon as possible following diagnosis or after the onset of related preoperative symptomatology, where an unnecessary delay could potentially endanger the patient's well-being and outcome [20]. Laparoscopies and inguinal hernia repairs were excluded, since they do not constitute high-risk laparotomies. Trauma- and vascular-related laparotomies were excluded, since they do not reflect the underlying pathophysiology of EGS patients. The Institutional Review Boards of both institutions approved this study granting a waiver of informed consent.

Definition of outcomes

Preoperative, intraoperative, and postoperative information was systematically collected in all patients that underwent an emergency laparotomy during the above study period. Standard American College of Surgeons National Surgical Quality Improvement Program (ACS–NSQIP) definitions were used [20]. The primary outcome of this study was 30-day mortality. Secondary outcomes included in-hospital morbidity and the requirement for postoperative ICU admission. Thirty-day mortality was defined as the death of any patient within 30 days from the index emergency laparotomy. Postoperative morbidity was a composite outcome including the occurrence within 30 days postoperatively of one or more of the following complications: superficial, deep, and organ/space surgical site infections, wound dehiscence, deep venous thrombosis, pulmonary embolism, pneumonia, unplanned intubation, progressive renal insufficiency, acute renal failure, urinary tract infection, cerebrovascular accident (stroke), cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, bleeding necessitating postoperative blood transfusions, sepsis, septic shock, ventilator requirement for > 48 h, coma > 24 h, peripheral nerve injury, and graft/prosthesis/flap failure. The requirement for postoperative ICU level of care was defined as postoperative ICU admission at any time during the index hospitalization.

Calculation of ESS

Algorithms were generated to calculate the ESS for each patient using the demographic data, comorbidities, and laboratory values included in the database. The variables included in the ESS have been thoroughly described in our previous studies by Sangji et al. [7, 8]. None of the patients included in the current analysis had missing data required for the calculation of ESS.

Statistical analyses

We assessed ESS's ability to predict 30-day mortality, in-hospital morbidity, and the postoperative need for ICU level of care using the receiver operator characteristic (ROC) analyses. Receiver operative characteristic curves were computed, and the *c*-statistics (area under the curve—AUROC) were calculated. The probability of a randomly chosen subject with a positive outcome having a higher score compared to a randomly selected subject without the outcome of interest is represented by the c-statistic [21]. Based on a common c-statistic classification, we described the correlation between the ESS score and the positive outcome as acceptable ($0.7 \leq AUROC < 0.8$), excellent ($0.8 \leq AUROC < 0.9$), and outstanding ($AUROC \geq 0.9$) [22].

Moreover, we compared the distribution of the variables used in the ESS calculation between the patients' two cohorts. Categorical variables were compared with Fisher's exact or Chi-square test, where indicated, and the results are summarized in an absolute number of patients and percentages. The significance level was set at a p value < 0.05. All statistical analyses were performed using the Stata v15.1 (StataCorp 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC).

Results

A total of 214 patients were included, 102 (48%) Greek, and 112 (52%) in the U.S. The mean age of the population was 64 ± 18 years, and 94 (44%) were females. The most common indication for surgery was hollow viscus perforation (25%), and the median ESS was 7 [4–10].

Greek vs. U.S. patient population

The distribution of the ESS in the Greek and U.S. patient populations is shown in Fig. 1. Table 1 compares the Greek and U.S. patient populations. Notably, Greek patients were more likely to be white (100% vs. 84%, p value < 0.001) and less likely to be transferred from an outside emergency department (1% vs. 18%, p value < 0.001) or an acute care hospital inpatient facility (2% vs. 34%, p value < 0.001). The rest of the patients presented directly to each of the hospital's EDs, rather than being transferred from another hospital's ED or were inpatients already at the time of consultation from the surgical team. Furthermore, Greek patients had lower rates of functional dependence (10% vs. 25%, p value = 0.004), steroid use (1% vs. 7%, p value = 0.037), and preoperative ventilator dependency (2% vs. 16%, p value < 0.001). Regarding the distribution of laboratory values, U.S. patients had higher alkaline phosphatase levels (23% vs. 12%, p value = 0.032) and international normalized ratio (28% vs. 10%, p value < 0.001). Finally, U.S. patients were found to have significantly higher ESS as compared to their Greek counterparts (median: 8 vs. 6, p value = 0.013).

ESS vs. mortality

The overall 30-day patient mortality rate was 16%; the unadjusted 30-day mortality was similar in Greek and US patients (15% vs. 18%, p value = 0.582). The median duration from the index surgical procedure to mortality was 4 [1–12] days. As ESS increased, the 30-day mortality rates gradually increased; for example, ESS of 1, 6, 11, and 19 were associated with 0%, 14%, 44%, and 100% mortality, respectively. The overall c-statistic for mortality was 0.81[95% CI: 0.74–0.88].

Figure 2 shows the receiver operative characteristic curves for the correlation of ESS with 30-day mortality in the Greek vs. U.S. cohorts of patients. Briefly, the ESS correlation was acceptable in the Greek cohort of patients (c-statistic = 0.79 [95% CI: 0.67–0.90]), and excellent with 30-day mortality in the U.S. population (c-statistic = 0.83 [95% CI: 0.74–0.92]). Specifically, for the Greek patients, the mortality rates for patients with ESS of 1, 6, 9, and 15 gradually increased from 0 to 20%, 50%, and 100%, respectively. Comparing the two ROC curves in the Greek and US population, we did not identify any significant differences regarding ESS's performance in the two cohorts of patients (p value = 0.53).

ESS vs. postoperative complications

The overall incidence of postoperative complications was 55%. Table 2 illustrates the rates of all isolated postoperative complications included in the composite morbidity

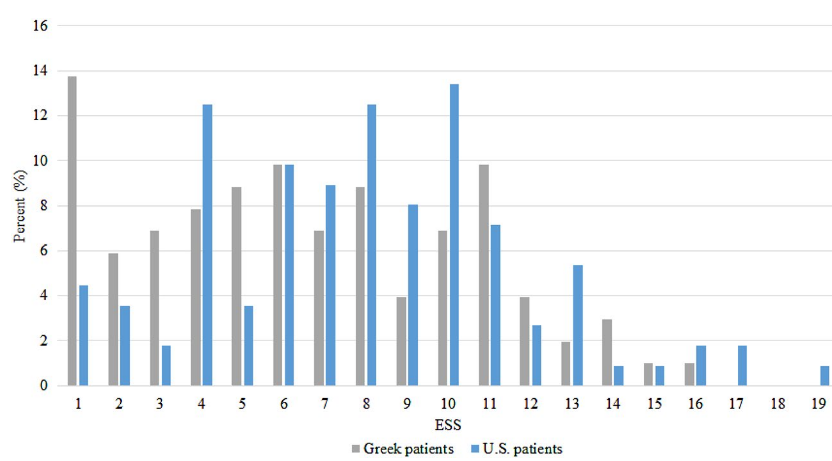

Fig. 1 Distribution of the ESS in Greek and U.S. patients

Table 1 Comparison of the variables used in the calculation of ESS, between the US and the Greek population

Variables	US patients ($n=112$)	Greek patients ($n=102$)	p value
Demographics (%)			
Age > 60 years	69 (62)	64 (63)	0.86*
White race	94 (84)	102 (100.0)	< 0.001*
Transfer status			
Outside emergency department	20 (18)	1 (1)	< 0.001†
Acute care hospital inpatient facility	38 (34)	2 (2)	< 0.001†
Comorbidities (%)			
Ascites	36 (32)	32 (31)	0.90*
BMI < 20 kg/m^2	11 (10)	4 (4)	0.11†
Disseminated cancer	9 (8)	14 (14)	0.18*
Dyspnea	33 (30)	20 (20)	0.10*
Functional dependence	28 (25)	10 (10)	0.004*
History of COPD	17 (15)	8 (8)	0.10*
Hypertension	62 (55)	66 (65)	0.16*
Steroid use	8 (7)	1 (1)	0.037†
Ventilator requirement within 48 h preoperatively	18 (16)	2 (2)	< 0.001†
Weight loss > 10% in the preceding 6 months	13 (12)	14 (14)	0.64*
Laboratory values (%)			
Albumin < 3.0 U/L	35 (31)	41 (40)	0.17*
Alkaline phosphatase > 125 U/L	26 (23)	12 (12)	0.029*
Blood urea nitrogen > 40 mg/dL	20 (18)	24 (24)	0.31*
Creatinine > 1.2 mg/dL	44 (39)	31 (30)	0.17*
International normalized ratio > 1.5	31 (28)	10 (10)	< 0.001*
Platelets < 150 × 103 /μL	19 (17)	17 (17)	0.95*
SGOT > 40 U/L	29 (26)	17 (17)	00.10*
Sodium > 145 mg/dL	9 (8)	10 (10)	0.65*
WBC			
WBC < 4.5 10^3 /μL	12 (11)	1 (1)	0.003†
WBC > 15 and ≤ 25 10^3 /μL	26 (23)	20 (20)	0.52*
WBC > 25 10^3 /μL	8 (7)	9 (9)	0.65*
ESS			
ESS, median (IQR)	8 (5, 10)	6 (3, 10)	0.013‡
ESS categories (%)			0.006*
Low score (1–3)	11 (10)	27 (26)	
Intermediate score (4–11)	85 (76)	64 (63)	
High score (12–19)	16 (14)	11 (11)	

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

*Chi-square test

†Fisher's exact test

‡Mann–Whitney *U* test

outcome. The most commonly observed complication was sepsis/septic shock (27%). As ESS increased, there was a step-wise increase in postoperative complications rates; for example, ESS of 1, 6, 11, and 19 were associated with 5%, 29%, 89%, and 100% morbidity rates, respectively. Figure 3 illustrates the receiver operative characteristic curves for ESS's correlation with postoperative morbidity in the Greek vs. U.S. patient populations. In summary, the ESS correlation regarding postoperative morbidity was excellent in the Greek population (c-statistic = 0.83 [95% CI: 0.76–0.91]) and acceptable (c-statistic = 0.79 [95% CI: 0.69–0.88]) in the U.S. cohort of patients. A comparison of the two ROC curves showed that ESS performed similarly in both patient populations (p value = 0.46).

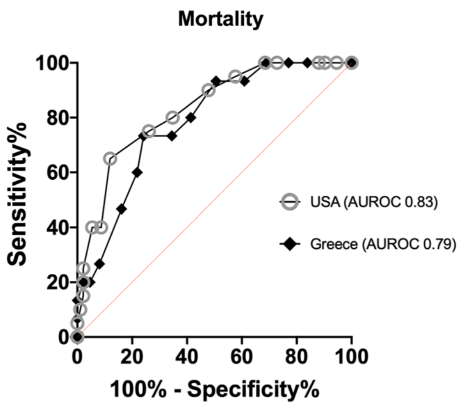

Fig. 2 Receiver operative characteristic curves and the corresponding *c*-statistic for the ESS versus 30-day mortality in Greek and U.S. patients

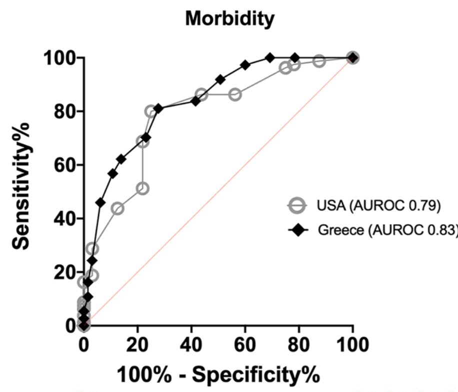

Fig. 3 Receiver operative characteristic curves and the corresponding *c*-statistic for the ESS versus postoperative morbidity in Greek and U.S. patients

Table 2 Incidence of postoperative complications included in the analysis

Complications	Incidence (%)
Sepsis/septic shock	57 (27)
Transfusion-requiring hemorrhage	38 (18)
Failure to wean off ventilator > 48 h after surgery	37 (17)
Pneumonia	28 (13)
Acute kidney injury requiring dialysis	22 (10)
Superficial surgical site infection	21 (10)
Progression of baseline renal insufficiency with creatinine > 2 mg/dL	17 (8)
Coma lasting > 24 h	17 (8)
Organ/space surgical site infection	16 (8)
Unplanned intubation	12 (6)
Cardiac arrest requiring cardiopulmonary resuscitation	12 (6)
Urinary tract infection	11 (5)
Deep surgical site infection	6 (3)
Abdominal wall dehiscence	6 (3)
Pulmonary embolism	6 (3)
Myocardial infarction	5 (2)
Deep venous thrombosis	5 (2)
Cerebrovascular accident with neurological deficits	2 (1)
Peripheral nerve injury	0 (0)
Graft/prosthesis/flap failure	0 (0)

ESS vs. need for ICU

A total of 86 patients (40%) were admitted to the ICU postoperatively. The most common indication for ICU admission was hemodynamic instability (26%), followed by the need for mechanical respiratory support (25%). ICU admission rates gradually increased at higher ESS; For example, ESS of 1, 6, 11, and 19 correlated with ICU admission rates of 0%, 24%, 72%, and 100%, respectively. The correlation between the ESS and the requirement for postoperative ICU level of care was excellent in both Greek and U.S. patients with the requirement of postoperative ICU level of care (Fig. 4, *c*-statistics of 0.88 [95% CI: 0.81–0.96] and 0.84 [95% CI: 0.77–0.91], respectively). A comparison of the two ROC curves showed that ESS performed similarly in both patient populations (p value = 0.43).

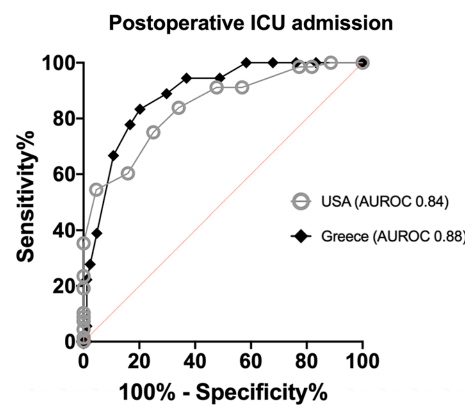

Fig. 4 Receiver operative characteristic curves and the corresponding *c*-statistic for the ESS versus the requirement for postoperative ICU admission in Greek and U.S. patients

Discussion

In this study, we demonstrate that ESS performs well in predicting mortality, morbidity, and the postoperative need for ICU admission, not only in U.S. patients but also in non-U.S. patients, specifically a Greek patient population undergoing high-risk emergency laparotomy. Despite some notable differences in the two populations' baseline characteristics, ESS retained its reliability in predicting surgical outcomes.

As such, our findings suggest that ESS could be used outside the U.S. for preoperative bedside counseling of patients and their families and for benchmarking the quality of EGS care on a broad scale.

A recent multidisciplinary survey highlighted that physicians use risk stratification tools, mostly preoperatively [23]. Many popular risk classification tools such as the ASA, the ACS–NSQIP, the P-POSSUM, and the APACHE calculators require intraoperative variables to be calculated [24–26]. The NEWS score, similarly to ESS, utilizes only preoperative variables in the ED; however, it was not explicitly designed for EGS patients [27, 28]. Therefore, ESS offers an advantage in EGS patients not only because it was derived from this specific patient population but also because it accounts for the acuity of disease on presentation, and its accuracy is superior. In addition, it exclusively utilizes preoperative variables and is thus amenable to use before the operation. While the ACS–NSQIP Surgical Risk Calculator performs well in various surgical settings, it falls short of ESS performance regarding EGS [26, 29–32], most probably because it does not include variables that specifically affect the outcome in EGS [33].

Unlike patients undergoing elective surgery, EGS patients often have a different pathophysiologic background, and many require ICU admission to recover [34]. ESS can be useful as a triage tool for ICU admission, especially in countries with limited access to critical care beds, such as Greece [35]. The previously proposed ESS cut-off value of ≥ 7 to admit a patient to the ICU [13] could be adjusted by each healthcare facility to reflect their specific existing resources and infrastructure. In addition, smaller facilities with a very limited number of available ICU beds could use the ESS to transfer patients to a healthcare facility of a higher level of care. Some studies have attempted to use the Surgical Apgar Score as a tool to predict the need for ICU admission [36, 37]. However, most of the cases involved elective surgery rather than EGS, and their performance is inferior to that of ESS [36] (c-statistic = 0.76).

Surgical risk is not linear, and artificial intelligence methods such as machine learning may improve our ability to assess surgical patients' risk beyond ESS in the future. For example, machine learning methods were recently used to develop the Predictive OpTimal Trees in Emergency Surgery (POTTER) Calculator [38]. The POTTER Calculator uses a machine learning method called Optimal Classification Trees [39] and demonstrates how the non-linear methods can provide evidence-based, accurate, user-friendly, and potentially actionable predictions of surgical outcomes in EGS patients [38, 40–42].

Our study has a few limitations. The main limitation of our study is that it included only EGS patients who underwent surgery. Therefore, it does not apply to EGS patients being managed non-operatively. Second, we limited our study to emergency laparotomy, and therefore cannot generalize our findings to other EGS procedures. Third, additional data points (e.g., other comorbidities, transfer locations, advance directives of the patients, CMO status, etc.) not included in the ESS calculation were not collected in this study and could not be accounted for. Fourth, we had a low number of patients included in both cohorts of patients, which may have affected our study results. Furthermore, differences in infrastructure, capabilities, and eligibility of patients for laparoscopy between the two departments were not accounted for and could potentially affect our results. Finally, despite its prospective nature, our study did not evaluate ESS's potential impact on decision-making in EGS patients.

Conclusion

We have therefore demonstrated that ESS performs well in predicting mortality, morbidity, and the need for postoperative ICU admission in a population outside the U.S. ESS could be used in various surgical settings as a tool for preoperative patient counseling, risk stratification, benchmarking the quality of care, and for postoperative patient triage to higher levels of care.

Author contributions Conceptualization: HMAK. Data curation: CDC, LN. Formal analysis: CDC, LN. Investigation: CDC, NK, AT, PS. Methodology: CDC, LN, NK, HMAK. Project administration: HMAK. Resources: CDC, LN, AT, GT, VNP, GCV, HMAK. Supervision: GT, VNP, GCV, HMAK. Visualization: CDC, LN. Writing—original draft: CDC, LN. Writing—review and editing: CDC, LN, NK, AT, PS, AT, GT, VNP, GCV, HMAK.

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Availability of data and material The data that support the findings of this study are available from the corresponding author, [HMAK], upon reasonable request.

Code availability Not applicable.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Ethical approval This is an observational study. The study was approved by the Institutional Review Boards of both centers, and no ethical approval was required.

Consent to participate/consent for publication Both Institutional Review Boards granted this study a waiver of consent, since data were collected in an anonymized manner.

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