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The role of the American Society of anesthesiologists physical status classification in predicting trauma mortality and outcomes

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Declaration of competing interest

The authors declare no additional conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2019.09.019.

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Abstract

Background: Trauma prediction scores such as Revised Trauma Score (RTS) and Trauma and Injury Severity Score (TRISS)) are used to predict mortality, but do not include comorbidities. We analyzed the American Society of Anesthesiologists physical status (ASA PS) for predicting mortality in trauma patients undergoing surgery.

Methods: This multicenter, retrospective study compared the mortality predictive ability of ASA PS, RTS, Injury Severity Score (ISS), and TRISS using a complete case analysis with mixed effects logistic regression. Associations with mortality and AROC were calculated for each measure alone and tested for differences using chi-square.

Results: Of 3,042 patients, 230 (8%) died. The AROC for mortality for TRISS was 0.938 (95%CI 0.921, 0.954), RTS 0.845 (95%CI 0.815, 0.875), and ASA PS 0.886 (95%CI 0.864, 0.908). ASA PS + TRISS did not improve mortality predictive ability (p = 0.18).

Conclusions: ASA PS was a good predictor of mortality in trauma patients, although combined with TRISS it did not improve predictive ability.

Keywords

ASA PS; Trauma scores; Mortality; Predictors; Outcomes

Introduction

Risk-adjusted analytic models have been developed to predict the risk of mortality in trauma patients. Such models help to guide patient care and may also be used to evaluate the quality

of trauma center performance. The American College of Surgeons (ACS) Committee on Trauma created the Trauma Quality Improvement Program (TQIP) which utilizes national data to objectively compare trauma hospitals' performances against a national average, typically using mortality as the primary outcome.[1]

Five variables (age, sex, mechanism of injury, and estimates of physiologic and anatomic severity) are considered to be essential in the risk-adjusted analysis of trauma mortality. However, there are inconsistencies and limitations in these existing models. A review of the ACS National Trauma Data Bank (NTDB) publications revealed that nearly half of the studies did not account for all 5 variables,[1] while important comorbidity and outcome data were underreported.[2] Such practice may adversely influence the results of current risk-stratification models.

Additionally, the derivative variables used in trauma mortality prediction models, which include the injury severity score (ISS) (which standardizes severity of traumatic injury based on worst injury of six body systems) and revised trauma score (RTS) (i.e. systolic blood pressure, respiratory rate (RR), and Glasgow coma score (GCS)), which together create the Trauma Score-Injury Severity Score (TRISS) have limitations that may influence risk analysis.[3] Current models do not account for patients' comorbidities and are derived from a single set of vital signs and physical examination taken upon arrival to the emergency department (ED). Depending on the time they were measured, the injuries with the most significant physiologic impact may be overlooked if evaluated too soon or immediately after initial pre-hospital resuscitation. Furthermore, they do not account for patient status deterioration that may develop after leaving the ED.

A potential measure, which quickly classifies patients' overall health status and comorbidities using a simple numeric scale (I-VI) which may be used to predict trauma mortality, is the American Society of Anesthesiologists physical status (ASA PS) score (Appendix A).[4] Several studies have demonstrated that the ASA PS is a reliable predictor of morbidity and mortality in surgical patients.[5,6] This led to its inclusion into risk-adjustment models for non-trauma surgical outcomes such as the National Surgical Quality Improvement Program (NSQIP).[5] Furthermore, pre-injury ASA PS scores have already been incorporated into several European trauma prediction models.[7–9] ASA PS is not currently used in U.S. trauma prediction models[10]; however, its inclusion may result in more accurate risk-stratification.

To our knowledge, this is the first study to examine ASA PS values to predict outcomes in U.S. adult trauma patients. Our aim is to analyze the ASA PS as an independent predictor of in-hospital mortality in trauma patients undergoing surgery within 24 h of admission at level I trauma centers. Our hypothesis is that ASA PS is an independent predictor of in-hospital mortality rates, post-operative length of stay (LOS), complications, and mechanical ventilation days. Our secondary objective was to determine whether a combination of ASA PS with RTS, ISS, and/or TRISS would prove superior in ability to predict mortality, assessed by the area under the ROC curve, than any of these models alone.

Materials and methods

We performed a multicenter retrospective review of trauma registry data evaluating adult trauma patients who underwent surgery within 24 h of admission from 01/01/2016–01/01/2017 at five U.S. level I trauma centers. The trauma registries of the following institutions were used: Los Angeles County Hospital at the University of Southern California (LAC + USC) in Los Angeles, CA; University of California, Irvine in Orange, CA; Ryder Trauma Center at the University of Miami in Miami, FL; University of Texas Southwestern in Dallas, TX; and Brigham and Women's Hospital in Boston, MA. The study was approved by the Institutional Review Board (IRB) of Keck School of Medicine at the USC (the primary study site), as well as the IRBs of the four aforementioned participating centers. This study followed the guidelines outlined in the statement of Strengthening the Reporting of Observational Studies in Epidemiology (STROBE).

All patients with trauma activations were included if they were ≥18 years of age and underwent surgery within 24 h of admission. Patients were not excluded based on their ISS value, mechanism of injury, or number of injuries (isolated orthopedic and neurosurgical injuries were included). Patients who presented to the ED in cardiac arrest and died within 24 h of admission were also included. Patients were excluded from analysis if they had an ASA PS score of VI, as this constitutes a declared brain-dead patient who is undergoing surgery for an organ procurement.

Our primary outcome was in-hospital mortality. Secondary outcomes included: hospital length of stay (LOS), intensive care unit (ICU) LOS, number of complications, and mechanical ventilation days. We collected information on patient characteristics (i.e., age, race, gender, type of injury, mechanism of injury, list of trauma injuries, first ED vital signs, social history, and comorbidities, etc.), ASA PS, ISS, surgery performed, surgery duration, type of anesthesia, and discharge disposition. RTS and TRISS scores were computed from the data collected. In-hospital mortality and other outcomes were obtained from the hospitals' electronic health records. All sites calculated the ISS based on the Abbreviated Injury Scale (AIS) score, which was generated through a formulary function based on the injury description information entered into the trauma databank system. The ASA PS score was obtained from the intraoperative record and had been assigned by the anesthesiologist providing operating room care. We did not separately categorize patients with an ASA PS score designated as emergent ("E") from those with the same scores that did not have the "E" designation. If an ASA PS was missing (<0.01% of the records were missing an ASA PS assignment), each site's primary investigator (CMK, JTN, IA, RU, RD) reviewed the patients' medical records and assigned a post-injury ASA PS based on data available when the patient was in the ED which included: the past medical history, nature of the traumatic injuries, and vital signs. All the sites entered their data into USC's REDCap™ database, a secure online database application.[11]

Statistical analysis

An *a priori* sample size calculation estimated the target patient population size to be 2,916. We used prior reported estimates of association of pre-injury ASA PS with mortality, along with estimates of the ASA PS distribution and mortality rates reported in a population of

trauma patients[7] to derive this sample size estimate, using 80% power and 2-sided alpha = 0.05.

ASA PS was compared to initial ED heart rate (HR), RR, total GCS, ISS, TRISS, and RTS for outcome (in-hospital mortality, hospital and ICU LOS). The analysis dataset included patients with complete data on all relevant trauma measures, which included initial ED HR, RR, GCS, ISS, ASA PS, and calculated RTS and TRISS. Patients who died during their hospitalization were compared to survivors (those who were discharged from the hospital). Logistic regression was used to evaluate the association of pre-surgical ASA PS and other trauma measures with this primary outcome of in-hospital mortality. As data were collected over multiple clinical sites, the analysis reflected the clustered sampling (within sites); logistic regressions were conducted as mixed effects models, specifying site as a random effect (with a random regression intercept specified for clinical site). As one site provided a relatively small number of patients, this site was combined with a site that reported a similar mortality rate. Linearity of continuous independent variables on the logit (mortality) scale were evaluated; transformations, including possible categorization, were considered if linearity did not hold. Both initial HR and RR were markedly non-linear; these variables were categorized into their respective quartile distributions and associations were estimated for each quartile (relative to the lowest quartile). Mortality associations for each trauma measure are presented as odds ratios (ORs) and 95% confidence intervals. To compare the predictive ability of ASA PS to the ISS, RTS, and TRISS at initial presentation, area under the receiving operator characteristic (AROC) curves was computed and tested for differences with a chi-square test statistic. In addition, the additional predictive utility of ASA PS was tested comparing AROCs from ISS-, RTS-, and TRISS-only models to respective models with ASA PS added. Associations of trauma measures with secondary outcomes of hospital and ICU LOS, mechanical ventilation days, and number of complications were tested among survivors, using mixed effects negative binomial regression, with site as a random effect. Trauma measures were each divided by their respective standard deviations (SD), so that effect estimates are interpreted per SD. Associations with RRs and HRs were non-linear, and are expressed by quartiles of these measures. Effects for each trauma measure were assessed alone and with the addition of ASA PS. Estimates of association are presented as incidence rate ratios (IRR) with 95% confidence intervals, interpreted as the fold-change in the mean outcome (per SD of the trauma measure), or relative to the lowest quartile for RRs and HRs. Missing values for ICU LOS and mechanical ventilation days were imputed as zero. STATA Version 15.0 (StataCorp LLC, College Station, TX) software was used for data analysis.

Results

Patient characteristics and demographics

There were 3,042 trauma patients who underwent surgery within 24 h of admission from 5 U.S. level I trauma centers. Of these 3,042 patients, 2,916 (96%) had ASA PS score of I–V and complete data on trauma and risk measures obtained in the ED (including initial HR and RR, ISS, GCS, RTS, TRISS and ASA PS). The following 126 patients were excluded: ASA PS of VI (n = 3); missing HR (n = 4); and missing TRISS (n = 119). Because TRISS scoring

applies to blunt and penetrating injuries, 77 subjects with burns, other, or unknown trauma type were excluded (leading to a missing TRISS score).

Of the 2,916 patients, 2,236 (76.7%) were male, 1,022 (35.0%) were white, 2,045 (70.1%) sustained blunt trauma, 1,148 (39.4%) were involved in a traffic accident, and 532 (17.4%) received blood products in the first 24 h (Table 1).

Primary outcome: in-hospital mortality

There were 230 (8%) patients who died in-hospital. Compared to survivors, patients who died were older ($p < 0.0001$), and were more likely to be involved in a traffic accident ($p < 0.0001$ for mechanism of injury) and receive blood products within 24 h ($p < 0.0001$; Table 1). All trauma measures (including initial HR and RR, GCS, ISS, RTS, TRISS and ASA PS) differed highly significantly between survivors and those who died in-hospital ($p < 0.0001$; Table 2). Non-survivors had higher ASA PS scores (median of 5 vs 2, 86.5% vs 18.3% at ASA IV and V), higher ISS (median 33 vs 9), lower GCS (median 6 vs 15), and lower RTS (median 5.03 vs 7.84) and TRISS (median 0.509 vs 0.990) scores (Table 2). In mixed effects logistic regression models, all outcomes were significantly associated with in-hospital mortality modeled separately (Table 3, all $p < 0.0001$). Mortality risk increased by approximately 4.5 times per increasing unit of the ASA PS (OR = 4.53, 95% CI 3.81–5.39).

ASA PS Mortality Predictive Ability Compared to Other Models (ISS, RTS, and TRISS).

Modeled separately, each trauma measure's AROC was significantly higher than 0.50 (Table 3). AROCs ranged from 0.628 (initial HR, modeled in quartiles) to 0.938 (TRISS). The AROC for ASA PS (0.886, 95% CI 0.864–0.908) was statistically significantly higher than AROCs for initial RR ($p < 0.0001$), initial HR ($p < 0.0001$) and RTS ($p = 0.02$); it did not significantly differ from AROCs for ISS ($p = 0.46$) and GCS ($p = 0.13$); and was significantly lower than the AROC for TRISS ($p < 0.0001$) (Table 3).

When added to models with ISS, RTS, and TRISS scores, the association of ASA PS with mortality remained highly statistically significant ($p < 0.0001$ for each model; Table 4). With the addition of ASA PS to ISS, the model AROC significantly improved (from 0.896 to 0.933, $p < 0.0001$). The addition of ASA PS to an RTS-only model also significantly increased the model AROC (from 0.845 to 0.926, $p < 0.0001$). Addition of ASA PS to a TRISS-only model did not significantly improve the AROC (from 0.938 to 0.946, $p = 0.18$).

Secondary outcomes: hospital and ICU LOS, complications, and mechanical ventilator days

Among the 2,868 trauma survivors, the median (25th, 75th percentile) hospital LOS was 7 (4, 14) days, with a range of 0–391 days. A total of 1123 (41.8%) of the sample spent some time in the ICU, with a median (25th, 75th percentile) of 5 (3, 11) days and a range of 1–124 ICU days. Mechanical ventilation was used in 445 (16.6%) of survivors, with a median (25th, 75th percentile) of 3 (2, 9) days and a range of 1–75 ventilation days. Complications occurred in 511 (19.0%) of survivors; among those with complications, the median (25th, 75th percentile) number of complications was 1 (1, 3) with a range of 1–9.

Table 5 through 8 provide estimates and tests of association of trauma measures with each of the secondary outcomes. ASA PS and ISS were each significantly positively associated with longer hospital and ICU LOS, more days of mechanical ventilation, and more complications, while GCS, RTS and TRISS were inversely associated with these outcomes (all $p < 0.0001$). For HR and RR, the middle quartiles tended to show lower means of each outcome (relative to the first quartile), while the upper quartile tended to show higher or equivalent means of each outcome (relative to the first quartile).

ASA PS Hospital and ICU LOS, Complications, and Mechanical Ventilator Days Predictive Ability Compared to Other Models (ISS, RTS, and TRISS).

Adding ASA PS to other trauma measures, all trauma measures remained significantly associated with each of the secondary outcomes (all $p < 0.003$); ASA PS significantly contributed additional explanation of each outcome, beyond that provided by the other trauma measures (all ASA PS $p < 0.0001$).

Discussion

To our knowledge, this is the first study to examine the predictive ability of ASA PS scores on trauma outcomes in U.S. adult trauma patients. Our results demonstrate that ASA PS is a good independent predictor of in-hospital mortality and post-operative outcomes following traumatic injury in adults. The mortality rate increased with increasing ASA PS scores (III–V). ASA PS increased the mortality predictive ability when combined with ISS, RTS, but not TRISS. Furthermore, it performed equally to ISS, better than RTS, and worse than TRISS. It did, however, demonstrate a statistically significant improvement in predicting secondary outcomes such as hospital and ICU LOS when combined with TRISS, ISS, and RTS.

Outcome prediction scoring systems are useful in trauma patients as they predict the risk of morbidity and mortality after trauma and surgery and may be used to prioritize clinical care,[3] predict expected hospital course, hospital readmission,[12] allocating resources, and to improve quality of care.[3] There are several trauma scoring systems which have been used to predict mortality. Patient data from the initial evaluation and assessment of the patient are used to calculate outcome scores. The variables in each scoring system can be found in Appendix B.[13–17]

Although the TRISS is the most common tool used to predict trauma outcomes,[9,18] comparisons of the various trauma scoring scales have produced discrepant results, making the ideal scoring system debatable.[18–21] Our results demonstrate that TRISS had the best mortality predictive ability when compared to RTS, ISS, and ASA PS. ASA PS was better at predicting mortality compared to RTS and equal to ISS. It is important to note that trauma scoring systems have been developed and validated in countries that have their own epidemiological and demographic specificities.[19] The scoring systems would need to be corrected for factors such as trauma system infrastructure, location and resources, patient population, and pre-hospital and hospital care received.[18] While each scoring system has its own set of limitations, they all primarily rely on injury characteristics and severity and

do not include comorbidities or other physiologic conditions that may influence patient outcomes.[3] Additionally, these scoring systems are used after trauma injury and have not been explicitly designed to predict outcomes in those trauma patients undergoing surgical intervention.

Patient's comorbidities prior to traumatic injury may influence mortality and outcomes.[8,22–25] A review of blunt trauma patients in Taiwan reported that the severity of comorbidities was associated with higher mortality.[25] There are several tools which can be used to define and measure comorbidity, which include the comorbidity-polypharmacy score,[26] Charlson Comorbidity Index,[12] and the ASA PS.[7–9,12,26] While none of these tools are optimal to quantify comorbidities, research has demonstrated promising results in regards to ASA PS.[7–9,12] There is substantial evidence supporting ASA PS as a good predictor of mortality and outcomes in non-trauma surgical patients.[5,27–34] Several studies, performed outside the U.S., have evaluated the role of ASA PS in trauma outcomes prediction and found it was associated with mortality[7–9] as well as predicting readmission rates.[12,35] The addition of comorbidity as a variable in survival prediction models may also result in improved outcome predictive ability.[7,9,36,37] Our study demonstrates that ASA PS has good mortality predictive ability, however, when ASA PS was combined with TRISS, the predictive ability of the latter was not improved. The possible explanation may include insufficient sample size. Additionally, it is important to note that identifying predictors of mortality and performing risk-adjusted mortality analysis are distinct and non-interchangeable concepts.[1] Although a variable, such as ASA PS, is a strong predictor of mortality after trauma, it may not necessarily provide additional discriminative ability to predict mortality using regression analyses if other variables (i.e. TRISS) are already in the model.[1] However, we did demonstrate that ASA PS combined with TRISS, ISS, and RTS had improved predictive ability of hospital and ICU LOS, number of complications, and mechanical ventilator days.

Our results demonstrate that ASA PS is an excellent independent predictor of in-hospital mortality and higher ASA PS scores (III–V) were associated with increased mortality. Several studies determined that the *pre-injury* ASA PS score independently predicts trauma mortality,[7,21] and it is a core data variable in the European trauma registry, the Utstein-style guidelines, and the Norwegian survival prediction model in trauma (NORMIT).[7–9] ASA PS is currently not used in U.S. trauma prediction models, such as the TQIP mortality risk-adjustment model.[10] Although this model includes individual comorbidities as one of its core variables, these data are often missing or unattainable due to the emergent and severe nature of trauma.[10] Using a surrogate for individual patient comorbidities and physiologic state using an easy tool such as the ASA PS, may be a reasonable variable to consider for future refinements of the TQIP morbidity and mortality risk-adjustment model, and it may even result in more accurate survival prediction and/or prediction of complications, as demonstrated in our study.[38] Although we propose that post-injury ASA PS should be used, to account for the drastic physiologic derangements associated with traumatic injury that may lead to worsened outcomes in even young healthy patients, additional research is required to determine whether pre- or post-injury ASA PS should be used.

Our study has several limitations, including those inherent to a retrospective study, such as selection bias and miscoding. Data, such as complications, may have been missed,

misclassified, or underestimated. Additionally, there is likely variability in the ASA assignment by providers.[39,40] It is unknown whether pre-injury or post-injury ASA was used. Furthermore, in trauma, there appears to be greater variability in consistency of ASA PS scoring among providers.[39,40] Therefore, it is possible that potential non-uniform ASA assignment by anesthesiologists, may have affected our outcomes. Although we performed a sample size calculation and included 5 level I U.S. trauma centers, it is possible we did not have enough patients to detect improved performance of mortality prediction compared to TRISS, which is already an excellent predictor of mortality. There is potential for confounding bias related to other variables we did not account for in our analysis. Furthermore, there was distribution variation between sites, which may have introduced additional bias. We did not look at 30-day mortality or early mortality (within 48 h of admission); it is possible our results would have been different if we looked at these measures of mortality as opposed to in-hospital mortality. In addition, we only chose to include patients undergoing surgery, thus our results are not generalizable to trauma patients that did not undergo surgery within 24 h. Finally, we only compared ASA PS to ISS, RTS, and TRISS, and not other models of mortality prediction in trauma. However, our study has major strengths including being a multicenter study with a relatively large number of patients included.

Conclusions

We report that ASA PS, used as a measure of comorbidities, is a strong independent predictor of mortality in adult trauma patients. The ASA PS performed worse than TRISS in mortality prediction. ASA PS combined with ISS and RTS enhanced mortality predictive ability, but not when combined with TRISS. However, ASA PS combined with TRISS did result in a statistically significant improvement in predicting hospital and ICU LOS, number of complications, and mechanical ventilator days. We believe incorporating ASA PS in trauma outcome prediction models is promising but additional research is needed.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Characteristics by in-hospital mortality (n = 2916).

	Survived (n = 2686)	Died (n = 230)	p-value
Age	36 (25, 51)	48.5 (30, 62)	<0.0001
Male	2052 (76.4%)	184 (80.0%)	0.21
Race			0.007
Caucasian	935 (34.8%)	87 (37.8%)	
Asian	105 (3.9%)	20 (8.7%)	
Black	515 (19.2%)	40 (17.4%)	
Hispanic/Latino	1069 (39.8%)	78 (33.9%)	
Other/Unknown	62 (2.3%)	5 (2.2%)	
Type of Injury [b]			0.39
Blunt	1878 (69.9%)	167 (72.6%)	
Penetrating	808 (30.1%)	63 (27.4%)	
Mechanism of Injury [a]			<0.0001
Fall	557 (20.7%)	45 (19.6%)	
Traffic	1034 (38.5%)	114 (49.6%)	
Gunshot Wound	389 (14.5%)	44 (19.1%)	
Stab Wound	280 (10.4%)	16 (7.0%)	
Other	424(15.8%)	11 (4.8%)	
Transfusion in first 24 h [a]	379 (21.4%)	140 (90.3%)	<0.0001

Numbers in table are median (25th, 75th percentiles) or frequency (percent). Group comparisons by Wilcoxon rank sum or chi-square tests.

[a] Missing data for: mechanism of injury (n = 2); transfusion in first 24 h (n = 992).

[b] Type of injury: 33 burns, 33 other type, and 11 unknown type of injury excluded (TRISS applies to blunt and penetrating trauma).

Table 2

Trauma measures by in-hospital mortality (n = 2916).

	Survived (n = 2686)	Died (n = 230)	p-value
ASA PS	2 (2, 3)	5 (4, 5)	<0.0001
1	521 (19.4%)	3 (1.3%)	<0.0001
2	1097 (40.8%)	12 (5.2%)	
3	577 (21.5%)	16 (7.0%)	
4	368 (13.7%)	77 (33.5%)	
5	123 (4.6%)	122 (53.0%)	
Injury Severity Score (ISS) [a]	9 (4, 17)	33 (26, 45)	<0.0001
Glasgow Coma Scale (GCS) [a]	15 (15, 15)	6 (3,14)	<0.0001
Initial HR [a]	90 (77, 103)	90 (60, 110)	0.08
<76	595 (22.1%)	85 (37.0%)	<0.0001
76–88	693 (25.8%)	290 (12.6%)	
89–103	728 (27.1%)	41 (17.8%)	
≥104	670 (24.9%)	75 (32.6%)	
Initial RR [a]	18 (16, 20)	18 (12, 22)	0.04
<16	374 (13.9%)	91 (39.6%)	<0.0001
16–17	672 (25.0%)	20 (8.7%)	
18–19	727 (27.1%)	20 (8.7%)	
≥20	913 (34.0%)	99 (43.0%)	
Revised Trauma Score (RTS) [a]	7.84 (7.84, 7.84)	5.03 (3.36, 7.55)	<0.0001
Trauma Score-Injury Severity Score (TRISS) [a]	0.990 (0.968, 0.994)	0.509 (0.107, 0.847)	<0.0001

Numbers in table are median (25th, 75th percentiles) or frequency (percent). Group comparisons by Wilcoxon rank sum or chi-square tests.

[a]Of 3042 subjects, 2916 had ASA PS in range of 1–5 and complete data on trauma measures. Missing data were: Injury Severity Score (n = 13); Glasgow Coma Scale (n = 28); initial HR (n = 5); initial RR (n = 2), Revised Trauma Score (n = 30); Trauma Score-Injury Severity Score (n = 119).

Table 3

In-hospital mortality area under the ROC (AROC) comparisons (n = 2916) [a].

Measure	OR (95% CI) [b]	AROC (95% CI)	p-value for AROC difference from ASA PS AROC
ASA PS (per unit)	4.53 (3.81, 5.39)	0.886 (0.864, 0.908)	––
Respiratory Rate [c]		0.712 (0.679, 0.744)	<0.0001
<16	1.0		
16–17	0.14 (0.09, 0.23)		
18–19	0.13 (0.08, 0.21)		
≥20	0.41 (0.30, 0.57)		
Heart Rate [c]		0.628 (0.593, 0.666)	<0.0001
<76	1.0		
76–88	0.28 (0.18, 0.44)		
89–103	0.39 (0.26, 0.57)		
≥104	0.68 (0.48, 0.95)		
ISS (per unit)	1.12 (1.11, 1.13)	0.896 (0.876, 0.916)	0.46
GCS (per unit)	0.73 (0.70, 0.75)	0.861 (0.833, 0.888)	0.13
RTS (per unit)	0.42 (0.38, 0.46)	0.845 (0.815, 0.875)	0.02
TRISS (per 0.10 units)	0.54 (0.50, 0.57)	0.938 (0.921, 0.954)	<0.0001

[a] Includes n = 230 (8%) dead, n = 2686 (92%) survived.

[b] All associations likelihood ratio p-value <0.0001.

[c] Respiratory rate and heart rate modeled as quartiles.

Table 4

In-hospital Mortality Area under the ROC (AROC) Comparisons: Added contribution of ASA PS to ISS, RTS, and TRISS (n = 2916).

Measure	OR (95% CI)	OR p-value	AROC (95% CI)	p-value for added contribution of ASA PS
ASA PS alone	4.53 (3.81, 5.39	<0.0001	0.886 (0.864, 0.908)	––
ISS alone	1.12 (1.11, 1.13)	<0.0001	0.896 (0.876, 0.916)	––
ISS plus ASA PS			0.931 (0.916, 0.947)	<0.0001
ISS	1.09 (1.07, 1.10)	<0.0001		
ASA PS	2.97 (2.46, 3.59)	<0.0001		
RTS alone	0.42 (0.38, 0.46)	<0.0001	0.845 (0.815, 0.875)	––
RTS plus ASA PS			0.926 (0.909, 0.943)	<0.0001
RTS	0.57 (0.51, 0.63)	<0.0001		
ASA PS	3.08 (2.56, 3.72)	<0.0001		
TRISS alone	0.54 (0.50, 0.57)	<0.0001	0.938 (0.921, 0.954)	––
TRISS plus ASA PS			0.946 (0.930, 0.961)	0.18
TRISS	0.63 (0.59, 0.67)	<0.0001		
ASA PS	2.81 (2.32, 3.41)	<0.0001		

Includes n = 230 (8%) dead, n = 2686 (92%) survived.

Table 5

Associations with hospital LOS.

Single Measures			Measures Modeled with ASA PS		
Measure	**RR (95% CI)**	**p-value**	**Measure**	**RR (95% CI)**	**p-value**
ASA PS	1.63 (1.57, 1.69)	<0.0001			
Respiratory Rate			Respiratory Rate		
<16	1.0 (referent)	<0.0001	<16	1.0 (referent)	<0.0001
16–17	0.87 (0.77, 0.98)		16–17	0.92 (0.83, 1.03)	
18–19	0.81 (0.72, 0.91)		18–19	0.89 (0.80, 0.99)	
≥20	1.15 (1.03, 1.29)		≥20	1.09 (0.98, 1.20)	
			ASA PS	1.61 (1.55, 1.67)	<0.0001
Heart Rate			Heart Rate		
<76	1.0 (referent)	<0.0001	<76	1.0 (referent)	<0.0001
76–88	0.82 (074, 0.90)		76–88	0.92 (0.84, 1.01)	
89–103	0.84 (0.76, 0.93)		89–103	0.91 (0.83, 1.00)	
≥104	1.40 (1.26, 1.55)		≥104	1.25 (1.14, 1.37)	
			ASA PS	1.59 (1.53, 1.64)	<0.0001
ISS	1.95 (1.87, 2.04)	<0.0001	ISS	1.68 (1.61, 1.75)	<0.0001
			ASA PS	1.33 (1.28, 1.38)	<0.0001
GCS	0.68 (0.65, 0.71)	<0.0001	GCS	0.78 (0.75, 0.82)	<0.0001
			ASA PS	1.50 (1.45, 1.56)	<0.0001
RTS	0.62 (0.58, 0.65)	<0.0001	RTS	0.75 (0.71, 0.79)	<0.0001
			ASA PS	1.51 (1.45, 1.57)	<0.0001
TRISS	0.55 (0.51, 0.59)	<0.0001	TRISS	0.69 (0.65, 0.74)	<0.0001
			ASA PS	1.51 (1.45, 1.57)	<0.0001

Associations tested by mixed effects negative binomial regression (random intercept for site), among survivors (n = 2682).

RRs represent the ratio of mean LOS per SD of the independent variable (ASA PS SD = 1.19; ISS SD = 12.7; GCS SD = 3.35; RTS SD = 1.32; TRISS SD = 0.20).

RRs<1 indicate the mean LOS is reduced with higher levels of the independent variable; RRs>1 indicate the mean LOS is increased with higher levels of the independent variable.

All associations are adjusted for hospital site, age, and gender.

Table 6

Associations with ICU LOS.

Single Measures			**Measures Modeled with ASA PS**		
Measure	**RR (95% CI)**	**p-value**	**Measure**	**RR (95% CI)**	**p-value**
ASA PS	2.56 (2.34, 2.81)	<0.0001			
Respiratory Rate			Respiratory Rate		
<16	1.0 (referent)	<0.0001	<16	1.0 (referent)	<0.0001
16–17	0.60 (0.45, 0.80)		16–17	0.75 (0.58, 0.98)	
18–19	0.59 (0.44, 0.79)		18–19	0.67 (0.52, 0.87)	
≥20	1.12 (0.85, 1.47)		≥20	1.07 (0.83, 1.36)	
			ASA PS	2.49 (2.27, 2.72)	<0.0001
Heart Rate			Heart Rate		
<76	1.0 (referent)	<0.0001	<76	1.0 (referent)	<0.0001
76–88	0.49 (0.38, 0.63)		76–88	0.60 (0.48, 0.76)	
89–103	0.55 (0.43, 0.70)		89–103	0.62 (0.50, 0.78)	
≥104	1.44 (1.12, 1.85)		≥104	1.22 (0.98, 1.53)	
			ASA PS	2.41 (2.20, 2.63)	<0.0001
ISS	4.44 (3.96, 4.87)	<0.0001	ISS	3.32 (2.98, 3.69)	<0.0001
			ASA PS	1.80 (1.67, 1.95)	<0.0001
GCS	0.51 (0.46, 0.57)	<0.0001	GCS	0.63 (0.57, 0.69)	<0.0001
			ASA PS	2.27 (2.08, 2.49)	<0.0001
RTS	0.43 (0.37, 0.50)	<0.0001	RTS	0.57 (0.50, 0.65)	<0.0001
			ASA PS	2.27 (2.08, 2.49)	<0.0001
TRISS	0.24 (0.18, 0.31)	<0.0001	TRISS	0.38 (0.31, 0.47)	<0.0001
			ASA PS	2.22 (2.03, 2.42)	<0.0001

Associations tested by mixed effects negative binomial regression (random intercept for site), among survivors (n = 2686).

RRs represent the ratio of mean LOS per SD of the independent variable (ASA PS SD = 1.19; ISS SD = 12.7; GCS SD = 3.35; RTS SD = 1.32; TRISS SD = 0.20).

RRs<1 indicate the mean LOS is reduced with higher levels of the independent variable; RRs>1 indicate the mean LOS is increased with higher levels of the independent variable.

All associations are adjusted for hospital site, age, and gender.

Table 7

Associations with mechanical ventilation days.

Single Measures			Measures Modeled with ASA PS		
Measure	**RR (95% CI)**	**p-value**	**Measure**	**RR (95% CI)**	**p-value**
ASA PS	2.70 (2.30, 3.18)	<0.0001			
Respiratory Rate			Respiratory Rate		
<16	1.0 (referent)	<0.0001	<16	1.0 (referent)	0.0005
16–17	0.57 (0.36, 0.91)		16–17	0.68 (0.44, 1.05)	
18–19	0.57 (0.35, 0.92)		18–19	0.56 (0.35, 0.89)	
≥20	1.38 (0.89, 2.15)		≥20	1.14 (0.75, 1.71)	
			ASA PS	2.55 (2.18, 2.99)	<0.0001
Heart Rate			Heart Rate		
<76	1.0 (referent)	<0.0001	<76	1.0 (referent)	<0.0001
76–88	0.40 (0.27, 0.60)		76–88	0.38 (0.26, 0.55)	
89–103	0.48 (0.32, 0.73)		89–103	0.45 (0.31, 0.67)	
≥104	1.60 (1.07, 2.40)		≥104	1.15 (0.79, 1.68)	
			ASA PS	2.65 (2.24, 3.12)	<0.0001
ISS	5.03 (4.15, 6.10)	<0.0001	ISS	4.20 (3.53, 5.01)	<0.0001
			ASA PS	2.23 (1.95, 2.55)	<0.0001
GCS	0.48 (0.41, 0.56)	<0.0001	GCS	0.56 (0.49, 0.65)	<0.0001
			ASA PS	2.37 (2.02, 2.77)	<0.0001
RTS	0.30 (0.24, 0.39)	<0.0001	RTS	0.40 (0.32, 0.49)	<0.0001
			ASA PS	2.31 (1.97, 2.71)	<0.0001
TRISS	0.22 (0.15, 0.33)	<0.0001	TRISS	0.30 (0.21, 0.42)	<0.0001
			ASA PS	2.47 (2.11, 2.89)	<0.0001

Associations tested by mixed effects negative binomial regression (random intercept for site), among survivors (n = 2686).

RRs represent the ratio of mean LOS per SD of the independent variable (ASA PS SD = 1.19; ISS SD = 12.7; GCS SD = 3.35; RTS SD = 1.32; TRISS SD = 0.20).

RRs<1 indicate the mean LOS is reduced with higher levels of the independent variable; RRs>1 indicate the mean LOS is increased with higher levels of the independent variable.

All associations are adjusted for hospital site, age, and gender.

Table 8

Associations with number of complications.

Single Measures			Measures Modeled with ASA PS		
Measure	**RR (95% CI)**	**p-value**	**Measure**	**RR (95% CI)**	**p-value**
ASA PS	1.97 (1.78, 2.17)	<0.0001			
Respiratory Rate			Respiratory Rate		
<16	1.0 (referent)	<0.0001	<16	1.0 (referent)	0.003
16–17	0.67 (0.48, 0.92)		16–17	0.75 (0.55, 1.02)	
18–19	0.59 (0.43, 0.81)		18–19	0.61 (0.45, 0.83)	
≥20	1.01 (0.76, 1.35)		≥20	0.93 (0.71, 1.22)	
			ASA PS	1.94 (1.76, 2.13)	<0.0001
Heart Rate			Heart Rate		
<76	1.0 (referent)	<0.0001	<76	1.0 (referent)	<0.0001
76–88	0.61 (0.45, 0.82)		76–88	0.68 (0.51, 0.90)	
89–103	0.70 (0.53, 0.94)		89–103	0.72 (0.55, 0.96)	
≥104	1.55 (1.18, 2.03)		≥104	1.27 (0.98, 1.64)	
			ASA PS	1.87 (1.70, 2.07)	<0.0001
ISS	2.46 (2.20, 2.75)	<0.0001	ISS	2.04 (1.83, 2.38)	<0.0001
			ASA PS	1.56 (1.41, 1.71)	<0.0001
GCS	0.58 (0.52, 0.64)	<0.0001	GCS	0.69 (0.62, 0.76)	<0.0001
			ASA PS	1.73 (1.56, 1.91)	<0.0001
RTS	0.50 (0.44, 0.57)	<0.0001	RTS	0.62 (0.55, 0.70)	<0.0001
			ASA PS	1.72 (1.56, 1.90)	<0.0001
TRISS	0.46 (0.40, 0.54)	<0.0001	TRISS	0.60 (0.52, 0.69)	<0.0001
			ASA PS	1.73 (1.57, 1.91)	<0.0001

Associations tested by mixed effects negative binomial regression (random intercept for site), among survivors (n = 2686).

RRs represent the ratio of mean LOS per SD of the independent variable (ASA PS SD = 1.19; ISS SD = 12.7; GCS SD = 3.35; RTS SD = 1.32; TRISS SD = 0.20).

RRs<1 indicate the mean LOS is reduced with higher levels of the independent variable; RRs>1 indicate the mean LOS is increased with higher levels of the independent variable.

All associations are adjusted for hospital site, age, and gender.