

ASA Physical Status Classification Improves Predictive Ability of a Validated Trauma Risk Score

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Abstract

Introduction: The Score for Trauma Triage in the Geriatric and Middle-Aged (STTGMA) is a validated mortality risk score that evaluates 4 major physiologic criteria: age, comorbidities, vital signs, and anatomic injuries. The aim of this study was to investigate whether the addition of ASA physical status classification system to the STTGMA tool would improve risk stratification of a middle-aged and elderly trauma population. **Methods:** A total of 1332 patients aged 55 years and older who sustained a hip fracture through a low-energy mechanism between October 2014 and February 2020 were included. The STTGMA and STTGMAASA mortality risk scores were calculated. The ability of the models to predict inpatient mortality was compared using area under the receiver operating characteristic curves (AUROCs) by DeLong's test. Patients were stratified into minimal, low, moderate, and high risk cohorts based on their risk scores. Comparative analyses between risk score stratification distribution of mortality, complications, length of stay, ICU admission, and readmission were performed using Fisher's exact test. Total cost of admission was fitted by univariate linear regression with STTGMA and STTGMAASA. **Results:** There were 27 inpatient mortalities (2.0%). When STTGMA was used, the AUROC was 0.742. When STTGMAASA was used, the AUROC was 0.823. DeLong's test resulted in significant difference in predictive capacity for inpatient mortality between STTGMA and STTGMAASA ($p = 0.04$). Risk score stratification yielded significantly different distribution of all outcomes between risk cohorts ($p < 0.01$). STTGMAASA stratification produced a larger percentage of all negative outcomes with increasing risk cohort. Total hospital cost was statistically correlated with both STTGMAASA ($p < 0.01$) and STTGMA ($p = 0.02$). **Conclusion:** Including ASA physical status as a variable in STTGMA improves the model's ability to predict inpatient mortality and risk stratify middle-aged and geriatric hip fracture patients.

Keywords

trauma surgery, geriatric trauma, economics of medicine, systems of care, geriatric medicine

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Introduction

With average life expectancy increasing and our population continuing to age, the incidence of hip fractures in the United States is expected to reach between 500,000 and 1 million annually by 2050.¹ Due to the significant morbidity and mortality associated with these injuries, some have labeled its increasing occurrence a major public health problem.² Additionally, hip fractures carry a significant economic burden secondary to the long hospital stays and subsequent months of rehabilitation often required.³ In the United States, hip fractures are estimated to cost the healthcare system between \$10.3 and \$15.2 billion annually.⁴ With healthcare costs increasing,

more cost-effective strategies for managing patients with hip fractures are sought.

The ASA physical status (ASA-PS) classification system categorizes a patient's physiological status immediately prior

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to surgery.⁵ Recent studies have shown ASA-PS is also a good predictor of inpatient mortality in the trauma population.^{6,7} In the orthopedic trauma population, several studies have demonstrated ASA-PS predicts readmissions, length of stay, and hospital costs.⁸⁻¹⁰ The ASA-PS system assigns patients a score from ASA 1 to ASA 6 based on the presence and severity of disease. In order to determine the score, clinicians take into account clinical factors including medical comorbidities, recent trauma, obesity, smoking status, alcohol use and whether the operation is required for survival.⁵ Critics argue that ASA-PS scores are inconsistently assigned between clinicians, but a recent study demonstrated strong inter-rater reliability in orthopedic trauma patients.¹¹

The Score for Trauma Triage in the Geriatric and Middle-Aged (STTGMA) is also a risk assessment tool, validated to predict inpatient mortality risk in orthopedic trauma patients 55 years and older.¹² The STTGMA tool calculates a mortality risk score using clinical data available when the patient first presents including the patient's age, comorbidities, injury severity, and Glasgow Coma Scale (GCS).¹² Given the success of STTGMA and ASA-PS in predicting patient outcomes, we are interested in whether including ASA-PS as a variable in the STTGMA score improves the model's ability to predict inpatient mortality, complications and cost in patients who sustained a hip fracture. Secondarily, we will assess how STTGMA compares to ASA-PS in predicting these outcomes.

Materials and Methods

Patient Characteristics

An Institutional Review Board approved geriatric trauma database was queried for any patient aged 55 and older who sustained a hip fracture through a low-energy mechanism of injury (defined as a fall from standing or from less than 2 stairs). Additional inclusion criteria for study analysis was assignment of an ASA-PS score and presence of an intertrochanteric, femoral neck, or subtrochanteric hip fractures [OTA/AO fracture classification 31A, 31B, and 32(A-C)]. Patients presenting with periprosthetic fractures were excluded from analysis. Between October 2014 and February 2020, all patients from 1 of 4 hospitals within a single academic medical center were analyzed.

Information regarding baseline demographics, injury status at presentation, and index hospitalization was retrospectively reviewed through electronic medical records. All patients who met inclusion criteria were included in the final study analysis. Demographic variables collected included patient sex, age, race, preinjury ambulatory status, comorbidities as measured by the Charlson Comorbidity Index without age adjustment (CCI), and ASA-PS score. Injury status comprised of the GCS and Abbreviated Injury Severity score for the head and neck (AIS-HN), chest (AIS-C), and pelvis and extremity (AIS-EXT). Aside from sex, race, AIS-EXT, and ASA-PS score these variables comprise the low-energy STTGMA score.

Hospital quality measure such as length of stay (LOS), LOS longer than the median 6-day LOS, need for intensive care unit (ICU), and discharge location were reviewed. Minor complications reviewed during index hospitalization included acute renal failure, acute kidney injury, surgical site infection, decubitus ulcer, urinary tract infection, acute anemia. Major complications reviewed during index hospitalization included sepsis, pneumonia, acute respiratory failure, myocardial infarction, cardiac arrest, stroke, deep vein thrombus, and pulmonary embolism. Cost data was obtained for 1 of the 4 hospitals involved in the study. After index hospitalization, patients were followed for mortality and readmission at 30 and 90 days after discharge.

Statistical Analysis

A modified STTGMA and ASA-PS inpatient mortality risk score (STTGMA_{ASA}) was created through a logistic regression analysis with inpatient mortality as the dependent variable and independent variables including the components of the original STTGMA score (age, GCS, AIS-HN, AIS-C, CCI, and ambulatory status) with the addition of ASA-PS. For comparison, additional inpatient mortality risk scores were created including a recalculation of original STTGMA coefficients for the hip fracture patients in this study (STTGMA_{Hip}) and inpatient mortality risk based on ASA-PS alone. The scores were created using all 1332 hip fracture patients meeting inclusion criteria by adding ASA-PS as an independent variable in addition to the components of the original STTGMA score in a logistic regression of inpatient mortality. Receiver operating characteristic (ROC) curves were constructed for each risk score's ability to predict inpatient mortality. The area under the receiver operating characteristic curve (AUROC) was calculated for all risk scores. ROC curves were compared using DeLong's test for correlated ROC with the alternative hypothesis that including more independent variables in the logistic regression or recalculating logistic regression coefficients on the current dataset would result in a greater AUROC for STTGMA_{ASA} relative to other risk scores evaluated in this study.¹³

Patients were stratified into risk cohorts based on their risk scores using quantiles. The cohorts comprised risk scores from the 0-50% quantile as minimal risk, 50-80% as low risk, 80-95% as moderate risk, and 95-100% as high risk. Comparative analyses between risk score stratifications were performed using Fisher's exact test. Least squares univariate linear regressions were performed with total cost of admission as dependent variable and STTGMA or STTGMA_{ASA} as independent variables. Statistical analyses were performed using R software version 4.02¹⁴ and the pROC package for R.¹⁵

Results

Between October 2014 and February 2020, 1332 patients ages 55 and older who sustained non-periprosthetic hip fractures [OTA/AO 31A, 31B, 32(A-C)] through low-energy mechanisms were enrolled in an orthopedic trauma database.

Table 1. Demographics.

	Overall (N = 1332)
Sex	
Male	385 (28.9%)
Female	947 (71.1%)
Age	80.95 (80.40, 81.50)
GCS	14.89 (14.86, 14.92)
CCI	1.51 (1.41, 1.60)
AIS H/N	0.04 (0.03, 0.06)
AIS C	0.02 (0.01, 0.03)
Ambulatory status	
Community ambulator	961 (72.1%)
Household ambulator	330 (24.8%)
Nonambulatory	41 (3.1%)
Fracture classification	
31A	684 (51.4%)
31B	544 (40.8%)
32A	60 (4.5%)
32B	4 (0.3%)
32C	40 (3.0%)
Treatment	
CRPP	108 (8.1%)
Hemiarthroplasty	300 (22.5%)
Long IMN	187 (14.0%)
Nonoperative	2 (0.2%)
Plating	31 (2.3%)
Short IMN	550 (41.3%)
Sliding hip screw	79 (5.9%)
Total hip arthroplasty	74 (5.6%)
Transferred	1 (0.1%)

Population characteristics that comprise the STTGMA score, as well as fracture pattern and treatment method demonstrate 71.1% female sex, mean age of 81.0 (95% CI = 80.4-81.5), mean GCS of 14.89 (95% CI = 14.86-14.92), mean CCI of 1.51 (95% CI = 1.41-1.60), mean AIS H/N of 0.04 (95% CI = 0.03-0.06), mean AIS C of 0.02 (95% CI = 0.01-0.03). Ambulatory status among subjects is split between 72.1% community ambulators, 24.8% household ambulators, and 3.1% non-ambulatory. OTA Hip fracture classification among subjects was distributed as follows: 51.3% 31A, 40.9% 31B, 4.5% 32A, 0.3% 32B, and 3.0% 32C. For treatment, 41.3% of subjects were repaired with a short intramedullary nail (IMN), 14% were repaired with a long IMN, 22.5% underwent hemiarthroplasty, 5.6% underwent total hip arthroplasty, 8.1% were repaired with closed reduction and percutaneous pinning (CRPP), 5.9% were repaired with a sliding hip screw, 2.3% were repaired with plate and screw fixation. 2 patients were managed non-operatively and 1 patient was transferred to another facility for management (Table 1).

The ROC curves for the 4 risk scores are presented in Figure 1. The AUROC for STTGMA_{ASA} is 0.823 (95% CI = 0.750-0.896). The AUROC for STTGMA is 0.742 (95% CI = 0.651-0.832). The AUROC for STTGMA_{Hip} is 0.745 (95% CI = 0.663-0.827). The AUROC for risk score generated from ASA-PS alone is 0.781 (95% CI = 0.700-0.861). ROC analysis of the 4 risk scores determined significantly larger

AUROC for STTGMA_{ASA} compared to all other risk scores with p values of 0.04, 0.04, and <0.01 when comparing STTGMA_{ASA} respectively to STTGMA, STTGMA_{Hip}, and risk score generated from ASA-PS alone (Table 2).

Stratification by STTGMA_{ASA} or STTGMA resulted in a different distribution of inpatient mortality, 30-day mortality, 1-year mortality, minor complications, major complications, ICU admissions, LOS longer than 6 days (the median length of stay), discharge home, 30-day readmission, and 90-day readmission among risk cohorts (p < 0.01 for all variables). Of note, while STTGMA_{ASA} stratification (Table 3) produced a larger percentage of all negative outcomes with increasing risk cohort, STTGMA stratification (Table 4) saw a larger percentage of minor complications among the low risk cohort compared to the moderate risk cohort.

Univariate linear regression of total hospital cost as a function of risk score demonstrated statistical correlation between total hospital cost with both STTGMA_{ASA} (p < 0.01) (Figure 2) and STTGMA (p = 0.02) (Figure 3). Both fits produced a high percentage of variance in total hospital cost that was not due to STTGMA_{ASA} (R² = 0.03) or STTGMA (R² < 0.01) but demonstrated positive correlation with the respective risk score.

Discussion

In this study, we assessed whether revising a validated inpatient mortality risk predictor tool improved its ability to predict patient outcomes. Since ASA-PS has proven capable of predicting a range of patient outcomes, we were interested to see if including ASA-PS as a variable in the STTGMA model improved the model's predictive ability. The new model, STTGMA_{ASA}, was compared against the original STTGMA model, a STTGMA model specific for hip fractures, and ASA-PS. It is important to note that STTGMA and ASA-PS have a few inherent differences. The STTGMA score represents an inpatient mortality risk percentage, while ASA-PS is an ordinal score from 1 to 6 representing a patient's pre-operative health status. Furthermore, the STTGMA score is calculated by a mathematical model, while ASA-PS is assigned by clinicians based on their determination of the patient's disease severity. The scores are similar in that they account for both acute and chronic health status.

STTGMA was originally developed as an inpatient mortality risk predictor for middle-aged and geriatric orthopedic trauma patients.¹² Since its development, STTGMA has also demonstrated the ability predict several other clinical outcomes, quality measures, and hospital costs for a range of orthopedic injuries including hip fractures, femur fractures, ankle fractures, and tibia fractures.¹⁶⁻²⁰ ASA-PS has shown similar predictive ability in orthopedic trauma patients. Several studies have shown higher ASA-PS scores correlated with increased mortality, complications, readmissions, and inpatient costs.⁶⁻¹⁰ Given these findings, we hypothesized including ASA-PS in STTGMA would improve the model and make it more accurate than either ASA-PS or STTGMA alone.

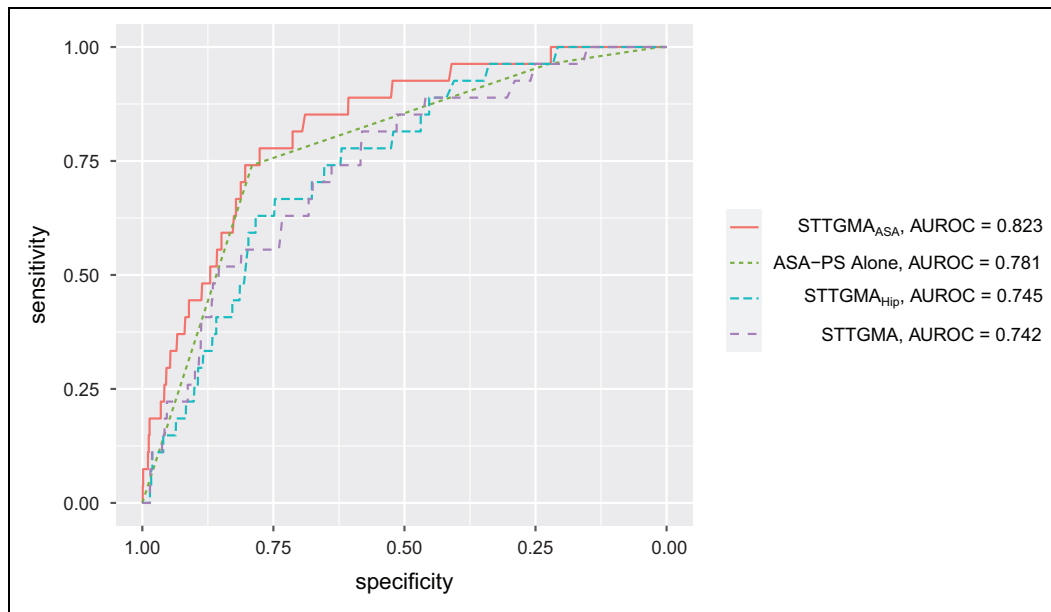


Figure 1. ROC curves generated from STTGMA_{ASA}, ASA-PS alone, STTGMA_{Hip}, and STTGMA risk scores with the area under each receiver operator curve (AUROC).

Table 2. Area Under the Receiver Operator Curve (AUROC) for Risk Scores and Comparison to STTGMA_{ASA} by DeLong's Test.

Risk Score	AUROC (95% CI)	p-value from DeLong's test compared to STTGMA _{ASA}
STTGMA _{ASA}	0.823 (0.750, 0.896)	
ASA-PS alone	0.781 (0.700, 0.861)	<0.01
STTGMA _{Hip}	0.745 (0.663, 0.827)	0.04
STTGMA	0.742 (0.651, 0.832)	0.04

Table 3. Outcomes stratified by STTGMA_{ASA} risk cohorts representing the 0-50th quantile, 50-80th quantile, 80-95th quantile, and 95-100th quantile. Note: 115 patients did not have 30 day mortality data recorded and 316 patients did not have 1 year mortality data recorded.

	Minimal Risk Cohort STTGMA _{ASA} : 0-0.8% (N = 666)	Low Risk Cohort STTGMA _{ASA} : 0.8-3.4% (N = 399)	Moderate Risk Cohort STTGMA _{ASA} : 3.4-8.2% (N = 201)	High Risk Cohort STTGMA _{ASA} : 9.0-100% (N = 66)	Total (N = 1332)	p value
Inpatient mortality	2 (0.3%)	6 (1.5%)	12 (6.0%)	7 (10.6%)	27 (2.0%)	< 0.01
30 day mortality	16 (2.7%)	14 (3.8%)	19 (10.2%)	8 (12.7%)	57 (4.7%)	< 0.01
1 year mortality	19 (3.9%)	34 (11.0%)	36 (22.8%)	22 (38.6%)	111 (10.9%)	< 0.01
Minor complications	255 (38.3%)	179 (44.9%)	104 (51.7%)	42 (63.6%)	580 (43.5%)	< 0.01
Major complications	42 (6.3%)	42 (10.5%)	51 (25.4%)	27 (40.9%)	162 (12.2%)	< 0.01
Need for ICU	48 (7.2%)	49 (12.3%)	58 (28.9%)	22 (33.3%)	177 (13.3%)	< 0.01
LOS over 6 days	223 (33.5%)	162 (40.6%)	118 (58.7%)	43 (65.2%)	546 (41.0%)	< 0.01
Discharge home	188 (28.2%)	44 (11.0%)	13 (6.5%)	3 (4.5%)	248 (18.6%)	< 0.01
30 day readmission	36 (5.4%)	33 (8.4%)	26 (13.8%)	12 (20.3%)	107 (8.2%)	< 0.01
90 day readmission	69 (10.4%)	63 (16.0%)	39 (20.6%)	20 (33.9%)	191 (14.6%)	< 0.01

As healthcare costs in the United States continue to rise, predictive risk tools are essential to providing high value care. There are a variety of clinical scenarios where predictive tools can impact the care a patient receives. For example, patients

predicted to have poor outcomes can trigger early palliative consultations to identify goals of care, which may reduce the use of expensive end of life care not aligned with the patient's wishes.¹² On the other hand, lower risk patients can be triaged

Table 4. Outcomes stratified by STTGMA risk cohorts representing the 0-50th quantile, 50-80th quantile, 80-95th quantile, and 95-100th quantile. Note: 115 patients did not have 30 day mortality data recorded and 316 patients did not have 1 year mortality data recorded.

	Minimal Risk Cohort STTGMA: 0-0.3% (N = 667)	Low Risk Cohort STTGMA: 0.3-1.5% (N = 398)	Moderate Risk Cohort STTGMA: 1.5-5.4% (N = 200)	High Risk Cohort STTGMA: 5.4-100% (N = 67)	Total (N = 1332)	p value
Inpatient mortality	4 (0.6%)	8 (2.0%)	9 (4.5%)	6 (9.0%)	27 (2.0%)	< 0.01
30 day mortality	17 (2.8%)	17 (4.7%)	15 (8.0%)	8 (12.9%)	57 (4.7%)	< 0.01
1 year mortality	25 (5.0%)	32 (10.4%)	38 (24.7%)	16 (30.8%)	111 (10.9%)	< 0.01
Minor complications	256 (38.4%)	198 (49.7%)	89 (44.5%)	37 (55.2%)	580 (43.5%)	< 0.01
Major complications	47 (7.0%)	54 (13.6%)	43 (21.5%)	18 (26.9%)	162 (12.2%)	< 0.01
Need for ICU	59 (8.8%)	63 (15.8%)	38 (19.0%)	17 (25.4%)	177 (13.3%)	< 0.01
LOS over 6 days	221 (33.1%)	178 (44.7%)	106 (53.0%)	41 (61.2%)	546 (41.0%)	< 0.01
Discharge home	177 (26.5%)	44 (11.1%)	21 (10.5%)	6 (9.0%)	248 (18.6%)	< 0.01
30 day readmission	39 (5.9%)	30 (7.7%)	27 (14.1%)	11 (18.0%)	107 (8.2%)	< 0.01
90 day readmission	64 (9.7%)	63 (16.2%)	45 (23.6%)	19 (31.1%)	191 (14.6%)	< 0.01

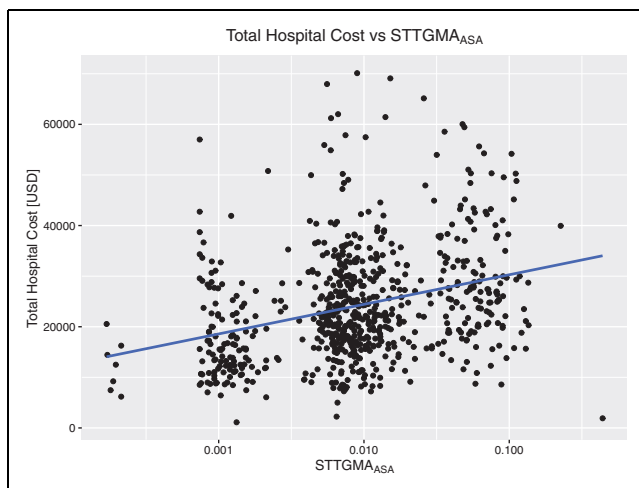


Figure 2. Total hospital cost vs STTGMA_{ASA} linear fit where Total Cost = 61,170 × STTGMA_{ASA} + 22,848. STTGMA_{ASA} coefficient p-value < 0.01, R² = 0.03.

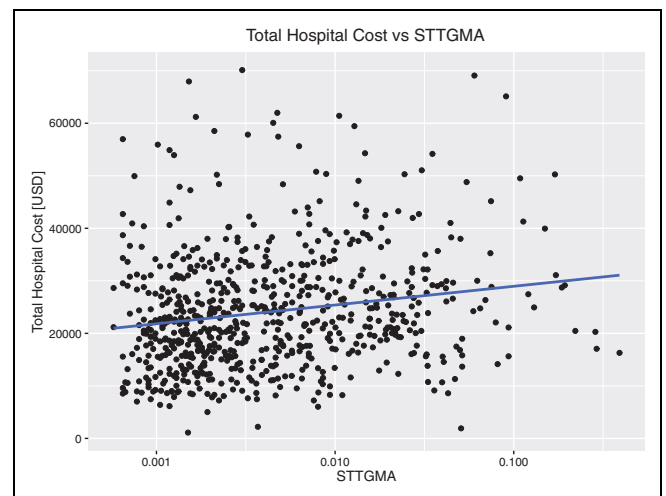


Figure 3. Total hospital cost vs STTGMA with linear fit where Total Cost = 32,995 × STTGMA + 23,676. STTGMA coefficient p-value = 0.02, R² < 0.01.

to cost-effective standardized care pathways specific to their injury. In addition, STTGMA’s ability to predict discharge locations allows providers to make discharge plans early in the admission and minimize unnecessary days in the hospital.¹⁶

Previous studies have also attempted to modify the STTGMA model to address specific clinical questions. In one study, Konda et al²¹ explored whether including additional “frailty” variables in the STTGMA model improved its inpatient mortality risk stratification. The new model, STTGMA_{Frailty}, accounted for additional “frailty variables” such as albumin level, baseline ambulatory status, and whether the patient used an assistive device for ambulation. The authors found that the STTGMA_{Frailty} was not superior to the original STTGMA model in predicting inpatient mortality. In a study prompted by the COVID-19 pandemic, Konda et al²² developed a new STTGMA model that incorporated a patient’s COVID-19 status.

While the original STTGMA struggled to predict outcomes in COVID-19 patients, the STTGMA_{COVID} model was able to accurately predict the increased morbidity and mortality seen in COVID-19 positive hip fracture patients. Ultimately, this study showed STTGMA is a malleable tool that can be adapted to specific clinical scenarios.

The new STTGMA_{ASA} model developed in this study is superior to the original STTGMA model at predicting inpatient mortality, as evidenced by the significant difference in AUROC between the 2 models (0.823 vs. 0.742, p = 0.04). Furthermore, STTGMA_{ASA} was significantly better than STTGMA_{Hip} and ASA-PS alone at predicting inpatient mortality. We were also interested in determining if the STTGMA_{ASA} can accurately stratify patients into minimal, low, moderate, and high-risk groups to predict their likelihood of various clinical outcomes and quality measures. Risk

groups can be used to triage patients to standardized care pathways. STTGMA care pathways have not yet been implemented in hospital systems but have the potential to improve the model further.

We found that using these risk stratification groups, STTGMA_{ASA} was able to predict short and long-term mortality, minor and major complications, the need for ICU, length of stay, discharge location, and readmissions. When comparing STTGMA_{ASA} to STTGMA, STTGMA_{ASA} was able to stratify more patients to the high risk cohort for 1 year mortality (38.6% vs. 30.8%), minor complications (63.6% vs. 55.2%), major complications (40.9% vs. 26.9%), and the need for ICU (33.3% vs. 25.4%). There were also subtle differences noted with the new model's ability to stratify patients to the high risk group for inpatient mortality, LOS, discharge location, and 30 and 90 day readmissions. These risk groups give providers an objective way to determine the level of care required for a patient aiding resource allocation. More specifically, risk stratification could inform providers to triage high-risk group patients to the ICU earlier in their admission to provide higher level of care to improve clinical outcomes. Conversely, patients in low risk groups can be placed in less resource intensive areas of the hospital to avoid overutilization and provide more cost-effective care.

The STTGMA_{ASA} model was significantly correlated with total hospital costs related to a patient's admission. Previous studies have demonstrated the largest cost drivers in geriatric orthopedic trauma population are room/board, procedures, and radiology costs.²³ Providers may minimize unnecessary tests and procedures unlikely to have an impact on patient outcomes by knowing which patients are prone to more costly admissions. For example, many providers order daily blood counts for patients even though this practice is unlikely to provide benefit to clinically stable patients.²⁴ Additionally, clinicians can reduce costs by focusing on early discharge planning for low risk patients to minimize room/board costs when they no longer require inpatient care.

One of the main useful features of the original STTGMA model is the ability to calculate STTGMA score upon hospital admission, as it is intended to inform treatment decisions at first presentation to the Emergency Department (ED). Calculating the STTGMA score requires providers to know the patient's age, GCS, mechanism of injury, injury severity, comorbidities, baseline functional status, anticoagulation status, and albumin level. These variables can be determined quickly through a history, physical exam, basic imaging, and routine bloodwork. On the other hand, ASA-PS is not available until determined by the anesthesiologist before a patient undergoes surgery. Therefore, ASA-PS is not available when the STTGMA score is calculated in the ED. Orthopedic providers will need to be trained to assign ASA-PS to use ASA-PS as a STTGMA variable. It is currently unclear if orthopedic providers can accurately determine ASA-PS when trauma patients first present to the ED. If this became standard practice, STTGMA_{ASA} has the potential to be used as a tool to determine if a patient can be discharged from the ED and receive surgery

on an outpatient basis. ASA-PS alone does not sufficiently select orthopedic patients who can safely undergo outpatient surgery, so it would be useful to determine if STTGMA_{ASA} would be superior in this respect^{25,26}

Another application of STTGMA_{ASA} would be the ability to update the risk score throughout the admission as more data becomes available. The original STTGMA score could be converted to STTGMA_{ASA} when ASA-PS is assigned. There are less barriers to implementation since orthopedic providers would not assign ASA-PS classification system, but it would be less useful for patients who never undergo surgery or undergo surgery several days into their hospital stay.

This study has several limitations. First, the study had a relatively small sample size. Since inpatient mortality is a rare event, only 27 (2%) of the 1332 patients in our cohort died during their admission. Larger sample sizes are needed to further support the model's ability to predict this outcome. Next, the STTGMA_{ASA} scores in this study were calculated retrospectively. To ensure clinical utility, it must be proven that STTGMA_{ASA} scores can be calculated prospectively with similar fidelity. Lastly, this study was conducted at large urban academic medical centers, so its findings may not be generalizable to patient populations in other practice settings.

In conclusion, this study suggests that including ASA-PS as a variable in STTGMA improves the model's ability to predict inpatient mortality and risk stratify middle-aged and geriatric hip fracture patients. Future studies are needed to determine whether orthopedic providers can accurately determine ASA-PS at time of admission before this new model can be considered a feasible option in the clinical setting. Additionally, future studies should explore whether STTGMA_{ASA} maintains its predictive ability for other orthopedic injuries outside of hip fractures

Authors' Note

Dr. Sanjit Konda and Dr. Kenneth Egol are co-inventors of the Personacare software that is owned by NYU. The Personacare software may use the algorithm developed by this research.



Declaration of Conflicting Interests

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