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# Predictors of in-hospital mortality and length of stay after severe traumatic brain injury: conventional regression versus machine learning-based analyses

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SCHOOL OF MEDICINE  
DEPARTMENT OF NEUROLOGICAL SURGERY

## INTRODUCTION

- Severe traumatic brain injury [sTBI, defined as Glasgow coma scale (GCS)  $\leq$  8] is a catastrophic form of TBI associated with high rates of mortality and morbidity
- Outcome prediction after sTBI is critical for clinical decision making and the realistic assessment of quality of care

## OBJECTIVE

To compare conventional statistical techniques including univariate correlation and multiple linear regression analyses and machine learning (ML)- based random forest model to identify predictors of hospital mortality and length of stay (LOS) in sTBI patients' cohort at an American College of Surgery (ACS)-verified level I trauma center

## MATERIALS AND METHODS

- Retrospective chart review of all patients (including both adult and pediatric) with sTBI (GCS  $\leq$  8) admitted between 2015-2018 (n = 168)
- Conventional univariate (Pearson's correlation coefficient, r) and multiple linear regression analyses were performed to determine the predictors of mortality and hospital LOS
- For random forest predictive modeling, 14 variables for mortality and 12 variables for LOS were evaluated as potential splitters at each node in the random forest model. The variable importance (in predicting mortality or LOS) was measured based on the Gini impurity index (mean decrease Gini/IncNodePurity)
- The Receiving Operating Characteristic (ROC) curve was used as a metric to measure random forest model's predictive performance

## RESULTS

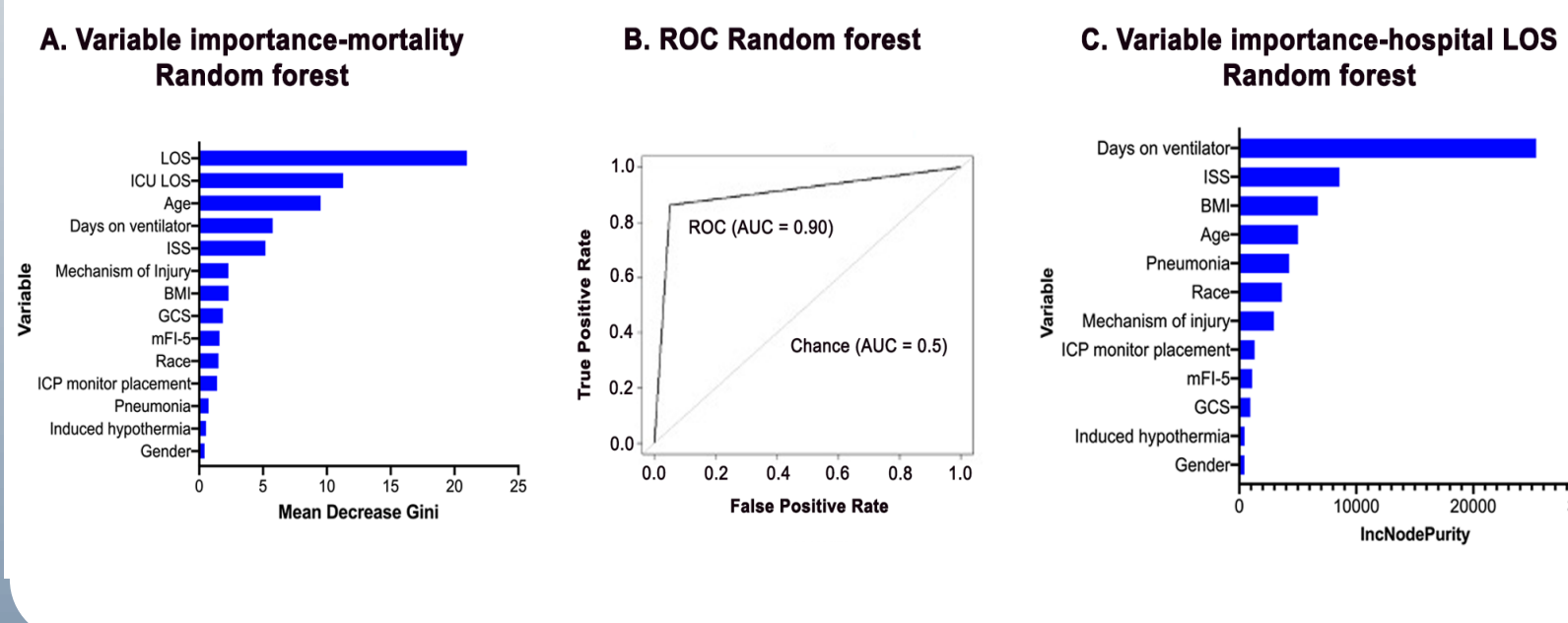
### 1. Study sample characteristics

Variable	Cohort (n = 168)
Age, yrs	39.7 (21.3-60.8)
M/F, n (%)	127 (75.5)/41 (24.5)
Race, n (%)	
Caucasian	117 (69.6)
Hispanic	31 (18.45)
Asian	4 (2.4)
Black	16 (9.5)
BMI, kg/m <sup>2</sup>	25 (22-28)
Insurance, n (%)	
Medicare	16 (9.5)
Medicaid	38 (22.6)
Private	102 (60.7)
Uninsured	9 (5.3)
Functionally dependent at baseline, n (%)	4 (2.4)
Mechanism of injury	
Motor vehicle	56 (33.3)
Motorcycle	14 (8.3)
Bicycle	6 (3.6)
Pedestrian	18 (10.7)
Fall	47 (28)
Suicide/self-harm/GSW	10 (6)
Assault	9 (5.4)
Other	3 (1.8)
Unknown	5 (3)
mFI-5	0.527 (0.070)
mFI-5-age (0-40 yrs)	0.224 (0.060)
mFI-5-age (41-50 yrs)	0.428 (0.202)
mFI-5-age (51-60 yrs)	0.667 (0.199)
mFI-5-age (61-70 yrs)	0.875 (0.256)
mFI-5-age (71-80 yrs)	1.778 (0.552)
mFI-5-age (> 80 yrs)	1.583 (0.287)
LOS (days)	10 (2-25)
ICU LOS (days)	6.5 (1-19)
Days on ventilator (days)	4 (1-14)
ICP monitor, n (%)	51 (30.9)
None	114 (69)
EVD	13 (7.8)
Licox	21 (12.7)
Both	17 (10.3)
ISS	27 (22-35)
Induced hypothermia, n (%)	39 (23.2)
Pneumonia, n (%)	53 (31.5)
Disposition, n (%)	
Died	68 (40.5)
Discharged Home	17 (10)
Discharged subacute/SNF	5 (3)
Rehab	75 (44.6)
Other	3 (1.8)

### 2. Comparison of survivors versus non-survivors after severe TBI

Variable	Survivors (n = 100)	Non-survivors (n = 68)	p-value
Age, yrs	29.7 (18.6-50.6)	57.7 (31.5-76.3)	< 0.0001†
M/F, n (%)	74 (74)/26 (26)	53 (78)/15 (22)	0.769
Race, n (%)			
Caucasian	66 (66)	51 (75)	0.213
Hispanic	23 (23)	8 (11.8)	0.065
Asian	2 (2)	2 (3)	0.694
Black	11 (11)	7 (10.3)	0.884
BMI, kg/m <sup>2</sup>	25 (23-28)	25 (21.75-28.25)	0.770
Mechanism of injury			
Motor vehicle	37 (37)	19 (27.9)	0.221
Motorcycle	10 (10)	4 (5.9)	0.343
Bicycle	4 (4)	2 (2.9)	0.716
Pedestrian	9 (9)	9 (13.2)	0.383
Fall	23 (23)	24 (35.3)	0.081
Suicide/self-harm/GSW	2 (2)	8 (11.8)	0.008†
Assault	8 (8)	1 (1.5)	0.065
Other	2 (2)	1 (1.5)	0.799
Unknown	5 (5)	0 (0)	--
mFI-5	0.45 (0.079)	0.641 (0.128)	0.183
LOS (days)	19 (12-27)	2 (1-5)	< 0.0001†
ICU LOS (days)	15.5 (6-23.5)	1 (1-4.75)	< 0.0001†
Days on ventilator (days)	10.5 (2-17.5)	2 (1-4.75)	< 0.0001†
ICP monitor, n (%)	36 (36)	15 (23)	0.079
None	64 (64)	50 (76.9)	0.079
EVD	6 (6)	7 (10.8)	0.266
Licox	18 (18)	3 (4.6)	0.011†
Both	12 (12)	5 (7.7)	0.373
ISS	26 (20-34)	31.5 (25-38)	0.048†
Induced hypothermia, n (%)	29 (29)	10 (14.7)	0.031†
Pneumonia, n (%)	42 (42)	11 (16.2)	0.0004†

### 5. Predictors of mortality and LOS based on random forest machine learning-based model.



## SUMMARY & CONCLUSIONS

- The age at presentation, mFI-5 frailty score, ISS, GCS, LOS, ICU LOS, days on ventilator, ICP monitoring, induced hypothermia, and diagnosis of pneumonia were identified as predictors of mortality after sTBI. The predictors of LOS included age at presentation, BMI, mechanism of injury, days on ventilator, ICP monitoring, induced hypothermia, and diagnosis of pneumonia
- Both conventional statistical methods and ML-based random forest modeling found similar predictors of mortality and LOS after sTBI
- ML-based random forest model was found to have high predictive performance for mortality after sTBI, achieving 90% accuracy based on ROC curve

### 3. Univariate and multiple regression analyses to evaluate predictors of mortality among various independent variables in our severe TBI study cohort

Predictors	Univariate analysis		Multiple linear regression			
	Pearson's r	p-value	Unstandardized	Standardized	t-value	p-value
Age	0.360	<0.001†	0.001	0.053	1.517	0.132
Gender	-0.045	0.562	-0.007	-0.006	-0.219	0.827
BMI	-0.052	0.522	-8.393e-4	-0.010	-0.307	0.759
Race	-0.029	0.711	0.005	0.009	0.323	0.747
Mechanism of injury	0.046	0.551	-0.008	-0.042	-1.279	0.203
mFI-5	0.104	0.183	0.036	0.071	2.141	0.034†
GCS	-0.202	0.009†	-0.003	-0.009	-0.296	0.768
ISS	0.162	0.036†	0.004	0.110	3.589	<0.001†
LOS	-0.504	<0.001†	-0.003	-0.117	-1.799	0.074
ICU LOS	-0.503	<0.001†	0.002	0.069	0.903	0.368
Days on ventilator	-0.446	<0.001†	5.546e-5	0.001	0.024	0.981
ICP monitor placement	-0.163	0.037†	0.016	0.036	0.522	0.602
Induced hypothermia	-0.166	0.031†	0.026	0.024	0.346	0.730
Pneumonia	-0.273	<0.001†	0.008	0.008	0.247	0.805

### 4. Univariate and multiple regression analyses to evaluate predictors of LOS among various independent variables in our severe TBI study cohort

Predictors	Univariate analysis		Multiple linear regression			
	Pearson's r	p-value	Unstandardized	Standardized	t-value	p-value
Age	0.143	0.065	0.022	0.025	0.538	0.591
Gender	-0.081	0.299	1.073	0.021	0.544	0.587
BMI	0.221	0.006†	-0.082	-0.021	-0.490	0.625
Race	0.110	0.157	-0.106	-0.004	-0.121	0.904
Mechanism of injury	-0.161	0.038†	0.652	0.075	1.736	0.085
mFI-5	-0.067	0.392	-0.752	-0.032	-0.718	0.474
GCS	0.019	0.811	0.015	0.001	0.029	0.977
ISS	0.120	0.124	0.057	0.030	0.720	0.473
Days on ventilator	0.702	<0.001†	-0.060	-0.026	-0.434	0.665
ICP monitor placement	0.193	0.014†	-1.213	-0.060	-0.655	0.513
Induced hypothermia	0.206	0.008†	1.706	0.034	0.371	0.711
Pneumonia	0.395	<0.001†	1.453	0.032	0.742	0.459