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The use of distributed random forest model to quantify risk predictors for tracheostomy requirements in septic patients

A retrospective cohort study

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Abstract

The search for early clinical risk factors in the intensive care setting may improve the outcome of critically ill patients. The objective of this retrospective study is to identify and quantify early predictors for patients who would require tracheostomy. Five hundred and forty four septic patients were divided in 2 groups: non-tracheostomized (NT) (n = 484) and tracheostomized (T) (n = 60). The patients consisted of 241 males (49.8%) in NT and 27 (45%) in T group, respectively ($P = .4971$). The median and interquartile range difference of age of NT group was of 72 years [59–82] and T of 75 [55.0–83.5] ($P = .4687$). The SAPS 3 for the group NTxT was 70 [55–85] and 85.5 [77–91] ($P = .0001$), the SOFA of 9 [6–13] and 12 [10–14] ($P = .0002$). The comparison of logistic regression analysis for predictors of non-tracheostomy and tracheostomy groups showed an adjusted odds ratio (OR) for SAPS 3 range between 74 and 87 of 18.14 (95%CI = 3.36–97.84) and between 88 and 116 of 27.77 (95%CI = 4.43–174.24) ($P < .05$). For SOFA, the adjusted OR between 10 and 13 was 12.23 (95%CI = 2.46–60.81) and between 14 and 20 was 8.45 (95%CI = 1.58–45.29) ($P < .05$). The need for blood transfusions and dialysis presented an OR of 2.74 (95%CI = 1.23–6.08) and 3.33 (95%CI = 1.43–7.73) ($P < .05$), respectively. Our data shows that SAPS 3 ≥ 74, SOFA ≥ 11, blood transfusions and the need for dialysis were independently associated and could be considered major predictors for tracheostomy requirements in septic patients.

Abbreviations: CAP = community-acquired pneumonia, CCI = Charlson comorbidity index, COPD = chronic obstructive pulmonary disease, HAP = hospital-acquired pneumonia, ICUs = intensive care units, LOS = length of stay, SAPS 3 = simplified acute physiology score, SOFA = sequential organ failure assessment, VAP = ventilator-associated pneumonia.

Keywords: ICU setting, SAPS 3, sepsis, SOFA, tracheostomy

1. Introduction

Tracheostomy is one of the most frequent procedures performed in an intensive care unit (ICU). More than 100,000 tracheostomies are carried out annually in the US.[1] About 10% of critically ill patients who require mechanical ventilation have a tracheostomy performed.[2,3] Because of its use, the patient can be transferred from ICU to wards or long-term ventilation facilities. The use of a tracheostomy for providing a safe airway route for ventilation is an everyday reality, especially for ventilator-dependent patients. Indeed, the procedure of this technique in the operating room or at ICU bedside has become easily feasible over time.[4] The placement of a tracheostomy has become a viable alternative to prolonged endotracheal intubation, with the benefits of improving patient comfort, aspiration of lung secretions, reduced sedation, decrease airway resistance, allowing easier care, and maintenance of the airways.[5] However, some issues remain unclear in the literature involving tracheostomy, makes it appropriate to the study of the clinical risk factors that lead to this procedure.[6,7] In various clinical situations such as neurological patients,[8,9] or elderly patients[10] some factors have been described, and therefore it could be considered common, but there is a possibility that there are other variables that can be classified as risk factors associated with a tracheostomy.

Despite the routine use of tracheostomy, there is a lack of data concerning the risk factors for these procedures in septic patients

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Data available on request from the authors. The data that support the findings of this study are available from the first author AB-F upon reasonable request.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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requiring tracheostomy. The objective of this retrospective study is to identify and quantify early predictors for septic patients who would require tracheostomy.

2. Methods

2.1. Study design and setting

This retrospective study was carried out in the Intensive Care Unit of San Francisco Hospital, São Paulo, Brazil. This tertiary ICU admits critically ill adults such as clinical cases or surgical patients. The study protocol was approved by the Research Ethics Committee of the Clinics Hospital of Ribeirão Preto Medical School, University of São Paulo (7076/2016 Protocol).

2.2. Patients and collected variables

Adult septic patients divided into 2 groups: non-tracheostomized and tracheostomized were analyzed between 2016 and 2018. All tracheostomies were performed exclusively in the operating room. The indications and timing of tracheostomy were made based upon literature protocols.[5] The diagnosis of sepsis was based on an international consensus definition of sepsis/septic shock (Sepsis-3).[11–13] The diagnostic criteria employed for community-acquired pneumonia (CAP), hospital-acquired pneumonia (HAP), and ventilator-associated pneumonia (VAP) were established by international guidelines.[14] All data were collected for the calculation of prognostic indices and physiological variables during the first 24 hours after the patients admission. Therefore, diagnostic data on arrival at ICU, comorbidities, and clinical characteristics have been documented. Clinical and physiological variables, as well as the Simplified Acute Physiology Score (SAPS 3),[15] Sequential [Sepsis-Related] Organ Failure Assessment (SOFA),[16] and Charlson Comorbidity Index (CCI)[17] were recorded. The SAPS 3 and SOFA calibration in this study was built to improve the performance of the scores, and it was based upon the comparison between predicted probabilities and observed results, which are the basis of Hosmer-Lemeshow goodness of fit test for logistic regression.

2.3. Statistical analysis

Comparisons of demographic and clinical data of the patients (non-tracheostomized and tracheostomized) were carried out using the test for two independent samples (rank-sum) of Mann–Whitney for quantitative variables and Fisher exact test for qualitative variables. All variables were presented as median and interquartile range or as the number (percentage) in tables.

In the present study, classification rules for the data set were based on conditional inference trees and logistic regression analysis. The primary purpose of the conditional inference trees is to determine a set of logical splits conditions that permit accurate prediction of classification of patients into groups with or without tracheostomy.[18] In these analyses, it was considered the following quantitative predictors: age, ICU length of stay, SAPS 3, SOFA, Chronic obstructive pulmonary disease (COPD), and hypotension. Also, it was also included the following categorical predictors: gender, ICU outcome, in-hospital outcome, diabetes, vasopressors 1st-hour admission, total use of vasopressors, blood transfusion, need of dialysis, community-acquired pneumonia (CAP) + hospital-acquired pneumonia (HAP), and ventilator-associated pneumonia (VAP). Models based on conditional inference trees can split the continuous values according to optimal cutoff points that best classify patients into the different groups. The model based on conditional inference trees was implemented in R using the package partykit.[19] A Distributed Random Forest (DRF) algorithm was performed to quantify the importance of each predictor in the classification. Random forests are ensembles of trees based on bootstrap sampling with replacement of the data to train a tree and determine the called "out of bag error" on the data, but not in this sample. Seventy percent of data was used for training, and 30% for validation. Considering that there is a different number of patients with or without tracheostomy in the data set, the algorithm oversampled the minority class (without tracheostomy) to balance the class distribution. The h2o.randomForest function of the R package H2O was used to fit the DRF algorithm to the data set. This package is able to perform machine learning and data analysis using a simple open-source framework.[20] Alternatively, a logistic regression model with variable selection based on lasso (least absolute shrinkage and selection operator) method was used to obtain a subset of relevant predictors to classify into patients with or without tracheostomy.[21] This model was fitted to data using the function glmnet of the R software.

Data comparison of SAPS 3, SOFA, CCI of non-tracheostomized (NT), and tracheostomized (T) patients were analyzed through the median and interquartile range. The ability of each prognostic index SAPS 3, SOFA, and CCI to predict mortality was analyzed by ROC curve (receiving operating characteristics curve) approach. The area under the ROC curve (AUC) and the confidence interval (95% CI) were used as a measure of the overall accuracy of the index. The non-parametric comparison between these curves was tested, as proposed by DeLong et al.[22] To estimate and interpret survival and/or risk functions of survival versus time data was held on a Kaplan–Meier curve for the 2 groups of patients (non-tracheostomized and tracheostomized). The nonparametric test of Gehan-Wilcoxon was used to compare these 2 survival curves. The level of significance for the statistical tests was set at $P < .05$. All statistical analyses were performed using MedCalc v.14 (Ostend, Belgium) and R software v. 3.5.0 (The R Foundation for Statistical Computing, Vienna, Austria).

3. Results

Five hundred and forty four patients were retrospectively studied that meet the criteria for the study (diagnosis of sepsis) among 2877 patients admitted to the ICU in the period analyzed. The groups of non-tracheostomized (n = 484) and tracheostomized (n = 60) consisted of 241 males (49.8%)/243 females and 27 males (45%)/33 females, respectively ($P = .4971$). The tracheostomy was performed at median day 9, interquartile range [7–12] after ICU admission. The median and interquartile range difference of age (in years) of NT group was of 72 [55–85] and T of 75 [55.0–83.5] ($P = .4687$). The Charlson Comorbidity Index (CCI) for the Group NTxT was 2 [1–3] and 2 [1–3] ($P = .4894$), the SAPS 3 was 70 [55–85] and 85.5 [77–91] ($P = .0001$), the SOFA of 9 [6–13] and 12 [9–17] ($P = .0002$). The ICU length of stay (ICU LOS) was to NT = 4 [2–8] and T = 12 [9–17]; the Hospital LOS, NT = 12 [6–22] and T = 28.0 [17–35.7] and mechanical ventilation days NT = 5 [2–9] and T = 11 [8.5–16] were all significantly greater for the group T, with values of $P < .0001$. The ICU and Hospital mortality of patients was similar in both groups (non-tracheostomy and tracheostomy). A plausible explanation for this is that mortality was related to the time course of disease (sepsis) and not to the procedure (tracheostomy) per se. The demographic characteristics

Table 1

Demographic and clinical characteristics of non-tracheostomized and tracheostomized septic patients admitted to an adult ICU.

Patients n = 544	Non-Tracheostomized n = 484 (89%)	Tracheostomized n = 60 (11%)	*P* value
Gender M(%)/F	241 (49.8)/243	27 (45.0)/33	.4971
Age (years)	72[59–82]*	75.0[55.0–83.5]	.4687
Charlson Comorbidity Index (CCI)	2[1–3]	2[1–3]	.4894
SAPS 3	70[55–85]	85.5[77–91]	.0001
SOFA	9[6–13]	12[10–14]	.0002
ICU Length of stay (days)	4[2–8]	12[9–17]	<.0001
Hospital Length of stay (days)	12[6–22]	28[17–35.7]	<.0001
Mechanical Ventilation (days)	5[2–9]	11[8.5–16]	<.0001
ICU mortality (%)	42.8	40.0	.7821
In-Hospital mortality (%)	48.7	56.6	.2748

* Results expressed as median[interquartile range].

and remaining clinical characteristics are listed in Table 1. The main clinical condition that led to sepsis was pulmonary infection (community and hospital-acquired pneumonia) prior ICU admission present at 39.3% of non-tracheostomized and 43.3% of tracheostomized patients ($P = .578$). The remaining diagnoses for both groups, corresponding to the criteria for case-mix admission in the ICU included major clinical or surgical system disorders such as thoracic, gastrointestinal, urologic cardiovascular, vascular and, to a lesser extent metabolic, oncologic, hematologic and, neurologic. In Table 2 are listed the clinical variables of the patients of both groups in the first 24 hours of admission and the corresponding *P* values.

The Hosmer-Lemeshow test for SAPS 3, SOFA, and CCI showed a level of $P = .6445$, .7708, and .0867, respectively. This result confirmed a proper calibration and an acceptable discriminatory power for both models. In the general population of the study (n = 544), the AUC and 95%CI for SAPS 3, SOFA, and CCI were 0.756 (0.718–0.792), 0.774 (0.736–0.808), and 0.582 (0.539–0.624), respectively (Figure 1). The pairwise comparison of ROC curves among the different prognostic indexes (SAPS 3, SOFA) did not show statistical significance. However, the comparison of these indexes with CCI was statistically significant ($P < .001$). The ROC curves and the values for AUC (95%CI) for the different prognostic indexes are depicted in Figure 1.

The comparison of the 2 survival curves, the Gehan-Wilcoxon test was performed to determine the occurrence of differences in the distribution of survival for both types of patients (non-tracheostomized vs. tracheostomized). The distribution of survival time for these patients, considering the ICU LOS and hospital LOS, are statistically different ($P = .01$). The values (in days) of median and 95%CI for the ICU LOS were 8 (7–9) and 15 (13–20) for NT vs T. For the hospital LOS these values were 22 (19–27) and 31 (28–42) for the non-tracheostomized and tracheostomized septic patients, respectively (Fig. 2).

Table 3 shows the simple and multiple logistic regression analysis for predictors and their respective adjusted Odds ratio of non-tracheostomy and tracheostomy groups. SAPS 3 ≥ 74, SOFA ≥ 11, blood transfusions and dialysis showed significant associations ($P < .05$) and were independently associated and could be considered major predictors for tracheostomy in septic patients. The percentage comparison of different ranges for SAPS 3 and SOFA for non-tracheostomy and tracheostomy groups are demonstrated in Figure 3.

4. Discussion

In a time of escalating medical care costs against the scarceness of resources, cost-effective medical strategies to improve patient outcomes in the critical care unit setting are widely justified. The search for early clinical risk factors in the critically ill patients may identify patients who would benefit from interventions, e.g., tracheostomy, in order to reduce the duration of mechanical ventilation. This procedure has the potential advantage to promote the ability of ventilator-dependent patients to achieve spontaneous ventilation by different maneuvers, reduce dead-space, and to be more comfortable, allowing the patient to eat and speak with the

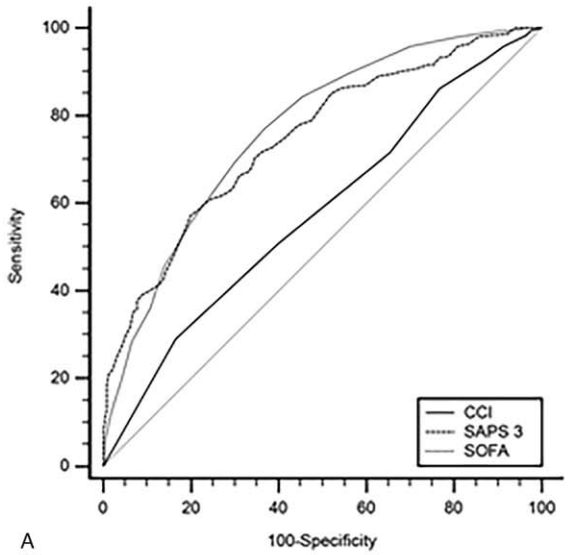
Table 2

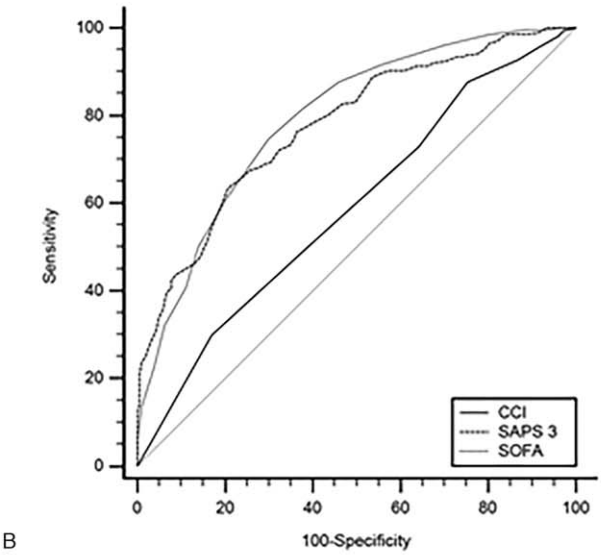
Parameters on admission to ICU of the general population, non-tracheostomized and tracheostomized septic patients.

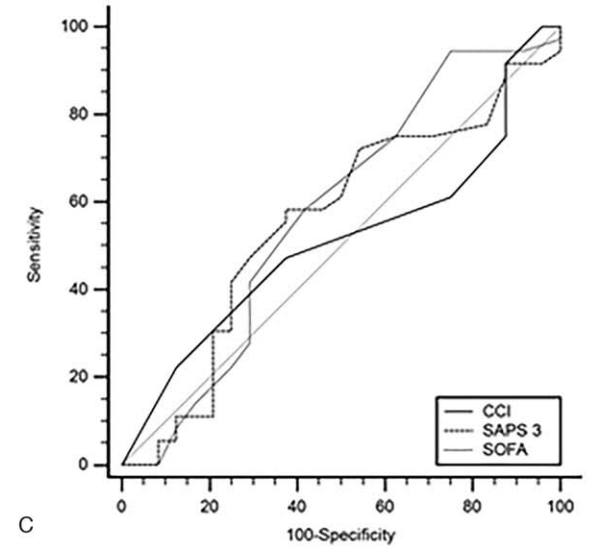
Parameters	Non-tracheostomized	Tracheostomized	*P* value
MAP (mmHg)	84.3[73.0–96.3]	82.8[70.5–96.7]	.6560
Leukocyte ($x10^3/\mu l$)	13.5[8.9–19.1]	13.1[10.0–18.4]	.8191
Platelets ($x10^3/\mu l$)	195[121–281]	245.5[174.5–316]	.0024
pH	7.34[7.29–7.40]	7.30[7.26–7.39]	.1352
PaO_2 (mm Hg)	88.5[71–136]	122.0[84.5–178.5.0]	.0001
$PaCO_2$ (mm Hg)	36[30–43]	39[33–47]	.0112
PaO_2/FiO_2 ratio	200[134–300]	179[111–260]	.1180
Lactate (mmol/L)	2.7[1.9–4.4]	2.95[2.0–4.0]	.9412
Bilirubin (mg/dl)	0.7[0.39–1.0]	0.48[0.3–1.0]	.0092
Urea (mg/dl)	70[43–117]	60.5[41.0–112.0]	.4371
Creatinine (mg/dl)	1.4[0.9–2.6]	1.4[0.9–2.3]	.8980

*Results expressed as median[interquartile range].

MAP = mean arterial pressure, PaO_2 = partial pressure of oxygen in arterial blood, $PaCO_2$ = partial pressure of carbon dioxide in arterial blood, FiO_2 = fraction of inspired oxygen.







Index	Overall (A) (n=544)		NT (B) (n=484)		T (C) (n=60)	
	AUC	95%CI	AUC	95% CI	AUC	95%CI
CCI	0.582	0.539-0.624	0.589	0.544-0.634	0.527	0.394-0.658
SAPS 3	0.756	0.718-0792	0.777	0.738-0.814	0.631	0.496-0.752
SOFA	0.774	0.736-0.808	0.793	0.754-0.828	0.650	0.516-0.769

Figure 1. Comparison of ROC curves of SAPS 3, SOFA, and Charlson Comorbidity Index (CCI) for overall (A), non-tracheostomized (B), and tracheostomized (C) septic patients and respective AUC and 95%CI values.

help of phonation valves, which in turn ameliorates patients psychological status and mobility.

Previous investigators have shown that mechanically ventilated patients receiving tracheostomy generally had a longer ICU and hospital LOS compared with patients who did not require tracheostomy.[23] Santana-Cabrera et al[7] studied the association between tracheostomy and outcomes in 448 tracheostomized patients. The authors concluded that tracheostomy performed in the ICU was associated with lower ICU mortality, but higher in-hospital rates. Conversely, in a retrospective study of 506 patients admitted to ICU requiring mechanical ventilation, Combes et al[24] observed that 166 of them (32.8%) were tracheostomized after a median of 12 days of mechanical ventilation. These authors verified that the non-tracheostomized patients had a higher ICU (42 vs 33%, $P = .06$) and in-hospital mortality (48 vs 37%, $P = .03$). Performing a tracheostomy was independently associated with a lower probability of ICU and in-hospital death (odds ratio = 0.58, 95% CI = 0.37–0.90), even after adjusting for other important prognostic factors. In addition, Frutos-Vivar et al,[6] in a prospective study of 361 ICUs in 12 countries of 5,081 patients mechanically ventilated for more than 12 hours, showed that 546 of these patients (10.7%) had tracheostomy during the ICU LOS. Tracheostomy was performed at a median time of 12 days (interquartile range 7–17), from the beginning of mechanical ventilation. The variables associated with the performance of tracheostomy were the duration of mechanical ventilation, need for reintubation, neurologic diseases as the primary reason for mechanical ventilation and difficult to wean from mechanical ventilation after the use of several techniques and attempts. Furthermore, these authors showed that ICU and Hospital LOS was higher for tracheostomized patients (21 vs 7 days and 36 vs 15 days, respectively). Tracheostomy was

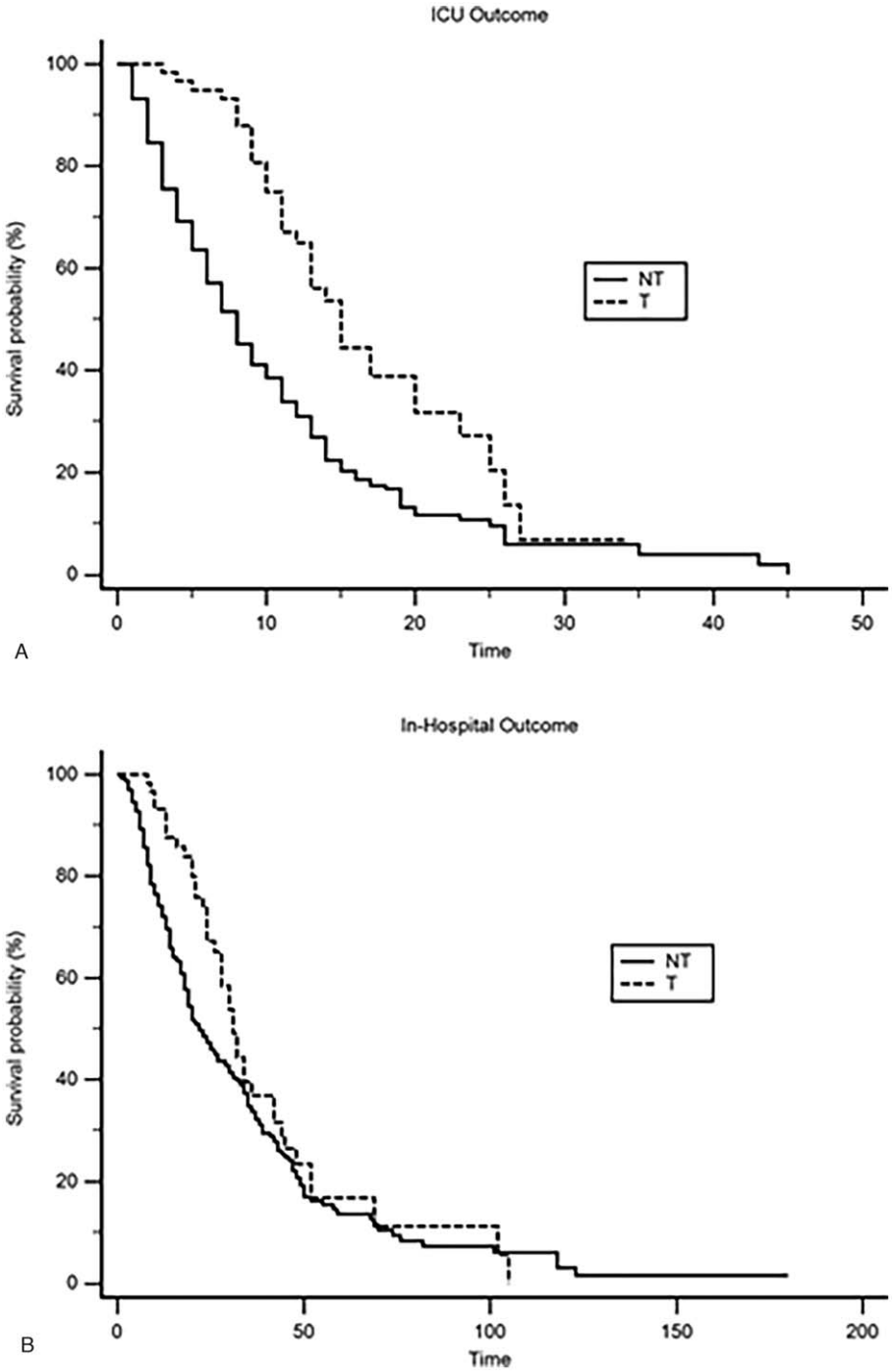


Figure 2. Survival curves for the ICU LOS (A) and in-Hospital LOS (B) for non-tracheostomized (NT) and tracheostomized (T) septic patients.

independently related to ICU survival (Odds ratio = 2.25, 95% CI = 1.72–2.86). ICU and in-hospital mortality were similar (NT = 40%, T = 39%).

Scores have been developed to predict whether the critically ill patient would require a tracheostomy. Szeder et al[25] identified in their TRACH score study the clinical and radiological predictors for tracheostomy in neurological mechanically ventilated patients with supratentorial intracerebral hemorrhage. This score employs the Glasgow outcome score and a radiological scale. According to the authors, this score was predictive of tracheostomy requirement with an AUC = 0.92. Moreover, the authors concluded that all patients with a TRACH score > 2.0 underwent a tracheostomy. Another score (SET score) has been recently validated. Schonenberger et al[26] in a single-center cohort of 71 patients after severe stroke found out predictors of tracheostomy need with a 64% of sensitivity and 86% of sensibility. However, these authors recommend the use of this score for tracheostomy combined with the judgment of experienced physicians. In a retrospective study of 345 consecutive patients with acute tetraplegia, Hou et al[27] applied a multiple logistic regression and a classification and

Table 3

Association between non-tracheostomy and tracheostomy variables (predictors). Crude and adjusted odds ratios (OR) obtained from simple and multiple logistic regression analysis, respectively.

		NT ($n=484$)	T ($n=60$)				
	Total %	%	%	Crude *OR*	95%CI	Adjusted *OR*	95%CI
Age (years)							
15–59	26.7	26.9	25.0	Ref.[§]		Ref.	
60–72	23.9	24.6	17.9	0.78	(0.33–1.82)	0.39	(0.14–1.14)
73–82	26.2	26.1	26.7	1.11	(0.51–2.38)	0.45	(0.17–1.21)
83–96	23.2	22.4	30.4	1.46	(0.69–3.10)	0.55	(0.20–1.50)
Gender							
Female	50.8	50.1	51.7	Ref.		Ref.	
Male	49.2	49.9	42.9	0.75	(0.43–1.32)	0.72	(0.38–1.37)
ICU Outcome							
0	42.5	42.9	39.3	Ref.		Ref.	
1	57.5	57.1	60.7	1.16	(0.66–2.04)	3.18	(1.39–7.30)*
In-Hospital Outcome							
0	49.4	48.7	55.4	Ref.		Ref.	
1	50.6	51.3	44.6	0.76	(0.44–1.33)	0.60	(0.27–1.33)
ICU LOS (days)							
0–5	52.5	52.8	7.1	Ref.		Ref.	
6–9	22.8	23.2	19.6	6.85	(2.14–21.97)	0.73	(0.15–3.47)
10–45	24.7	19.0	73.2	31.08	(10.84–89.13)	1.27	(0.23–6.93)
SAPS 3							
30–57.8	25.0	27.3	5.4	Ref.			
57.9–73	26.5	27.7	16.1	2.96	(0.78–11.16)	3.47	(0.64–18.84)
74–87	23.9	22.6	35.7	8.07	(2.34–27.89)*	18.14	(3.36–97.84)*
88–116	24.6	22.4	42.8	9.78	(2.87–33.35)*	27.77	(4.43–174.24)*
SOFA							
0–6	25.6	28.2	3.6	Ref.		Ref.	
7 –10	27.3	27.3	26.8	7.73	(1.73–34.43)*	4.64	(0.97–22.31)
11–13	22.8	20.7	41.1	15.64	(3.61–67.83)*	2.95	(2.46–60.81)*
14–20	24.3	23.8	28.5	9.46	(2.13–41.99)*	8.45	(1.58–45.29)*
COPD							
0	86.6	87.2	80.7	Ref.		Ref.	
1	13.4	12.8	19.3	1.62	(0.77–3.39)	1.87	(0.80–4.36)
Diabetes							
0	65.0	65.0	65.3	Ref.		Ref.	
1	35.0	35.0	34.7	0.98	(0.54–1.79)	1.14	(0.58–2.24)
Vasopressors							
0	42.9	45.3	21.4	Ref.		Ref.	
1	57.1	54.7	78.6	3.04	(1.57–5.90)*	0.97	(0.40–2.34)
Blood transfusion							
0	86.8	88.2	75.0	Ref.		Ref.	
1	13.2	11.8	25.0	2.49	(1.28–4.84)*	2.74	(1.23–6.08)*
Dialysis							
0	89.2	90.5	78.6	Ref.		Ref.	
1	10.8	9.5	21.4	2.59	(1.28–5.25)*	3.33	(1.43–7.73)*
MAP (mm Hg)							
27–73	27.2	26.9	30.4	Ref.		Ref.	
74–84	23.4	23.6	21.4	0.80	(0.37–1.76)	0.70	(0.28–1.75)
85–96	24.7	25.1	21.4	0.76	(0.35–1.65)	1.04	(0.43–2.51)
97–139	24.7	24.4	26.8	0.97	(0.46–2.03)	1.23	(0.51–2.98)
MV (days)**							
0–2	54.4	60.5	1.8	Ref.		Ref.	
3–7	21.2	21.5	17.9	28.08	(3.55–>100)	16.0	(1.68–>100)
8–45	24.5	18.0	80.4	151.03	(20.52–>100)	102.5	(8.73–>100)
CAP + HAP							
0	60.1	60.7	55.4	Ref.		Ref.	
1	39.9	39.3	43.3	1.24	(0.71–2.17)	1.48	(0.72–3.04)
VAP							
0	88.3	88.8	83.9	Ref.		Ref.	
1	11.7	11.2	16.1	1.52	(0.71–3.28)	1.27	(0.50–3.26)

* significant associations ($P<.05$); MAP = mean blood pressure.

** the range of the correspondent confidence intervals was very large due the small sample size observed in the reference class for the tracheotomized group (n = 1); LOS = length of stay; MV = mechanical ventilation; CAP = community-acquired pneumonia; HAP = hospital-acquired pneumonia; VAP = ventilator-associated pneumonia; 0 = False; 1 = True.

§ Ref. = reference category (OR = 1.0).

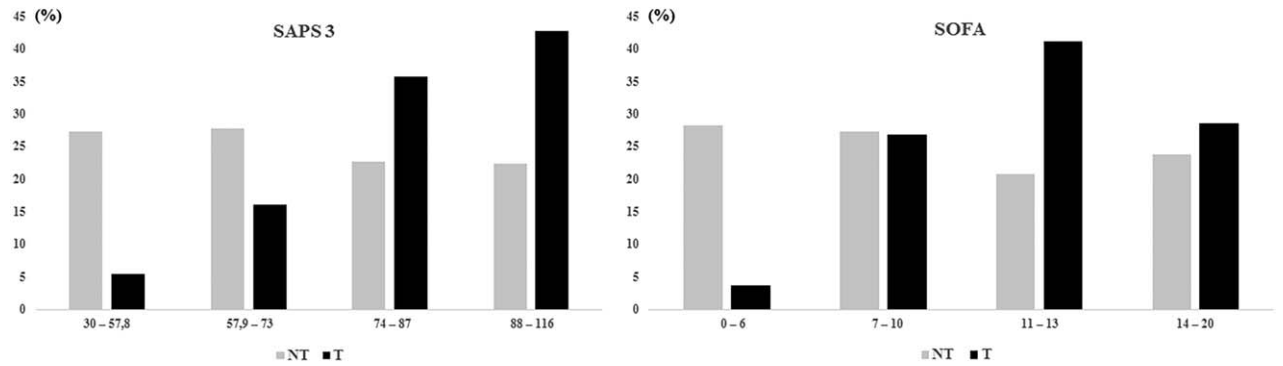


Figure 3. Comparison of different ranges of main tracheostomy predictors SAPS 3 and SOFA between non-tracheostomized (NT) and tracheostomized (T) septic patients. Percentage values are represented in Table 3.

regression tree model (CART) to explore predictors for tracheostomy. The CART model was based upon the American Spinal Injury Association (ASIA), and motor score designated as Admission Asia Motor Score (AAMS). These authors found that patients with AAMS $\leq$ 1 exhibit an increased likelihood of requiring tracheostomy. Thus, Lee et al[8] developed decision-making for tracheostomy in 105 patients following a traumatic cervical spinal cord injury (CSCI). A tracheostomy was performed in 20% of patients on a median hospital day 4. Patients who underwent tracheostomy tended to be more injured measured by Injury Severity Score (ISS) and Glasgow coma scale, which it seems to be obvious more frequent intubation in emergency room (ER). The multiple logistic regression showed that age $\geq$ 55 years, injury above C5, ISS $\geq$ 16, car accident, intubation in ER, and complete CSCI were independently associated with tracheostomy after CSCI. The authors also pointed out that these factors can predict whether a patient needs future tracheostomy with 91.4% of accuracy. Kollef et al[2] in order to identify clinical predictors for tracheostomy in a prospective study of 521 patients requiring mechanical ventilation in an ICU for more than 12 hours observed that the in-hospital mortality without tracheostomy was higher than those who received tracheostomy (26.4 vs 13.7%, $P = .048$). 9.8% of patients required tracheostomy in their population study. The days of mechanical ventilation, the ICU and hospital LOS were longer in patients with tracheostomy. Therefore, the logistic regression demonstrated that hospital-acquired pneumonia and reintubation were independent variables associated with patients undergoing tracheostomy and prolonged mechanical ventilation. Hence, Kabil et al[28] showed that the need of tracheostomy in mechanically ventilated COPD patients was related to an old age, high APACHE II score (acute physiology and chronic health evaluation) (>24.2), acidemia, and hypoalbuminemia on admission and, renal impairment (blood creatinine level > 1.4 mg/dl). Conversely, as shown previously in our study, pulmonary data such as CPOD, CAP, VAP, and blood gases analysis and mechanical ventilation parameters themselves were unable to detect which patients may benefit from tracheostomy. The primary data of our study compared the demographic and clinical characteristics of non-tracheostomized and tracheostomized septic patients. We have used a machine learning analysis procedure for distributed random forest model to estimate the odds ratio of tracheostomized patients while controlling variables. This approach allows us to identify variables for multivariate logistic regression analysis and quantify early risk predictors for tracheostomy requirements in septic patients. One should keep in mind that this data focused on search and quantification of risk predictors for tracheostomy requirements in septic patients, and therefore not specifically in sepsis outcome improvement. Although it seems axiomatic in prior observations that sicker patients with higher SAPS 3 and SOFA scores are more likely to require tracheostomy, our investigation is an attempt to quantify how sick a patient is to request a tracheostomy. For this reason, our data obtained by machine learning analysis showed that a score of SAPS 3 $\geq$ 74 and SOFA $\geq$ 11 after adjustment for characteristics of patients contribute to a strong likelihood that reinforces the prediction of tracheostomy requirements in septic patients.

This study has some limitations. It is a study carried out in a single-center, which limits the extent of the results to other populations and generalizations. Furthermore, the protocol design was observational and retrospective. However, through this study, we would like to deliver a message to anesthesiologists, intensivists, and surgeons, indicating the *importance* of *predictors in* estimating the tracheostomy requirements in septic patients.

5. Conclusions

The use of distributed random forest model to quantify risk predictors for non-tracheostomy and tracheostomy groups showed in the present study that SAPS 3, SOFA, blood transfusions, and dialysis were independently associated with tracheostomy and could be considered major risk predictors for tracheostomy requirements in septic patients.

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