neurocritical care society Neurocrit Care (2010) 13:40–46
DOI 10.1007/s12028-010-9346-1

ORIGINAL ARTICLE

The TRACH Score: Clinical and Radiological Predictors of Tracheostomy in Supratentorial Spontaneous Intracerebral Hemorrhage

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Published online: 15 April 2010
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Abstract
Background and Purpose Spontaneous intracerebral hemorrhage (sICH) continues to have high morbidity and mortality. Patients with sICH and poor mental status are at high risk of airway compromise and frequently require intubation. The traditional ventilatory weaning parameters are not reliable in patients with brain pathology. The objective of this study is to identify clinical and radiological predictors for tracheostomy in mechanically ventilated patients with sICH and to develop a scale that will accurately predict the need for tracheostomy in these patients.
Methods Only patients with supratentorial sICH intubated on the field or on admission who survived the first 3 days were included. Univariate and multivariate logistic regression analysis of clinical and radiological variables was performed, and independent predictors were identified. A risk stratification scale (TRACH Score) was developed using these independent predictors.
Results Several independent factors were associated with early tracheostomy. The signficant clinical predictor was Glasgow Coma Scale (GCS) score ($P < 0.003$). Radiological predictors were presence of hydrocephalus (OR: 12.5; $P < 0.002$), septum pellucidum shift (OR: 9; $P < 0.025$), and location of sICH in the thalamus (OR: 9; $P < 0.025$). The TRACH score was defined by two variables radiological scale (RScale) and Glasgow Outcome Score (GOS). TRACH score $= 3 + (1 \times \text{RScale}) - (0.5\times \text{GCS})$. The RScale (L + H + S) was obtained by adding individual points assigned according presence of: sICH location in the thalamus (L) 2 points, hydrocephalus (H) 1.5 points, septum pellucidum shift (S) 3 points. The scale was very predictive of tracheostomy needs (OR: 2.57, $P < 0.0001$) with an ROC = 0.92, sensitivity of 94%, positive predictive value of 83%, and negative predictive value of 95%.
Conclusions The TRACH Score is a practical clinical grading scale that will allow physicians to identify patients who will be needing tracheostomy. Application of this scale could have significant impact on length of stay and cost of hospitalization.

Keywords Intracerebral hemorrhage · Tracheostomy · Mechanically ventilated · Predictor · Outcome · Prognosis

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Introduction

Outcome of spontaneous intracerebral hemorrhage (sICH) patients remains grim especially in patients requiring mechanical ventilation [1–3]. Very often families of sICH patients will ask physicians to prognosticate about survival, independence, and need for prolonged ventilatory support. Although several prognostic models/scores were designed to predict favorable versus unfavorable outcome or death following sICH, none were designed to predict prolonged ventilatory and ultimately tracheostomy need [4–8].

A large proportion of sICH patients with poor mental status are at risk of airway compromise and require intubation and mechanical ventilation (MV) [3, 9]. Some will ultimately get extubated. The rest will require a tracheostomy. In general, tracheostomy is usually indicated after 14–21 days of MV not only to prevent complications of prolonged intubation such as vocal cord injury, tracheomalacia, and ventilator-associated pneumonia but also to facilitate discharge of the patient from the intensive care unit. Extubation delay is associated with increased morbidity, mortality, length of intensive care unit (ICU), and hospital stay and consequently increased hospital charges [10–12]. Therefore, an early predictive model to determine whether extubation or early tracheostomy should be considered could have a great clinical and financial impact.

The traditional respiratory weaning parameters are not reliable in brain injury patients [11, 13]. Although several predisposing factors, such as presence of obstructive lung disease, hematoma volume, poor Glascow Coma Scale (GCS), ganglionic hemorrhage, presence of hydrocephalus and loss of brainstem reflexes, for tracheostomy in sICH have been reported [14, 15], to date no easy to use prognostication scale have been developed.

The primary objective of this study is to identify clinical and radiological predictors for tracheostomy in mechanically ventilated patients with sICH and develop a scale that will accurately predict the need for tracheostomy.

Patients and Methods

We identified all patients ($n = 150$) admitted to a tertiary care university hospital during 1998–2000 using a prospective computerized database. We only included patients with supratentorial sICH intubated on the field or on admission who survived the first 3 days of hospitalization. We excluded patient with ICH secondary to oral anticoagulation, trauma, tumor, subarachnoid hemorrhage, and vascular malformations. We also excluded patients with missing admission head CT scan images or patients who underwent surgical evacuation. We performed a chart review and collected data on patients' demographics and clinical history, including clinical presentation, patient age, gender, past medical history, blood pressure on admission, neurological exam on admission including presence or absence of gag reflex, GCS on admission and on day 3, duration of mechanical ventilation (MV) and time to tracheostomy, length of stay in the hospital (LOSHOSP), and length of the stay in the ICU (LOSICU). Discharge data were collated on mortality, Glasgow outcome score (GOS) at hospital discharge. Discharge status was classified as home, acute rehabilitation and chronic care facility.

All patients received medical treatment consistent with the American Heart Association guidelines [16]. Patients who required surgical evacuation were excluded from the study. Extraventricular drainage device was placed based on the discretion of the treating physician. The neurocritical care unit ventilator management protocol at the time of the study consisted of placing patients on synchronized intermittent mechanical ventilation (SIMV) with respiratory rate varying between 6 and 12 bpm, tidal volume 5–10 ml/kg, positive end expiratory pressure (PEEP) of 5 and pressure support (PS) of 5. Adjustments were made to the ventilator to maintain normal pCO2 and normal plateau pressure. Weaning was initiated when FiO2 $\leq$ 40% and the rapid shallow breathing index (RSBI) $<$ 105. Patients were extubated if weaning trial was successful and GCS level were $\geq$8. If they failed weaning or extubation tracheostomy was planned around day 10–14 of mechanical ventilation.

Neuroradiologic Data

A neuroradiologist, blinded to the clinical status of the patients, reviewed the admission head CT scan. Hemorrhage location was categorized as lobar, basal ganglia (including caudate, putamen, and globus pallidus), and thalamic. The hematoma size was measured according to the ellipsoid formula ABC/2 method [17] and was reported as a continuos variable. Intraventricular hemorrhage (IVH) was documented using a modified GRAEB score [18, 19]. The minimum score was 0 and maximum score was 20 points. The variation, from the original GRAEB score, included adding 1-point for each expanded ventricles beyond normal anatomic limits. Scoring of the third and fourth ventricles was also modified. A score of zero was given if no blood was present, two if $<$50% of the ventricle was filled, four if $>$50% of the ventricle was filled, and an additional 1-point if the ventricle was expanded. Hydrocephalus was defined as ballooning of any ventricles. It was determined as present or absent by evaluating the frontal horn, atrium, and temporal horn of each lateral ventricle and the third and fourth ventricles [4]. Pineal shift and septum pellucidum shift were measured (in millimeters).

Statistical Analysis

Intubated patients were divided into 2 groups: those who underwent tracheostomy and those who were extubated. Analysis was performed using SPSS 11.0 (SPSS Inc., Chicago, IL). Patient characteristics were summarized using frequency distributions, means, standard errors, and percentiles as appropriate. Comparisons between groups were performed using Fisher's exact test, t-test, or Chi-square. Univariate and multivariate logistic regression analyses were performed to identify predictive factors for tracheostomy. The variables were divided into radiological and clinical variables. Only variables with $P < 0.1$ were entered into the multivariate logistic regression. Variables with $P < 0.05$ were considered statistically significant and were incorporated into the scale. The score value of each parameter was defined as the coefficient of the variables in the multivariate regression model. Subsequently performance of the model was calculated using a Receiver Operating characteristic (ROC) curve approach. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated. When any cell was empty a value of 0.5 was added to each cell in the 2×2 tables. The level of significance was set as $P = 0.05$, and all tests were two-tailed unless otherwise specified.

Results

Only 90 out of 150 patients were admitted with supratentorial sICH. Only 41 patients underwent intubation. Tracheostomy was performed in 44% of intubated patients within 14 ± 2 days. No significant sex, age, and race difference was found between successfully extubated and tracheostomy patients (Table 1). Upon review of past medical history the only significant difference observed was that hypertension was more prevalent in the tracheostomy group (75% vs. 45%, $P = 0.035$) in comparison to the intubated group. None of the patients had chronic obstructive lung disease.

The GCS on admission was not significantly different between groups. On day 3, GCS was significantly lower in tracheostomy group compared to the extubated group (Median GCS of 9 vs. 14, respectively; $P = 0.001$)

Table 1 Patients demographics and disposition

	Non-trached (23 patients)	Trached (18 patients)	*P*-value
Age	58.83 ± 3.90	62.39 ± 3.30	NS
Sex (Male)	52%	55%	NS
Race			
AA	48%	61%	NS
Caucasian	39%	38%	
Other	13%	0%	
Past medical history			
Diabetes mellitus	13%	15%	NS
Hypertension	45%	75%	$P = 0.035$
COPD	0%	0%	NS
Asthma	3%	10%	NS
Smoking	26%	15%	NS
CAD	19%	10%	NS
GCS on day 3 (Median)	14	9	$P = 0.0001$
LOSICU	2.94 ± 0.48	13.53 ± 1.92	$P < 0.0001$
LOSHOSP	13.13 ± 2.01	35.83 ± 3.76	$P < 0.0001$
Discharge location			
Home	29%	15%	$P < 0.0001$
Acute rehabilitation	61%	20%	
Chronic care facility	10%	65%	
GOS			
1	0%	17%	$P < 0.001$
2	9%	17%	
3	61%	61%	
4	22%	5%	
5	8%	0%	

Non-trached, patients did not undergo tracheostomy; Trached, patients underwent tracheostomy

AA African American, *COPD* chronic obstructive pulmonary disease, *CAD* coronary artery disease, *GCS* Glasgow coma score, *GOS* Glasgow outcome scale, *LOSICU* length of stay in the ICU, *LOSHOSP* length of stay in the hospital, *NS* statistically non-significant

(Table 1). Risk of tracheostomy was significantly higher in patients with GCS < 11 on day 3 (OR: 21, 95% CI 2.3–242.3, $P = 0.003$).

Radiological Predictors

Intracerebral hemorrhage volume was comparable between groups. Mean sICH volume on initial CT scan in extubated patients was 29.38 ± 8.0 cm^3 compared to 26.77 ± 5.25 cm^3 in tracheostomy patients. Hemorrhage location, extent of pineal gland shift, septum pellucidum shift, presence of hydrocephalus, and IVH grade were statistically different between the 2 groups (Tables 2, 3). Lobar hemorrhage was more common in extubated patients whereas thalamic hemorrhage was more common in tracheostomy patients ($P = 0.1$). Tracheostomy group had significantly increased pineal gland and septum pellucidum shift ($P = 0.003$). Hydrocephalus was also more prevalent (44% vs. 9%, $P = 0.008$). Extubated patients had less IVH ($P = 0.03$). Univariate regression analysis showed that hydrocephalus, presence of septum pellucidum shift, IVH, and thalamic hemorrhage were found to be predictive of need for tracheostomy. In an attempt to simplify the scale the extent of pineal and septum pellucidum shift was dichotomized as present and absent.

TRACH Score

In a multivariate regression analysis, GCS, hydrocephalus, thalamic hemorrhage, and presence of septum pellucidum shift were found to be significant independent predictors of tracheostomy and hence included in the model (Table 3). The TRACH score was developed from the logistic regression model for all ventilated sICH patients in our cohort, $n = 41$. The coefficient of each of the variable in the model was incorporated as the actual score in the final TRACH scoring.

Table 3 Radiological predictors

Radiological predictor	OR	*P*-value
Hydrocephalus	12.5	0.0024
Septum pellucidum shift	9	0.025
IVH	2.5	0.002
sICH in the thalamus	9	0.025

Radiological Scale (RScale) = L + H + S

The radiological scale is the sum of points of significant predictors (L—sICH location, H—presence of hydrocephalus, S—presence of septum pellucidum shift). The coefficients from the logistic regression analysis were used to assign points for the specific predictor chosen.

Location (L):	Thalamus = 2
	Other = 0
Hydrocephalus (H):	Present = 1.5
	Absent = 0
Septum pellucidum shift (S):	Present = 3
	Absent = 0

$$\text{TRACH Score} = 3 + (1 \times \text{RScale}) - (0.5 \times \text{GCS})$$

The scale was very reliable in predicting patients who underwent tracheostomy (OR: 2.57, $P < 0.0001$) with an ROC = 0.92 (Fig. 1). Scores varied between −4.5 and 4.5. All patients with score <0.7 were extubated without any difficulties, whereas all patients with TRACH score >2.0 underwent a tracheostomy. The sensitivity of the model to predict extubation was 94% with a specificity of 83%, positive predictive value of 83%, and negative predictive value of 95%. Figure 2 portrays a visual representation of the scale based on its two components: the radiological scale and GCS.

Table 2 Summary of radiological findings on admission CT

	Non-trached (23 patients)	Trached (18 patients)	
ICH clot size	29.38 ± 8.0	26.77 ± 5.25	NS
Clot location			
Lobar	50%	29%	$P = 0.1$
Basal ganglia	46%	38%	
Thalamus	4%	33%	
IVH grade	3.57 ± 1.21	8.05 ± 1.72	$P = 0.03$
Pineal shift (mm)	0.78 ± 0.37	2.33 ± 0.64	$P = 0.03$
Septum pellucidum (mm)	1.74 ± 0.69	4.22 ± 0.68	$P = 0.02$
Hydrocephalus (yes)	9%	44%	$P = 0.008$

ICH intracranial hemorrhage, *IVH* intraventricular hemorrhage

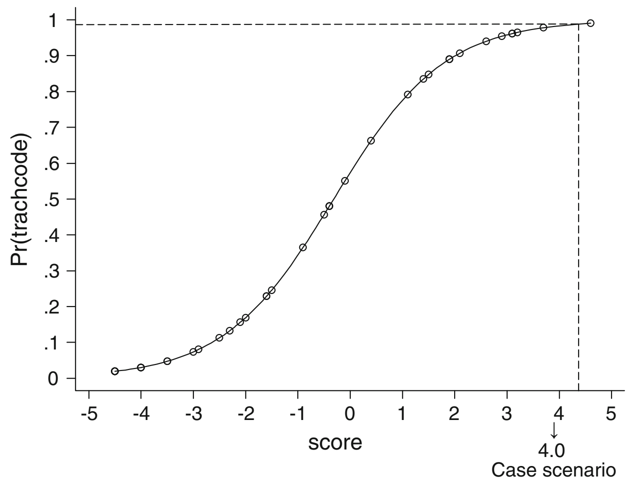

Fig. 1 TRACH probability graph. *Note*: Case scenario—Patient presents with GCS of 3 and the CT shows sICH located in the thalamus, hydrocephalus, and no septum pellucidum shift; RScale = L + H + S = 2 + 1.5 + 0 = 3.5; TRACH Score = 3 + (1 × RSCALE) − (0.5 × GCS) = 3 + (1 × 3.5) − (0.5 × 3) = 4. The probability of this patient getting the tracheostomy is almost 1. This patient did get a tracheostomy

Length of Stay and Discharge Disposition

Tracheostomy patients had a statistically significant longer LOSICU compared to extubated patients (13.53 ± 2 days, vs. 3 ± 0.5 days, $P < 0.0001$) and a longer LOSHOSP. Length of stay in hospital was 36 ± 4 days in tracheostomy patients and 13 ± 2 days in extubated patients ($P < 0.0001$) (Table 1). Following their tracheostomy patients only stayed 3 ± 1 more days in the ICU. Sixty-five percent of tracheostomy patients were discharged to a chronic care facility in comparison to 10% of extubated patients. In contrast, 61% of extubated patients were discharged to acute rehabilitation ($P < 0.0001$). The outcome of extubated patients was signficantly different than tracheostomy patients ($P < 0.001$). Only 8% had good recovery (GOS 5), 22% moderate disability (GOS 4), 61% severe disability (GOS 3), and 9% vegetative state (GOS 4) and no mortality. In comparison tracheostomy patients had worse outcome with 17% of patient dead (GOS 1), 17% in vegetative state (GOS 2), 61% with severe disability (GOS 3) and 5% with moderate disability (GOS 2).

Discussion

Weaning remains a controversial area in clinical practice with no clear guidelines or algorithms, especially in patients with brain injury. Commonly used standard “weaning parameters” such as vital capacity, minute ventilation, maximum inspiratory pressure, and rapid shallow breathing index have practical limitations in patients with sICH since they do not account for extent of neurological deficits or the extent of brain injury [11, 12]. Concern about patient’s level of consciousness is a primary reason for prolonged intubation in majority of cases [13]. Our data show that patients with low GCS on day 3 have a significantly high rate of tracheostomy. We did not find any correlation between GCS on admission and the need for a tracheostomy in consistence with the published literature [14]. This is not surprising given that on admission patient neurological exam may be overshadowed by sedatives and paralytics given during intubation. This is the first study that report on the correlation between GCS on day 3 and need for tracheostomy.

The novelty of our TRACH score is incorporating radiological predictors into the model. Hematoma location and volume, presence, and amount of IVH were found to be associated with poor outcome in previous models [6, 8, 20–22]. In our study we have investigated sICH location, ICH volume, presence of IVH, hydrocephalus; presence of

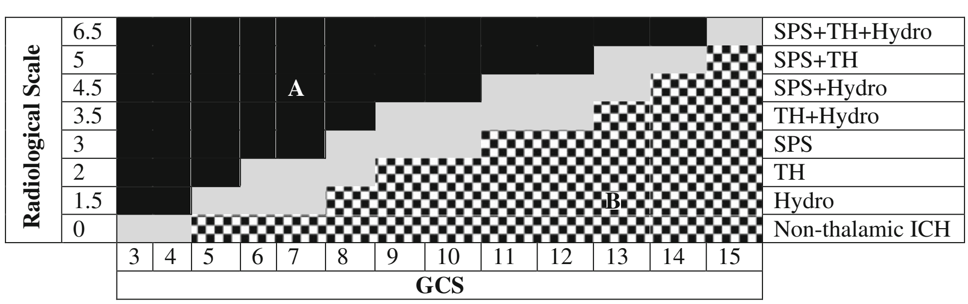

Fig. 2 Ventilatory wean prediction table. *Note*: *Black shaded area* represents patients who need tracheostomy. *Dotted area* represents patients who can be extubated. *Gray shaded area* represents patients that the scale cannot predict accurately. Patient A has a GCS of 7 with septum pellucidum shift and hydrocephalus. The model predicts that he will need a tracheostomy. On the other hand, patient B has a GCS 13 and has hydro and non-thalamic ICH and can be safely extubated. *Abbreviations*: GCS–Glasgow Coma Score; Hydro—hydrocephalus present; TH—ThalamicHemorrhage; SPS—Septum pellucidum shift.

septum pellucidum and/or pineal shift. We found that patients with thalamic hemorrhage, hydrocephalus, and/or septal pellucidum shift have a higher rate of tracheostomy. These results are consistent with the findings of Huttner et al. [14] with the exception that septum pellucidum shift was not reported in their series.

Early Tracheostomy and Hospital Length of Stay

There continues to be controversy regarding the optimal timing of tracheostomy. Some studies [23–25] suggest that increased glottic and subglottic stenosis is more severe with prolonged endotracheal intubation than with tracheostomy; others suggest that endotracheal tubes can be left in place for as long as 3 weeks [26, 27]. Generally tracheostomy is performed as soon as the need for prolonged airway support is recognized.

Koh and colleagues [28] in a retrospective chart review reported that early tracheostomy for patients admitted to a neuro-intensive care unit with a low GCS (≤ 8) had shorter ICU stays compared with patients who were given extubation trials before tracheostomy. Kluger et al. [29] reported that early tracheostomy in patients with head injury resulted in lower frequency of pneumonias. In a randomized prospective trial, Rodriguez et al. [30] noted a significant decrease in ventilator days and ICU and hospital length of stay (LOS) in patients who underwent tracheostomy within 7 days of intubation.

Although there is some evidence in the literature to suggest that early tracheostomy might be beneficial, nevertheless none of these studies included sICH patients. In our cohort, patients were discharged from the ICU 2–3 days following their tracheostomy. This suggests that the ICU stay was mostly due to ventilatory support, and hence if tracheostomy was performed earlier we may significantly shorten length of stay. Considering the number of new sICH cases nationally, 12–15 per 100,000 annually, this may have significant economic implication

TRACH score

A clinical grading scale should be generally applicable, simple to use without any special training or extensive time commitment. It should be also reliable and include elements which are assessed as part of the patient daily routine. However, the simplicity should not omit pertinent information that might compromise accuracy of the outcome prediction [6]. Conversely, a complicated scale with multiple components would provide great detail, but may be quickly abandoned because of its complexity.

The GCS score is a simple, practical, and widely used measure of neurological status and hence was added to the TRACH score. The radiological predictors such as presence of sICH in the thalamus (L, location), presence of hydrocephalus (H), and presence of septum pellucidum shift (S) are all easily measurable and could be applied easily to the score in daily assessments.

We have not included any standard weaning parameters in our model because previous studies have shown that brain-injured patients who met standard weaning criteria but were not awake at the time could not be extubated with clear certainty [11]. We also believe that the GCS score as a marker of the patient's neurological status gives better information about the patient's ability to clear respiratory tract secretions or to protect their airways from aspiration, than the traditional "weaning parameters." This idea is supported by Coplin et al. [11] where patients were successfully extubated despite the absence of cough, gag, or increased suctioning need.

Our study has limitations. Due to the retrospective nature of the study, decisions regarding the timing of tracheostomy were not standardized. We excluded patients with large supratentorial sICH who died early in the course of the disease. So the generalizability of the study is limited to supratentorial sICH who survive the first 3 days of hospital admission. The effect of the GCS may be overemphasized since part of the clinical practice was to attempt extubation only when GCS > 8. Given the limitations discussed, prospective validation of this model is essential before any clinical application.

Conclusion

The TRACH score is the first grading system that incorporates clinical and radiological predictors to determine the need for tracheostomy in patients with supratentorial sICH. It provides an accurate way of predicting the need for tracheostomy, and its application may significantly result in decreased length of stay and cost of hospitalization. The validity and impact of this scale on clinical outcome require future prospective analysis.

Acknowledgment and Funding None

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