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Association of APACHE-II Scores With 30-Day Mortality After Tracheostomy: A Retrospective Study

Matthew J. Marget, MD; Raven Dunn, MD; Christie L. Morgan, MD

Objective: The objective of this study was to assess whether the Acute Physiology, Age, Chronic Health Evaluation II (APACHE-II) score is a reliable predictor of 30-day mortality in the setting of adult patients with ventilator-dependent respiratory failure (VDRF) who undergo tracheostomy.

Methods: This is a retrospective, single-institution study. Potential subjects were identified using the current procedural terminology codes for the tracheostomy procedure and International Classification of Diseases, 10th Revision, codes for VDRF. APACHE-II scores were retrospectively calculated. Tracheostomies were performed in our population over an 18-month period (November 2018 through April 2020). Our study population did not include patients with novel coronavirus. The primary outcome was mortality at 30 days after tracheostomy.

Results: A total of 238 patients with VDRF who had a tracheostomy were included in this study. Twenty-eight (11.8%) patients died within 30 days of tracheostomy. The mean (standard deviation) APACHE-II score was 22.5 (10.2) for patients who died within 30 days of tracheostomy and 19.8 (7.4) for patients living within 30 days of tracheostomy ($p = 0.30$). Patients with APACHE-II scores greater than or equal to 30 showed higher odds of death within 30 days of tracheostomy (odds ratio, 3.0; 95% CI, 1.14–7.89, $p = 0.03$).

Conclusion: An APACHE-II score of 30 and above is associated with mortality within 30 days of tracheostomy in patients with VDRF. APACHE-II scores may be a promising tool for assessing risk of mortality in patients with VDRF after tracheostomy.

Key Words: APACHE-II score, mortality, tracheostomy.

Level of Evidence: 3

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INTRODUCTION

Prolonged endotracheal intubation increases risk of laryngeal injury in ventilator-dependent patients.[1] For this reason, a surgical airway in the form of a tracheostomy is often pursued to minimize this risk. Tracheostomy plays a large role in reducing risk of complications among survivors of critical illness. Early tracheostomy has been shown to improve patient-centric outcomes during critical illness, including return to oral intake, ability to verbally communicate, and earlier participation in physical rehabilitation.[2] It has also been argued that tracheostomy reduces the risk of post-intensive care syndrome (the long-term physical, cognitive, and mental health sequelae associated with prolonged critical illness).[3,4] In the age of the novel coronavirus pandemic, tracheostomy, which is associated with earlier ventilatory wean, may have an integral role in resource utilization, allowing for more available ventilators, ICU beds, and staff.[3] At our institution, the Department of Otolaryngology-Head and Neck Surgery is routinely consulted to evaluate patients with ventilator-dependent respiratory failure (VDRF) for possible tracheostomy. Unfortunately, some patients who undergo tracheostomy will not survive the critical illness for which they have been hospitalized, raising the question of whether it is possible to identify which patients may be at higher risk for 30-day mortality after tracheostomy.

Kashlan et al. recently studied various patient factors associated with 30-day mortality after tracheostomy.[5] Their study found that the presence of medical comorbidities calculated using the Charlson comorbidity index (CCI) was linked with mortality after tracheostomy, with higher Charlson comorbidity index scores associated with increased 30-day mortality post-tracheostomy. Although the CCI provides predictive value about mortality risk in critically ill patients,[6] it is based solely on medical comorbidities at the time of admission, omitting the acute severity of the patient's present illness. The objective of our study was to evaluate whether an acute illness severity score, rather than a comorbidity index, could also be used to predict 30-day mortality after tracheostomy.

The Acute Physiology, Age, Chronic Health Evaluation II (APACHE-II) score is the most widely utilized disease severity scale in intensive care units (ICUs) as reported in the English-language medical literature.[7] The scoring system utilizes the worst values of 12 physiological variables, such as temperature, heart rate, Glasgow Coma Scale score, and white blood cell count, during the first 24 hours of ICU admission (Table I). Additionally,

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TABLE I.
The Acute Physiology, Age, Chronic Health Evaluation (APACHE) II score.

Physiologic Variable*	+4	+3	+2	+1	0	+1	+2	+3	+4
Temperature (°C)	≥41	39–40.9	—	38.5–38.9	36–38.4	34–35.9	32–33.9	30–31.9	≤29.9
Mean arterial pressure (mmHg)	≥160	130–159	110–129	—	70–109	—	50–69	—	≤49
Heart rate (min^{-1})	≥180	140–179	110–139	—	70–109	—	55–69	40–54	≤39
Respiratory rate (min^{-1})	≥50	35–49	—	25–34	12–24	10–11	6–9	—	≤5
Oxygenation (mmHg)									
A-aDO_2 if FiO_2 ≥50%	≥500	350–499	200–349	—	<200	—	—	—	—
FiO_2 <50% using PaO_2	—	—	—	—	>70	61–70	—	55–60	<55
Arterial pH	≥7.7	7.6–7.69	—	7.5–7.59	7.33–7.49	—	7.25–7.32	7.15–7.24	<7.15
Sodium (mmol/L)	≥180	160–179	155–159	150–154	130–149	—	120–129	111–119	≤110
Potassium (mmol/L)	≥7	6–6.9	—	5.5–5.9	3.5–5.4	3–3.4	2.5–2.9	—	<2.5
Creatinine (mg/dl)†	≥3.5	2–3.4	1.5–1.9	—	0.6–1.4	—	<0.6	—	—
Hematocrit (%)	≥60	—	50–59.9	46–49.9	30–45.9	—	20–29.9	—	<20
White blood count ($1000/mm^3$)	≥40	—	20–39.9	15–19.9	3–14.9	—	1–2.9	—	<1
Glasgow Coma Scale (GCS)	Calculated as 15 minus actual GCS								
Serum HCO_3 (mmol/L)‡	≥52	41–51.9	—	32–40.9	22–31.9	—	18–21.9	15–17.9	<15

A = Total acute physiology score (APS) = Sum of all the physiologic variables.
B = Age points: add +0 for <44, +2 for 45–54, +3 for 55–64, +5 for 65–74, and +6 for ≥75.
C = Chronic health points: if previous history of severe organ system disease or immunocompromise, +2 for elective postoperative patients, +5 for nonoperative or emergency postoperative patients.
APACHE II Score = A (APS) + B (Age) + C (Chronic).
*Based upon the worst variable in the past 24 hours.
†Doubled if acute renal failure.
‡If no arterial blood gas is available.

the scoring system incorporates an evaluation of the patient's chronic health and admission diagnoses.[8] APACHE-II scores have been shown to be predictive of overall mortality in mechanically ventilated patients.[9] The maximum APACHE-II score is 71, though it is rare for a patient to score higher than 55.[8] A score of 25 indicates a predicted all-cause mortality of 50%, whereas a score of over 35 represents a predicted all-cause mortality of 80%.[10]

In this study, APACHE-II scores were retrospectively calculated for patients with VDRF who had undergone tracheostomy between November 2018 and April 2020. These scores were then analyzed for the association of score magnitude with patient mortality within 30 days after tracheostomy. The primary hypothesis of our study was that higher APACHE-II scores would be associated with 30-day mortality after tracheostomy. Our aim was to perform a proof-of-principle study to ascertain the utility of a specific disease severity scoring system for assessing risk of death within 30 days of tracheostomy within the context of VRDF.

The family members and caregivers of critically ill patients are often tasked with making difficult decisions about the goals of care for their loved one. The ultimate goal of our study is to determine whether APACHE-II scores might be a useful guide for surgeons, intensivists, and the tracheostomy care team as a whole when making the decision to pursue tracheostomy in critically ill patients. We sought to investigate whether APACHE-II scores would be beneficial to better counsel patients and families about tracheostomy within the setting of VDRF.

MATERIALS AND METHODS

The study was approved by the institutional review board, with the need for consent waived. A total of 238 patients were included in the study. Potential subjects were identified using the current procedural terminology codes for the tracheostomy procedure and International Classification of Diseases, 10th Revision, codes for VDRF. Patients who underwent tracheostomy for other indications, such as obstructive sleep apnea, upper airway obstruction, head and neck cancer, etc., were excluded from the study. All patients underwent open tracheostomy (none performed using the percutaneous method). Patients who underwent tracheostomy by services other than the Department of Otolaryngology were excluded. APACHE-II scores were retrospectively calculated using the worst value (furthest from baseline/normal) within 24 hours of ICU admission. The study patient population is composed of all patients at our institution who received a tracheostomy for VDRF over an 18-month period (November 2018 through April 2020). Of note, no patients in our study population were diagnosed with novel coronavirus infection at the time of their hospitalization.

The distribution of APACHE-II scores within the two groups (alive vs. deceased at 30 days) was examined using various plots. Normality assumptions of this distribution were violated, thus, a Wilcoxon rank sum test was used for comparison between the two groups.

The odds ratio of mortality within 30 days of tracheostomy was calculated for patients with APACHE-II scores above and below a score of 30. As described by Knaus et al., the APACHE scoring system does not define a specific low or high APACHE score.[8] Therefore, a score of 30 was chosen as our setpoint based on the results of the original validation study, which demonstrated increased odds of mortality at this threshold.[8] In that study, Knaus et al. demonstrated that APACHE-II scores of 30–34 had a 73% risk of mortality, compared with 55% in patients with scores of 25–29. Additionally, an APACHE-II score of

30 has been shown to meaningfully correlate with increased odds of death in several published studies.[11–13]

Statistical significance was set at $p < 0.05$. All analyses were performed using SAS 9.4 (SAS Institute Inc, Cary, NC).

RESULTS

A total of 238 patients with VDRF who had a tracheostomy were included in this study (139 men and 99 women); the mean (standard deviation) age was 60.8 (14.6) years (Table II). Of these 238 patients, 28 (11.8%) patients died within 30 days of tracheostomy. When including deaths after 30 days, a total of 60 patients in our study population did not survive their critical illness (25.2%). Documented cause of death in our study population can be found in Table III. Of note, 29 patients (12.2%) were either terminally weaned in the ICU or discharged to hospice/comfort care. Of those, 18 patients were terminally weaned or transitioned to hospice/comfort care within 30 days of tracheostomy (7.6%).

The mean (standard deviation) APACHE-II score was 22.5 (10.2) for patients who died within 30 days of tracheostomy and 19.8 (7.4) for patients living within 30 days of tracheostomy ($p = 0.30$). However, patients with APACHE-II scores greater than or equal to 30 showed higher odds of death within 30 days of tracheostomy (odds ratio, 3.0; 95% CI, 1.14–7.89, $p = 0.03$). In our study population, 28 patients had an APACHE-II score of 30 or higher (see Fig. 1). No patient scored higher than 43.

For patients who died beyond 30 days of tracheostomy, the mean (standard deviation) APACHE-II score was 20.6 (5.7). There was no significant difference in APACHE-II scores between patients who died within 30 days of tracheostomy and patients who died after 30 days ($p = 0.38$). The mean (standard deviation) time-to-death for patients who died within 30 days of tracheostomy was 14.9 (7.3) days, whereas patients who died beyond 30 days after tracheostomy had a mean (standard) time-to-death of 52.5 (26.8) days ($p < 0.001$).

TABLE II.
Descriptive Statistics of Study Population ($N = 238$).

Variable	Value
Age, year	
Mean (SD)	60.8 (14.6)
Median (Q25, Q75)	63 (51, 71)
Sex, *n* (%)	
Male	139 (58.4)
Mean age (SD)	60.9 (13.8)
Female	99 (41.6)
Mean age (SD)	60.5 (15.8)
Chronic health status, *n* (%)	
Yes	68 (28.6)
No	170 (71.4)
30-day survival, *n* (%)	
Yes	210 (88.2)
No	28 (11.8)
APACHE	
Range	3–43
Mean (SD)	20.1 (7.8)
Median (Q25, Q75)	19.5 (15.0, 2)

APACHE = Acute Physiology, Age, Chronic Health Evaluation; SD = standard deviation.

TABLE III.
Documented Cause of Death in Deceased Patients ($N = 60$).

	Total (%)
Terminal wean in ICU	**16 (26.7%)**
Within 30 days of tracheostomy	14 (23.3%)
Beyond 30 days of tracheostomy	2 (3.3%)
Discharge to hospice/comfort care	**13 (21.7%)**
Within 30 days of tracheostomy	4 (6.7%)
Beyond 30 days of tracheostomy	9 (15.0%)
Cardiopulmonary arrest	**12 (20%)**
Within 30 days of tracheostomy	4 (6.7%)
Beyond 30 days of tracheostomy	8 (13.3%)
Sepsis	**5 (8.3%)**
Within 30 days of tracheostomy	2 (3.3%)
Beyond 30 days of tracheostomy	3 (5.0%)
Brain death	**1 (1.7%)**
Within 30 days of tracheostomy	0 (0%)
Beyond 30 days of tracheostomy	1 (1.7%)
Cause unknown/not documented	**13 (21.7%)**
Within 30 days of tracheostomy	4 (6.7%)
Beyond 30 days of tracheostomy	9 (15%)

ICU = intensive care unit.

DISCUSSION

Illness severity scores, such as the APACHE-II system, can be helpful in guiding clinical practice. Proponents of these scoring systems argue that they are useful in predicting outcomes and risk stratifying patients, as well as widely used for clinical trial enrollment and as a quality-improvement metric for ICU performance.[14] With the rise of the electronic medical record and advances in information technology, illness severity scores have become more widely incorporated into medical decision-making through the use of computerized clinical decision support systems.[15] Despite their perceived usefulness, these systems often fail to be accepted into the daily clinical decision-making of physicians. Liberati et al. found that physicians often view these systems as unreliable, overwhelming, or even as a threat to physician autonomy.[16] Our study presents an easy, efficient, and potentially beneficial application of the APACHE-II scoring system during evaluation of patients with VDRF for tracheostomy.

Perioperative mortality at 30 days remains a fundamental safety assessment for hospitals and the health care community, and it has been validated in numerous studies as a consistent quality metric. The APACHE-II score is one of the

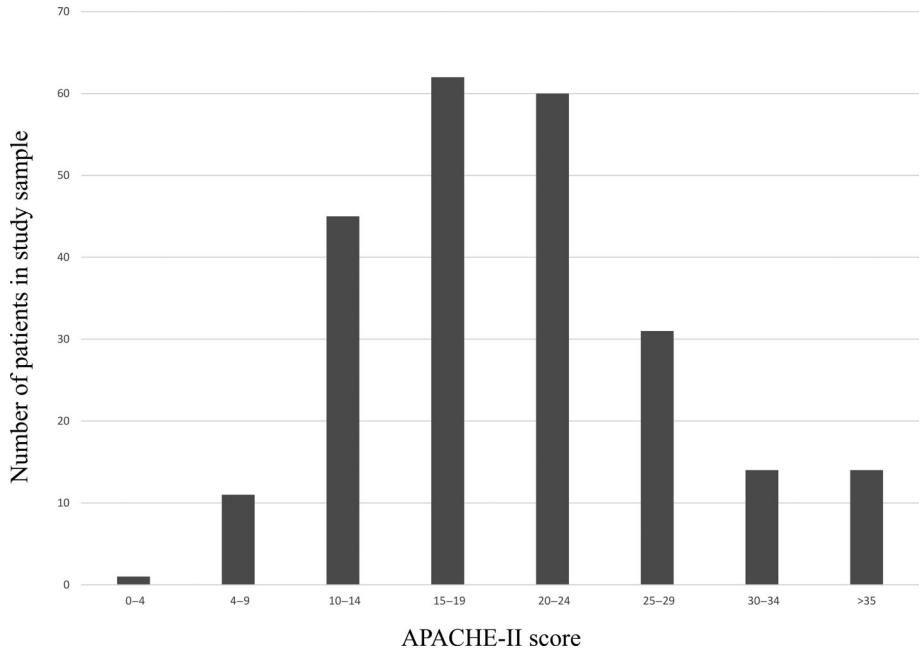

Fig. 1. Distribution of APACHE-II scores in study population

most widely used illness severity scores[7] and has been validated in numerous studies.[17] We chose to use the APACHE-II score in our study over the more recent APACHE scoring systems, such as the APACHE-III and APACHE-IV scores, because the APACHE-II score remains more widely used in ICUs. APACHE-II is also freely available and easily accessible online and on smartphone apps, such as MDCalc.[18]

The APACHE-II score is more widely used than the Charlson comorbidity index[7] and has been shown to be a superior predictor of inpatient mortality.[19] Quach et al. postulated that the APACHE-II outperforms CCI because the APACHE-II's validation study only included ICU patients, whereas the validation study of the CCI consisted of inpatients of all kinds.[19] Our group theorizes that the APACHE-II score may be a more holistic representation of the patient's acute illness, though this was not investigated in the present study. Future study is needed to directly compare the predictive value of CCI versus APACHE-II scores among patients who have undergone tracheostomy.

In this observational study, we assessed the utility of using the APACHE-II score as a tool to evaluate risk of 30-day mortality in patients with VDRF who received a tracheostomy. Although patients who died within 30 days of tracheostomy did not have a significantly higher mean APACHE-II score than patients who did not die, we observed that APACHE-II scores greater than 30 are indicative of a three-fold increased risk of death within 30 days of tracheostomy.

Our study has several limitations. As a retrospective study, findings cannot be generalized to the population at large. We assessed patients at one institution, and practices around treating VDRF and performing tracheostomy at other institutions may result in different trends. Our study included a small sample population, and larger prospective studies are warranted to confirm the utility of APACHE-II as a predictor of mortality for a similar patient population.

Our study population solely included patients who had undergone open tracheostomies performed by the Department of Otolaryngology; therefore, patients who underwent percutaneous tracheostomy or tracheostomy performed by other services were excluded. It is possible that this may have resulted in a selection bias based upon how patients are deemed candidates for open tracheostomy by our department. Although our criteria are likely similar to others, there is a specific emphasis on patient stability (stable vital signs, minimal pressor requirements), minimal ventilator settings (generally, FiO_2 ≤50%, PEEP ≤8), and patient prognosis. However, the overall mortality (25.2%) among all patients is roughly equivalent to rates reported in other large studies, with typical estimates of 18%–25%.[20] Additional data that may affect overall survival, such as timing of tracheostomy, duration of ventilation prior to tracheostomy, and ventilator settings, were not collected.

In our study population, 48.3% of patients who died after tracheostomy were either terminally weaned in the ICU or discharged to hospice/comfort care. This statistic emphasizes the complexity of patient selection and the imperfect ability of physicians (both surgeons and intensivists) to predict the course of critical illness. Additional investigation into withdrawal of care after tracheostomy is needed but beyond the scope of the present study. In select circumstances, tracheostomy can be a palliative measure at the end of life to reduce patient suffering.[21]

By only studying patients whose families consented for tracheostomy and who underwent the procedure, patients whose families did not consent for surgery (for whatever reason) were excluded from the data. Furthermore, given the changing demographics of ICU populations due to the COVID-19 pandemic, our results

may not be generalizable to patients with prolonged intubation secondary to active COVID-19 infection. However, our findings regarding the association of APACHE-II score magnitude and the odds of 30-day post-tracheostomy mortality are compelling and warrant further investigation.

Although 30-day mortality continues to be an important quality metric for patients, surgeons, hospitals, and payers, some have argued that this outcome measure may underestimate the true risk of a procedure.[22–24] In our study population, there was no significant difference in the APACHE-II scores between those patients who died within 30 days of tracheostomy and those who died beyond 30 days. For patients and their families, the distinction between mortality before 30 days and after 30 days may be irrelevant.

The decision to pursue tracheostomy is often complex and has implications on both the hospital course and future quality of life for critically ill patients. For many patients, tracheostomy is the next step in advancing toward a resolution of critical illness, while some patients will unfortunately not survive the critical illness for which they are hospitalized. In the past, pursuing tracheostomy was a binary choice led by the proceduralist in consultation with family; however, the approach to the procedure and its role in care pathways has evolved. Quality-improvement initiatives, like the Global Tracheostomy Collaborative, seek to improve care through interdisciplinary education, patient and family involvement, and data driven efforts.[25] These endeavors have been shown to significantly improve quality, safety, and organizational efficiency, with the potential to produce dramatic cost savings for health systems as a whole.[26] Multidisciplinary approaches to tracheostomy care have been linked with significant effects on individual patient lives, through improved outcomes such as decreased time to decannulation, reduced airway-related adverse events, and greater adoption of speaking valve use.[27] We hope that the results of this study prove useful to multidisciplinary stakeholders in tracheostomy care.

Multidisciplinary approaches are now even more crucial in the continued time of the COVID-19 pandemic. Approaching tracheostomy in this patient population requires consideration of many aspects, including the physical and biopsychosocial factors of the patient, the resources of the health system, and the safety of health care workers, patients, and patient families.[28] A 10–21-day period has been suggested as the window for tracheostomy in COVID-19 afflicted patients where all of the aforementioned factors may be considered and best balanced.[28,29] The pandemic unfortunately only adds difficulty in the challenge of caring for patients who may require tracheostomy.

Tracheostomy has widespread implications for patients and families. The choice to consent to tracheostomy can be challenging and unclear for families of critically ill patients. Even in the best of circumstances, caring for a loved one with a tracheostomy can be full of daunting challenges, which can range considerably, from frustrations with coordinating home care and supplies to the dangers of inadequate emergency airway training.[30] Families may have a wide range of concerns at the time of initial tracheostomy consultation: how the tracheostomy will affect the patient's course of illness, whether the tracheostomy may prolong or even increase the suffering of their loved one, or whether their loved one may succumb to their critical illness despite the tracheostomy. It is our desire that this study can further aid clinicians in guiding patients' family members and caregivers when making the decision to consent to tracheostomy.

CONCLUSION

An APACHE-II score of 30 and above is a potentially useful clinical indicator of increased risk of mortality within 30 days of tracheostomy in patients with VDRF. This tool may prove a valuable resource for ICU physicians and surgeons who are considering tracheostomy for patients with VDRF. APACHE-II scores may also be of benefit to health care providers as they help to assist family and caregivers in making complex decisions about the goals of care for their loved one.

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