High Resource Utilization Does Not Affect Mortality in Acute Respiratory Failure Patients Managed With Tracheostomy

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BACKGROUND: Tracheostomy practice in patients with acute respiratory failure (ARF) varies greatly among institutions. This variability has the potential to be reflected in the resources expended providing care. In various healthcare environments, increased resource expenditure has been associated with a favorable effect on outcome. OBJECTIVE: To examine the association between institutional resource expenditure and mortality in ARF patients managed with tracheostomy. METHODS: We developed analytic models employing the University Health Systems Consortium (Oakbrook, Illinois) database. Administrative coding data were used to identify patients with the principal diagnosis of ARF, procedures, complications, post-discharge destination, and survival. Mean resource intensity of participating academic medical centers was determined using risk-adjusted estimates of costs. Mortality risk was determined using a multivariable approach that incorporated patient-level demographic and clinical variables and institution-level resource intensity. RESULTS: We analyzed data from 44,124 ARF subjects, 4,776 (10.8%) of whom underwent tracheostomy. Compared to low-resource-intensity settings, treatment in high-resource-intensity academic medical centers was associated with increased risk of mortality (odds ratio 1.11, 95% CI 1.05–1.76), including those managed with tracheostomy (odds ratio high-resource-intensity academic medical center with tracheostomy 1.10, 95% CI 1.04–1.17). We examined the relationship between complication development and outcome. While neither the profile nor number of complications accumulated differed comparing treatment environments (*P* > .05 for both), mortality for tracheostomy patients experiencing complications was greater in high-resource-intensity (95/313, 30.3%) versus low-resource-intensity (552/2,587, 21.3%) academic medical centers (*P* < .001). CONCLUSIONS: We were unable to demonstrate a positive relationship between resource expenditure and outcome in ARF patients managed with tracheostomy. *Key words: tracheostomy; acute respiratory failure; mechanical ventilation; critical illness; practice variation; quality assurance.* [Respir Care 2013;58(11):1863–1872.

Introduction

Tracheostomy is one of the most commonly performed surgical procedures among patients with acute respiratory failure (ARF).[1-4] Though a minority of all individuals requiring ventilatory support, tracheostomy patients place substantial demands on ventilator, ICU, hospital, and post-

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hospital discharge resources.[5-7] Financial expenditures to support the care of tracheostomy patients are among the highest of any diagnostic or procedural group.[8] Efforts to refine tracheostomy practice have the potential to affect both the quality of care provided this segment of the critically ill population, as well as the resources expended delivering this care.[9-11]

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Despite decades of experience, the potential advantages of tracheostomy, relative to prolonged translaryngeal intubation, remain poorly defined, as do the risks associated with this procedure.[2,9] The timing of tracheostomy has been particularly debated. Rodriguez et al reported that tracheostomy performed within the first week of ICU admission following major trauma was associated with significantly shorter duration of mechanical ventilation and ICU stay, compared with tracheostomy performed later in the course of respiratory failure.[12] Other investigators have confirmed[13,14] and contradicted[15-17] the putative benefits of early tracheostomy. Three recently completed randomized controlled trials suggest that the timing of tracheostomy does not affect the incidence of infectious complications, duration of mechanical ventilation, or ICU or hospital stay.[18-20] Currently, there are no well established standards to guide patient selection or other aspects of this procedure. Absent such standards, tracheostomy appears to be used in, at worst, an arbitrary, or, at best, a variable fashion.[5,21,22]

As is the case with critical care practice in general, variation in management of tracheostomy patients has the potential to be reflected in variability in the resources utilized in providing care.[23] In some healthcare settings, increased resource expenditure appears to be associated with favorable effects on outcome.[24-27] We undertook the current investigation to examine the hypothesis that increased resource expenditure associated with the management of tracheostomy patients—controlling for potentially confounding variables—is associated with a beneficial effect on mortality.

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QUICK LOOK

Current knowledge

Tracheostomy is one of the most common surgeries in patients with acute respiratory failure. Tracheostomy patients place substantial demands on ICU, hospital, and post-hospital resources. The costs of care for tracheostomy patients are among the highest of any diagnostic or procedural group.

What this paper contributes to our knowledge

There was no positive relationship between resource expenditure and outcome in tracheostomy patients. It is imperative to identify clinically beneficial strategies related to tracheostomy, including patient selection, timing, technique, and post-procedure management, and to assess the cost-effectiveness of these strategies.

Methods

Description of Data Resource and Identification of Patients

This study is based on analysis of the University Health Systems Consortium, (Oakbrook, Illinois) data resource. The University Health Systems Consortium is a network of university-based tertiary care institutions and affiliated hospitals representing 90% of the nation's non-profit academic medical centers. University Health Systems Consortium has developed a highly detailed administrative database that enables comparative analysis in clinical, operational, financial, and patient safety domains among participants.

Adult patients (≥ 18 years of age) with the principal diagnosis of ARF (International Classification of Diseases, 9th Revision [ICD-9] diagnosis code 518.81) and requiring mechanical ventilation were identified through use of the ICD-9 procedure codes for ventilator support of any duration (96.70 Continuous invasive mechanical ventilation of unspecified duration, 96.71 Continuous invasive mechanical ventilation for less than 96 consecutive hours, 96.72 Continuous invasive mechanical ventilation for 96 consecutive hours or more, 96.7 Other continuous invasive mechanical ventilation). Patients undergoing tracheostomy were identified in a similar fashion (31.1 Temporary tracheostomy).

Risk Adjustment

The approach to risk adjustment used in this study has been previously described.[28-30] Briefly, 2 independent models (hospital cost and probability of in-patient mortality) were constructed for each diagnosis-related group (DRG) or base Medicare severity DRG. Each model incorporated an all-patient-refined DRG severity of illness or risk of mortality category (severity of illness and risk of mortality each are assigned a score on a 4-point scale of 1 = "minor" to 4 = "extreme"), as well as 29 specific comorbidities identified by the Agency for Healthcare Research and Quality as influencing the outcome of interest.[31]

For model development, data were partitioned into derivation and validation data sets and assessed using standard diagnostics (concordance index, Hosmer-Lemeshow test, and R^2). In the event that it was not possible to develop a stable model by this approach, each case in the DRG or base Medicare severity DRG was assigned the average observed value, stratified first by severity of illness or risk of mortality, and then by transfer status within each severity-of-illness or risk-of-mortality level. Cost of patient care was assessed using the ratio of cost to charges methodology. Detailed charges were collected at the revenue code level and were mapped into departments and cost centers, consistent with the Centers for Medicare and Medicaid Services descriptions. Centers for Medicare and Medicaid Services cost reports were used to obtain service line costs and charges, which were used to calculate a cost-to-charge ratio for each service. In addition, a cost-to-charge ratio for each cost center within the hospital, as well as a global cost-to-charge ratio for the hospital, was generated. These cost-to-charge ratios were used to estimate percentiles for refining or trimming the data, to eliminate outliers. Estimated service center costs were derived from multiplying charges by the cost-to-charge ratio. Total costs were computed by summing individual cost center estimates. A predicted value of cost and probability of mortality were assigned to each patient record in the data set.

Identification of Complications

The University Health Systems Consortium has developed and validated methodology to identify 25 specific complications based on diagnosis and procedural codes: postoperative stroke, aspiration pneumonia, postoperative pulmonary compromise, postoperative gastrointestinal hemorrhage or ulceration, postoperative urinary tract complication, cellulitis or decubitis ulcer, septicemia, postoperative/intra-operative shock due to anesthesia, reopening of surgical site, mechanical complication due to device or implant, miscellaneous complications, shock or respiratory arrest, central or peripheral nervous system complication, postoperative acute myocardial infarction, postoperative myocardial abnormality (excluding myocardial infarction), postoperative infections excluding pneumonia or wounds, procedure related perforations or lacerations, postoperative coma or stupor, postoperative pneumonia, postoperative physiologic or metabolic derangements, complications related to anesthetic or central nervous system agents, venous thrombosis/pulmonary embolism, wound infection, post-procedure hemorrhage or hematoma, and other complications of procedures.

Approach to Analysis

We evaluated the relationship between in-patient mortality, presence of tracheostomy, and resource-intensity using multivariable logistic regression. Resource intensity was operationalized for all ARF patients in a given facility: not for the individual patient. We took this approach because we have previously documented significant inter-institutional differences in tracheostomy practice (in terms of proportion of patients undergoing this procedure, as well as timing) and felt that institution-level resource intensity would reflect this variation.[5] Average resource intensity was estimated for each facility by dividing total costs associated with providing care by expected cost, as predicted by the University Health Systems Consortium algorithm. We hypothesized that increased resource intensity would result in a beneficial effect on survival, and took 2 approaches to incorporating resource intensity into our analytic model. In the first approach, resource intensity was modeled as a dichotomous variable, such that a facility that consumed $\geq$ 25% of predicted resources (ie, a proportional expense ratio $\geq$ 1.25) was considered high resource intensity, while a facility providing care associated with a proportional expense ratio $<$ 1.25 was considered low resource intensity. Institutional proportional expense ratio was stable over the years included in this study, so we pooled data over this time period for analysis (see the supplementary materials at http://www.rcjournal.com). Stratifying the institutions into high and low resource-intensity categories has the potential to introduce bias. To compensate for this potential bias, and to more generally examine the relationship between resource expenditure and outcome, we also modeled resource intensity as a continuous variable. Univariate analyses were conducted using logistic regression to identify variables that could confound the relationship between mortality and resource use. In building our multivariable model we controlled for the possibility that the relationship between mortality and tracheostomy might vary by level of resource intensity by including these 2 variables as an interaction term. All analyses were conducted using statistics software (SAS 9.2, SAS Institute, Cary North, Carolina). For ease of presentation, findings presented in the Results section represent the dichotomous model; the supplementary materials at http://www.rcjournal.com present the findings of resource intensity modeled as a continuous variable.

Table 1. Baseline Characteristics of Adult Subjects With Acute Respiratory Failure Cared for in Academic Medical Centers

	All Subjects $n = 44{,}124$	Non-tracheostomy Subjects $n = 39{,}348$	Tracheostomy Subjects $n = 4{,}776$	P*
Age, mean ± SD y	61.3 ± 21.0	61.4 ± 19.8	60.4 ± 13.8	< .001
Male	22,635 (51.3)	20,146 (51.2)	2,478 (51.9)	.42
Ethnicity				.005
White	25,680 (58.2)	22,782 (57.9)	2,870 (60.1)	
African American	13,237 (30.0)	11,096 (28.2)	1,232 (25.8)	
Hispanic	1,941 (4.4)	1,770 (4.5)	205 (4.3)	
Other	4,147 (9.4)	3,699 (9.4)	468 (9.8)	
Admission status				< .001
Emergency	31,857 (72.2)	28,763 (73.1)	3,109 (65.1)	
Urgent	10,060 (22.8)	8,735 (22.2)	1,337 (28.0)	
Elective	1,676 (3.8)	1,416 (3.6)	243 (5.1)	
Other or no data	485 (1.1)	393 (1.0)	86 (1.8)	
Comorbidities				
Hypertension	23,165 (52.5)	20,893 (53.1)	2,306 (48.3)	< .001
Fluid and electrolyte disorders	21,753 (49.3)	18,926 (48.1)	2,808 (58.8)	< .001
Chronic pulmonary disease	21,488 (48.7)	19,280 (49.0)	2,173 (45.5)	< .001
Congestive heart failure	15,972 (36.2)	14,283 (36.3)	1,685 (35.3)	.19
Diabetes	13,104 (29.7)	11,725 (29.8)	1,399 (29.3)	.51
Anemia	11,560 (26.2)	10,033 (25.5)	1,542 (32.3)	< .001
Neurological disorder	9,177 (20.8)	7,987 (20.3)	1,217 (25.5)	< .001
Renal failure	7,809 (17.7)	7,043 (17.9)	773 (16.2)	.005
Psychiatric disorder (depression, psychoses)	7,015 (15.9)	6,295 (16.0)	716 (15.0)	.07
Malignancy	4,324 (9.8)	3,895 (9.9)	454 (9.5)	.48
Weight loss	1,720 (3.9)	983 (2.5)	750 (15.7)	< .001
Valvular heart disease	794 (1.8)	629 (1.6)	1,141 (23.9)	< .001
Peripheral vascular disease	485 (1.1)	189 (0.5)	314 (6.6)	< .001
Hypothyroidism	441 (1.0)	138 (0.5)	286 (6.0)	< .001
Peptic ulcer disease	383 (0.9)	338 (0.9)	45 (0.9)	.63
Collagen vascular disease	105 (0.2)	106 (0.3)	1 (0.1)	.001
Acquired immune deficiency syndrome	83 (0.2)	43 (0.1)	40 (0.8)	< .001
Pulmonary vascular disease	70.5 (0.1)	70 (0.2)	2 (0.1)	.044
Coagulopathy	61.7 (0.1)	51 (0.1)	13 (0.3)	.02
Liver disease	52 (0.2)	11 (0.0)	40 (0.8)	< .001
Payer source				< .001
Commercial insurance	7,898 (17.9)	6,964 (17.7)	916 (19.2)	
Medicare	23,782 (53.9)	21,147 (54.0)	2,536 (53.1)	
Medicaid	7,324 (16.6)	6,374 (16.2)	917 (19.2)	
Self pay	1,985 (4.5)	1,888 (4.8)	119 (2.5)	
Other	2,912 (6.6)	2,675 (6.8)	258 (5.4)	
No data available	176 (0.4)	157 (0.4)	24 (0.5)	

Values are number (%) unless otherwise indicated.
* P values for tracheostomy versus non-tracheostomy subjects.

Human Subjects Protection

The data used in this analysis represented a limited data set (ie, contained no direct patient identifiers) that was originally collected for non-research purposes. As such, this study was classified as exempt by the Washington University School of Medicine Human Research Protection Office (ie, did not involve human subjects) (HRPO 10–1190).

Results

Characteristics of the Academic Medical Centers, Subjects, and Tracheostomy Practice

We analyzed data from 44,124 subjects with the principal diagnosis of ARF, cared for in 102 academic medical centers (mean ± SD 575 ± 218.1 licensed beds,

Table 2. Outcomes of Adult Subjects With Acute Respiratory Failure Cared for in Academic Medical Centers

	All Subjects n = 44,124	Non-tracheostomy Subjects n = 39,348	Tracheostomy Subjects n = 4,776	P
Complications	5,780 (13.1)	2,872 (7.3)	2,899 (60.7)	< .001
Mortality	11,781 (26.7)	10,781 (27.4)	984 (20.6)	< .001
ICU stay, mean ± SD d	8.5 ± 10.5	6.6 ± 7.9	24.3 ± 20.7	< .001
Hospital stay, mean ± SD d	14.1 ± 21.0	11.3 ± 19.8	36.6 ± 27.6	< .001
Total hospital costs, mean ± SD $	107,705 ± 151,131	86,118 ± 107,771	285,509 ± 292,813	< .001
Discharge destination (survivors)				< .001
Home (out-patient care)	18,929 (42.9)	18,493 (47.0)	602 (12.6)	
Hospice	1,014 (2.3)	944 (2.4)	72 (1.5)	
In-patient setting (eg, acute care hospital, rehabilitation, skilled nursing facility)	23,959 (54.3)	19,753 (50.2)	4,069 (85.2)	
No data available	221 (0.5)	157 (0.4)	33 (0.7)	

Values are number (%) unless otherwise indicated.

Table 3. Outcomes of Adult Subjects With Acute Respiratory Failure Cared for in High Versus Low Resource Intensity Institutions

	All Subjects n = 44,124	High Resource Intensity n = 4,435	Low Resource Intensity n = 39,689	P
Complications, no. (%)	5,780 (13.1)	638 (14.4)	5,159 (13.0)	.007
Mortality, no. (%)	11,781 (26.7)	1,357 (30.6)	10,438 (26.3)	< .001
Tracheostomy, no. (%)	4,765 (10.8)	510 (11.5)	4,246 (10.7)	.13
ICU stay, mean ± SD d	8.5 ± 10.5	9.8 ± 13.3	8.4 ± 19.9	< .001
Hospital stay, mean ± SD d	14.1 ± 21.0	17.5 ± 20.0	13.7 ± 19.9	< .001
Total hospital costs, mean ± SD $	107,705 ± 153,131	182,106 ± 263,986	99,289 ± 132,681	< .001

432.5 ± 258.5 subjects per center) over a 7-year period (2002 through 2008). Overall, 4,776 subjects (10.8%) underwent tracheostomy (rate per center 10.8 ± 3.0%). The tracheostomy and non-tracheostomy subjects differed significantly with respect to several baseline variables: age, ethnicity, admission status, comorbidity, and payer source (Table 1). The tracheostomy subjects also had a higher morbidity rate, but a lower mortality rate than the non-tracheostomy subjects. The tracheostomy subjects were also more resource-intensive to manage, as evidenced by longer ICU and hospital stay, higher total hospital costs, and greater likelihood of being discharged to an in-patient facility (long-term care facility, skilled nursing facility, rehabilitation facility) (Table 2).

Differences in Tracheostomy Subject Outcomes Analyzed by Resource Intensity of the Care Environment

We analyzed data from 102 university-affiliated academic medical centers. Twelve centers were designated as high resource intensity (ie, proportional expense ratio ≥ 1.25, 4,435 subjects, mean ± SD subjects per center 369.5 ± 200.6), and 90 centers as low resource intensity (ie, proportional expense ratio < 1.25, 39,689 subjects, mean ± SD subjects per center 441.0 ± 265.6). The high and low resource intensity institutions were similar with respect to number of licensed beds (603.6 ± 273.7 vs 571.5 ± 213.8, P = .64) and number of annual discharges of subjects with ARF (370 ± 200 vs 441 ± 265, P = .44). The rates of tracheostomy did not differ, comparing these 2 environments (510/4,435 [11.5%] in the high-resource-intensity institutions vs 4,246/39,689 [10.7%] in the low-resource-intensity institutions, P = .13) (Table 3).

Variables found to be associated with mortality in univariate analysis were age, sex, probability of in-patient mortality, ICU stay, non-ICU stay, ethnicity, admission status (emergency vs non-emergency), payer source, presence of complications, and comorbidities present on admission (Table 4). In our multivariable analysis we found that being cared for in a high-resource-intensity environment was associated with increased risk of mortality (odds ratio = 1.11, 95% CI 1.05–1.76), while use of tracheostomy had no mortality effect (odds ratio = 0.99, 95% CI 0.92–1.06). However, the interaction term in our multivariable model demonstrated that tracheostomy subjects

Table 4. Baseline Characteristics of Acute Respiratory Failure Tracheostomy Subjects in High Versus Low Resource Intensity Institutions

	High Resource Intensity $n = 510$	Low Resource Intensity $n = 4,266$	P
Age, mean ± SD y	64.6 ± 17.2	59.9 ± 15.9	< .001
Male	243 (47.8)	2,231 (52.3)	.06
Ethnicity			< .001
White	256 (50.3)	2,611 (61.2)	
African American	111 (21.8)	1,122 (26.3)	
Hispanic	46 (9.0)	158 (3.7)	
Other	96 (18.8)	371 (8.7)	
Admission status			< .001
Emergency	350 (68.6)	2,755 (64.6)	
Urgent	119 (23.3)	1,220 (28.6)	
Elective	18 (3.5)	226 (5.3)	
Other or no data	23 (4.5)	60 (1.4)	
Comorbidities			
Acquired immune deficiency syndrome	6 (1.2)	38 (0.9)	.78
Anemia	147 (28.8)	1,394 (32.7)	.08
Chronic pulmonary disease	198 (38.8)	1,974 (46.3)	.002
Coagulopathy	76 (14.9)	657 (15.4)	.80
Collagen vascular disease	22 (4.3)	132 (3.1)	.17
Congestive heart failure	179 (35.1)	1,505 (35.3)	.95
Diabetes	109 (21.4)	1,288 (30.2)	< .001
Fluid and electrolyte disorders	259 (50.8)	2,546 (59.7)	< .001
Hypertension	228 (44.9)	2,073 (48.6)	.12
Hypothyroidism	38 (7.4)	375 (8.8)	.34
Liver disease	23 (4.5)	196 (4.6)	.89
Malignancy	90 (17.6)	367 (8.6)	< .001
Neurological disorder	137 (26.9)	1,079 (25.3)	.48
Peptic ulcer disease	2 (0.4)	17 (0.4)	.79
Peripheral vascular disease	22 (4.3)	188 (4.4)	.99
Psychiatric disorder (depression, psychoses)	59 (11.6)	657 (15.4)	.02
Pulmonary vascular disease	48 (9.4)	447 (10.5)	.50
Renal failure	79 (15.5)	695 (16.3)	.67
Valvular heart disease	52 (10.2)	375 (8.8)	.32
Weight loss	84 (16.5)	947 (22.2)	.004
Payer source			.20
Commercial insurance	108 (21.2)	810 (19.0)	
Medicare	281 (55.1)	2,252 (52.8)	
Medicaid	84 (16.5)	836 (19.6)	
Other	37 (7.2)	367 (8.6)	

Values are number (%) unless otherwise indicated.

managed in high-resource-intensity settings were at increased risk of death (odds ratio = 1.10, 95% CI 1.04 −1.17) (Table 5). Results were comparable whether resource intensity was modeled as a dichotomous or continuous variable (see the supplementary materials at http://www.rcjournal.com).

We explored possible reasons that might underlie our finding of an unfavorable relationship between resource intensity and outcome for tracheostomy subjects. To examine whether this relationship might be the result of early discharge of subjects at high risk of mortality from low-resource-intensity settings, we analyzed post-hospital discharge destination. We found that there was not a statistically significant trend toward high-resource-intensity settings being more likely to transfer subjects to other in-patient institutions following discharge (skilled nursing facilities 115/406 [28.5%], intermediate care facilities 156/406 [38.5%], rehabilitation centers 72/406 [17.7%], general hospitals 36/406 [8.9%], other environments 26/406 [6.4%], with low-resource-intensity settings being more likely to discharge subjects to home) (Table 6).

We considered whether the increased risk of mortality we observed may be related to an increased number or type of complications in high-resource-intensity settings. However, we found that the average number of complications per subject (1.54 ± 0.65 in low resource intensity vs 1.60 ± 0.22 in high resource intensity, $P = .13$), the incidence of complications per subject per day (0.036 ± 0.065 in low resource intensity vs 0.034 ± 0.072 in high resource intensity, $P = .11$), and profile of complications ($P > .05$ for all) were similar.

Finally, we examined the relationship between complications and mortality. We found that mortality for tracheostomy subjects experiencing complications was greater in the high-resource-intensity than in the low-resource-intensity environments: 95/313 (30.3%) vs 552/2587 (21.3%) ($P < .001$). In contrast, mortality rates in the tracheostomy subjects with no complications were similar: 41/197 (20.8%) vs 297/1679 (17.7%) ($P = .33$).

Discussion

The relationship between resource expenditure and outcome in healthcare settings is variable.[23-27] Studies have found that higher expenditure was associated with lower 30-day mortality, 1-year mortality, and major cardiac events among patients presenting to acute care hospitals with a variety of diagnoses.[24,25] In contrast, Garland et al reported that variation in discretionary resource use among individual medical intensivists did not translate into differences in in-hospital mortality or stay.[23] Given the variability in tracheostomy utilization and the resource consumption associated with providing care to patients undergoing this procedure, we examined the effects of resource expenditure in this setting. Consistent with the findings of prior studies, the resource expenditure associated with providing care to this patient population was significant, with total aggregate costs exceeding $1.6 billion.[1,3,4] Though representing only 10% of our sample, tracheostomy subjects accounted for 28.4% of these costs (collectively, $463 million). We

Table 5. Univariate Analysis and Odds Ratios for Variables Included in Logistic Regression Model for Mortality

	Univariate Analysis		*P*	Multivariable Analysis	
	Non-survivors *n* = 11,798	Survivors *n* = 32,326		Odds Ratio	95% CI
Variables significant in multivariable model					
Complications (≥ 1)	1,439 (12.2)	4,368 (13.5)	< .001	1.18	1.10–1.28
High resource intensity institution	1,357 (11.5)	3,073 (9.5)	< .001	1.11	1.05–1.76
Tracheostomy × High resource intensity institution	165 (1.4)	453 (1.4)	.88	1.10	1.04–1.17
Expected Death Rate, mean ± SD %	37.5 ± 20.0	23.8 ± 14.4	< .001	1.03	1.03–1.04
Age, mean ± SD y	65.3 ± 21.7	59.9 ± 17.9	< .001	1.01	1.01–1.01
ICU stay, mean ± SD d	9.0 ± 12.3	8.4 ± 10.9	< .001	1.01	1.00–1.01
Non-ICU stay, mean ± SD d	3.0 ± 11.4	6.5 ± 11.7	< .001	0.93	0.92–0.93
Admission status (emergency, non-emergency)	8,223 (69.7)	23,684 (73.2)	< .001	0.91	0.86–0.96
Comorbidities					
Solid tumor with metastasis	1,392 (11.8)	906 (2.8)	< .001	2.18	1.98–2.41
Coagulopathy	2,159 (18.3)	2,880 (8.9)	< .001	1.48	1.38–1.59
Solid tumor without metastasis	802 (6.8)	1,229 (3.8)	< .001	1.45	1.31–1.60
Liver disease	932 (7.9)	1,585 (4.9)	< .001	1.42	1.29–1.57
Lymphoma	354 (3.0)	388 (1.2)	< .001	1.44	1.22–1.70
Rheumatoid arthritis/collagen vascular disease	460 (3.9)	971 (3.0)	< .001	1.36	1.20–1.54
Fluid and electrolyte abnormality	6,335 (53.7)	14,140 (43.7)	< .001	1.14	1.08–1.20
Renal failure	2,218 (18.8)	5,597 (17.3)	< .001	1.14	1.07–1.22
Paralysis	448 (3.8)	1,650 (5.1)	< .001	0.87	0.78–0.97
Congestive heart failure	4,070 (34.5)	11,907 (36.8)	< .001	0.87	0.82–0.92
Obesity	743 (6.3)	3,656 (11.3)	< .001	0.84	0.77–0.92
Alcohol abuse	755 (6.4)	3,170 (9.8)	< .001	0.83	0.75–0.91
Deficiency anemias	2,394 (20.3)	8,541 (26.4)	< .001	0.75	0.71–0.79
Depression	708 (6.0)	3,494 (10.8)	< .001	0.75	0.69–0.82
Hypertension	5,403 (45.8)	17,795 (55.0)	< .001	0.75	0.71–0.79
Drug abuse	365 (3.1)	2,847 (8.8)	< .001	0.64	0.58–0.74
Psychoses	354 (3.0)	2,491 (7.7)	< .001	0.63	0.56–0.71
Chronic pulmonary disease	4,377 (37.1)	17,083 (52.8)	< .001	0.63	0.60–0.66
Variables not significant in multivariable model					
Payer source (Medicaid)	1,380 (11.7)	4,885 (15.1)	< .001	1.04	0.97–1.12
Tracheostomy	979 (8.3)	3,785 (11.7)	< .001	0.99	0.92–1.06
Female	5,568 (47.2)	15,919 (49.2)	< .001	0.97	0.92–1.02
Ethnicity non-white	4,613 (39.1)	13,880 (42.9)	< .001	0.96	0.91–1.01
Comorbidities					
Valvular heart disease	1,226 (10.4)	2,912 (9.0)	< .001	1.00	0.93–1.09
Diabetes (without complications)	2,667 (22.6)	8,218 (25.4)	< .001	0.95	0.90–1.01
Chronic blood loss anemia	189 (1.6)	421 (1.3)	.01	0.95	0.79–1.14
Diabetes (with complications)	519 (4.4)	1,714 (5.3)	< .001	0.94	0.84–1.05

Values are number (%) unless otherwise indicated.

limited our analysis to subjects with the principal diagnosis of ARF, assuming that indication for tracheostomy would be more consistent across institutions than if all individuals, irrespective of principal diagnosis, were included. Nonetheless, individuals in this study were complex, had substantial comorbidities, and had a death rate of > 25%. The tracheostomy subjects had a lower mortality rate than the non-tracheostomy subjects. Whether this resulted from practitioners targeting tracheostomy to individuals most likely to survive the acute episode of illness, or whether subjects undergoing tracheostomy survived until transfer to a non-acute hospital setting and then succumbed cannot be discerned from this analysis. Furthermore, the tracheostomy subjects had a higher complication rate, longer ICU and hospital stay, and higher overall costs than the non-tracheostomy subjects. We based institutional resource intensity on risk-adjusted estimates of costs associated with providing care. In contrast both to prior studies and our stated hypothesis, we found an inverse relationship between resource expenditure and outcome.[23-27]

Table 6. Outcomes of Acute Respiratory Failure Tracheostomy Subjects in High Versus Low Resource Intensity Institutions

	High Resource Intensity $n = 510$	Low Resource Intensity $n = 4,266$	*P*
Complications, no. (%)	313 (61.4)	2,585 (60.6)	.79
Mortality, no. (%)	136 (26.7)	849 (19.9)	< .001
ICU stay, mean ± SD d	28.1 ± 26.4	23.9 ± 18.8	.04
Hospital stay, mean ± SD d	44.8 ± 38.1	35.6 ± 30.5	< .001
Total hospital costs, mean ± SD $	166,567 ± 145,410	95,972 ± 78,557	< .001
Discharge destination (survivors), no. (%)			.057
Home (out-patient care)	96 (18.9)	1,041 (24.4)	
Hospice	4 (0.8)	64 (1.5)	
In-patient setting (eg, acute care hospital, rehabilitation, skilled nursing)	406 (79.7)	3,123 (73.2)	
No data available	2 (0.5)	34 (0.8)	

Specifically, compared with low-resource-intensity settings, subjects managed in high-resource-intensity institutions had higher in-hospital mortality, and tracheostomy was associated with as great as 17% higher likelihood of death. Thus, not only did institutions appear to differ with respect to the costs of care, the additional resources expended in high-resource-intensity settings did not appear to positively affect outcome.

We took 2 complementary approaches to performing our analysis: one in which the institutions were stratified into high and low resource-intensity categories, and the second in which resource intensity was modeled as a continuous variable. The intent of this latter approach was to compensate for any bias that discrete modeling of this variable might introduce (ie, arbitrary assignment of the high and low designation). Both methodologies produced comparable findings. We explored reasons that might underlie the observed relationship between resource intensity and mortality. We reasoned that low-resource-intensity environments may appear to have more favorable outcomes for tracheostomy subjects because of more timely transfer to other in-patient settings (such as skilled nursing or long-term weaning facilities). Deaths occurring in such settings would not be captured as in-patient mortality. However, not only were the low and high resource-intensity environments similar with respect to post-hospital discharge destinations, there was a trend for low-resource-intensity environments to more commonly discharge subjects to home. We similarly reasoned that higher rates of complications may underlie the greater resource expenditure and higher mortality in high-resource-intensity environments. Again, we found that low and high-resource-intensity environments were similar with respect to the incidence and total number of complications. However, mortality for the tracheostomy subjects who had complications was greater in the high-resource-intensity environments, suggesting a limited ability to rescue subjects following the development of complications. Potentially, these findings result from important differences in the patient populations between the low and high resource-intensity settings, which were not adequately adjusted for in our analysis. Thus, high-resource-intensity institutions may have managed subjects of greater acuity, explaining more common discharge to in-patient settings and higher mortality following the occurrence of complications. Accordingly, one must be circumspect in these interpretations.

Recent studies examining tracheostomy implementation have focused on specific outcomes such as duration of mechanical ventilation, ICU stay, and sedative use.[18-20] One interpretation of the current analysis is that it is difficult to disaggregate the use of tracheostomy from other facets of care. ICUs that apply differing approaches to ventilator weaning, sedation, venous thromboembolism prophylaxis, and other interventions may likewise differ significantly in the manner in which they apply tracheostomy.[32-34] Furthermore, post-tracheostomy care (approaches to phonation, nutrition, re-conditioning, and decannulation) might differ among institutions and influence outcome.[9] Our data set did not provide us with information on how care was provided, which limits our ability to identify factors and behaviors underlying the outcomes observed. We lack knowledge of factors that might prompt the decision for tracheostomy (eg, repetitive extubation failure, lack of progress on sequential weaning trial attempts). An appreciable proportion of the subjects described in this study had Medicare or Medicaid as a payer source; reimbursement considerations and similar non-clinical factors may have influenced the decision for tracheostomy in some contexts. Determining these factors (eg, through site visits or inventory of practices) and translating approaches effective at well-performing institutions to those that perform suboptimally would be one approach to enhancing patient safety and quality.

Our investigation has several additional limitations. The University Health Systems Consortium is a network of academic medical centers that may be self-selecting in terms of commitment to quality-assurance initiatives and other attributes. The severity of illness and complexity of patients cared for in these institutions may differ substantially from other settings (particularly non-academic institutions), limiting the ability to generalize these findings. In addition, this analysis is based on administrative coding data. These codes are designed to enable billing and are not necessarily a direct reflection of medical care received. Inaccuracy is potentially introduced through code attribution by non-clinical personnel. These shortcomings are partly offset by the fact that such codes are standardized, appropriately updated, and reasonably specific. Their availability in large numbers has the potential to "drown out" statistical noise and error. Also, our analysis might be confounded by the possibility that patient complexity is directly related to both resource intensity and likelihood of poor outcome. We structured our multivariable model so as to control for this possibility, stratifying hospitals based on previously validated risk-adjusted estimates of costs associated with providing care.[28-30] Though this method was uniformly applied to all institutions in our sample, it might not adequately account for all factors critical to outcome. For instance, geography and setting (ie, urban, suburban) may be an influential demographic factor that we did not capture.

These and other types of limitations might be further magnified by the lack of inclusion of physiologic data (eg, Acute Physiology and Chronic Health Evaluation score) that might have allowed us to further refine our estimates of illness acuity. Similarly, while we identified a large number of complications, many were defined in the context of the postoperative state. Thus, some important adverse events might go undetected. Finally, we undertook an institution-wide assessment of tracheostomy practice, focusing on patients with ARF. This approach ignores the very real differences in tracheostomy utilization and critical care practice that might exist within specific hospital domains (eg, comparing surgical and medical ICUs), and our findings might not be reflective of other disease processes (eg, acute neurological insult or polytrauma).

Conclusions

We were unable to demonstrate a positive relationship between resource expenditure and outcome in ARF patients managed with tracheostomy. Given the exploratory nature of this study, one must be circumspect about any conclusions drawn. Our analysis does suggest several potential avenues of further inquiry. Among these are investigations that focus on identifying clinically beneficial strategies related to tracheostomy patient selection, timing, technique, and post-procedure management, and assessing the cost-effectiveness of these strategies when applied across diverse clinical environments.

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