Patient and Hospital Characteristics Associated with Interhospital Transfer for Adults with Ventilator-Dependent Respiratory Failure

Nandita R. Nadig¹, Andrew J. Goodwin¹, Annie N. Simpson², Kit N. Simpson², Jeremy Richards¹, and Dee W. Ford¹

¹Division of Pulmonary and Critical Care Medicine, Department of Medicine, and ²Department of Healthcare Leadership and Management, Medical University of South Carolina, Charleston, South Carolina

Abstract

Rationale: Patients with ventilator-dependent respiratory failure have improved outcomes at centers with greater expertise; yet, most patients are not treated in such facilities. Efforts to align care for respiratory failure and hospital capability would necessarily require interhospital transfer.

Objectives: To characterize the prevalence and the patient and hospital factors associated with interhospital transfer of adults residing in Florida with ventilator-dependent respiratory failure.

Methods: We performed a retrospective, observational study using Florida Healthcare Cost and Utilization Project data. We selected patients 18 years of age and older with International Classification of Diseases, Ninth Revision, codes of respiratory failure and mechanical ventilation during 2012 and 2013, and we identified cohorts of patients that did and did not undergo interhospital transfer. We obtained patient sociodemographic and clinical variables and categorized hospitals into subtypes on the basis of patient volume and services provided: large, medium (nonprofit or for-profit), and small.

Results: Interhospital transfer was our primary outcome measure. Patient sociodemographics, clinical variables, and hospital types were

used as covariates. We identified 2,580 patients with ventilator-dependent respiratory failure who underwent interhospital transfer. Overall, transfer was uncommon, with only 2.9% of patients being transferred. In a hierarchical model, age less than 65 years (odds ratio [OR], 2.09; 95% confidence interval [CI], 1.77–2.45) and tracheostomy (OR, 3.19; 95% CI, 2.80–3.65) were associated with higher odds of transfer, whereas having Medicaid was associated with lower odds of transfer than having commercial insurance (OR, 0.65; 95% CI, 0.56–0.75). Additionally, care in medium-sized for-profit hospitals was associated with lower odds of transfer (OR, 1.37 vs. 2.70) than care in medium nonprofit hospitals, despite similar hospital characteristics.

Conclusions: In Florida, interhospital transfer of patients with ventilator-dependent respiratory failure is uncommon and more likely among younger, commercially insured, medically resource-intensive patients. For-profit hospitals are less likely to transfer than nonprofit hospitals. In future studies, researchers should test for geographic variations and examine the clinical implications of selectivity in interhospital transfer of patients with ventilator-dependent respiratory failure.

Keywords: profit status; Healthcare Cost and Utilization Project; state inpatient database; nonprofit status

Supported by the South Carolina Clinical and Translational Research (SCTR) Institute at the Medical University of South Carolina, National Institutes of Health/National Center for Advancing Translational Sciences grants KL2 TR000060 and UL1 TR000062 (A.J.G.), and the Duke Endowment Foundation Health Care Division (D.W.F.).

Author Contributions: N.R.N. and K.N.S.: had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis; N.R.N., A.J.G., and D.W.F.: were active participants in all aspects of the study (design and conduct of the study; collection, management, analysis, and interpretation of the data, and preparation of the manuscript); K.N.S. and A.N.S.: design, analysis, and interpretation of the data and preparation of the manuscript; and J.R.: interpretation of the data and preparation of the manuscript.

Correspondence and requests for reprints should be addressed to Nandita R. Nadig, M.D., M.S.C.R., Division of Pulmonary and Critical Care Medicine, Department of Medicine, Medical University of South Carolina, 96 Jonathan Lucas Street, Suite 816 CSB, Charleston, SC 29425. E-mail: nadig@muscc.edu

Ann Am Thorac Soc Vol 14, No 5, pp 730–736, May 2017

Copyright © 2017 by the American Thoracic Society

DOI: 10.1513/AnnalsATS.201611-918OC

Internet address: www.atsjournals.org

Patients with ventilator-dependent respiratory failure (VDRF) experience high rates of morbidity and mortality and account for over half of admissions to intensive care units (ICUs) (1, 2). The

incidence of VDRF has been increasing over the past decade, driven by increased patient complexity and the aging of the U.S. population (3). Studies have shown that VDRF outcomes are improved by

intensivist-directed care and receiving care at higher-volume centers with greater experience (4–7). This association likely has many causes, including differences in the adoption rate of evidence-based care (8),

provider expertise/staffing models (7, 9, 10), and referral bias (11). Thus, various professional organizations are actively debating a tiered system of regionalization for patients with VDRF (12, 13) that would be similar to existing systems in trauma and high-risk neonatology (14–16).

Although interhospital transfer of patients is a core element of a regionalization system for VDRF care, little is known about the current transfer practice in this population. In one study in which researchers evaluated Medicare claims data, approximately 5% of all critically ill Medicare recipients were reportedly transferred between hospitals (17), although the proportion of these patients who had VDRF is unknown. Further, two single-center studies (18, 19) in which researchers evaluated the outcomes of interhospital transfer of critically ill patients suggested that transferred patients experience higher mortality and longer stay than nontransferred patients, even after adjustment for illness severity. Although the adequacy of risk adjustment of these studies limits their generalizability, they are provocative and highlight the importance of a deeper understanding of factors associated with interhospital transfer. It is especially important to ascertain whether this practice is driven by clinical indication, patient/family, or hospital-level variables.

The lack of insight into the clinical, demographic, and hospital-level variables that influence interhospital transfer of patients with VDRF represents a critical knowledge gap, particularly as U.S. health systems move toward more integrated care. We postulated that interhospital transfer of patients with VDRF would be associated with a combination of patient and hospital variables. Thus, the aim of this exploratory study was to identify potential differences in demographic, clinical, and hospital variables between patients with VDRF who underwent interhospital transfer and those who did not to better understand the factors that influence the decision to transfer these vulnerable patients between hospitals.

Methods

Study Design and Data Source

We conducted a retrospective cohort study of all adult patients (aged ≥ 18 yr) admitted to nonfederal acute care hospitals in Florida in 2012 and 2013. We obtained

administrative data from Florida's Healthcare Cost and Utilization Project (HCUP) state inpatient database (SID). We selected Florida because its SID data contain unique identifiers that allow tracking of individual patients between different acute care hospitals, thus allowing for the creation of an interhospital transfer cohort. In addition, the Florida HCUP dataset retains specific digits in the anonymous hospital identification numbers, which allows for the identification of long-term acute care (LTAC) hospitals such that transfers into these facilities could be excluded to obtain the cohort of interest.

Cohort Identification and Exclusions

All adult patients with an International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM), diagnosis code corresponding to acute respiratory failure (518.xx) and a procedure code corresponding to mechanical ventilation (96.70, 96.71, and 96.72) were identified as the VDRF cohort (20). We excluded patients who were transferred either to or from facilities designated as LTAC hospitals in the HCUP dataset because this was not our population of interest. To further ensure that patients receiving care at LTAC hospitals were not included owing to hospital miscoding, patients were also excluded if they were transferred to or from hospitals with an average patient length of stay greater than 25 days because this characteristic is indicative of LTAC facilities (21, 22). In addition, we also excluded patients in psychiatric hospitals and one large hospital system where the hospital identification number was shared by a number of smaller system hospitals.

The VDRF cohort was then partitioned into a transfer cohort and a nontransfer cohort. The transfer cohort was identified using two methods: first, all patients with VDRF with a discharge destination code of interfacility transfer to a second acute care hospital were initially included; second, all patients with VDRF discharged and then subsequently admitted to a different acute care hospital within the same calendar day were included. This strategy was used to compensate for coding errors in discharge destination. Additionally, we accessed the Florida Emergency Department Database to identify patients transferred from the emergency department to another hospital,

and we found that they represented less than 3% of all transferred patients with VDRF and hence excluded them from the final analysis. All patients who were not classified into the transfer cohort were assigned into the nontransfer cohort.

Variable Development

We hypothesized that both patient-level and hospital-level variables would influence whether a patient with VDRF received interhospital transfer. Thus, we selected sets of variables *a priori* and examined their associations with interhospital transfer.

Patient and Clinical Variables

Patient variables included demographics such as age, sex, race, insurance, and comorbidities (Charlson comorbidity index [23]). Clinical variables included length of stay for transferred (at initial hospital) and nontransferred patients. In addition, we wanted to determine associations between the timing of mechanical ventilation initiation and hospital transfer; hence, we constructed an early mechanical ventilation variable using the date and time of the admission combined with the date for the first procedure code corresponding to mechanical ventilation (96.7x).

We then classified any patient receiving mechanical ventilation within 0–2 days of the admission date and time as having had early mechanical ventilation (24). In addition, diagnoses/procedures common to patients with VDRF were examined. These included a diagnosis of shock (ICD-9-CM codes 785.5x, 040.82, 276.5x), renal failure requiring dialysis (ICD-9-CM code 39.95), tracheostomy (Clinical Classifications Software for Services and Procedures variable 34), and major surgery (by a specific indicator in the SID). For the transfer cohort, these variables were assessed at the initial hospital.

Hospital-Level Variables

We hypothesized that hospital-level variables contribute to patient transfers, but informative hospital-specific variables are not available in HCUP. Thus, we used a combination of available HCUP hospital variables and variables we constructed on the basis of patient-level data associated with each hospital. These constructed variables included hospital-specific case volume(s) and inferred available critical care resources based on specific procedure codes.

We first characterized hospitals on the basis of bed size (>300, 100–300, and <100), profit status, and urban versus rural location using available HCUP variables; however, we believed these variables were insufficient to adequately characterize hospital expertise and capabilities. Thus, we used patient data associated with each hospital to determine hospital-specific annual case volumes of VDRF (in increments of 100 VDRF cases) (25), annual emergency department case volume and annual overall ICU case volume. We also examined patient-level procedure codes for solid organ transplant (39.65) and/or extracorporeal membrane oxygenation not associated with cardiac surgery (55.6x) as measures of advanced critical care resources.

Using these patient-level variables, we created hospital categories ranging from high-volume, high-resource, large hospitals to lower-volume, lower-resource, small hospitals. We had initially planned to group hospitals into more discrete categories, but HCUP requires hospital confidentiality, and very few sites in Florida provided certain advanced treatments; therefore, we simplified and collapsed the hospital categories into small, medium-size for-profit, medium nonprofit, and large. Medium-size hospitals were the only hospital category separated into for-profit and nonprofit status, because we identified significant variation between the two groups in only the medium-size hospitals and not for the other hospital categories.

Statistical and Analytic Approach

Descriptive statistics of both the transferred and nontransferred cohorts were calculated; however, hypothesis testing of bivariate statistical differences between the transferred and nontransferred groups are not displayed, because the large sample size resulted in statistically significant but clinically irrelevant differences in nearly all variables (26, 27). Manually fitted multivariable logistic regression was used to identify the associations between patient variables and hospital category and the odds of an interhospital transfer. Models were estimated using clinical variables first, then adding patient demographic variables, and finally adding hospital categories. Significant predictors were chosen by including all predictors in the model and removing them manually, one at a time,

based on a set of predictive model-building criteria referred to as *purposeful selection* (28). Predictors with significance levels less than 0.25 were examined closely prior to their potential removal using acceptance guidelines of removal based on the following statistical criteria: (1) no more than 20% change in other parametric estimates after removal; (2) smaller Akaike information criterion/Bayesian information criterion, indicating a better model fit without the covariate; and (3) likelihood ratio test.

All final models were assessed for overall goodness of fit using the Hosmer-Lemeshow goodness-of-fit statistic (29). If covariates improved the model fit, they remained in the model, regardless of whether they met the statistical significance level of less than 0.05. To assess if variation differences caused by the nesting of patients within hospitals significantly impacted model performance, a final parsimonious multilevel generalized linear mixed model, also known as a *hierarchical model*, was fitted using the SAS/STAT 9.1 production GLIMMIX procedure, which allows for the clustering of patients within hospitals (30). The same purposeful selection criteria as described above were used for the multilevel model (27). Model performance was evaluated by c-statistics.

Referent values for nondichotomous variables in the models included white race, commercial insurance, age over 80 years, and large-hospital category. All presented odds ratios (ORs) represent adjusted odds from the multivariable model. We examined interaction terms between variables, and none were found to be significant. Data were analyzed using SAS 9.4 software (SAS Institute, Cary, NC), and we considered a

two-sided $\alpha < 0.05$ as the threshold for statistical significance.

Results

We examined a total of 89,943 acute care hospital records of patients with VDRF, of whom 2,580 (2.9%) had undergone an interhospital transfer. We excluded 489 transfer patients whom we were unable to find in a second receiving hospital, creating a total interhospital transfer cohort of 2,091 patients and a total sample size of 89,454 (Figure 1). Transferred patients were more likely to be younger than 65 years (53.4% vs. 44.1%) and to have commercial insurance (22.6% vs. 17.2%) than nontransferred patients. Transferred patients were more likely than nontransferred patients to have undergone a tracheostomy (19.4% vs. 9.9%). Conversely, the nontransferred cohort had higher percentages of patients with shock (33.1% vs. 29.9%) or who had undergone major surgery (37.2% vs. 31.9%) (Table 1). A large majority (>70%) in both the transferred and nontransferred cohorts received early mechanical ventilation (within the first 2 d of admission).

The hospital categories and associated hospital variables, proportion of overall VDRF cases, and proportion of VDRF transfers are presented in Table 2. One-half of patients presented to large hospitals; the remaining 50% presented to medium-sized and small hospitals. Regardless of hospital category, the prevalence of interhospital transfer for patients with VDRF was quite low at 2.9% overall and ranging from a maximum of 10% of VDRF cases being

Figure 1. Patients with ventilator-dependent respiratory failure (VDRF) in Florida who have undergone interhospital transfer (includes all patients in Florida with VDRF who did and did not undergo interhospital transfer during the 2012 and 2013 calendar years).

Table 1. Characteristics of patients with ventilator-dependent respiratory failure transferred versus not transferred (n = 89,454)

Variable	Transferred (n = 2,091)	Not Transferred (n = 87,363)
Age, yr, mean (SD)	61.1 (16.4)	65.3 (16.8)
Female sex, n (%)	901 (43.1)	39,736 (45.5)
Race/ethnicity, n (%)		
White	1,445 (69.6)	58,743 (67.2)
Black	326 (15.6)	14,036 (16.0)
Hispanic	239 (11.4)	11,636 (13.3)
Other	81 (3.8)	2,948 (3.3)
Insurance, n (%)		
Medicare	1,225 (58.6)	56,109 (64.2)
Medicaid	393 (18.7)	16,166 (18.5)
Commercial	473 (22.6)	15,088 (17.2)
Hospital length of stay, median (IQR)	9 (4–18)*	10 (5–18)
Early mechanical ventilation†	1,498 (71.6%)	62,965 (72.1%)
Shock, n (%)	626 (29.9)	28,959 (33.1)
Major surgery, n (%)	667 (31.9)	32,469 (37.2)
Dialysis, n (%)	243 (11.6)	9,148 (10.4)
Tracheostomy, n (%)	405 (19.4)	8,663 (9.9)
Charlson comorbidity index, mean (SD)	2.10 (2.00)	2.31 (2.30)

Definition of abbreviation: IQR = interquartile range.

*Initial hospital length of stay for transfers.

†Within 2 days of admission.

transferred at small hospitals to a low of 1.6% at large hospitals.

The transfer pattern of each hospital category is shown in (Table 3). In general, patients with VDRF from medium-sized nonprofit (66.6%) and small (60.5%) hospitals were transferred to large hospitals. However, medium-sized for-profit hospitals transferred as many cases (41.6%) to other medium-sized for-profit hospitals (44.2%) as large hospitals.

Multivariable logistic regression and generalized linear mixed hierarchical models (Table 4) were used to identify predictors for interhospital transfer in the VDRF population. Use of the final parsimonious hierarchical model accounted for variation of clustered patients with hospitals and primarily improved the hospital category variable. Of significant note among demographic variables, odds of transfer for patients under age 65 years

were 2.09 higher than those over 80 years of age (OR, 2.09; 95% confidence interval [CI], 1.77–2.45). Additionally, transferred patients were 35% less likely to have Medicaid (OR, 0.65; 95% CI, 0.56–0.75) than commercial insurance.

Patients who were ventilated early in their hospital course had a 19% lower odds of transfer (OR, 0.81; 95% CI, 0.73–0.90), whereas patients who had received a tracheostomy had a greater than threefold higher odds of being transferred (OR, 3.19; 95% CI, 2.80–3.65). Even after adjustment for patient demographic and clinical variables, patients in small hospitals had 7.69 times higher odds of transfer (OR, 7.69; 95% CI, 4.60–12.79) than those in large hospitals. However, patients in medium-sized nonprofit hospitals were much more likely to be transferred (OR, 2.70; 95% CI, 1.74–4.16), whereas patients in medium-sized for-profit hospitals had an OR of 1.37 (95% CI, 0.97–1.95) of being transferred.

The final hierarchical parsimonious model closely resembled the full logistic model as well as the smaller logistic models of patient demographics, clinical characteristics, and hospital characteristics, although demographic variables such as sex and race were not associated with transfer (Table 4). Multivariable logistic model performance was evaluated by the c-statistic (concordance index) and ranged from a low of 0.62–0.65 (full model) to a high of 0.72 (final parsimonious model), indicating acceptable performance (29).

Table 2. Hospital categories and defining variables

Variables	Hospital Categories			
	Large	Medium-sized For-Profit	Medium-sized Nonprofit	Small
Number of hospitals in each category	42	67	25	19
Bed number category	>300	100–300	100–300	<100
Annual VDRF case volume, mean (SD)	683 (415)	337 (172)	200 (82)	95 (48)
Annual ED case volume, mean (SD)	16,173 (6,754)	10,562 (4,593)	6,608 (2,526)	3,138 (1,292)
Annual ICU case volume, mean (SD)	8,646 (7,250)	4,444 (2,683)	3,310 (2,395)	1,132 (704)
Noncardiac ECMO*	Yes	No	No	No
Solid organ transplant*	Yes	No	No	No
Number (%) of all VDRF admissions†	45,528 (50.9%)	32,511 (36.3%)	9,341 (10.4%)	2,073 (2.3%)
Number (%) of patients with VDRF undergoing interhospital transfer‡	768 (1.68%)	639 (1.97%)	476 (5.10%)	208 (10.03%)

Definition of abbreviations: ECMO = extracorporeal membrane oxygenation; ED = emergency department; ICU = intensive care unit; VDRF = ventilator-dependent respiratory failure.

*One or more cases of ECMO or any solid organ transplant in the dataset between 2012 and 2013.

†VDRF admissions (n [%]) numerator/denominator = VDRF admissions in each hospital category/total number of VDRF admissions (89,943) × 100.

‡Patients with VDRF undergoing interhospital transfer (n [%]) numerator/denominator = patients with VDRF receiving transfer in each hospital category/total number of patients with VDRF in each hospital category × 100.

Table 3. Interhospital transfer patterns by hospital category for ventilator-dependent respiratory failure cases (n = 2,091)

Transferring Hospital Category	Receiving Hospital Category			
	Small	Medium-sized For-Profit	Medium-sized Nonprofit	Large
Small	7 (3.3)	59 (28.3)	16 (7.6)	126 (60.5)
Medium-sized for-profit	38 (5.9)	266 (41.6)	52 (8.1)	283 (44.2)
Medium-sized nonprofit	30 (6.3)	78 (16.3)	51 (10.7)	317 (66.6)
Large	60 (7.8)	158 (20.5)	167 (21.7)	383 (49.8)

All categories are reported as unadjusted number (percent).

Discussion

To our knowledge, this is the first study to use claims data to evaluate interhospital transfer among patients admitted with VDRF. We found that nearly 50% of patients are treated in small and medium-sized hospitals with lower expertise; yet, interhospital transfer is rare, despite the benefits of treatment in larger hospitals with more robust case volumes (25).

Furthermore, we found that early mechanical ventilation was associated with reduced probability of transfer, suggesting that hospitals are potentially more likely to pursue transfer for more complex patients who developed VDRF despite the care received early in their hospital course. Last, our data suggest that the typical patient with VDRF who is transferred between hospitals is younger, commercially insured, and requires prolonged mechanical

ventilation, as evidenced by tracheostomy increasing the odds of transfer.

In addition, we observed that medium-sized nonprofit hospitals were more likely to transfer patients with VDRF, typically to larger centers, than were medium-sized for-profit hospitals. The motivations behind this difference are not known; however, one hypothesis is that for-profit hospitals are reluctant to lose revenue by transferring patients elsewhere. Further, patients with

Table 4. Predictors of transfer among patients with ventilator-dependent respiratory failure, adjusted model results (n = 89,454)

Predictors	Patient Clinical Model AOR (95% CI)	Patient Demographic Model AOR (95% CI)	Hospital Model AOR (95% CI)	Full Logistic Model AOR (95% CI)	Full Hierarchical Model AOR (95% CI)
Patient clinical variables					
LOS less than median	1.66 (1.49–1.85)			1.58 (1.42–1.76)	1.53 (1.37–1.71)
Early mechanical ventilation*	0.81 (0.73–0.90)			0.82 (0.74–0.92)	0.81 (0.73–0.90)
Shock	0.88 (0.80–0.97)			0.87 (0.79–0.96)	0.68 (0.78–0.95)
Major surgery	0.74 (0.67–0.82)			0.87 (0.78–0.96)	0.85 (0.77–0.95)
Dialysis	1.22 (1.06–1.40)			1.17 (1.01–1.35)	1.14 (0.98–1.31)
Tracheostomy	2.99 (2.64–3.39)			3.25 (2.86–3.70)	3.19 (2.80–3.65)
Charlson comorbidity index score	0.96 (0.94–0.98)			0.96 (0.94–0.98)	0.95 (0.93–0.97)
Patient demographic variables					
Age category, yr					
80+		Reference		Reference	Reference
<65		2.17 (1.86–2.55)		2.16 (1.84–2.53)	2.09 (1.77–2.45)
65–79		1.79 (1.55–2.07)		1.78 (1.55–2.06)	1.79 (1.55–2.08)
Female sex		0.95 (0.87–1.04)		NS	NS
Race category					
White		Reference		Reference	Reference
Black		0.85 (0.75–0.97)		NS	NS
Other		0.91 (0.81–1.03)		NS	NS
Insurance provider					
Commercial		Reference		Reference	Reference
Medicare		0.94 (0.83–1.07)		0.86 (0.75–0.98)	0.84 (0.73–0.96)
Medicaid		0.75 (0.65–0.86)		0.71 (0.61–0.81)	0.65 (0.56–0.75)
Hospital characteristic variables					
Hospital category					
Large hospital			Reference	Reference	Reference
Medium-sized for-profit			0.86 (0.77–0.98)	0.86 (0.77–0.97)	1.37 (0.97–1.95)
Medium-sized nonprofit			1.99 (1.74–2.28)	1.99 (1.74–2.28)	2.70 (1.74–4.16)
Small hospital			3.49 (2.91–4.20)	3.49 (2.91–4.20)	7.67 (4.60–12.79)
Annual VDRF admissions (in 100s)			0.88 (0.86–0.90)	0.88 (0.86–0.90)	0.95 (0.92–0.99)
Model c-statistic	0.62	0.65	0.72	0.72	—

Definition of abbreviations: AOR = adjusted odds ratio; CI = confidence interval; LOS = length of stay less than median (9 d); NS = not a significant contributor to the model, thus removed; VDRF = ventilator-dependent respiratory failure.

*Less than 2 days.

commercial insurance had increased odds of transfer; thus, it is possible that receiving hospitals may preferentially accept patients on the basis of insurance status.

Although these hypotheses cannot be proven with the available data, these observations raise the question whether financial bias influences the transfer patterns of patients with VDRF. Because previous literature has demonstrated worse outcomes in for-profit hospitals for a variety of conditions, including heart disease (31) and end-stage renal disease requiring dialysis (32, 33), it is important to further study the reasons for this discrepant transfer practice to understand the degree to which hospital mission and financial factors influence clinical decision making and outcomes.

There is limited insight into how ICU patients are selected for transfer because the only study in which researchers evaluated key stakeholder perceptions demonstrated poor consensus between patients, transferring physicians, and receiving physicians (34). We observed in our present study that older patients were less likely to be transferred. This finding is congruent with previous studies (35, 36) showing that older, critically ill patients are treated less aggressively than their younger counterparts.

Commercially insured patients in our study had higher odds of transfer than patients with government payer insurance (Medicare or Medicaid), which is consistent with prior results demonstrating that well-reimbursed coverage was associated with interhospital transfer (37). It is notable that other studies have shown that Medicaid patients presenting to the emergency department are more likely to be transferred; however, this relationship may be influenced by the Emergency

Medical Treatment and Labor Act, which mandates that acute care hospitals accept patients in transfer from emergency departments when a request has been issued for a higher level of care (38).

Our findings suggest that patients who develop VDRF later in their hospital course, despite receiving inpatient care, are more likely to be transferred than those who develop it early. This may be because hospitals are more inclined to pursue transfer for patients who are deemed medically complex or as not responding to therapy.

Similarly, patients who undergo tracheostomy may also represent a more complex and resource-intensive population, which may explain the observed relationship between this procedure and patient transfer. This hypothesis is supported by the work of Unroe and colleagues (39), who demonstrated that chronically ill, resource-intensive patients are more likely to undergo interfacility transfer multiple times and subsequently experience poor outcomes. Future prospective studies examining the relationship between medical complexity and patient transfer may offer further insight into these findings.

Limitations

Using billing codes to identify patients, procedures, and diagnoses may misclassify patients because they are not always correctly coded. Also, these data lack insight into the motivations and decision-making processes of the individuals involved in the interhospital transfer. We can merely speculate regarding factors such as family requests, availability of consultants or procedures, and ICU structure; however, it is likely that these and other factors influence transfer practices (34).

Because we used claims-based data, we were unable to adjust for illness severity other than comorbidities. This inability, combined with the evident bias between transferred and nontransferred groups, limits our ability to compare clinical outcomes. Also, as HCUP datasets are state specific, these results may not be generalizable. The retrospective nature of the study prohibited us from establishing causality. Geographic differences in interhospital transfer practices may limit generalization of our results to other states and regions of the United States.

Conclusions

To our knowledge, this is the first study which identifies patient and hospital factors that influence interhospital transfer of patients with VDRF. We found that one-half of patients in Florida with VDRF were treated in small and medium-sized hospitals and that interhospital transfer was very rare. Those patients who were transferred were more likely to be younger, commercially insured, resource intensive, and medically complex. In addition, medium-sized for-profit and medium-sized nonprofit hospitals had very different odds of transfer despite otherwise similar hospital characteristics, raising the question whether profit status affects clinical decision making. Future efforts should be made to evaluate the clinical outcomes associated with VDRF transfers, to seek knowledge regarding patient groups most likely to benefit from transfer, and to test for geographic variation in interhospital VDRF transfer practices. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

References

- Esteban A, Anzueto A, Frutos F, Alía I, Brochard L, Stewart TE, Benito S, Epstein SK, Apezteguía C, Nightingale P, *et al.*: Mechanical Ventilation International Study Group. Characteristics and outcomes in adult patients receiving mechanical ventilation: a 28-day international study. *JAMA* 2002;287:345–355.
- Metnitz PG, Metnitz B, Moreno RP, Bauer P, Del Sorbo L, Hoermann C, de Carvalho SA, Ranieri VM; SAPS 3 Investigators. Epidemiology of mechanical ventilation: analysis of the SAPS 3 database. *Intensive Care Med* 2009;35:816–825.
- Carson SS, Cox CE, Holmes GM, Howard A, Carey TS. The changing epidemiology of mechanical ventilation: a population-based study. *J Intensive Care Med* 2006;21:173–182.
- Glance LG, Li Y, Osler TM, Dick A, Mukamel DB. Impact of patient volume on the mortality rate of adult intensive care unit patients. *Crit Care Med* 2006;34:1925–1934.
- Kahn JM, Goss CH, Heagerty PJ, Kramer AA, O'Brien CR, Rubenfeld GD. Hospital volume and the outcomes of mechanical ventilation. *N Engl J Med* 2006;355:41–50.
- Needham DM, Bronskill SE, Rothwell DM, Sibbald WJ, Pronovost PJ, Laupacis A, Stukel TA. Hospital volume and mortality for mechanical ventilation of medical and surgical patients: a population-based analysis using administrative data. *Crit Care Med* 2006;34:2349–2354.
- Pronovost PJ, Angus DC, Dorman T, Robinson KA, Dremiszov TT, Young TL. Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. *JAMA* 2002;288:2151–2162.

- 8 Holcomb BW, Wheeler AP, Ely EW. New ways to reduce unnecessary variation and improve outcomes in the intensive care unit. *Curr Opin Crit Care* 2001;7:304–311.
- 9 Dudley RA, Johansen KL, Brand R, Rennie DJ, Milstein A. Selective referral to high-volume hospitals: estimating potentially avoidable deaths. *JAMA* 2000;283:1159–1166.
- 10 Wilcox ME, Chong CA, Niven DJ, Rubenfeld GD, Rowan KM, Wunsch H, Fan E. Do intensivists staffing patterns influence hospital mortality following ICU admission? A systematic review and meta-analyses. *Crit Care Med* 2013;41:2253–2274.
- 11 Luft HS, Hunt SS, Maerki SC. The volume-outcome relationship: practice-makes-perfect or selective-referral patterns? *Health Serv Res* 1987;22:157–182.
- 12 Barnato AE, Kahn JM, Rubenfeld GD, McCauley K, Fontaine D, Frassica JJ, Hubmayr R, Jacobi J, Brower RG, Chalfin D, et al. Prioritizing the organization and management of intensive care services in the United States: the PROMIS Conference. *Crit Care Med* 2007;35:1003–1011.
- 13 Ewart GW, Marcus L, Gaba MM, Bradner RH, Medina JL, Chandler EB. The critical care medicine crisis: a call for federal action: a white paper from the critical care professional societies. *Chest* 2004;125:1518–1521.
- 14 MacKenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Eggleston BL, Salkever DS, Scharfstein DO. A national evaluation of the effect of trauma-center care on mortality. *N Engl J Med* 2006;354:366–378.
- 15 Lasswell SM, Barfield WD, Rochat RW, Blackmon L. Perinatal regionalization for very low-birth-weight and very preterm infants: a meta-analysis. *JAMA* 2010;304:992–1000.
- 16 Phipps CS, Baker LC, Caughey AB, Danielsen B, Schmitt SK, Phipps RH. Level and volume of neonatal intensive care and mortality in very-low-birth-weight infants. *N Engl J Med* 2007;356:2165–2175.
- 17 Iwashyna TJ, Christie JD, Moody J, Kahn JM, Asch DA. The structure of critical care transfer networks. *Med Care* 2009;47:787–793.
- 18 Rosenberg AL, Hofer TP, Strachan C, Watts CM, Hayward RA. Accepting critically ill transfer patients: adverse effect on a referral center's outcome and benchmark measures. *Ann Intern Med* 2003;138:886–890.
- 19 Combes A, Luyt CE, Trouillet JL, Chastre J, Gibert C. Adverse effect on a referral intensive care unit's performance of accepting patients transferred from another intensive care unit. *Crit Care Med* 2005;33:705–710.
- 20 Kahn JM, Ten Have TR, Iwashyna TJ. The relationship between hospital volume and mortality in mechanical ventilation: an instrumental variable analysis. *Health Serv Res* 2009;44:862–879.
- 21 HHS takes steps to further limit Medicaid loophole. *Health Care Financ Rev* 2002;23:171–172.
- 22 Liu K, Baseggio C, Wissoker D, Maxwell S, Haley J, Long S. Long-term care hospitals under Medicare: facility-level characteristics. *Health Care Financ Rev* 2001;23:1–18.
- 23 Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373–383.
- 24 Ford DW, Goodwin AJ, Simpson AN, Johnson E, Nadig N, Simpson KN. A severe sepsis mortality prediction model and score for use with administrative data. *Crit Care Med* 2016;44:319–327.
- 25 Kahn JM, Linde-Zwirble WT, Wunsch H, Barnato AE, Iwashyna TJ, Roberts MS, Lave JR, Angus DC. Potential value of regionalized intensive care for mechanically ventilated medical patients. *Am J Respir Crit Care Med* 2008;177:285–291.
- 26 Wasserstein RL, Lazar NA. The ASA's statement on *p*-values: context, process, and purpose. *Am Stat* 2016;70:129–133.
- 27 Greenland S, Senn SJ, Rothman KJ, Carlin JB, Poole C, Goodman SN, Altman DG. Statistical tests, *P* values, confidence intervals, and power: a guide to misinterpretations. *Eur J Epidemiol* 2016;31:337–350.
- 28 Hosmer DW Jr, Lemeshow S, Sturdivant RX. Applied logistic regression. 3rd ed. Hoboken, NJ: John Wiley & Sons; 2013.
- 29 Hosmer DW, Lemeshow S. Applied logistic regression. 2nd ed. Hoboken, NJ: John Wiley & Sons; 2000.
- 30 SAS Institute. SAS/STAT 9.1 production GLIMMIX procedure for Windows. Cary, NC: SAS Institute; 2005.
- 31 Cutler DM, editor. The changing hospital industry: comparing for-profit and not-for-profit institutions. Chicago: University of Chicago Press; 2000.
- 32 Devereaux PJ, Schünemann HJ, Ravindran N, Bhandari M, Garg AX, Choi PT, Grant BJ, Haines T, Lacchetti C, Weaver B, et al. Comparison of mortality between private for-profit and private not-for-profit hemodialysis centers: a systematic review and meta-analysis. *JAMA* 2002;288:2449–2457.
- 33 Garg PP, Frick KD, Diener-West M, Powe NR. Effect of the ownership of dialysis facilities on patients' survival and referral for transplantation. *N Engl J Med* 1999;341:1653–1660.
- 34 Wagner J, Iwashyna TJ, Kahn JM. Reasons underlying interhospital transfers to an academic medical intensive care unit. *J Crit Care* 2013;28:202–208.
- 35 Hamel MB, Lynn J, Teno JM, Covinsky KE, Wu AW, Galanos A, Desbiens NA, Phillips RS. Age-related differences in care preferences, treatment decisions, and clinical outcomes of seriously ill hospitalized adults: lessons from SUPPORT. *J Am Geriatr Soc* 2000;48(5 Suppl):S176–S182.
- 36 Lautrette A, Garrouste-Orgeas M, Bertrand PM, Goldgran-Toledano D, Jamali S, Laurent V, Argaud L, Schwebel C, Mourvillier B, Darmon M, et al.; Outcomerea Study Group. Respective impact of no escalation of treatment, withholding and withdrawal of life-sustaining treatment on ICU patients' prognosis: a multicenter study of the Outcomerea Research Group. *Intensive Care Med* 2015;41:1763–1772.
- 37 Green A, Showstack J, Rennie D, Goldman L. The relationship of insurance status, hospital ownership, and teaching status with interhospital transfers in California in 2000. *Acad Med* 2005;80:774–779.
- 38 Kindermann DR, Mutter RL, Cartwright-Smith L, Rosenbaum S, Pines JM. Admit or transfer? The role of insurance in high-transfer-rate medical conditions in the emergency department. *Ann Emerg Med* 2014;63:561–571.e8.
- 39 Unroe M, Kahn JM, Carson SS, Govert JA, Martinu T, Sathy SJ, Clay AS, Chia J, Gray A, Tulsy JA, et al. One-year trajectories of care and resource utilization for recipients of prolonged mechanical ventilation: a cohort study. *Ann Intern Med* 2010;153:167–175.