Daily cost of an intensive care unit day: The contribution of mechanical ventilation*

Joseph F. Dasta, MSc, FCCM; Trent P. McLaughlin, PhD; Samir H. Mody, PharmD, MBA; Catherine Tak Piech, MBA

Objective: **To quantify the mean daily cost of intensive care, identify key factors associated with increased cost, and determine the incremental cost of mechanical ventilation during a day in the intensive care unit.**

Design: **Retrospective cohort analysis using data from NDCHealth's Hospital Patient Level Database.**

Setting: **A total of 253 geographically diverse U.S. hospitals.**

Patients: **The study included 51,009 patients ≥18 yrs of age admitted to an intensive care unit between October 1, 2002, and December 31, 2002.**

Interventions: **None.**

Measurements and Main Results: **Days of intensive care and mechanical ventilation were identified using billing data, and daily costs were calculated as the sum of daily charges multiplied by hospital-specific cost-to-charge ratios. Cost data are presented as mean (±SD). Incremental daily cost of mechanical ventilation was calculated using log-linear regression, adjusting for patient and hospital characteristics.**

Approximately 36% of identified patients were mechanically ventilated at some point during their intensive care unit stay. Mechanically ventilated patients were older (63.5 yrs vs. 61.7 yrs, $p < .0001$) and more likely to be male (56.1% vs. 51.8%, $p < 0.0001$), compared with patients who were not mechanically ventilated, and required mechanical ventilation for a mean duration of 5.6 days ± 9.6. Mean intensive care unit cost and length of stay were $31,574 ± 42,570 and 14.4 days ± 15.8 for patients requiring mechanical ventilation and $12,931 ± 20,569 and 8.5 days ± 10.5 for those not requiring mechanical ventilation. Daily costs were greatest on intensive care unit day 1 (mechanical ventilation, $10,794; no mechanical ventilation, $6,667), decreased on day 2 (mechanical ventilation:, $4,796; no mechanical ventilation, $3,496), and became stable after day 3 (mechanical ventilation, $3,968; no mechanical ventilation, $3,184). Adjusting for patient and hospital characteristics, the mean incremental cost of mechanical ventilation in intensive care unit patients was $1,522 per day ($p < .001$).

Conclusions: **Intensive care unit costs are highest during the first 2 days of admission, stabilizing at a lower level thereafter. Mechanical ventilation is associated with significantly higher daily costs for patients receiving treatment in the intensive care unit throughout their entire intensive care unit stay. Interventions that result in reduced intensive care unit length of stay and/or duration of mechanical ventilation could lead to substantial reductions in total inpatient cost. (Crit Care Med 2005; 33:1266–1271)**

KEY WORDS: critical care; costs and cost analysis; length of stay; mechanical ventilation

It has been estimated that health care consumes 14% of the United States' gross domestic product, and inpatient care is responsible for approximately one third of these health care costs (1–2). One of the largest cost drivers in the hospital setting is the intensive care unit (ICU), which despite accounting for <10% of the beds in U.S. hospitals, accounts for nearly a third of total inpatient costs (3–5). It has been estimated that daily ICU care costs three to five times more than care provided on a general medical/surgical floor (3–5). Much of this increased cost may be due to interventions such as mechanical ventilation (MV). Patients who require MV represent approximately 33% of all patients admitted to the ICU and incur a disproportionately high share of the total cost of ICU treatment (6–7).

Studies demonstrate that ICU patients who require >3 wks of MV account for >50% of ICU cost (8). In addition to the economic consequences, it is well established that prolonged ICU stays and MV predispose patients to a greater risk of nosocomial infection and death (9). Patients with ventilator-associated pneumonia have been shown to have significantly longer ICU length of stay and hospital costs compared with noninfected patients (10).

Despite the high costs associated with ICU stays, to date there is a relative dearth of information relating to the daily cost of ICU care and/or MV in the United States. Intensive care patients require therapy that varies considerably in type, duration, and cost, making it difficult to predict patient resource use and actual costs in the aggregate (11). Recent literature has consisted of case studies focused on average ICU treatment and associated costs from a single hospital, with only one published attempt to address the variability in treatment and costs in ICU patients (12). Therefore, the objectives of this analysis were to study actual ICU admissions in the presence or absence of MV from a sufficiently large and repre-

*See also p. 1434.

From The Ohio State University, Columbus, OH (JFD); NDCHealth, Phoenix, AZ (TPM); and Ortho Biotech Products, L.P., Bridgewater, NJ (SHM, CTP).

Supported, in part, by Ortho Biotech Clinical Affairs, LLC, Bridgewater, NJ,

Samir H. Mody and Catherine Tak Piech are employees of Ortho Biotech Clinical Affairs, LLC. Joseph F. Dasta acts as a consultant and is a member of the Speakers Bureau for Ortho Biotech Clinical Affairs, LLC, Bridgewater, NJ. Dr. McLaughlin is an employee of NDCHealth, and NDCHealth was paid to conduct this study.

DOI: 10.1097/01.CCM.0000164543.14619.00

sentative number of hospitals distributed across the United States and then determine the average cost per day of ICU care, identify key factors affecting ICU cost, and estimate the incremental cost of MV per ICU day.

METHODS

Data Source. The NDCHealth Hospital Patient Level Database was used for this study. NDCHealth is a information solutions company serving all sectors of health care, automating the exchange of information among pharmacies, payers, hospitals, and physicians. This database contains operational data from a geographically diverse sample of approximately 300 U.S. general medical/surgical hospitals, representing >4,000,000 inpatient visits annually. These hospitals are private (nongovernment) for-profit entities that receive services from NDCHealth. The HIPAA-compliant, de-identified data are from hospitals' operational billing systems, which are used to compile Uniform Bill-92 (UB-92) forms and therefore are regularly audited for accuracy. As no protected health information was included in the dataset, the need for internal review board approval was waived. The database also includes patient demographic and hospital data, including detailed diagnosis and procedure data, and American Hospital Association-defined hospital characteristics, and it has been previously used to characterize treatment in the hospital setting (13). Data from 253 hospitals with documented admissions to ICUs from October to December 2002 were used for this analysis. Sample hospitals were well distributed across a number of criteria and can be considered to be representative of the larger U.S. hospital population with respect to geographic, bed size, and teaching status. Distribution of hospitals by bed size category and other characteristics are presented in Table 1.

Patient Selection. Figure 1 presents the method of identifying study patients. Only patients discharged, alive or dead, after a hospital stay requiring ICU care between October 1 and December 31, 2002, were included. Patients were required to be >18 yrs of age on the date of admission. Admissions involving ICU treatment were defined as all hospital admissions having hospital charges associated with UB-92 revenue codes of 200 (general ICU), 201 (surgical ICU), 202 (medical ICU), or 208 (trauma ICU). Admissions to pediatric (UB-92 203), psychiatric (UB-92 204), or burn (UB-92 207) ICUs were not included in the analysis. Patients admitted to coronary care units were not included in the analysis unless also treated in a general, surgical, medical, or trauma ICU. Patients were further classified into three mutually exclusive categories in the following order: trauma (having a primary discharge diagnosis of 800.xx-959.9), surgical (not trauma and having a surgical primary

Table 1. Hospital characteristics

	No.	%
Hospitals, total	253	
Size		
≤200 beds	178	70.4
200–399 beds	34	13.4
≥400 beds	41	16.2
Region		
East	92	36.4
North	53	20.9
South	77	30.4
West	31	12.3
Type		
Nonteaching	135	53.4
Teaching	118	46.6
Urban		
Rural	25	9.9
Urban	228	90.1

procedure code), or medical (all others). Surgical procedure codes were identified using ICD-9 surgical codes, after excluding those codes associated with nonsurgical procedures (i.e., insertion of central catheters, closed needle biopsy, etc.). ICU admissions were then divided into two cohorts based on MV use, which was defined as having a daily charge containing a UB-92 revenue code of 410 and a billing description indicating intubations or MV (14–15).

Data Analysis. Patient demographics, hospital characteristics, and billing data were collected for each admission. Hospital days were classified as non-MV or MV days using daily hospital charges as indicated previously. All categorical variables (gender, payer type, etc.) were presented as number of admissions (n) and percentages (%). Values for continuous variables were presented as mean (±SD). For each cohort, patient demographics (age, gender, payer type, admission source, discharge status, mortality, length of stay) and daily costs were reported.

Daily costs were estimated by multiplying daily hospital charges by hospital specific cost-to-charge ratios (16). Total cost, cost of ICU and MV days, and number of ICU and MV days were calculated for each admission based on billing during a particular day. Mean daily cost was reported by ICU day for each of the first 7 days of ICU care, stratified by the presence of an MV charge on the day. For patients remaining in ICU for >7 days, average daily cost is presented for days 8–14 and day 15 or greater.

Ordinary least squares regression was used to evaluate the influence of patient and hospital characteristics on daily ICU costs. The adjusted incremental cost of MV was calculated using multivariate regression of natural-log transformed cost, with covariates of patient demographics, hospital characteristics, ICU day, and patient category (medical, surgical, trauma). Adjusted daily incremental cost of MV by patient type was calculated by creating interaction terms between MV, patient category (medical/surgical/trauma), and day, for

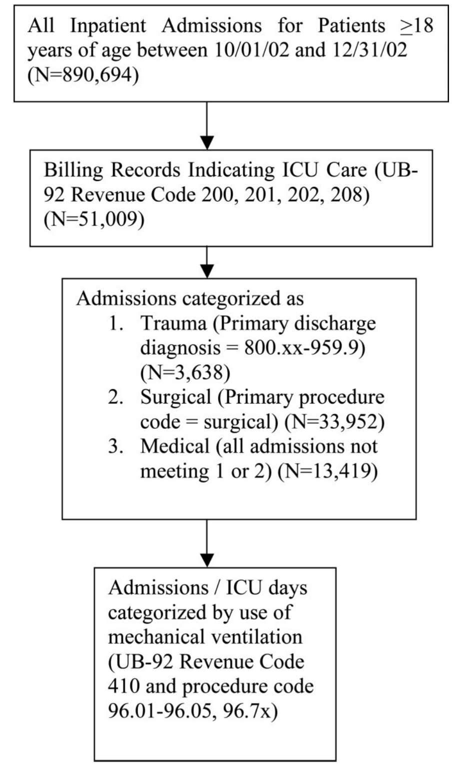

Figure 1. Patient selection process. *ICU,* intensive care unit.

days 1, 2, and 3 or more. Adjusted log costs were retransformed to real dollars, and the Smearing method was used to correct for bias associated with log retransformation (17). All analyses were conducted using SAS version 8.2 (18). All costs are presented in 2002 U.S. dollars, and the level of significance for statistical comparisons was $\alpha = .05$.

RESULTS

Patient Demographics. We identified 51,009 ICU admissions with a mean age of 62.4 (±17.1) years. The majority of patients (53.3%) were male. Two thirds of patients were classified as surgical (n = 33,952, 66.6%), one quarter as medical (13,419, 26.3%), and 7.1% as trauma (n = 3,638) (Table 2). Of all ICU admissions, 36.4% (n = 18,590) were mechanically ventilated at some point during their ICU stay; compared with trauma (41.9%) and medical (42.4%), surgical patients (33.5%) were significantly less likely to have received MV during their hospital admission. MV patients were older (63.5 yrs vs. 61.7 yrs, $p < .001$) and more likely to be male (56.1% vs. 51.8%, $p < .001$) than non-MV patients. Finally, ICU patients requiring MV had a significantly higher crude mortality rate than non-MV ICU patients (23.7% vs. 5.9%) and were

Table 2. Sample demographics

	MV		Non-MV		Total	
	No.	%	No.	%	No.	%
Patients	18,590	36.4	32,419	63.6	51,009	100.0
Category[a]						
Medical	5,695	30.6	7,724	23.8	13,419	26.30
Surgical	11,369	61.2	22,583	69.7	33,952	66.56
Trauma	1,526	8.2	2,112	6.5	3,638	7.13
	Mean	SD	Mean	SD	Mean	SD
Age[a,b]	63.47	16.31	61.73	17.48	62.37	17.08
Age group[a]						
19–39	1,696	9.1	3,999	12.3	5,695	11.2
40–64	7,044	37.9	12,688	39.1	19,732	38.7
65–80	7,278	39.2	11,064	34.1	18,342	36.0
>80	2,572	13.8	4,668	14.4	7,240	14.2
Gender[a]						
Female	8,164	43.9	15,633	48.2	23,797	46.7
Male	10,426	56.1	16,786	51.8	27,212	53.3
Admit source[a]						
ED	10,142	54.6	18,188	56.1	28,330	55.5
Referral from physician	1,498	8.1	3,139	9.7	4,637	9.1
Routine admission	4,186	22.5	8,056	24.8	12,242	24.0
Transfer from facility	2,081	11.2	1,902	5.9	3,983	7.8
Other	683	3.7	1,134	3.5	1,817	3.6
Discharge status[a]						
Death	4,408	23.7	1,926	5.9	6,334	12.4
Home	6,558	35.3	19,764	61.0	26,322	51.6
Referred to home care	1,112	6.0	1,461	4.5	2,573	5.0
Transferred to SNF	2,171	11.7	3,116	9.6	5,287	10.4
Transferred to facility	4,183	22.5	5,717	17.6	9,900	19.4
Other	158	0.8	435	1.3	593	1.2
Insurance[a]						
Blue Cross/Blue Shield	1,805	9.7	3,464	10.7	5,269	10.3
Commercial	2,892	15.6	5,165	15.9	8,057	15.8
HMO/PPO	2,165	11.6	4,516	13.9	6,681	13.1
Medicaid	1,798	9.7	3,026	9.3	4,824	9.5
Medicare	9,278	49.9	14,801	45.7	24,079	47.2
Other	652	3.5	1,447	4.5	2,099	4.1

MV, mechanical ventilation; ED, emergency department; SNF, skilled nursing facility; HMO, health maintenance organization; PPO, preferred provider organization.

[a]Chi-square $p < .0001$; [b]analysis of variance $p < .0001$.

more likely to be transferred to a skilled nursing facility or other treatment facility. MV patients were ventilated a mean of 5.6 days ± 9.6 (Table 3).

Mean hospital cost and length of stay were $32,253 ± 45,818 and 10.7 ± 13.3 days. Patients were in the ICU a mean of 4.3 ± 6.7 days with a mean ICU cost of $19,725 ± 31,778 (Table 3). MV patients had significantly more ICU days than non-MV patients (6.9 vs. 2.9, $p < .001$) and accrued significantly more cost during their ICU stay ($31,574 vs. $12,931, $p < .001$). Mean overall hospitalization cost and length of stay was $47,158 ± 57,703 and 14.4 days ± 16.1 for patients requiring MV and $23,707 ± 34,545 and 8.5 days ± 10.7 for patients not requiring MV.

Daily Costs. Mean daily ICU costs were greatest on the first day of ICU treatment, ($7,728 ± 8,509), decreased on day 2 ($3,872 ± 4,223), and became stable from day 3 forward ($3,436 ± 3,550). The greatest day 1 cost occurred in surgical patients (mean $9,165 ± 9,438), followed by the trauma ICU cohort (mean $8,199 ± $7,880). By day 3, daily costs were stable in all cohorts, approximately $3,500/day in the surgical ICU and trauma ICU cohorts and approximately $3,000/day in the medical ICU cohort (Table 4).

Adjusted Costs. Adjusting for patient and hospital characteristics, ICU costs were significantly greater for male patients ($p < .0001$), surgical patients (vs. medical, $p < .0001$), and trauma patients (vs. medical, $p < .0001$). Mechanical ventilation was the greatest independent predictor of cost ($p < .0001$). Compared with daily ICU cost for the second week of ICU treatment, costs were significantly greater on day 1 ($p < .0001$), day 2 ($p < .0001$), and day 3 ($p = .0374$) (Table 5). Adjusting for patient and hospital characteristics, the mean incremental daily cost of MV among patients in the ICU was $1,522/patient/day (Table 6).

Accounting for patient type and day, adjusted mean costs were greatest for surgical patients, with mean daily costs for the first three ICU days of $13,566, $5,093, and $4,368, for patients requiring MV and $6,536, $3,329, and $3,141 for patients not requiring MV, respectively. Trauma patients followed, with mean daily costs for the first three ICU days of $10,299, $4,887, and $3,876 for patients requiring MV and $5,973, $3,275, and $3,059 for patients not requiring MV, respectively. Medical patients were the least expensive, with mean daily ICU costs of

Table 3. Length of stay and costs in relation to mechanical ventilation (MV)

	Mean	SD	Median	25th Percentile	75th Percentile
Length of stay, days					
MV	14.43	16.13	10.00	6.00	18.00
Non-MV	8.51	10.69	6.00	3.00	10.00
All patients	10.66	13.25	7.00	4.00	13.00
ICU days					
MV	6.90	9.29	4.00	2.00	8.00
Non-MV	2.88	3.87	2.00	1.00	3.00
All patients	4.34	6.69	2.00	1.00	5.00
MV days					
MV	5.60	9.61	2.00	1.00	6.00
Total cost, $					
MV	47,158	57,703	30,369	17,644	54,271
Non-MV	23,707	34,545	15,182	8,608	26,705
All patients	32,253	45,818	19,462	10,439	36,276
ICU cost					
MV	31,574	42,570	18,954	10,426	35,752
Non-MV	12,931	20,569	8,317	4,449	14,942
All patients	19,725	31,778	11,184	5,613	21,420
MV cost					
MV	25,834	38,991	15,271	7,940	27,625

ICU, intensive care unit.

Table 4. Mean daily intensive care unit (ICU) cost

ICU Day	No. of Patients Remaining	Medical, $		Surgical, $		Trauma, $		Total, $	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	51,009	3,963	3,681	9,165	9,438	8,199	7,880	7,728	8,509
2	15,734	3,370	3,084	4,043	4,599	4,296	4,405	3,872	4,223
3	10,134	3,033	3,076	3,577	3,707	3,813	3,790	3,436	3,550
4	7,721	3,003	3,238	3,591	3,678	3,755	3,565	3,431	3,553
5	5,929	2,988	2,247	3,625	3,794	3,826	3,827	3,456	3,429
6	4,657	2,954	2,053	3,627	3,451	3,884	3,798	3,455	3,164
7	3,698	2,974	2,163	3,624	3,208	3,806	3,297	3,457	2,974
8–14	2,937	3,026	2,282	3,709	3,264	3,765	3,203	3,548	3,058
≥15	865	2,951	2,126	3,750	3,769	3,668	3,140	3,635	3,525

$5,366, $4,306, and $3,759 for patients requiring MV and $3,531, $3,153, and $2,809 for patients not requiring MV, respectively (Table 7).

DISCUSSION

To value therapies aimed at decreasing ICU cost or length of stay, it is first necessary to quantify the averted costs in a meaningful way such as in a representative sample of patients encompassing different ICU settings and/or hospital types. This is the first study to investigate the daily costs of ICU care and MV across a large and diverse sample of U.S. hospitals. In this study, we found ICU costs to be greatest on the first ICU day, decrease by approximately 50% by day 2, and become stable after day 3, averaging approximately $3,500/day. Daily costs were consistently greater for patients requiring MV, and the incremental cost was greatest on ICU day 1, particularly in surgical patients.

Previous research has shown that ICU patients have a mortality rate of 17%, roughly ten times that of all other patients (19). In this study, the overall mortality rate was 12.4%; however, nearly 70% of ICU mortality occurred in MV patients, with these patients having more than four times greater mortality rate than non-MV ICU patients. Although mortality rate and interventions related to the reduction of mortality rate are obviously important, other metrics related to ICU care, such as ICU length of stay and daily cost, warrant attention given the increasing role of ICUs in the hospital setting associated with an aging population and the development of more aggressive treatment. In this analysis of >51,000 patients in the ICU, the average patient incurred approximately $19,725 over 4 days, which accounted for >60% of the total hospital bill and close to 40% of the total hospital length of stay.

In addition to having higher mean daily ICU costs, MV patients also remained in the ICU and thus the hospital significantly longer than non-MV ICU patients; MV patients, on average, were in the ICU an extra 4 days and the hospital an extra 6 days in total, compared with patients who did not receive MV. The prevalence and financial impact of MV appeared to differ by patient cohort: Surgical patients were significantly less likely to receive MV during their ICU stay compared with trauma or medical patients; however, MV had much less impact on daily ICU cost in medical patients compared with those classified as trauma or surgical.

Noteworthy is the proportion of patients who remained in the ICU for sustained periods of time: 25% of patients remained in the ICU for >5 days (in MV patients, the 75th percentile was 8 days). Although it may not be possible for current interventions to avoid ICU/MV care entirely, there is a clear opportunity to continually review care associated with

Table 5. Regression: log daily intensive care unit (ICU) cost

Variable	Referent	β[a]	*p* Value
Patient			
Age	Unit change	.000	.1143
Female	Male	−.028	<.0001
Surgical	Medical	.261	<.0001
Trauma	Medical	.176	<.0001
Insurance			
Blue Cross/Blue Shield	Medicare	.092	<.0001
Commercial	Medicare	.058	<.0001
HMO/PPO	Medicare	.136	<.0001
Medicaid	Medicare	−.067	<.0001
Other	Medicare	−.158	<.0001
Hospital characteristics			
≤200 beds	≥400 beds	−.298	<.0001
200–399 beds	≥400 beds	−.185	<.0001
Nonteaching	Teaching	−.039	<.0001
East	West	−.048	<.0001
North	West	−.351	<.0001
South	West	−.371	<.0001
Day			
1	8–14	.685	<.0001
2	8–14	.106	<.0001
3	8–14	.012	.0374
4	8–14	.003	.6787
5	8–14	.000	.9560
6	8–14	−.004	.5699
7	8–14	−.001	.9136
15 or more	8–14	−.030	<.0001
Cohort mechanically ventilated	ICU only	.384	<.0001

HMO/PPO, health maintenance organization/preferred provider organization.

[a]β-coefficient can be interpreted as percent change in daily cost due to covariate; for example, females compared with males (after accounting for other covariates) averaged 2.8% lower daily ICU cost. $R^2 = .276$.

Table 6. Adjusted mean incremental daily cost: Mechanical ventilation (MV)

Cohort	Adjusted Mean, $	95% Confidence Limits, $	
MV	4772	4744	4800
Non-MV	3250	3233	3267
Adjusted incremental daily cost of MV	1522[a]		

[a]$p < .0001$ vs. null.

Table 7. Adjusted mean incremental costs

Category	Day	MV[a]	Non-MV[a]	Incremental Cost of MV, $
Medical	1	5,366 (5,263–5,471)	3,531 (3,484–3,579)	1,834
	2	4,306 (4,216–4,398)	3,153 (3,101–3,206)	1,153
	3+	3,759 (3,719–3,798)	2,809 (2,781–2,838)	950
Surgical	1	13,566 (13,373–13,763)	6,536 (6,481–6,591)	7,030
	2	5,093 (5,005–5,182)	3,329 (3,295–3,364)	1,764
	3+	4,368 (4,335–4,400)	3,141 (3,120–3,161)	1,227
Trauma	1	10,299 (9,915–10,697)	5,973 (5,826–6,124)	4,326
	2	4,887 (4,687–5,096)	3,275 (3,174–3,379)	1,612
	3+	3,876 (3,819–3,934)	3,059 (3,014–3,105)	817

MV, mechanical ventilation.

[a]Mean (95% confidence interval), in dollars. $R^2 = .303$.

patients remaining in the ICU for prolonged periods of time. After day 3, mean daily cost stabilized at a lower level than that observed initially. Although it was unclear why this stabilization occurred, it is likely that most of the variable costs in this setting relate to pharmaceutical/medical care conducted in the first few days of admission, whereas costs incurred after that time period generally are fixed (including nursing care, monitoring equipment, etc.). The consistency of daily ICU costs after day 3 suggests that shortening such encounters by even 1 day would result in significant cost savings as well as provide other benefits such as a decreased risk of nosocomial infection (9).

Rapoport et al. (20) estimated that the first ICU day is approximately four times more expensive, and other ICU days approximately 2.5 times more expensive, than non-ICU hospital days, which is comparable to the results presented here (mean non-ICU daily cost was $2,132 for non-MV patients, or approximately 50% of their mean daily ICU cost) (16). Given the size of the sample used in this analysis, it was possible to gather more specific cost estimates down to the day of ICU stay, something not before attempted.

Although the hospitals included in the study sample were distributed geographically and by size, the sample tended to have a greater number of larger, teaching hospitals compared with the national average, which could have biased the cost estimates due to the potential for patients with more severe illness being primarily treated at such institutions. The predominance of larger teaching hospitals may also have biased the types of patients receiving mechanical ventilation, limiting the generalizability of the results. The costs reported here were estimated from hospital-reported charge data, using hospital-specific cost-to-charge ratios, an established methodology for converting recorded charges to an estimate of true cost. Although the total cost figure approximates costs for this population, the departmental costs may not necessarily represent true economic costs as a specific methodology has not been developed to measure true cost at this level of granularity. However, cost-to-charge ratios remain the only practical way of estimating cost in many circumstances and thus are commonly used in economic studies (20, 21). As noted previously, published information regarding cost of ICU care is sparse or dated, and much of the published work suffers from inadequate or nonspecific cost estimates (12).

Although not a primary objective of this analysis, some attempt was made to differentiate between medical, surgical, and trauma ICU admissions to identify any differences in incremental cost of MV across these different groups. As the definition of "surgical" relied on the pres-

Interventions that result in reduced intensive care unit length of stay and/or duration of mechanical ventilation could lead to substantial reductions in total inpatient cost.

ence of a broad list of ICD-9 surgical codes, some of which might not be interpreted as "surgery," it is likely that some misclassification of medical and surgical patients did occur.

Costs obtained from this database are obtained from departmental charges, which represent the average cost per unit of service. Daily charges for ICU care and overhead are fixed charges within a hospital, and daily medications, supplies, and labs are variable costs. As these are daily costs, it is possible that extraneous costs (operating room, emergency room, etc.), especially on day 1, are included in the cost estimates. Importantly, we were not able to account for differences in disease state or severity or validate the collected billing information through chart review. However, a study design to collect more rigorous economic data would require detailed manual observation of utilization and costing of specific time and resources, which would not be feasible on as large a scale as the present study.

Acknowledging the significance of patient characteristics on variation in the cost of critical care, Jacobs et al. (11) used a similar design to study the daily cost of critical care in a small sample of patients in a UK hospital. Similar to Jacobs, we found a positive association between surgical patients and use of MV with greater daily costs of critically ill patients. The impact of MV, additionally, should be considered to represent all of the factors associated with this event—that is, not only the costs associated with the ventilator, but also respiratory therapy, the greater severity of illness inherent in these patients, and sequelae such as ventilator-associated pneumonia.

CONCLUSIONS

ICU care is associated with significant cost, with the highest daily cost in the initial few days. However, costs remain relatively consistent throughout the entire ICU stay. Mechanical ventilation further adds to these costs and is a significant predictor of less favorable outcome, especially early in the ICU stay. Given these high daily costs, coupled with the number of patients remaining in these settings for sustained periods of time, interventions that result in even nominal decreases in length of time spent in the ICU or the duration of MV have the opportunity to significantly reduce hospitalization costs.

REFERENCES

1. Cohen IL, Chalfin DB: Economics of mechanical ventilation: Surviving the 90's. *Clin Pulm Medicine* 1994; 1:100–197
2. Heffler S, Smith S, Keehan S, et al: Health Spending Projections For 2002–2012. Millwood, Health Aff, 2003
3. Kalb PE, Miller DH: Utilization strategies for intensive care units. *JAMA* 1989; 261: 2389–2395
4. Sirio CA, Angus DC, Rosenthal GE: Cleveland Health Quality Choice (CHQC)—An ongoing collaborative, community-based outcomes assessment program. *New Horiz* 1994; 2:321–325
5. Shorr, AF: An update on cost-effectiveness analysis in critical care. *Curr Opin Crit Care* 2002; 8:337–343
6. Esteban A, Anzueto A, Frutos F, et al: Characteristics and outcomes in adult patients receiving mechanical ventilation: A 28-day international study. *JAMA* 2002; 287: 345–355
7. Hebert PC, Blajchman MA, Cook DJ, et al: Do blood transfusions improve outcomes related to mechanical ventilation? *Chest* 2001; 119: 1850–1857
8. Cohen IL, Booth FV: Cost containment and mechanical ventilation in the United States. *New Horiz* 1994; 2:283–290
9. Vincent JL, Bihari DJ, Suter PM, et al: The prevalence of nosocomial infection in intensive care units in Europe. Results of the European Prevalence of Infection in Intensive Care (EPIC) Study. EPIC International Advisory Committee. *JAMA* 1995; 274: 639–644
10. Warren DK, Shukla SJ, Olsen MA, et al: Outcome and attributable cost of ventilator-associated pneumonia among intensive care unit patients in a suburban medical center. *Crit Care Med* 2003; 31:1312–1317
11. Jacobs P, Edbrooke D, Hibbert C, et al: Descriptive patient data as an explanation for the variation in average daily costs in intensive care. *Anaesthesia* 2001; 56:643–647
12. Gyldmark M: A review of cost studies of intensive care units: Problems with the cost concept. *Crit Care Med* 1995; 23:964–972
13. Pendergraft TB, Stanford RH, Beasley R, et al: Rates and characteristics of intensive care unit admissions and intubations among asthma-related hospitalizations. *Ann Allergy Asthma Immunol* 2004; 93:29–35
14. Behrendt CE: Acute respiratory failure in the United States: Incidence and 31-day survival. *Chest,* 2000; 118:1100–1105
15. Vamvakas EC, Carven JH: Allogeneic blood transfusion and postoperative duration of mechanical ventilation: Effect of red cell supernatant, platelet supernatant, plasma components and total transfused fluid. *Vox Sanguinis* 2002; 82:141–149
16. CMS Files for Download for the Prospective Payment System. Prospective payment system payment impact file. Available at: http://cms.hhs.gov/providers/pufdownload/default.asp. Accessed July 25, 2002
17. Duan N: Smearing estimate: A nonparametric retransformation method. *J Am Stat Assoc* 1983; 78:605–610
18. SAS Institute: SAS Procedures Guide, Version 8.2. Cary, NC, SAS Institute, 2002
19. Knaus WA, Wagner DP, Draper EA, et al: The APACHE III prognostic system. Risk prediction of hospital mortality for critically ill hospitalized adults. *Chest* 1991; 100: 1619–1636
20. Rapoport J, Teres D, Zhao Y, et al: Length of stay data as a guide to hospital economic performance for ICU patients. *Med Care* 2003; 41:386–397
21. Shwartz M, Young DW, Siegrist R: The ratio of costs to charges: How good a basis for estimating costs? *Inquiry* 1995; 32:476–481
22. Chrischilles EA, Scholz DA: Dollars and sense: A practical guide to cost analysis for hospital epidemiology and infection control. *Clin Perform Qual Health Care* 1999; 7:107–11