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ICU Costs Higher for Patients Dying Before Discharge

The high cost of critical care has engendered research into identifying influential factors. However, previous studies have not considered patient vital status at ICU discharge. This is what a new study has found: The largest drivers of ICU costs at the patient level are day 1 room occupancy and day 1 mechanical ventilation, and mortality before unit discharge is associated with substantially higher costs.

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"Patients who did not survive their ICU stay had a 12% increase in overall costs. The increase was most evident for patients with an extended ICU stay who were receiving mechanical ventilation," according to researchers. "Studies evaluating costs among ICUs need to take mortality into account."

To date, most studies evaluating the cost of a patient's ICU stay either used administrative data or were completed over a decade ago. They demonstrated that costs are highly influenced by the following factors: age, diagnosis (especially cardiac conditions), hospital teaching status, higher utilisation of services, length of stay in the ICU (ICULOS), and receiving mechanical ventilation. However, there may be additional patient-specific factors that impact cost. These include, among others, severity of illness, time on mechanical ventilation, the ICU admitting diagnosis, and whether or not the patient survived to ICU discharge.

The present study – covering 26 ICUs at 13 hospitals in the U.S. – attempted to explore the association between ICU discharge status and total costs in a large patient cohort. The objective was to develop a multivariable model that incorporated previously defined factors such as ICULOS, mechanical ventilation, diagnosis, and age to determine if death before ICU discharge had a distinct impact on the total cost of an ICU stay. Data for 58,344 admissions from 1 January 2012 through 30 June 2016, at the 13 hospitals, were obtained from a commercial ICU database.

The median observed cost of a unit stay was $9,619 (mean = $16,353). A multivariable regression model was developed on the log of total costs for a unit stay, using severity of illness, unit admitting diagnosis, mortality in the unit, daily unit occupancy (occupying a bed at midnight), and length of mechanical ventilation. This model had an "r2" of 0.67 and a median difference between observed and expected costs of $437. The first few days of care and the first day of receiving mechanical ventilation had the largest effect on total costs.

"What might account for mortality being associated with higher costs? Since we adjusted for severity of illness, diagnosis, and a patient receiving mechanical ventilation, the higher costs associated with patient death cannot be attributed to case-mix. The most likely explanation lies in the considerable number of resources incurred at the end of life. Care before end of life may include additional procedures, diagnostic tests, and laboratory tests," the authors explain.

They also note the prolonged use of such therapies as IV vasopressors, blood products, sedatives, and analgesics as needed for the patient to die with dignity while receiving comfort care. Moreover, terminal patients with a do not resuscitate order might continue to receive mechanical ventilation and as needed comfort care while languishing in the unit, resulting in an extended LOS and associated costs of care.

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The Impact of Mortality on Total Costs Within the ICU

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Objectives: The high cost of critical care has engendered research into identifying influential factors. However, existing studies have not considered patient vital status at ICU discharge. This study sought to determine the effect of mortality upon the total cost of an ICU stay.
Design: Retrospective cohort study.
Setting: Twenty-six ICUs at 13 hospitals in the United States.
Patients: 58,344 admissions from January 1, 2012, to June 30, 2016, obtained from a commercial ICU database.
Interventions: None.
Measurements and Main Results: The median observed cost of a unit stay was $9,619 (mean = $16,353). A multivariable regression model was developed on the log of total costs for a unit stay, using severity of illness, unit admitting diagnosis, mortality in the unit, daily unit occupancy (occupying a bed at midnight), and length of mechanical ventilation. This model had an r^2 of 0.67 and a median difference between observed and expected costs of $437. The first few days of care and the first day receiving mechanical ventilation had the largest effect on total costs. Patients dying before unit discharge had 12.4% greater costs than survivors ($p < 0.01$; 99% CI = 9.3–15.5%) after multivariable adjustment. This effect was most pronounced for patients with an extended ICU stay who were receiving mechanical ventilation.
Conclusions: While the largest drivers of ICU costs at the patient level are day 1 room occupancy and day 1 mechanical ventilation, mortality before unit discharge is associated with substantially higher costs. The increase was most evident for patients with an extended ICU stay who were receiving mechanical ventilation. Studies evaluating costs among ICUs need to take mortality into account. (*Crit Care Med* 2017; 45:1457–1463)
Key Words: costs; intensive care unit; mortality

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The number of ICU beds in the United States has increased more than 25% over the past 20 years (1–4), with a corresponding increase in costs. Patients with a hospital stay that includes ICU care are 2.5 times more resource intensive than hospital stays not requiring ICU care (5). In one study of 51,009 patients at 253 U.S. hospitals in 2002 (6), the first day of ICU care was associated with substantially more costs than succeeding days. Daily costs increased less on days 2 and 3 in the ICU and then remained level thereafter. Being placed on mechanical ventilation more than doubled overall costs, which is notable because 30–35% of these patients have respiratory failure (7–9).

To date, most studies evaluating the cost of a patient's ICU stay either used administrative data or were completed over a decade ago (5, 6). They demonstrated that costs are highly influenced by the following factors: age, diagnosis (especially cardiac conditions), hospital teaching status, higher utilization of services, length of stay in the ICU (ICULOS), and receiving mechanical ventilation. While these factors are undoubtedly important, there may be additional patient-specific factors that impact cost. These include, among others, severity of illness (10), whether or not the patient survived to ICU discharge (11), time on mechanical ventilation (6, 11), and the ICU admitting diagnosis (5, 10); the latter is not necessarily the hospital admitting diagnosis.

A study of 15,003 admissions during 2006–2010 at four hospitals which were using an electronic medical record (EMR) database (10) lent credence to the importance of patient factors. A multivariable regression model revealed that both receiving mechanical ventilation on the first day after ICU admission and the patient's Acute Physiology and Chronic

Health Evaluation (APACHE) IV Acute Physiology Score (APS) were the main predictors of cost. The authors concluded that life-supporting therapy and physiologic derangement greatly impact total ICU cost. However, the small number of hospitals makes the findings limited.

A more recent study (12) of admissions during 2013, albeit to a single medical center, used EMR data to develop a multivariable model of costs. The results showed that the remarkable "day 1" effect only occurred in the two surgical ICUs, with daily costs being flat in the other types of ICUs.

The cost differential between patients who survived versus those who expired before ICU discharge has not been examined when adjusting for patient case-mix. Despite this shortcoming, there is an overriding sentiment that a unit's overall costs are attenuated when there is a high-mortality rate. This study attempts to explore the association between ICU discharge status and total costs in a large patient cohort. The objective was to develop a multivariable model that incorporated previously defined factors such as ICULOS, mechanical ventilation, diagnosis, and age to determine if death before ICU discharge had a distinct impact on the total cost of an ICU stay.

MATERIAL AND METHODS

Data were obtained for admissions from January 1, 2012, through June 30, 2016, at hospitals using the ICUTracker database system (Medical Decision Network, Charlottesville, VA). Sites allow ICUTracker to collect all information on a patient while in the ICU, if that data can be transmitted electronically. After deidentification, data from ICUTracker were made available for this study. **Table 1** shows the variables used in our analysis. As the data were deidentified and retrospective, and the outcome was financial, this was not considered human subjects research and Institutional Review Board approval was not deemed necessary.

Total charges for an ICU stay were available, and to convert charges to cost, we used the Centers for Medicare & Medicaid Services' (CMS) cost-to-charge ratios for each hospital in the study (13). Since ICU costs are skewed (14), the natural log of total costs (LTC) was used. Daily charge data were not available. Transplant patients were excluded since their frequency was low and associated costs were extremely high. We also excluded coronary artery bypass graft patients as their outcomes were radically different from patients with other diagnoses (15).

There were two stages to the multivariable analysis. First, a multivariable linear regression model of LTC was developed that contained the predictor variables shown in Table 1. The main effect was ICU discharge status (nonsurvivor vs survivor). Severity of illness was measured by the APACHE IV's APS, which was obtained at the end of day 1 after discharge. Previous LOS and age were the other continuous variables. The APACHE diagnostic groups were used; however, diagnoses with a frequency less than 100 were aggregated into the closest group; there were 11 such diagnoses. ICU type, payor, readmission (second or greater ICU admission within a hospital encounter), admission after emergency surgery, and gender were the categorical variables included in the models. For each categorical variable, the level with the median frequency was chosen as the reference group.

TABLE 1. Predictor Variables Included in the Initial Multivariable Linear Model of Log (Total Cost)

Variable Name	Description	Measurement
APS	APS	0–230
Age	Age	17–95
Hosp1 to Hosp13	Whether patient was admitted to hospital X	12 binary variables, each corresponding to one hospital
Prelos	Previous length of stay	Square root (ICU admit date-time – hospital admit date-time)
Emerg	Patient admitted after undergoing emergency surgery	Binary
ICU_Type	Coronary, cardiothoracic, medical, mixed, neurologic/trauma, surgical	Six binary variables
ICUdead	Patient expire before ICU discharge?	Binary
Roomday1 to Roomday30	Was patient still in ICU at midnight on day x	Thirty binary variables
Xiculos	No. of days past 30 a patient remained in the ICU	Continuous
Ventday1 to Ventday30	Was patient still on a ventilator at midnight on day x	Thirty binary variables
Xventday	No. of days past 30 a patient remained on mechanical ventilation	Continuous
Readmission	Second or greater ICU admission	Binary
Dx_group	105 diagnostic groups	105 binary variables
Payor	Government, insurance, self-pay, misc/other	Four binary variables

APS = Acute Physiology Score.

We wanted to model ICULOS in the same way that hospitals charge patients. Thus, we included binary variables for the first 30 days a patient could potentially stay in the ICU. These variables received a value of one if the patient occupied an ICU bed at midnight, 0 otherwise. Thus, it would be possible for a patient to not receive any room charges, if that patient stayed less than 24 hours and was not in an ICU bed at midnight. If a patient stayed in the ICU longer than 30 days, the extra LOS would be recorded as a continuous variable, for example, 31.2 days would get an extra LOS equals to 1.2 days. Duration of mechanical ventilation was handled similarly to ICULOS, with two modifications: the patient had to be placed on a ventilator any time within the first 24 hours after admission and the "midnight rule" did not apply. The latter change was made since being placed on mechanical ventilation incurs a charge for initial set-up regardless of the time of day. Specific information on how ICULOS and duration of mechanical ventilation were modeled appears in the **online data supplement** (Supplemental Digital Content 1, http://links.lww.com/CCM/C682).

The initial multivariable model was created for two purposes: 1) identify extreme outliers and 2) determine if successive days after ICU admission were equivalent in their effect (i.e., regression coefficients were not statistically different). Outliers were defined as admissions for which the prediction's standardized residual was greater than 4.0; these admissions were subsequently excluded. To determine the equivalency of the coefficients for successive days after ICU admission, *F*-tests were derived for the model mean squares comparing equations with differing coefficients for each roomday as opposed to them having equal coefficients. Coefficients found to be insignificant from one another were constrained to have identical coefficients in the final model. An identical process was conducted for time on mechanical ventilation. Details seem in the online data supplement (Supplemental Digital Content 1, http://links.lww.com/CCM/C682).

The above led to the second stage of the analyses. Here, the modifications of the variables for individual days and mechanical ventilation as described above were used in a multivariable model. The model was developed using a backward stepwise approach, with a p value of less than 0.01 required to remain. Predicted values of LTC were obtained for each patient. Observed and predicted costs were then transformed back into their original units, that is, dollars, and compared. The mean total costs for staying in the ICU dependent on vital status at discharge (nonsurvivor vs survivor) were calculated and stratified by whether or not the patient received mechanical ventilation on day 1. Since hospitals entered ICUTracker at various time points during the data collection period, it was not possible to track LTC by hospital over time.

In a sensitivity analyses, the final multivariable model was modified to include hospitals as random effects, with ICUs nested within hospitals. Results were then compared with the fixed effects model to determine if any differences existed. All analyses were carried out using SAS v9.4 (Cary, NC).

RESULTS

There were 60,784 admissions (58,452 patients) from the 29 ICUs in 13 hospitals. We eliminated 132 admissions with incorrect dates for start of mechanical ventilation and one admission was excluded because of a transplant diagnosis. Also excluded were 2,298 admissions (3.8%) in which the electronic feeds for charges failed and 1,108 patients admitted after surgery for coronary artery bypass grafts. Thus, there were 58,334 admissions (56,194 patients) available for analysis. Characteristics of the admissions, hospitals, and ICUs are given in **Table E1** (Supplemental Digital Content 1, http://links.lww.com/CCM/C682). Almost half of the ICUs were mixed medical-surgical units (44.8%), and 46.2% of the hospitals were level 1 or 2 trauma sites. The frequency of ICU mortality was 6.3% and mean ICULOS was 3.3 days. Mean total cost was \$16,353 (stderr = \$98), median total cost was \$9,619 (interquartile range = \$5,197–\$18,709), and survivors had a significantly lower APS than nonsurvivors (40.0 vs 85.1; $p < 0.001$).

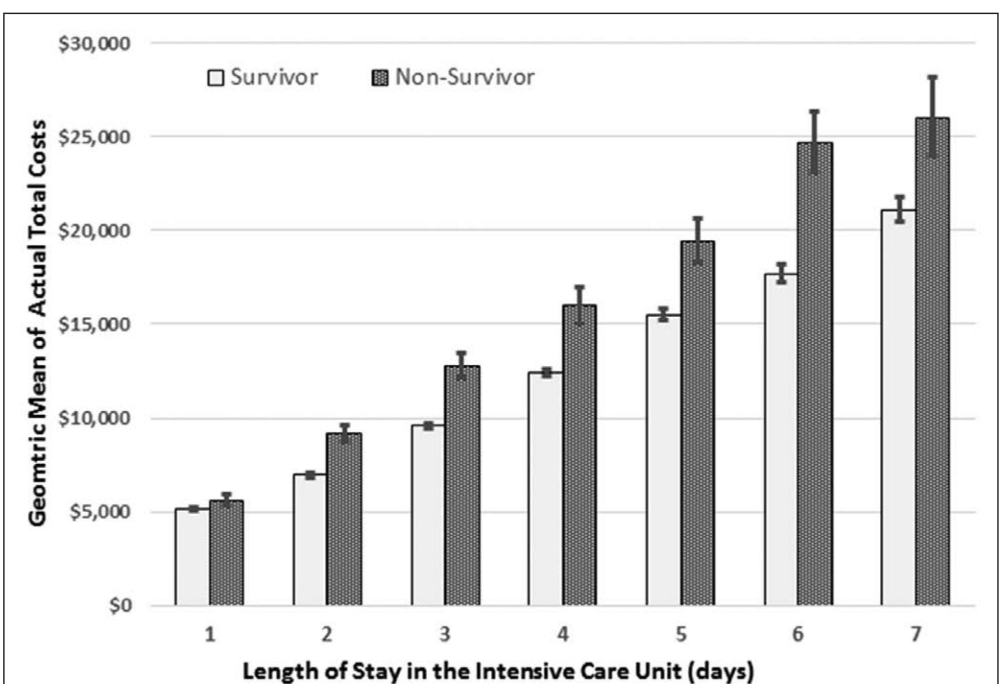

Figure1. Geometric mean observed total cost (with 95% CI) by number of days a patient remained in the ICU (in a bed at midnight), stratified by the patient's discharge status.

Figure 1 shows the actual mean costs by the number of days a patient stayed in the ICU, stratified by the patient's discharge status. Regardless of the ICULOS, total costs were greater for patients expiring before ICU discharge than for survivors, with the difference being significant ($p < 0.05$) from day 2 onwards. The gap between the costs for these two groups widened with increasing ICULOS, until day 7, where it remained level.

The initial linear model was established specifically for outlier detection and equivalency of coefficients for days in the ICU as well as placement on mechanical ventilation. The results from this model identified 175 admissions (0.3%) as extreme outliers; these admissions were removed from further modeling. Coefficients for roomday15 through roomday30 were not significantly different (F-test = 0.79; $p = 0.70$), and thus, these days were constrained to have identical coefficients in the next model. The coefficients for room costs corresponding to days 9–14 were equivalent (F-test = 0.31; $p = 0.90$) as were the coefficients for days 5 through 8 (F-test = 0.57; $p = 0.63$). The test of equivalence for the coefficients corresponding to days 2–30 of mechanical ventilation was not significant (F-test = 1.54; $p = 0.06$) and was therefore constrained to be identical in the final model.

The final model's r^2 was 0.694, meaning that 69.4% of the variation in LTC was explained by the linear model. When predicted and observed values for each admission were transformed back into dollars, the median difference was $97, which was 1.0% of the overall median cost of $9,619.

Table 2 reports the coefficients for the primary variables of interest in the final model, along with the corresponding change in LTC. The full set of coefficients appears in **Tables E2a–E2c** (Supplemental Digital Content 1, http://links.lww.com/CCM/C682). ICU mortality was significantly associated with a 12.4% increase in costs (99% CI = 9.3–15.5%). **Figure 2** displays the predicted mean costs by the number of days a patient stayed in the ICU, stratified by the patient's discharge status. Similar to the results seen for observed costs, nonsurvivors had a higher predicted total cost than survivors, even after adjusting for the severity of illness, diagnosis, age, and whether or not the patient received mechanical ventilation. This difference between survivors and nonsurvivors costs was significant ($p < 0.05$) from day 2 onwards.

Age (increase in 10 yr) only produced a 1.2% decrease in costs, gender (females) constituted a 2.5% decrease in costs and APS (increase in 10 yr) produced a 2.0% increase in costs; these variables had almost no effect on LTC (Table 2). Admission after emergency surgery was associated with a 12.8% decrease in costs. Surgical ICUs were associated with the highest relative LTC (16.1%). Diagnosis had a much more profound effect on LTC. The five diagnoses with the biggest impact increased costs by 136.8– 216.0%, whereas the five diagnoses that most decreased costs did so by 24.1– 29.2% (Table 2). Receiving mechanical ventilation on the first day in the unit incurred a 26.3% cost increase, but subsequent days increased cost by just 1.4%. In terms of stay in the ICU, the first day increased costs by 101.6%, the second day by 48.6%, the third day by 33.4%, and the fourth day by 25.3%. Thereafter costs increased less dramatically.

Figure 3 shows the mean predicted costs for patients who survived versus nonsurvivors, stratified by whether or not the patient received mechanical ventilation: the results shown

TABLE 2. Results[a] From the Final Model of Log (Total Cost): Intercept = $2,576[b]

Predictor Variable	Coefficient	% Change in Total Cost
Roomday1	0.701	101.6
Roomday2	0.396	48.6
Roomday3	0.288	33.4
Roomday4	0.226	25.3
Sum(Roomday5 to Roomday8)	0.143	15.4
Sum(Roomday9 to Roomday14)	0.082	8.5
Sum(Roomday15 to Roomday30)	0.042	4.3
Sum length of stay > 30 d	0.010	1.0
Ventday1	0.234	26.3
Sum(Ventdays2 to Ventdays30)	0.014	1.4
Acute physiology score (gain 10 points)	0.002	0.2
Age (gain 10 yr)	−0.002	−1.2
Female gender	−0.025	−2.5
Mortality before ICU discharge	0.117	12.4
Admission after emergency surgery	−0.137	−12.8
Readmission	−0.106	−10.0
Cardiac ICU	0.077	8.0
Surgical ICU	0.149	16.1
Neurologic/trauma ICU	0.074	7.7
Payor = government	0.022	2.3
Diagnoses with five highest relative increases in costs		
Aortic aneurysm, elective repair	1.151	216.0
Laminectomy, fusion, spinal cord surgery	1.143	213.7
Valvular heart surgery	0.959	160.9
Acute myocardial infarction: anterior	0.895	144.8
Acute myocardial infarction: inferior/lateral	0.862	136.8
Diagnoses with five highest relative decreases in costs		
Airway obstruction	−0.345	−29.2
Diabetic ketoacidosis	−0.339	−28.7
Cardiac drug toxicity	−0.302	−26.1
Drug overdose	−0.288	−25.0
Metabolic/endocrine miscellaneous disorders	−0.275	−24.1

[a]All variables listed had a $p < 0.01$.

[b]$2,576 is the base charge with all other variables set to zero or the null category.

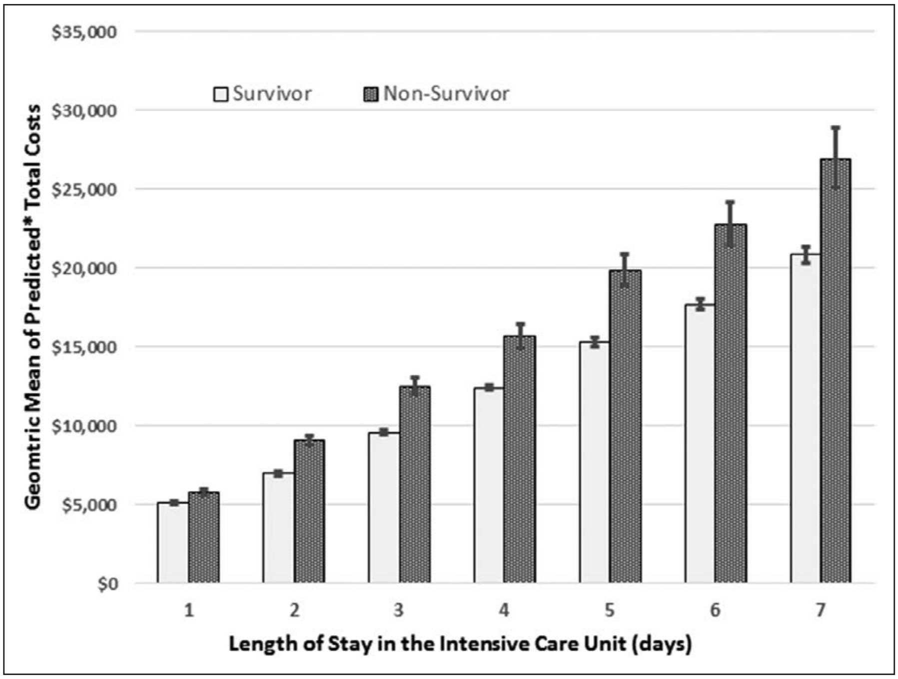

Figure 2. Geometric mean predicted total cost (with 95% CI) by number of days a patient remained in the ICU (in a bed at midnight), stratified by the patient's discharge status. *Predicted value for an admission based on the reference value for diagnostic group, ICU type, hospital, emergency surgery, and readmission; a 65-yr old male patient; an Acute Physiology Score = 36 (median).

here are for an ICULOS equals to 2 days (median ICULOS) and 5 days (extended ICU stay). Of the four comparisons, two were significant ($p < 0.01$), patients with an ICULOS equals to 2 days and not receiving mechanical ventilation, as well as patients with an ICULOS equals to 5 days and receiving mechanical ventilation. For the latter group, the difference between nonsurvivors and survivors was $2,831 (14.4%). The remaining two groups did not have a significant difference in costs between nonsurvivors and survivors.

In our sensitivity analysis, the mixed effects model showed similar results to the fixed effects model. Coefficients from the mixed effects model were generally within 0.01 of what was obtained in the fixed effects model.

DISCUSSION

ICULOS is the predominant factor behind costs, followed by whether or not a patient received mechanical ventilation. Since mortality in essence censures ICULOS, it is statistically possible that higher mortality rates might artificially result in lower costs for a patient cohort. The results of our study show that patients who expire before ICU discharge actually have an increased total cost after adjustment for multiple factors. This is particularly evident in ventilated patients with an extended ICULOS.

What might account for mortality being associated with higher costs? Since we adjusted for severity of illness, diagnosis, and a patient receiving mechanical ventilation, the higher costs associated with patient death cannot be attributed to case-mix. The most likely explanation lies in the considerable number of resources incurred at the end of life (16–19). Care before end of life may include additional procedures, diagnostic tests, and laboratory tests. There is also the prolonged use of such therapies as IV vasopressors, blood products, sedatives, and analgesics as needed for the patient to die with dignity while receiving comfort care (20). Infrequently used expensive and/or investigative treatments might also be driving end-of-life costs. Finally, terminal patients with a do not resuscitate order might continue to receive mechanical ventilation and as needed comfort care while languishing in the unit, resulting in an extended LOS and associated costs of care.

Patients in our study with an ICULOS of 2 days did not have a large cost difference by discharge status, which might be explained by the relatively high cost of the first day in the ICU dwarfing other costs. However, patients who had an ICULOS of 5 days and died before discharge had higher costs than those who survived, particularly if receiving mechanical ventilation. By day 5,

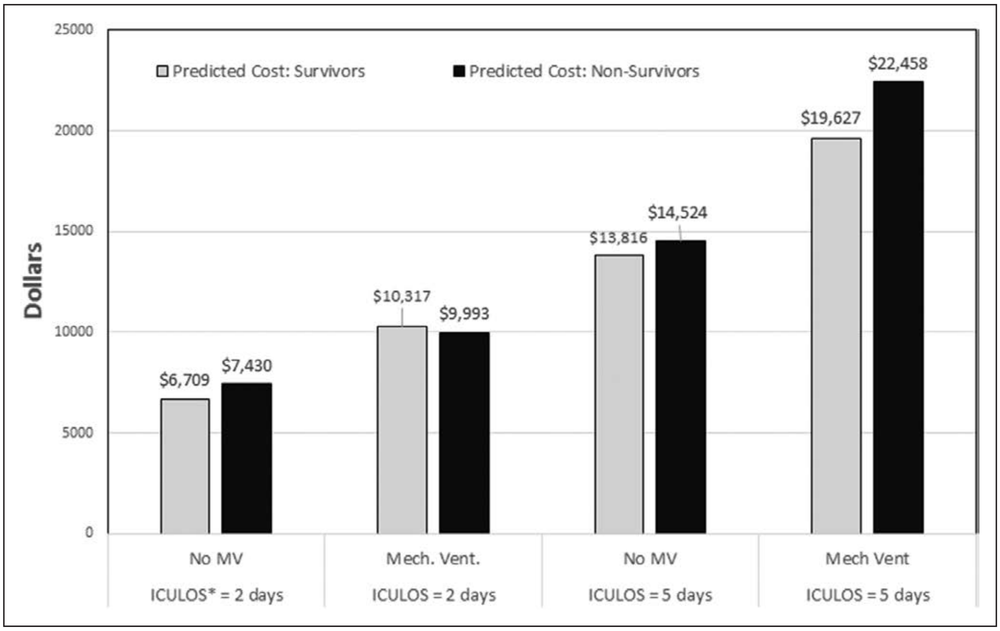

Figure 3. Geometric mean total cost by discharge status, stratified by the number of days a patient remained in the unit (2 vs 5 d) and whether or not a patient was mechanically ventilated on day 1. ICULOS = ICU length of stay.

the large day 1 costs are more than offset by additional resources being extended in attempts to treat extremely ill patients.

This is the first study to quantify the additional costs specific to the ICU for survivors compared with nonsurvivors. Our findings are strengthened by the fact that there were numerous confounders accounted for in our model: reason for ICU admission, age, APS, ICU type, and time spent on the floor before admission to the ICU. The model's high r^2 and the relatively small difference between observed and predicted costs further support our findings. The projected total ICU cost in nonventilated patients was $11,470, and for patients receiving mechanical ventilation, it was $34,183. The comparable costs in the other large study (2002 data) (6) were $12,931 and $31,574, respectively. The effect on daily costs was similar to results from other studies since day 1 had the highest effect, followed by less but still meaningful increases on subsequent days. Costs associated with receiving mechanical ventilation were predominantly confined to the first day in our study. Although this finding is different from other results (6), we feel our modeling ventilatory support was closer to how hospitals bill this treatment. Further, our results support the work by Kahn et al (21), who maintain that reducing duration of mechanical ventilation is of modest financial benefit.

A curious result was that patients admitted after emergency surgery had a noticeable decrease in costs (–12.8%). This represents the marginal cost after multivariable adjustment. There were several types of surgery that had a much higher frequency in emergent rather than elective surgery: gastrointestinal tract (GI) obstruction, GI perforation, multiple trauma (excluding the head), and repair of peripheral ischemia. As Table E2b (Supplemental Digital Content 1, http://links.lww.com/CCM/C682) shows, these diagnoses had a highly elevated cost. Thus, the decrease in cost associated with emergency surgery may be merely the residual offset from the high cost of common types of emergency surgery.

Factors previously found to be increase costs include age, APS, and gender. These variables were inconsequential in our model of costs. By including discharge status in our model, as well as ICU type, and ICU admitting diagnosis, it is possible that the factors mentioned above might have been confounders in previous studies.

There were several limitations with this study. First, total costs were used rather than separate categories (i.e., fixed vs variable, clinician services vs medications). As a result, we could not specify the exact reasons why mortality had a high relative cost. Second, the impact of adverse events such as hospital-acquired infections could not be ascertained. Third, the dataset had only 13 hospitals, which is not a nationally representative sample. However, the number of hospitals here was larger than in most other studies of hospital costs/charges. Fourth, we did not have information on advanced directives or other limitations of medical treatment. It is possible that having that information would have resulted in an even higher mortality-associated cost, as patients with limited care have lower costs; this decrease would push up the "mortality effect." Finally, the costs were derived from CMS' cost-to-charge ratios specific to each hospital in this study. The use of hospital cost-to-charge ratios rather than those based on diagnoses has been debated (22, 23).

CONCLUSIONS

Patients who did not survive their ICU stay had a 12% increase in overall costs. The increase was most evident for patients with an extended ICU stay who were receiving mechanical ventilation. Studies evaluating costs among ICUs need to take mortality into account.

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