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Economic Implications of Night Time Attending Intensivist Coverage in a Medical ICU

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Abstract

Objective—Our objective was to assess the cost implications of changing the ICU staffing model from on-demand presence to mandatory 24 hour in-house critical care specialist presence.

Design—A pre-post comparison was undertaken among the prospectively assessed cohorts of patients admitted to our medical ICU one year before and after the change. Our data was stratified by APACHE III quartile and whether a patient was admitted during the day or at night. Costs were modeled using a generalized linear model with log-link and gamma distributed errors.

Setting—A large academic center in the Midwest.

Patients—All patients admitted to the adult medical ICU on or after January 1, 2005 and discharged on or before December 31, 2006. Patients receiving care under both staffing models were excluded.

Intervention—Changing the ICU staffing model from on-demand presence to mandatory 24 hour in-house critical care specialist presence.

Measurements—Total cost estimates of hospitalization were calculated for each patient starting from the day of ICU admission to day of hospital discharge.

Main Results—Adjusted mean total cost estimates were 61% lower in the post-period relative to the pre-period for patients admitted during night hours (7PM to 7AM) who were in the highest APACHE III quartile. No significant differences were seen at other severity levels. Unadjusted ICU length of stay fell in the post-period relative to the pre-period (3.5 vs. 4.8) with no change in non-ICU length of stay.

Conclusions—We find 24-hour ICU intensivist staffing reduces lengths of stay and cost estimates for the sickest patients admitted at night. The costs of introducing such a staffing model need to be weighed against the potential total savings generated for such patients in smaller ICUs, especially ones that predominantly care for lower acuity patients.

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Keywords

Critical Care; Intensive Care; Health Care Costs; Costs and Cost Analysis; Economics; APACHE

Introduction

Evidence is mixed on whether ICU patients whose care is directed by specialists in critical care medicine have improved outcomes, including reduction in mortality rates and hospital lengths of stay.(1-3) However, the intensivist staffing models vary and which model provides the greatest health care value (high-quality, low-cost) is not known. The Leapfrog Group, a consortium of major purchasers of health care, has recommended that intensivists be present to direct care of ICU patients during daytime hours seven days per week and be available by page at other times to direct other providers' care. An economic analysis that financially modeled the Leapfrog Group recommendations demonstrated cost savings from a healthcare provider perspective with intensivist staffed ICUs compared to non-intensivist staffed ICUs.(4) While many hospitals are beginning to implement these recommendations, only about 30% of hospitals currently satisfy the Leapfrog Group standard.

Some organizations, including the Society for Critical Care Medicine, recommend utilization of level-1 ICU 24 hour in-house intensivists as the ideal model.(5) Because the first few hours of intensive care are the most critical for many patients, this could particularly benefit the sickest patients admitted to the ICU at night. However, a projected shortfall in the intensivist workforce may preclude wide spread adoption of this model.(6) Moreover, the economic implications of staffing an ICU with 24 hour in-house intensivists compared to the Leapfrog model have not been studied.

With the intent to improve the quality of care, the staffing model in one of our adult medical ICUs was changed from on-demand night time coverage with in-house residents and a critical care fellow to mandatory in-house coverage by a critical care trained attending physician (in addition to in-house residents and fellows). In order to cover the additional shift requirements an additional 2.1 full-time employee (FTE) intensivists were added. Patient outcomes and family and provider satisfaction during the pre- and post-change periods have been previously reported.(7) There was no change in hospital mortality, and family and patient satisfaction were similar during the two periods. Meanwhile staff satisfaction and perceptions about patient safety, education, organization and function significantly improved with the new model of care. In addition, ICU and hospital lengths of stay decreased during the period of in-house intensivist presence, suggesting the potential for reduced costs, but the effects on total costs were not studied.

We undertook the present study to analyze the economic implications of the increased staff coverage to the institution after adjusting for other potential changes including any temporal confounding. We hypothesized that from the healthcare provider's perspective the new staffing model would reduce ICU and overall direct costs of patient care due to savings related to more rapid decision-making, decreased diagnostic testing and fewer ICU and post-ICU hospital days. We also hypothesized that the greatest reduction in direct costs of care would be seen in the most severely ill patients admitted at night. These patients should have the largest gap in ideal versus received care when intensivists were not onsite during the night shift in the pre-period.

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Materials and Methods

Study Design

Due to the fact that we were unable to develop either a randomized or controlled design, we set up the economic analysis as a pre-post comparison among the prospectively assessed cohorts of patients admitted to the ICU one year before and after the change from on-demand presence to required mandatory 24 hour in-house critical care specialist presence. Because other factors could have effects over time, in addition to a comparison between the two groups, we treated the data as a short time series, examining the mean cost estimates per patient over the 24 month timeframe with adjustments for seasonal factors and a secular time trend. Our analysis also investigated the robustness of this time trend.

Staffing change

Prior to the staffing change, the ICU was staffed by two intensivists during the day (7 am to 7 pm) with an intensivist on call at night who would be physically present as necessary. Attending physicians on-call in the pre-period had electronic access to patient charts at home. They were required to be within 30 minutes of the ICU and would come in when they felt it was necessary. Being on-call was considered part of regular work expectations and intensivists were not paid extra to come in to see patients. During the “on demand” period, the attending physicians provided care after hours at their discretion based on subjective judgment about patient condition and the ability of junior staff to provide adequate care. Indeed, the burden of after hours presence with increased resident supervision was one of the main reasons that our group moved to addition of the night shift.

At night the ICU was staffed with a critical care fellow, a junior internal medicine resident and a senior resident. The nurse staffing was based on ICU census and patient demand. Respiratory therapists were continuously available in the ICU. Pharmacists and nutritionists were available during daytime hours. The only change in staffing was the addition of the intensivist during the nighttime hours. All other support staff remained unchanged. A step down unit was not utilized during the study period.

Semi structured (SBAR – situation, background, assessment, recommendation) hand off occurs during a 15 minute attending rounds at the end of each shift, followed by a formal rounds of incoming attending physician with house staff.

Night time attending coverage is not unique to the medical ICU. In-house attending physicians cover the majority of Mayo Clinic ICUs. There has been no change in ICU admission criteria. In a case that one of the ICUs is full, overflow patients are admitted to other ICUs.

Study population

All patients admitted to the adult medical ICU (capacity 24 beds) at St. Mary’s hospital in Rochester, MN on or after January 1, 2005 and discharged from the ICU on or before December 31, 2006 were identified using our ICU APACHE III database. While our earlier paper (7) excluded a significant number of patients admitted to the ICU for low risk monitoring, a comprehensive economic evaluation, as undertaken in this paper, demanded the inclusion of all ICU patients, except those who denied authorization to use their medical data for research purposes (<5%). This study was approved by our Institutional Review Board.

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Data collection and episode definition

Mayo Clinic Rochester (MCR) has two hospitals (St. Mary's and Rochester Methodist hospitals), separately licensed, but administered and staffed as a single entity within its integrated group practice. Administrative billing data were captured from both hospitals, if necessary, for patients eligible for the study. Hospital episodes consisting of uninterrupted and continuous stays within the MCR acute care system were created from the billing data. Data including costs were then classified into ICU versus non-ICU timeframes based on dates of ICU services. Any patient having missing APACHE III scores was excluded from the study population.

Cost data prior to the first ICU admission for a given patient were excluded. Transfers of care to either rehabilitation or psychiatric wards were beyond the scope of our study and considered as hospital discharge.

Intervention timeframe

The change to 24 hour mandatory intensivist presence took place on January 3, 2006. Patients admitted to the ICU prior to this date were considered pre-intervention, while patients admitted on or after this date were considered post-intervention. Cases with ICU readmissions where ICU stays occurred both before and after the change were excluded. Additionally, 14 hospital episodes with a continuing ICU stay on January 3, 2006 were also excluded.

Cost Measures

Cost analyses were conducted using the healthcare provider's perspective and included only direct medical costs of care. We used administrative data to track medical resource utilization and related billed expenditures for each hospital episode of interest. Due to well-known discrepancies between billed charges and true resource use, we valued utilization using standard methods which use both physician and institutional components of care by grouping services into the Medicare Part A and Part B classification. This method adjusts Part A hospital billed charges, identified by UB Revenue codes, with department level cost-to-charge ratios and wage indices. Part B physician services, identified by CPT4 codes, were proxied with Medicare reimbursement rates. This approach provides a standardized value for each unit of service. This methodology has been used elsewhere in the literature.(8-10) All cost estimates were adjusted to constant 2007 dollars.

Total cost estimates of hospitalization were calculated for each patient starting from the day of ICU admission to day of hospital discharge. The change in staffing practice was unique to the study ICU. Costs occurring in other ICUs during the episode (if any) were included in total cost estimates.

In order to cover the additional shift requirements in the post-period, Mayo Clinic hired an additional 2.1 FTE intensivists. We estimate that the salary costs for these new hires amounted to approximately $634,000 ($302,000 per FTE), in 2007 dollars.(11). Assuming an additional 30% in benefit costs, this totals to approximately $825,000.

Comparison of cohorts

Student's t-tests, Wilcoxon rank-sum tests, and chi-square tests were used as appropriate for univariate comparisons before and after the intervention. We also compared unadjusted economic variables (cost and length of stay) across the pre- and post-intervention period, paying special attention to differences between mean cost estimates in the corresponding pre- and post-APACHE III quartiles. This comparison was also made by quartile for those admitted at night.

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Model Specification

Our goal was to adjust for differential risk among patients. We modeled total hospital costs as a function of four sets of variables:

1. Demographic characteristics including age and gender;
2. Severity of illness based on the APACHE III, categorized into quartiles and diagnostic category related to the reason for ICU admission;
3. ICU admission characteristics including day versus night admission and source of admission: internal transfer or transfers external to Mayo;
4. A linear time trend to capture secular changes over time and monthly indicator variables for November and December to adjust for seasonal factors relating to patient admissions in those months.

We stratified our data by APACHE III quartile and whether a patient was admitted during the day or at night. This created eight subgroups (strata). We used an identical regression specification across the various strata and included an indicator variable for the post-intervention period. This variable is the main focus of our study. It describes changes in costs associated with 24-hour intensivist care in the ICU.

Statistical methodology

Costs were modeled using a generalized linear model with log-link and gamma distributed errors. There is a substantial statistical and economic literature that recommends using such techniques when modeling health care costs due to unique features of such data, namely that they tend to be differentially dispersed around the mean (heteroskedastic) and prone to large outliers (right-skewed).(12,13).

Results

Table 1 presents information concerning the creation of the analysis cohorts. Across both periods, 15 individuals were excluded due to missing APACHE III scores and 15 were excluded because they had study ICU admissions in both pre- and post-periods. Five patients admitted in the post period were removed for being discharged from the ICU after the end of the analysis period.

The two cohorts are compared on patient and admission characteristics in Table 2. There were more patients in the ICU in the year subsequent to the staffing change than in the prior year (2073 versus 1730). An increased number of low risk monitoring patients (322 vs 472) primarily falling into the lowest two APACHE 3 quartiles, was seen after the staffing change. Patients discharged to either a psychiatric or rehabilitation ward totaled 156 (9.0%) and 203 (9.8%) in 2005 and 2006, respectively. Costs incurred in these facilities were excluded from our analyses. A total of 48 and 52 individuals were transferred from the study ICU to another ICU within the hospital system in 2005 and 2006, respectively. The proportion of patients who were admitted to the ICU from within the hospital did not change between time periods with 418 (24.2%) before the staffing change and 515 (24.8%) after the change. There was also no change in the proportion of ICU patients admitted from other hospitals: 210 (12.1%) patients in the pre-period versus 253 (12.2%) patients in the post-period. After the change in staffing, a higher percentage of ICU patients were admitted for cardiovascular conditions (25.0% vs. 19.8%) and the mean APACHE III score was lower (58.5 versus 60.9) although not significant at the 0.01 level. There were no significant differences in APACHE III scores when stratified by quartile. Mean length of stay in the ICU was also significantly lower after the staffing change (2.6 days versus 3.0 days), but no

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changes were seen in post-ICU hospital stay. The average daily census on the unit increased from 14.4 in 2005 to 15.0 in 2006.

Table 3a presents means and standard deviations of total cost estimates stratified by the APACHE III score quartile for each patient in the pre- and post-period along with p-values for t-tests of the difference in unadjusted mean costs across periods. Mean total cost estimates are significantly higher in the pre-period relative to the post-period for all patients, as well as all patients admitted at night, and patients in the sickest APACHE III quartile. The magnitude of the difference between the two cohorts also appears to increase in sicker APACHE III quartiles. Although it is difficult to generalize, APACHE III quartile 4 patients tended to be older (mean: 71 vs. 60), more likely to be admitted from the floor (29% vs. 21%) or another hospital (16% vs. 11%), more likely to be admitted for cardiovascular problems (37% vs. 18%) and less likely to be admitted for neurologic (4% vs. 19%) or gastrointestinal problems (23% vs. 15%) than less ill patients. When we restrict attention to patients admitted during night hours, we see that the magnitude of difference between pre- and post-period patients is highest in the sickest APACHE III quartile. Tables 3b and 3c present similar information for ICU and non-ICU length of stay (LOS) by quartile. Note that the sickest patients at night show a statistically significant reduction in ICU LOS. This difference is still apparent for all night patients. There was no difference in ICU or hospital mortality rates for the sickest APACHE3 quartile patients admitted at night.

Table 4 presents results of the regression analysis for patients in APACHE III quartile 4 who were admitted to the ICU at night. The key coefficient of interest, the post period indicator, is highly negative and significant. The interpretation is that after controlling for other factors, including observable clinical differences, seasonal factors, and a secular time trend, the sickest patients admitted to the ICU at night after the staffing change have total hospital cost estimates that are 61% lower than similar patients admitted prior to the change. In order to test the robustness of the model due to the secular time trend, this same analysis was conducted excluding the secular time trend and yielded similar results: the estimated cost reduction of the staffing change reduced (29%) but the standard error of the estimate was also reduced resulting in a p-value of 0.001. This suggests collinearity between the time trend and the staffing change indicator.

Table 5 presents the staffing indicator coefficients from all APACHE III-day/night strata. The coefficient is not significant in any other stratum. However, in our sensitivity analysis which removed the secular trend the APACHE III quartile 1 day patients had a significant decrease in the staffing indicator coefficient (p=0.006) as well as the APACHE III day patients (p=0.050).

Discussion

After implementing 24 hour intensivist staffing, there was a significant decline in adjusted total hospital cost estimates among the sickest patients admitted at night with no significant changes among less-ill patients admitted at night or among patients admitted during the day. There were also increased numbers of total ICU admissions. Although this increase might have been effected by shorter ICU stays and hence, more available beds, the increase in ICU admissions is part of an overall trend. The demand for medical ICU care has been steadily increasing at our institution from 1200 admissions in 1997 to 2600 admissions in 2009. These findings could be related to the implementation of the new staffing model. We previously reported that adherence to evidence-based processes of care and ICU complications both improved with a greater intensivist presence.(7) Together, these findings are consistent with the hypothesis that sicker patients may benefit from the 24-hour presence of experienced clinicians. These results are neither sensitive to changes in sets of

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explanatory variables (e.g. using different combinations of clinical variables) nor to a specification that uses the full sample and includes multiple interaction terms including one for each treatment-quartile-day/night combination (these results are available from the authors upon request). Our results are consistent with previous studies that suggest that preventable adverse events are more likely during nighttime hours when house officers are less likely to be supervised.(14). The observed findings are likely to be even more pronounced in teaching hospitals where night time medical ICU coverage is provided by internal medicine residents only without full time presence of at least a critical care fellow.

Although we have incorporated adjustments for overall trends and possible differences in ICU cohorts before and after the staffing change, this study remains an uncontrolled retrospective analysis that may not have accommodated important factors. To the best of our knowledge, there were no other projects undertaken at the ICU that may have influenced the costs of care of the sickest patients admitted at night.

Recent articles have identified the scarcity of evidence for appropriate ICU staffing models.(1,2,15) In combination with our earlier study (7) that showed improvements in quality, we provide evidence that 24-hour in-house intensivist staffing also reduces costs among the sickest patients admitted at night. Our finding of reduced cost is consistent with our earlier findings of decreased ICU and total length of stay for patients treated by 24-hour intensivists. Indeed, parallel analyses examining ICU and total length of stay show that reductions in these were also focused on the sickest patients admitted at night. The magnitude of these reductions in length of stay corresponds to estimated reductions in costs for the sickest night patients of $5000 and $5500 per day for total and ICU costs, respectively. Changes in types of ancillary services (e.g., laboratory, pharmacy, radiology) were not significant. We suspect these results are due to more rapid introduction of effective intervention and might explain the decreased cost estimates associated with 24-hour coverage. Future studies examining the timing of critical processes of care might be especially useful in understanding the mechanism by which 24-hour staffing has its effects. Similar insights may be generated by examining changes in diagnostic and therapeutic plans instituted when attending physicians who are not in-house overnight first see patients in the morning. It is difficult to predict precisely which specific clinical decisions most likely explain these patterns given the diversity of such decisions made by intensivists. However, the possibility that errors may be avoided must also be considered.

Regardless of the mechanisms explaining our observed findings, the fact that the benefits seem to be greatest among the sickest patients suggests there may be opportunities to focus efforts to improve costs and outcomes through 24-hour staffing in institutions that see the sickest patients. Alternatively, one could imagine having on-call intensivists come in to see all patients who exceed some level of severity rather than making decisions from home though staff satisfaction surveys at our institution suggest attending intensivists prefer the 24-hour staffing model to the on-demand model.(7)

The cost savings we observe in this paper of somewhat more than $10,000 per patient among the sickest patients admitted at night suggest the potential for large savings for specific patients that are big enough to make this economically attractive even for quite small ICUs. For example, assume that overnight presence of an ICU physician cost $2,500 per night, a hospital would then have to admit only one patient to the ICU each night on average to justify the expense from an economic perspective. This is because the savings of $10,000 are realized on 4th quartile patients (who average one in four) and the assumed cost of hiring an intensivist for four nights in this example is also $10,000. Of course, savings could be far less if much of the cost savings come from reductions in ICU and hospital length of stay that are effectively fixed costs. Furthermore, the overall distribution of

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patients in such ICUs would need to be similar in terms of APACHE III scores to the patient population in our ICU in order to see similar savings with nighttime intensivists.

Our study only focuses on costs incurred within the hospital stay. Downstream costs associated with follow-up care are relevant from a societal perspective, as are indirect costs associated with work loss and long term care. However, such data were not available. This paper is an uncontrolled observational study based on an analysis of administrative billing data combined with information from the APACHE database and so is subject to the limitations of such a study design. In addition, the continuous staff intensivist presence may have facilitated faster ICU transfer of critically ill patients and more rapid resuscitation measures. This in turn could explain not only a shorter length of stay but also higher APACHE III scores calculated in the ICU. Although DNR status on admission did not differ between the two periods (p=0.758), it is possible that the continuous presence of attending physicians facilitated end of life discussions. Detailed accounts of end of life care were not available at the time of this cost analysis. Furthermore, this was a single center study within one intensive care unit in a large tertiary referral center. Results may not be generalizable to all ICUs.

Despite these limitations, our study suggests that 24-hour intensivist staffing is particularly beneficial for the sickest patients and seems to manifest itself in terms of reduced length of stay that in turn translates into reduced total cost estimates. Further investigation into the various components of such reductions in costs, including whether the difference stems from changes in practice patterns for night patients, and whether the fixed costs of hiring additional intensivist staff are outweighed by savings from reduced lengths of stay and other components, especially in smaller ICUs that may not see the sickest patients on a regular basis, is warranted.

Conclusions

We find 24-hour ICU intensivist staffing reduces lengths of stay and cost estimates for the sickest patients admitted at night. The costs of introducing such a staffing model need to be weighed against the potential total savings generated for such patients in smaller ICUs especially ones that predominantly care for lower acuity patients.

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Table 1

Sample Selection

All Pre-period cases	1,755
Removed for missing APACHE III score	10
Removed for ICU stay overlapping staffing change	11
Removed for ICU stays in both time periods	4
Remaining Pre-period cases	1,730
All Post-period cases	2,088
Removed for missing APACHE III score	5
Removed for having ICU discharge after 2006	5
Remaining Post-period cases	2,073
Total hospital episodes used	3,803

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Table 2

Description of key baseline characteristics

	Pre-period	Post-period	p-value
Age (SD)	62.9 (19.1)	62.2 (19.3)	0.268
APACHE III Score (overall)	60.9 (28.5)	58.8 (28.1)	0.019
Q1	27.9 (8.0)	27.3 (8.1)	0.322
Q2	48.4 (4.9)	48.6 (4.8)	0.511
Q3	64.7 (5.0)	64.7 (5.2)	0.802
Q4	97.4(22.8)	96.7 (22.5)	0.373
ICU LOS	3.0 (4.0)	2.6 (3.4)	<0.001
Total LOS	8.8 (13.0)	8.1 (11.0)	0.123
Female (%)	45.6	47.2	0.319
ICU Night Admission (%)	45.3	47.0	0.288
Transferred to other ICU (%)	2.8	2.5	0.610
Discharged to Rehab/Psych (%)	9.0	9.8	0.416
Discharged home (%)	51.4	51.9	0.800
Internal ICU transfer (%)	24.2	24.8	0.627
External hospital transfer (%)	12.1	12.2	0.951

SD – standard deviation.

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Table 3

a Unadjusted Total Cost Estimates by APACHE III Quartile

	Pre-period	**Post-period**	
All admissions	*Mean (SD)*	*Mean (SD)*	*p-value*
APACHE III Q1	$15,819 (26,656)	$14,632 (24,632)	0.550
APACHE III Q2	$29,732 (40,719)	$26,857 (40,486)	0.086
APACHE III Q3	$33,105 (43,209)	$32,131 (35,663)	0.688
APACHE III Q4	$50,033 (70,924)	$41,053 (47,431)	0.026
Total	*$32,834 (50,372)*	*$28,473 (39,078)*	*0.004*
Day admissions	*Mean (SD)*	*Mean (SD)*	*p-value*
APACHE III Q1	$19,350 (27,136)	$16,311 (17,633)	0.880
APACHE III Q2	$32,845 (45,203)	$29,218 (46,381)	0.141
APACHE III Q3	$37,425 (50,471)	$34,838 (38,882)	0.512
APACHE III Q4	$48,707 (59,631)	$42,717 (47,281)	0.255
Total	*$35,231 (48,769)*	*$31,210 (40,930)*	*0.221*
Night Admissions	*Mean (SD)*	*Mean (SD)*	*p-value*
APACHE III Q1	$12,252 (25,742)	$13,087 (30,097)	0.550
APACHE III Q2	$25,125 (32,561)	$24,234 (32,609)	0.518
APACHE III Q3	$27,423 (30,394)	$28,949 (31,244)	0.927
APACHE III Q4	$51,461 (81,467)	$38,780 (47,652)	0.032
Total	*$29,935 (52,129)*	*$25,384 (36,652)*	*0.007*

b Unadjusted ICU Length of Stay by APACHE III Quartile

	Pre-period	**Post-period**	
Day admissions	*Mean (SD)*	*Mean (SD)*	*p-value*
APACHE III Q1	1.64 (2.01)	1.54 (1.43)	0.853
APACHE III Q2	2.69 (3.51)	2.22 (3.17)	0.119
APACHE III Q3	3.18 (3.98)	2.93 (3.23)	0.897
APACHE III Q4	4.73 (5.13)	4.24 (4.58)	0.171
Total	*3.11 (4.02)*	*2.78 (3.49)*	*0.087*
Night admissions	*Mean (SD)*	*Mean (SD)*	*p-value*
APACHE III Q1	1.40 (1.07)	1.34 (1.54)	0.086
APACHE III Q2	1.93 (2.12)	2.22 (3.70)	0.246
APACHE III Q3	2.87 (4.65)	2.48 (3.25)	0.058
APACHE III Q4	4.77 (5.22)	3.50 (4.34)	0.002
Total	*2.83 (3.99)*	*2.31 (3.38)*	*<0.001*

c Unadjusted Non-ICU Length of Stay by APACHE III Quartile

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	Pre-period	Post-period	
Day admissions	*Mean (SD)*	*Mean (SD)*	*p-value*
APACHE III Q1	3.64 (6.29)	3.31 (4.58)	0.515
APACHE III Q2	6.37 (10.38)	6.21 (9.22)	0.397
APACHE III Q3	7.11 (11.87)	7.15 (9.27)	0.250
APACHE III Q4	7.20 (11.98)	6.57 (10.80)	0.670
Total	*6.21 (10.62)*	*5.87 (8.98)*	*0.556*
Night admissions	*Mean (SD)*	*Mean (SD)*	*p-value*
APACHE III Q1	2.15 (5.81)	2.54 (9.26)	0.783
APACHE III Q2	5.41 (7.78)	5.39 (10.17)	0.423
APACHE III Q3	5.11 (5.00)	6.51 (9.24)	0.288
APACHE III Q4	8.29 (18.84)	7.06 (14.41)	0.994
Total	*5.34 (11.55)*	*5.22 (10.59)*	*0.807*

SD – standard deviation

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Table 4

Parameter Estimates from Multivariable Generalized Linear Model for Total Cost on APACHE III Q4 Night Patients Stratum

Variable	Coefficient	SE	Degrees of Freedom	Chi-square	p-value
Intercept	11.466	0.302	1	1439.8	<.001
Staffing change status	-0.610	0.246	1	6.1	0.013
November	-0.339	0.182	1	3.5	0.063
December	-0.467	0.194	1	5.8	0.016
Age	-0.010	0.003	1	7.6	0.006
Female	-0.149	0.087	1	3.0	0.086
Internal_admit	0.096	0.101	1	0.9	0.345
External_admit	0.240	0.133	1	3.2	0.072
Time Trend	0.026	0.018	1	2.0	0.163
Other factors[1]			19	56.3	<0.001

SE – standard error

Note:

[1] Other factors include ICU admission diagnosis (e.g. cardiac arrest, GI bleed, respiratory arrest, sepsis etc.).

[2] Variable definitions

- **a.** November, December: indicators for ICU admissions in these months
- **b.** Female: 1 if patient is female, 0 male
- **c.** Internal_admit, External_admit: value 1 if patient was admitted to the ICU from the hospital floor (internal) or other hospital (external), otherwise 0

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Table 5

Staffing change coefficient for all APACHE III – Day/Night strata

Strata	Post staffing change status coefficient	SE	p-value
Day APACHE III Q1	-0.004	0.183	0.984
Day APACHE III Q2	-0.078	0.177	0.658
Day APACHE III Q3	0.179	0.172	0.296
Day APACHE III Q4	-0.092	0.186	0.621
Night APACHE III Q1	0.152	0.162	0.348
Night APACHE III Q2	-0.006	0.208	0.978
Night APACHE III Q3	-0.082	0.191	0.666
Night APACHE III Q4	-0.610	0.246	0.013

SE – standard error