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COSTS AND COST-EFFECTIVENESS OF A TELE-ICU PROGRAM IN SIX INTENSIVE CARE UNITS IN A LARGE HEALTHCARE SYSTEM

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Abstract

Purpose—To estimate the costs and cost-effectiveness of a tele-ICU program.

Materials and methods—We used an observational study with ICU patients cared for during the pre-tele-ICU period and ICU patients cared for during the post-tele-ICU period in 6 ICUs at 5 hospitals, part of a large non-profit health care system in the Gulf Coast region. We obtained data on a sample of 4142 ICU patients: 2,034 in the pre-tele-ICU period and 2,108 in the post-tele-ICU period. Economic outcomes were hospital costs, ICU costs and floor costs, measured for average daily costs, costs per case, and costs per patient.

Results—After the implementation of the tele-ICU, the hospital daily cost increased from $4,302 to $5,340 (24%), the hospital cost per case from $21,967 to $31,318 (43%), and the cost per patient from $20,231 to $25,846 (28%). While the tele-ICU intervention was not cost effective in patients with SAPS II ≤ 50, it was cost effective in the sickest patients with SAPS II > 50 (17% of patients) as it decreased hospital mortality without increasing costs significantly.

Conclusions—Hospital administrators may conclude that a tele-ICU program aimed at the sickest patients is cost effective.

Keywords

economic analysis; telemedicine; intensive care units

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INTRODUCTION

Each year, over 5 million patients in the U.S. are admitted to intensive care units (ICU). These patients are usually the frailest and the sickest and ICU mortality rates tend to be high.[1] ICU care is very expensive, representing about 30% of hospital costs in the U.S.[2] Evidence suggests that the quality of care in ICU varies and that ICUs staffed with intensivists achieve better outcomes than those staffed by traditional attending physicians.[3,4] A national shortage of intensivists has lead to the development of tele-ICU programs which allow intensivists to remotely care for patients in several ICUs simultaneously.[5] The costs of acquiring, installing, and operating tele-ICUs are significant, with $2 to $5 million setting-up costs and annual operating costs of upwards of $1.5 million.[6,7]

Tele-ICU programs have recently been expanding despite scant evidence in the published literature on their effectiveness and cost-effectiveness. While some reports and abstracts report improved clinical outcomes with tele-ICU[6], recent reviews of the effectiveness of tele-ICU found little published literature and conflicting conclusions about its impact on patient outcomes.[8,9] Because of the high cost of these programs, it is also important to consider the cost-effectiveness of tele-ICU programs before further expansion. One study, systematically evaluating costs and effectiveness of a tele-ICU program, found a reduction in hospital and ICU mortality and 25% lower costs per case. It concluded that the tele-ICU program was cost-saving because higher hospital revenues due to increased ICU cases more than covered the tele-ICU program costs.[10] More recent studies did not find similar positive findings.[11,12] We evaluated the effectiveness of a tele-ICU program in 6 ICUs in a large non-profit health care system and found it did not reduce complications, length of stay or mortality in the general population of ICU patients. Only among the sickest patients was implementation of the tele-ICU associated with reduced mortality and length of stay.[12] This paper reports on the costs and cost-effectiveness of the tele-ICU program.[12] The contribution of this paper on the cost-effectiveness of the tele-ICU program is important given the paucity of studies addressing early costs associated with new technology.

METHODS

Description of setting and study design

A full description of the study is provided in Thomas et al.[12]. This study has IRB approval HSC-MS-04-303 *Measuring the Value of Remote ICU Monitoring*. Briefly, the study was carried out in 6 ICUs at 5 hospitals, part of a large non-profit health care system in the Gulf Coast region. The study was an observational study with two independent groups of patients for which we obtained cost outcomes: 1,913 ICU patients cared for during the pre-tele-ICU period from January 2003 to August 2005 (pre-period) and 2,057 ICU patients cared for during the post-tele-ICU period from July 2004 to July 2006 (post-period). Dates for pre- and post-periods overlap because the implementation of the tele-ICU program was staggered among hospitals. For each ICU, the pre- and post-ICU periods span an average of 15 months. Patient age, gender, and Simplified Acute Physiology Score II (SAPSII) scores were similar in the pre- and post-periods, while racial/ethnic composition was somewhat different. There was no overall mortality reduction, but ICU and hospital mortality was reduced (40% and 37% respectively) in patients with SAPS II>50.[12] There were 658 patients or 17% of the sample with SAPS II>50 of which 343 in the pre-period and 315 in the post-period.

Economic evaluation

Perspective—The hospital perspective is taken in evaluating the cost-effectiveness of the tele-ICU program, consistent with other studies evaluating the cost-effectiveness of tele-

ICUs and most other cost studies in critical care.[10,12–14] Reasons to choose a hospital perspective include the nature of ICU care and ensuing data limitations. The outcome measures for ICU care (complications, length of stay, and short term mortality) are all measured at the hospital level. Furthermore, only hospital financial outcomes are relevant to the decision to implement a tele-ICU program, given that the decision is taken at the hospital level.

Financial outcomes—The hospital financial outcomes considered in this study were hospital costs and costs of operating the tele-ICU. Hospital costs were divided into ICU costs and floor costs. Floor costs represent hospital costs when the patient is not in the ICU but is on a non-ICU floor. Hospital costs were assigned to ICU costs for the days the patient was in the ICU and floor costs for the other days. Costs were computed using the proprietary cost-accounting system at the health care system, which measures the value of resources used and is closer to the concept of economic cost. We obtained daily costs by revenue center (department) for the duration of the inpatient episode for each patient included in the study. The cost of the tele-ICU program consisted of hourly fees paid to the physicians and other health care providers for staffing the tele-ICU and monthly per-bed fees charged by the commercial telemedicine provider (VISICU Inc.). The monthly per-bed fees included charges for hardware and software required for installing the tele-ICU and the tele-ICU operating expenses. Tele-ICU capital costs were annualized. All the costs of operating the tele-ICU program were obtained from the tele-ICU administration.

Cost measures—To better capture costs, we used several cost measures: average daily costs, costs per case, and costs per patient. Each type of cost was first computed for each ICU and then over the whole sample.

Average daily costs were computed for each patient. Costs were allocated to day of service and were considered ICU costs if the patient had an ICU room and board cost on that day, otherwise they were considered floor costs. A daily cost for each ICU and for all ICUs combined was computed for each day by adding the appropriate costs on that day for all patients and dividing by the number of patients on that day. Average daily costs were computed as ICU daily costs and floor daily costs and as pre- and post-period daily costs. Additionally, pre- and post-period costs were computed by department to illustrate the contribution of each department to the changes in daily costs. The advantage of the daily costs measure is that, unlike costs per patient, they do not depend on length of stay and the issues associated with length of stay and hospital deaths.

Costs per case were computed by multiplying the average daily cost by the corresponding average length of stay.

Costs per patient were computed as the ICU costs per patient, the floor costs per patient, and the total hospital costs (ICU and floor) per patient. We then averaged the costs per patient in the pre-and post-period to obtain the average cost per patient in the pre-period and the post-period. Costs per patient represent the actual patient costs and are used in the cost-effectiveness analysis. The cost per patient differs from the cost per case because the cost per case reflects the average cost for an average patient (with average length of stay) while the cost per patient is obtained by computing the actual costs incurred by each patient and then averaging over the patients.

Cost and cost-effectiveness analysis—The economic analysis was carried out in two parts. First, we did a cost analysis by comparing costs in the pre- and post-tele-ICU periods. Next, we combined patient costs with patient clinical outcomes to investigate the cost-effectiveness of the tele-ICU program.

Statistical analysis

Cost analysis—To test the difference between the pre- and post-periods, we used t tests for independent samples for average daily cost (since we found that the distribution of average daily costs can be represented by a normal distribution) and the non parametric Wilcoxon-Mann-Whitney tests for costs per patient which did not have a normal distribution. Then, we decomposed changes in average daily costs into changes in departmental costs.

Next we further investigated the statistically significance of differences in patient costs between the pre- and post-periods controlling for hospital and severity using regression analysis. We did not control for demographic characteristics as the samples in the pre-and post-tele-ICU periods had similar demographic characteristics. Because patient costs did not follow a normal distribution, we used OLS regression with a log transformation for patient costs as the dependent variable. Following the statistical models used in Thomas et al.12 for clinical outcomes, the regression reflected the 6 (hospital) × 2 (SAPS II<=50 and SAPS II>50) × 2 (pre-post) factorial design with main effects and joint effects. The main effects represent the simple effect of a factor on the dependent variable and the joint effects represent the interaction effects of two or more factors on the dependent variable. Because we found that the tele-ICU intervention was effective only in the sickest patients with SAPS II >50, we repeated the costs per patient computations and regressions for patients stratified by SAPS II (patients with SAPS II ≤ 50 and patients with SAPS II > 50). All analyses used StataIC 10.0.

Cost-effectiveness analysis—Next we compared differences in costs and clinical outcomes in the pre-and post-periods. We computed the cost-effectiveness ratio of the tele-ICU program in decreasing mortality in patients with SAPS II>50, since we found significant differences in mortality among this group of sickest patients.12 The cost analyses which were stratified by acuity score cut-off were retrospective.

RESULTS

Average daily costs and costs per case

Table 1 describes the ICU and the floor average daily costs and costs per case. The average daily costs and the costs per case increased in all six ICUs after implementation of the tele-ICU (post period) from the period before implementation of the Tele-ICU (pre-period). Overall, the daily average ICU increased from $2,851 to $3,653 or a 28% increase in the post period. Two ICUs (ICU4 and ICU5) experienced cost increases greater than 30%. The floor daily average costs increased from $1,451 to $1,687 or a 16% increase in the post period. The overall ICU costs per case increased from $13,029 in the pre-period to $19,324 in the post period (48% increase). The overall floor cost per case increased from $8,938 to $11,994 (34% increase).

Average daily costs by department

No clear patterns of departmental drivers for cost increases emerged. Among floor costs, only Floor Operating and Recovery costs increased in all units between pre-and post-periods. Among ICU costs, there was a consistent increase in all units in ICU costs and an evident increase in the costs of operating the tele-ICU. Other departments presented a mix of cost increases and decreases between pre-and post-periods across the units. (See Supplementary Table for detailed changes in ICU and floor average daily costs by department).

Average costs per patient

Average hospital costs per patient, average ICU costs per patient, and average floor costs per patient across all the 6 ICUs are presented in Table 2. Average hospital cost per patient was $20,231 in the pre-period and $25,846 in the post-period. The difference in the overall average cost per patient was $5,615 (28%), which was statistically significant. Costs per patient were statistically significantly greater by 35% in the post-period for patients with SAPS II ≤ 50 but were not significantly different for patients with SAPS II >50.

Patient costs

Results from the regression analysis are reported in Table 3. Regression analysis indicated that there was a significant main effect on costs of the tele-ICU intervention. Patient costs also differed by hospital and SAPS II status (SAPS II ≤ 50 or SAPS II >50) but the interaction terms (joint effects) were not significant. Similar results were obtained for ICU patient costs and floor patient costs, except that there were no significant effects of tele-ICU when controlling for interaction terms for floor costs. After controlling for hospital, costs were significantly higher in the post-period in patients with SAPS II ≤ 50 but not for patients with SAPS II >50. The same results were obtained when severity was entered as a continuous variable in the regressions for all patients and for patients stratified by SAPS II status.

Cost Effectiveness

The results from the cost effectiveness analysis are presented in Table 4. For patients with SAPS II ≤ 50, costs per patients significantly increased by $6,415 between the pre- and post-periods while hospital mortality did not change significantly. Given costs increased and mortality did not improve, the tele-ICU intervention is not cost effective in this group of patients. For patients with SAPS II > 50, costs per patient increased by $2,985, which was not statistically significant, and hospital mortality decreased significantly by 11.4%. Given that costs were unchanged and mortality reduced, the tele-ICU intervention is cost effective in this group of sickest patients.

DISCUSSION

Overall, the introduction of the tele-ICU in the six ICUs at this large non-profit health care system in the Gulf Coast region was associated with higher costs. After the implementation of the tele-ICU, the hospital daily cost increased from $4,302 to $5,340 (24%), the hospital cost per case from $21,967 to $31,318 (43%), and the cost per patient from $20,231 to $25,846 (28%). Most of these increases in costs are due to increases in ICU costs (77% for average daily costs, 67% for costs per case and 50% for patient costs). These increases in costs after the introduction of the tele-ICU are in contrast with Breslow et al. (2004) which found that tele-ICU was cost saving,10 but support the findings of increasing costs by Morrison et al. (2009).11

The higher costs in the post-period could not be explained by medical inflation. From 2003 to 2006, when cost data were collected, the medical inflation rate was less than 4% which is well below the increase in costs reported in this study. We did not adjust for medical inflation because cost data were collected within one year for three ICUs and within 15 months for two ICUs. Only for one ICU, ICU5, the pre-period extended for 14 months and overall data collection for over 2 years. It is unclear if other potential cost drivers were operating at the healthcare system during the study period. During that period, there was a significant increase in the number of ICU beds in the healthcare system which would increase overall costs, but not necessarily per patient costs.

The tele-ICU implementation did not reduce length of stay, complications, or mortality in the overall sample. The main positive clinical outcome was a reduction in ICU and hospital mortality in the sickest patients, those with SAPS II > 50 which represent 17% of patients.[12] In this subgroup of sickest patients, the tele-ICU intervention was cost effective as it decreased hospital mortality without increasing costs significantly. In the patients who were less sick, those with SAPS II ≤ 50 or 83% of the patients, the tele-ICU intervention was not cost effective as it increased per patient costs without improving hospital mortality. While this study does not support the use of tele-ICU in less sick patients, hospital administrators may well conclude that a tele-ICU program aimed at the sickest patients is worth implementing.

A limitation of this study is the use of the health care system perspective in the cost-effectiveness analysis. Health economists usually recommend adopting a societal perspective when conducting cost-effectiveness studies. However, there are several challenges in using a societal perspective in cost-effectiveness studies with ICU patients. While the societal perspective tends to use quality adjusted survival as an outcome, the outcome measures used in ICUs tend to be short term and hospital based, such as complications, length of stay, or hospital mortality, which occur in the hospital and do not lend themselves to a societal perspective. Therefore, it has been recommended that cost-effectiveness studies in ICUs present a 'data rich' case which is generated from data on actual patient outcomes and costs measured at the hospital level.[15] Unlike some other studies that report on volume or revenue measures, we were not able to address the impact of the tele-ICU on hospital volume and revenue because of lack of data. Other limitations, including the lack of randomization, are discussed in our previous publication.[12] Notably, about 2/3 of the physicians in the monitored ICUs gave the tele-ICU only minimal delegation (the tele-ICU could only intervene for life threatening situations as judged by the tele-ICU staff), but did not give full delegation (the tele-ICU could give routine orders, change treatment plans, and intervene for life threatening situations). Furthermore, the tele-ICU software was not fully integrated with the hospital system's electronic medical record. Therefore, ICUs with better physician acceptance and integration of information systems may have more favorable clinical and outcomes. One further limitation is that all the costs of operating the tele-ICU program were obtained from the tele-ICU administration.

As reported,[12] the strengths of the study are numerous. It is the largest study of tele-ICU programs to date, includes a diverse mix of ICUs, and results are based on high quality data.

CONCLUSION

Our results support tele-ICU monitoring in the sickest patients as it has the potential to reduce mortality without significantly increase cost in this specific group of patients. While widespread implementation of tele-ICU programs may be premature, administrators could install tele-ICU systems only for a limited number of beds so that the sickest ICU patients can be monitored remotely. This should reduce overall costs for installing and operating the tele-ICU system compared to having tele-ICU monitoring for all ICU patients. Furthermore, we suggest as next steps that studies to test the cost-effectiveness of the Tele-ICU programs be carried out in different settings to confirm our findings.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Average daily costs and costs per case in the pre-tele-ICU period (N=1,913 patients) and the post-tele-ICU period (N=2,057 patients).

Cost	Overall	ICU1	ICU2	ICU3	ICU4	ICU5	ICU6
ICU average daily costs							
Pre-period	$2,851	$2,586	$3,647	$4,248	$3,155	$2,355	$2,370
Post-period	$3,653	$3,272	$4,307	$4,252	$4,131	$3,275	$2,746
Pre-post difference	$802[1]	$686[1]	$660[1]	$4	$976[1]	$920[1]	$376[1]
Percentage change	28%	27%	18%	0%	31%	39%	16%
Floor average daily costs							
Pre-period	$1,451	$957	$1,434	$1,837	$2,230	$1,204	$976
Post-period	$1,687	$1,169	$1,748	$1,558	$2,421	$1,299	$1,113
Pre-post difference	$236[1]	$212[1]	$314[1]	$-278[1]	$191	$95	$138[1]
Percentage change	16%	22%	22%	−15%	9%	8%	14%
ICU costs per case[2]							
Pre-period	$13,029	$7,422	$12,912	$26,296	$8,770	$13,328	$15,167
Post-period	$19,324	$10,797	$18,519	$33,594	$19,002	$15,392	$18,947
Pre-post difference	$6,295	$3,374	$5,608	$7,298	$10,232	$2,065	$3,780
Percentage change	48%	45%	43%	28%	117%	15%	25%
Floor costs per case[2]							
Pre-period	$8,938	$3,368	$7,488	$16,933	$22,501	$7,360	$2,761
Post-period	$11,994	$4,700	$10,594	$18,120	$26,272	$9,016	$3,551
Pre-post difference	$3,056	$1,332	$3,107	$1,187	$3,771	$1,656	$790
Percentage change	34%	40%	41%	7%	17%	23%	29%

[1] Differences between pre-period and post-period significant at $p<0.05$ using t test.

[2] Cost per case is calculated as average daily cost multiplied by mean length of stay

Table 2

Average costs per patient in the pre-tele-ICU period and the post-tele-ICU period

Number of patients	Pre-period N=1,913[1]	Post-Period N=2,057[2]	P-value Wilcoxon-Mann-Whitney test
Average cost per patient			
All patients	$20,231	$25,846	< 0.01
Patients with SAPS II ≤ 50	$18,355	$24,770	< 0.01
Patients with SAPS II > 50	$28,814	$31,799	0.16
Average ICU cost per patient			
All patients	$11,295	$14,104	< 0.01
Patients with SAPS II ≤ 50	$9,352	$12,503	< 0.01
Patients with SAPS II > 50	$20,183	$22,958	0.13
Average floor cost per patient			
All patients	$8,936	$11,742	< 0.01
Patients with SAPS II ≤ 50	$9,002	$12,266	< 0.01
Patients with SAPS II > 50	$8,631	$8,841	0.21

[1] 1,570 patients with SAPS II<50 and 343 patients with SAPS II>50.

[2] 1,742 patients with SAPS II<50 and 315 patients with SAPS II>50.

Table 3

Regression of log(costs) on tele-ICU and controls

	Total Patient Costs		ICU Costs		Floor Costs	
Samples and controls	**β[1]**	**95% CI**	**β[1]**	**95% CI**	**β[1]**	**95% CI**
All patients: Hospital [2], SAPS II50 [2]	0.20[2]	(0.14,0.25)	0.16[2]	(0.10, 0.22)	0.29 [2]	(0.19, 0.39)
All patients: Hospital [2], SAPS II50 [2], Interactions [3]	0.32 [2]	(0.16, 0.48)	0.36 [2]	(0.17, 0.55)	0.09	(−0.24, 0.42)
Patients with SAPS II ≤50: Hospital[2]	0.21 [2]	(0.16,0.27)	0.18 [2]	(0.11,0.25)	0.36 [2]	(0.25, 0.46)
Patients with SAPS II > 50: Hospital[2]	0.12	(−0.02, 0.30)	0.10	(−0.05, 0.25)	−0.08	(−0.38, 0.22)

[1] Coefficient of tele-ICU

[2] $p < 0.05$.

[3] Interactions included two and three way interactions between hospital, SAPS II50 (dummy for SAPS II>50), and tele-ICU

Table 4

Cost Effectiveness of the tele-ICU stratified by SAPS II scores

Number of patients	**Patients with SAPS II ≤ 50 3,312**	**Patients with SAPS II > 50 658**
Incremental hospital average cost per patient[1]	$6,415[3]	$2,985 [4]
Incremental hospital mortality [2]	5.7%−4.4% = 1.3%[4]	19.3%−30.7%= −11.4% [3]

[1](Cost per patient in post-tele-ICU period) - (Cost per patient in pre-tele-ICU period)

[2](Observed hospital mortality in post-tele-ICU period) - (Observed hospital mortality in pre-tele-ICU period)

[3]Statistically significant different from 0 at 5% error level.

[4]Not statistically significant different from 0 at 5% error level.