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Original Research Article

The effectiveness of a tele-intensive care unit implementation at a secondary hospital in Eastern Saudi Arabia

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ABSTRACT

Background: Tele-intensive care units (tele-ICUs) are promising medical solutions for improving critical care quality, enhancing access to health care, and increasing the productivity of intensivists. King Faisal Specialist Hospital and Research Center (KFSHRC) initiated a tele-ICU implementation in Saudi Arabia during 2009/2010, with the aim of creating 28 tele-ICU-connected hospitals throughout the region by 2014. However, the effect of tele-ICUs on patient outcomes remains unclear. This study assessed the effectiveness of a tele-ICU intervention program on patient outcomes.
Methods: A retrospective pre-post study was performed in an adult medical-surgical ICU at a secondary hospital in Eastern Saudi Arabia. Tele-intensivists were located at the KFSHRC. The sample comprised adult patients (≥12 years, as per hospital policy) admitted to the ICU. Patients were allocated into pre-intervention (January 1 to April 29, 2012) and post-intervention (May 1 to August 31, 2012) groups; each group had 178 patients. The tele-ICU was implemented on April 30, 2012.
Results: According to a Mann–Whitney U-test, the groups did not differ on length of stay (LOS) (U=16097.50, p=0.78). Medians and interquartile ranges in length of stay for both groups were 2 days. Regarding mortality, 10 (5.6%) pre-intervention patients died, while 12 (6.7%) post-intervention patients died. This difference was not significant (p=0.51).
Conclusions: The tele-ICU program did not appear to impact patient outcomes in terms of mortality or LOS.

Keywords: Telehealth, Telemedicine, Tele-ICU, E-health

INTRODUCTION

One major issue currently faced by intensive care units (ICUs) is the shortage of certified onsite intensivists. With a rapidly aging population, the demand for such professionals is expected to increase, making it more difficult to meet proposed standards of care.[1] Studies have shown that hospitals with dedicated intensivists exhibit significant reductions in ICU mortality and average LOS.[2]

An emerging solution for this issue is the use of tele-medicine technology. The tele-ICU is one application that refers to the provision of health care for critically ill patients via remotely located intensivists.[3] Tele-ICUs were created primarily to deliver critical care in a way that ensures better patient outcomes and adherence to critical care best practices, particularly within hospitals lacking adequate access to intensivists.[1,3]

Recently, health care centers in Saudi Arabia have begun introducing surgeries and treatments that require more advanced critical care capabilities.[4] In 2012, the total number of ICU beds in Saudi Arabia was 5,249, with the total number of certified ICU physicians totaling 348; thus, the intensivist-to-patient ratio is roughly 1:15. This is problematic, as patient care and staff well-being are negatively affected at similarly high physician to patient ratios (i.e., greater than 1:14).[5,6] To counteract this lack of intensivists, King Faisal Specialist Hospital and Research Center in Riyadh began establishing tele-ICUs throughout Saudi Arabia in 2009/2010, with the aim of creating 28 tele-ICU-connected hospitals by 2014.

Although tele-ICUs are a promising medical solution for improving critical care quality, their efficacy regarding patient outcomes remains unclear, especially in Saudi Arabia.[1,7] Thus, the present study assessed the effectiveness of tele-ICU implementation on mortality and length of stay (LOS) rates as outcome measures in a secondary hospital within Eastern Saudi Arabia.

METHODS

An observational, retrospective pre-post study was conducted. Ethical approval and informed consent were not required given the retrospective nature of the study. This study followed the principles of Helsinki Declaration. The study was performed in an adult medical-surgical ICU at a secondary hospital in Eastern Saudi Arabia; the tele-intensivists were located at the KFSHRC in Riyadh. The tele-ICU program provided an audiovisual connection and the ability to share radiological tests for medical consultations. Furthermore, the program involved scheduled lectures and weekly grand rounds for educating staff. The ICU had a total of 10 beds, covering all specialties (including pediatrics). The ICU medical team comprised one consultant, two specialists, two registrars, two residents, and one nurse for every two beds.

The sample included adult patients (≥12 years, according to hospital policy) admitted to the ICU between January 1 and August 31, 2012. Patients were divided into two groups based on admittance date: admissions between January 1 and April 29 were placed into the pre-intervention group, and admissions between May 1 and August 31 were placed in the post-intervention group. This grouping was based on the tele-ICU program being implemented on April 30, 2012. All included patients are consecutively admitted. As per hospital policy, I excluded pediatric patients (<12 years) from this study.

Based on previous studies, the estimated sample size was 178 for each group.[1,3] A proportion formula was used, and the average LOS proportion was 3%, with an acceptable error rate of.025 and 95% confidence interval (CI).[8]

Data were collected as follows. The researcher, alongside ICU staff, reviewed charts and collected data for both groups using case report forms. The data collection periods (as mentioned above) were chosen to ensure the desired sample size was obtained. This included approximately 60 patients per month given the average turnover rate for adult patients in the ICU. The setting was the same during both data collection periods in terms of staff, equipment, and admission protocols.

The following variables were collected for both groups: medical record number, age, gender, ICU admission date, discharge date, type of diagnosis, and date of death. The primary outcomes were ICU mortality and LOS. LOS was defined as the number of days the patient stayed in the ICU (date of admission until the date of discharge or death).

Data were collected, coded, and transferred into IBM SPSS Statistics 21.0 (IBM Corp., Armonk, NY) for data entry, analysis, and management. I initially calculated descriptive statistics, including means and SDs, medians, interquartile ranges (IQR), frequencies, and percentages. Independent Mann-Whitney U-tests were conducted to determine differences in ICU LOS between the two groups, as LOS followed a non-normal distribution. Since other variables (i.e., age, gender, and type of diagnosis) could influence this difference, analysis of covariance (ANCOVA) was used to determine if the tele-ICU implementation influenced LOS after controlling for general characteristics that showed significant relationships with LOS. As LOS data included outliers, data points that were greater than 60 days were changed to the next highest point, plus one.[8] Finally, chi-square tests were used to determine if the two groups differed in terms of mortality rates. Furthermore, since other variables (i.e., age, gender, and type of diagnosis) could influence this difference, a logistic regression analysis was conducted with mortality as the outcome variable, each period as the independent variable, and age and type of diagnosis as covariates. Odds ratios and 95% CIs were calculated for inference testing.

RESULTS

A total of 356 medical records were investigated (178 each in the pre- and post-intervention groups). Table 1 shows characteristics of the two groups. Although the pre-intervention group had a slightly higher percentage of men (54.5%) and higher mean ages (53.7±22.9 years) than the post-intervention group (50.6% and 50.2±20.3 years, respectively), these differences were not significant. The same applied to differences in principle diagnosis on admission.

A test of normality for age and LOS indicated non-normality (Table 2). Thus, I used a Mann–Whitney U-test, as mentioned above, to determine whether age and LOS differed between the two groups. The two groups did not differ in terms of age (U=14216.50, p=0.09). Regarding LOS, the median LOS for both groups was 2 days (IQR=2 days), and LOS ranged from 1 to 54 days in the pre-intervention group and from 1 to 53 days in the post-intervention group. The two groups did not differ significantly in terms of LOS (U=16097.50, p=0.78; Figure 1; Table 3 and 4).

Table 1: Comparison of patients' characteristics in pre- and post-intervention period.

Characteristics	Pre (n=178)		Post (n=178)		χ^2	P value
	n	%	n	%		
Age (years)						
<40	51	28.7	51	28.7	3.587	0.166
40–59	49	27.5	64	36.0		
≥60	78	43.8	63	35.4		
Gender						
Male	97	54.5	90	50.6	0.552	0.458
Female	81	45.5	88	49.4		
Type of diagnosis						
CVS	79	44.4	83	46.6	9.421	0.308
Endocrine	17	9.6	19	10.7		
GIT	17	9.6	12	6.7		
Hematology	3	1.7	7	3.9		
Nephrology	9	5.1	5	2.8		
Neurology	10	5.6	10	5.6		
OB/GYN	0	0.0	4	2.2		
Orthopedics	28	15.7	20	11.2		
Pulmonary	15	8.4	18	10.1		

CVS- cardiovascular system, GIT- gastrointestinal tract, OB/GYN- obstetrics and gynecology.

Table 2: Test of normality for age and the length of stay.

Variables	Group	Kolmogorov–Smirnov[a]			Shapiro-Wilk		
		Statistic	df	P	Statistic	df	P value
Age	Pre	0.085	178	0.003	0.961	178	0.000
	Post	0.095	178	0.000	0.964	178	0.000
Length of stay	Pre	0.354	178	0.000	0.406	178	0.000
	Post	0.355	178	0.000	0.471	178	0.000

Df- degrees of freedom, [a]Lilliefors significance correction.

Table 3: Independent samples Mann-Whitney U test.

Total N	356
Mann-Whitney U	16,097.500
Wilcoxon W	32,028.500
Test statistic	16,097.500
Standards error	913.072
Standardized test statistic	0.280
Asymptotic sig. (2-sided test)	0.780

Table 4: Comparison of LOS in pre- and post-intervention patients.

	Pre (n=178)	Post (n=178)
Minimum	1	1
Maximum	82	53
Mean	4.73	4.62
95% confidence interval for mean	3.26-6.20	3.37-5.87
Standard deviation	9.961	8.443
Median	2.00	2.00
Interquartile range	2	2

Table 5: Mortality by gender.

Groups	Gender	Mortality		P value
		No (n, %)	Yes (n, %)	
Pre	Male	92, 94.8	5, 5.2	0.77
	Female	76, 93.8	5, 6.2	
Post	Male	86, 95.6	4, 4.4	0.22
	Female	80, 90.9	8, 9.1	

Table 6: Best fitting multiple logistic regression model for the risk of mortality.

	Wald	Df	P value	OR	95.0% CI for OR	
					Upper	Lower
Constant	39.175	1	0.000	0.002		
Age	17.290	1	0.000	1.061	1.032	1.090

Nagelkerke R-square= 0.17; Hosmer and Lemeshow test= P=0.859; Omnibus tests of model coefficients= P<0.001. Variables omitted from the final model: gender and diagnosis. df- degrees of freedom; OR- odds ratio; CI- confidence interval

Other factors related to LOS might have influenced this difference. Age was significantly correlated with LOS in both the pre-intervention (r=0.006, p=0.01) and post-intervention group (r=0.045, p=0.01), thus indicating that older patients tended to have longer stays. However, a Mann-Whitney U-test revealed no difference in LOS between men and women in either the pre-intervention (U=3717.50, p=0.51) or post-intervention group (U=3420.50, p=0.09).

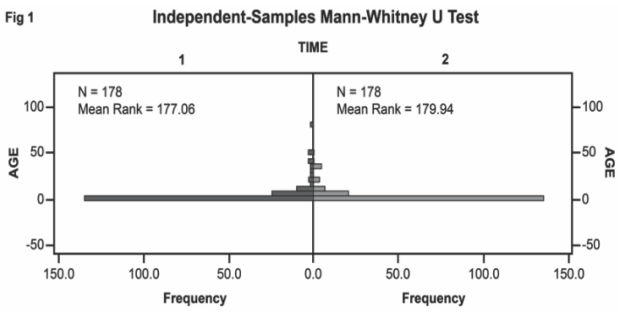

Figure 1: Comparison of LOS distributions between patients in the pre- and post-intervention groups. 1, pre-intervention, 2, post-intervention.

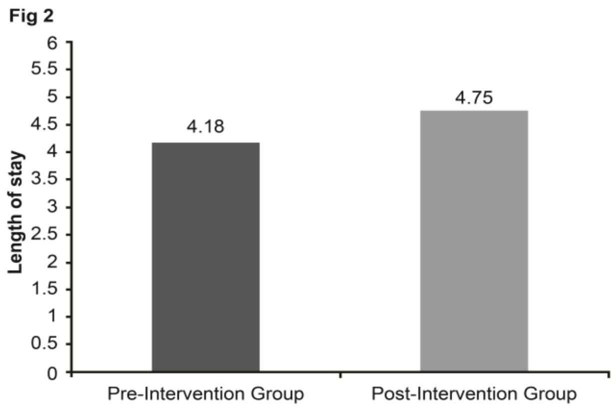

Figure 2: LOS for the pre- and post-intervention groups after controlling for age and type of diagnosis.

Based on these findings, I used an ANCOVA to control for age and type of diagnosis; however, this yielded non-significant results $F_{(1,350)}$=0.42 (p=0.52; Figure 2), indicating that the post-intervention period did not facilitate a shorter LOS than the pre-intervention period. In other words, the tele-ICU program did not appear to influence ICU LOS.

For mortality, 10 (5.6%) of the 178 patients in the pre-intervention group died, whereas 12 (6.7%) of the 178 in the post-intervention group died. A chi-square test revealed no significant difference in mortality between the groups, χ^2 (1) =0.44 (p=0.51).

I then investigated whether any demographic factors influenced this lack of difference. A chi-square test indicated that mortality rates did not differ by gender in either the pre-intervention, χ^2 (1) =.086 (p=0.77), or post-intervention group, χ^2 (1)=1.528 (p=0.22), even though 6.2% and 5.2% of women and men in the pre-intervention group died, respectively (and 9.1% and 4.4% in the post-intervention period; Table 5). Among the 10 deaths in the pre-intervention group, diagnoses were as follows: 9 had a diagnosis related to the cardiovascular system (CVS) and one related to hematology. In contrast, among the 12 deaths in the post-intervention group, diagnoses were as follows: 6 related to the CVS, 2 related to the gastrointestinal tract, 1 related to hematology, 1 related to nephrology, 1 related to orthopedics, and 1 related to pulmonary medicine.

A best-fitting multiple logistic regression model for the odds of mortality was conducted to examine the various predictors of mortality. The only significant predictor was age (odds ratio [OR]=1.06, p<0.01; Table 6).

DISCUSSION

This study was designed to evaluate the efficacy of a tele-ICU program on mortality and LOS. There was no association between tele-ICU implementation and either of these patient outcomes. These results differed from previous studies, which revealed trends towards improvement in ICU mortality and LOS.[2,7] However, similar to the present study, Thomas et al. reported no significant difference between pre- and post-intervention periods for LOS.[9] Another similar study by Morisson et al revealed no reduction in mortality or LOS attributable to tele-ICU implementation. However, their study was slightly different from the current study as data were collected from two suburban Chicago community hospitals across two waves. The first was 1 year after baseline, and the second was 1 year after the tele-ICU became fully operational.[10]

The findings of the present study can be interpreted in light of three factors that may have influenced tele-ICU program efficacy: (1) the role of remote intensivists in altering care within the ICU; (2) the tele-ICU consultation protocol; and (3) physicians' acceptance of tele-ICU technology.

First, the implemented program narrowed the role of remote intensivists for medical consultations; sometimes, these consultations resulted in the need to send medications or intensive care devices unavailable at the secondary hospital. Although this service was available 24 hours/7 days a week, the tele-ICU intensivist could not completely manage all cases. The intensivists could not adequately monitor all patients or respond to alerts because the tele-ICU program was not designed to have these features. This, unfortunately, deprived critical cases with timely consultation, preventing highly complex cases from being fully managed and monitored. These limitations are in line with a previous study, which showed that two-thirds of patients had physicians who chose minimal delegation to tele-ICU intensivists. This might have contributed to the lack of beneficial outcomes observed in the present study.[9]

Conversely, Lilly et al. and others have observed a significant favorable association between tele-ICU implementation and various outcomes, so long as full participation of tele-ICU intensivists is facilitated.[3,11] Physicians and nurses who utilize tele-ICUs have access to real-time vital signs and wave tracings, laboratory values, imaging studies, and medication administration records. Staff can even share clinical notes and computerized physician order entries in a common electronic record. These characteristics, coupled with the fact that most tele-ICU programs from previous studies were designed to give full delegation to tele-ICU intensivists, may underlie why several previous studies observed favorable associations between tele-ICU implementation and mortality and LOS.[3,7]

Second, the present tele-ICU program did not have a standardized protocol for medical consultations with intensivists. This likely produced subjective variations in assessments for cases requiring medical consultations, keeping the assessment open to physicians' opinions and viewpoints. Conversely, Sadaka et al's study in which dozens of protocols were instituted during the tele-ICU implementation process revealed favorable outcomes.[1] It is important that these protocols adhere fully to best practice procedures. One study observed that tele-ICU programs whose protocols mentioned adherence to best practices had fewer complications, shorter response times to alerts and alarms, and greater support of early intensivist case involvement. All of these improvements ultimately led to better care at a lower cost.[3] It is worth noting that a major reason some studies failed to detect significant associations between tele-ICU interventions and outcomes was the low rate of collaboration (e.g., 34–36%) between tele-ICU and bedside physicians and nurses.[8,10] Thus, establishing protocols that foster collaboration among the tele-ICU and bedside teams is important.

Finally, it is necessary to consider clinicians' acceptance of tele-medicine and how information and communication technology is used in clinical practice. The implementation of a tele-ICU program is a multipart process, containing several discrete elements aimed at introducing improved methods for managing ICU patients. Similarly, promoting program acceptance, and building relationships between the bedside team and tele-ICU intensivists, may take time and patience.[12] Several studies have shown a high level of acceptance among medical staff for tele-medicine and general information and communication technology; however, tele-medicine programs are relatively new, especially in developing countries. Thus, it is necessary to consider the factors related to the implementation process that might affect program efficacy.[13,14]

In the original proposal for the present study, the data collection plan included APS and APACHE scores as measures of disease severity. However, this information was not available from patient charts, and not all items necessary for their calculation were available. However, it is important to note that there was a standardized ICU policy for accepting patients, which was applied to all cases from all specialties before admission. This policy ensured admission only for patients who required ICU care. Another limitation was the fact that this study was conducted in a single medical center. As such, the results may not generalize to other institutions.

Overall, the design and implementation of the tele-ICU program assessed in the present study were not associated with a reduction in ICU mortality or LOS. These results suggest that it may be time to scale up the program throughout Saudi Arabia, ensuring that tele-ICU intensivists are given full case management. Furthermore, the tele-ICU designed for the present study program will need to adopt a standardized protocol for medical consultations that fosters collaboration between the tele-ICU and bedside teams (i.e., administrators, physicians, and nurses). Finally, further studies on tele-medicine in Saudi Arabia are recommended. This is important that

that tele-medicine is not only a relatively new field, but the Ministry of Health is planning to implement tele-medicine programs throughout Saudi Arabia Kingdom in the coming years.

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