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Tele-ICU: Efficacy and Cost-Effectiveness Approach of Remotely Managing the Critical Care

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Abstract: Tele-ICU has an off-site command center in which a critical care team (intensivists and critical care nurses) is connected with patients in distance intensive care units (ICUs) through a real-time audio, visual and electronic means and health information is exchanged. The aim of this paper is to review literature to explore the available studies related to efficacy and cost effectiveness of Tele-ICU applications and to study the possible barriers to broader adoption. While studies draw conclusions on cost based on the mortality and Length of Stay (LOS), actual cost was not reported. Another problem in the studies was the lack of consistent measurement, reporting and adjustment for patient severity. From the data available, Tele-ICU seems to be a promising path, especially in the United States where there is a limited number of board-certified intensivists.

Keywords: Cost-effectiveness, critical care, Telehealth.

INTRODUCTION

There is a shortage of Intensivists in the United States, and the demand for them is only going to get worse with the aging population [1]. As of 2010, less than 15% of Intensive Care Units (ICU) are able to provide intensivist care [2]. There are 6000 ICUs but only 5500 board-certified intensivists [3]. Studies have shown that hospitals with a dedicated intensivist on staff had a significant reduction in ICU mortality and average Length of Stay (LOS) [4, 5]. Complexity of today's ICU services emphasizes the need for sharing health information through off-site ICU centers [6]. Tele-ICU is the use of health information exchanged from hospital critical care unit to another *via* electronic communications [7]. Tele-ICU intensivists provide real-time services to multiple care centers regardless of their locations. Tele-ICU has an off-site command center in which a critical care team (intensivists and critical care nurses) is connected with patients in distant ICUs through a real-time audio, visual and electronic means. Similar to a bedside team, offsite Tele-ICU intensivists require full access to patient data. Tele -ICU is capable of providing: a real time monitoring of patient instability or any abnormality in laboratory, order diagnostics tests, making diagnosis and order treatment, implementing any intervention through controlling life support devices. As a result, Tele-ICU holds great promise in improving the quality of critical care patients and increasing the productivity of intensivists. This paper aims to explore the available studies related to efficacy and cost effectiveness of Tele-ICU applications and to outline possible barriers to broader adoption.

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METHODS

Electronic databases were searched to identify relevant articles. Searches were limited to the English language and the earliest available publication date for each database to March 2012. PubMed/Medline, EMBASE, CINAHL with Full Text, PsychINFO, EBM Reviews (e.g. Cochrane Database of Systematic Reviews, ACP Journal Club, Database of Abstracts of Reviews of Effects, Cochrane Central Register of Controlled Trials, Cochrane Methodology Register, Health Technology Assessment, and NHS Economic Evaluation Database), Scopus, Education Resource Information Center (ERIC), and Turning Research into Practice (TRIP) were used to conduct the literature searches. Searches used subject headings and subheadings if available and were combined with keywords. Search terms used included telehealth, benefits of tele-ICU, tele-ICU outcomes, telemedicine in the ICU and tele-ICU cost.

Selection Criteria

The article was included if 1) it pertained to uses of telemedicine in ICU; 2) Assessed the outcome of implementing Tele-ICU through measuring its effect on mortality rate and on length of stay (LOS); 3) Explored the staff attitude toward implemented Tele-ICU. Articles not relevant to the topic were excluded. Potential eligibility of the articles was first determined from the title and abstracts identified from the searches. Full-text articles were then retrieved and evaluated for relevance. Articles were excluded at this point if they were not found to meet the above criteria once the full text was examined (for flow chart of article retrieval see Fig. **1**). A second researcher confirmed the relevance and findings from the selected articles.

Data Extraction and Outcome Measures

The articles were reviewed and a data extraction form was used to include details pertaining to the study quality such as study design, number of subjects, study population,

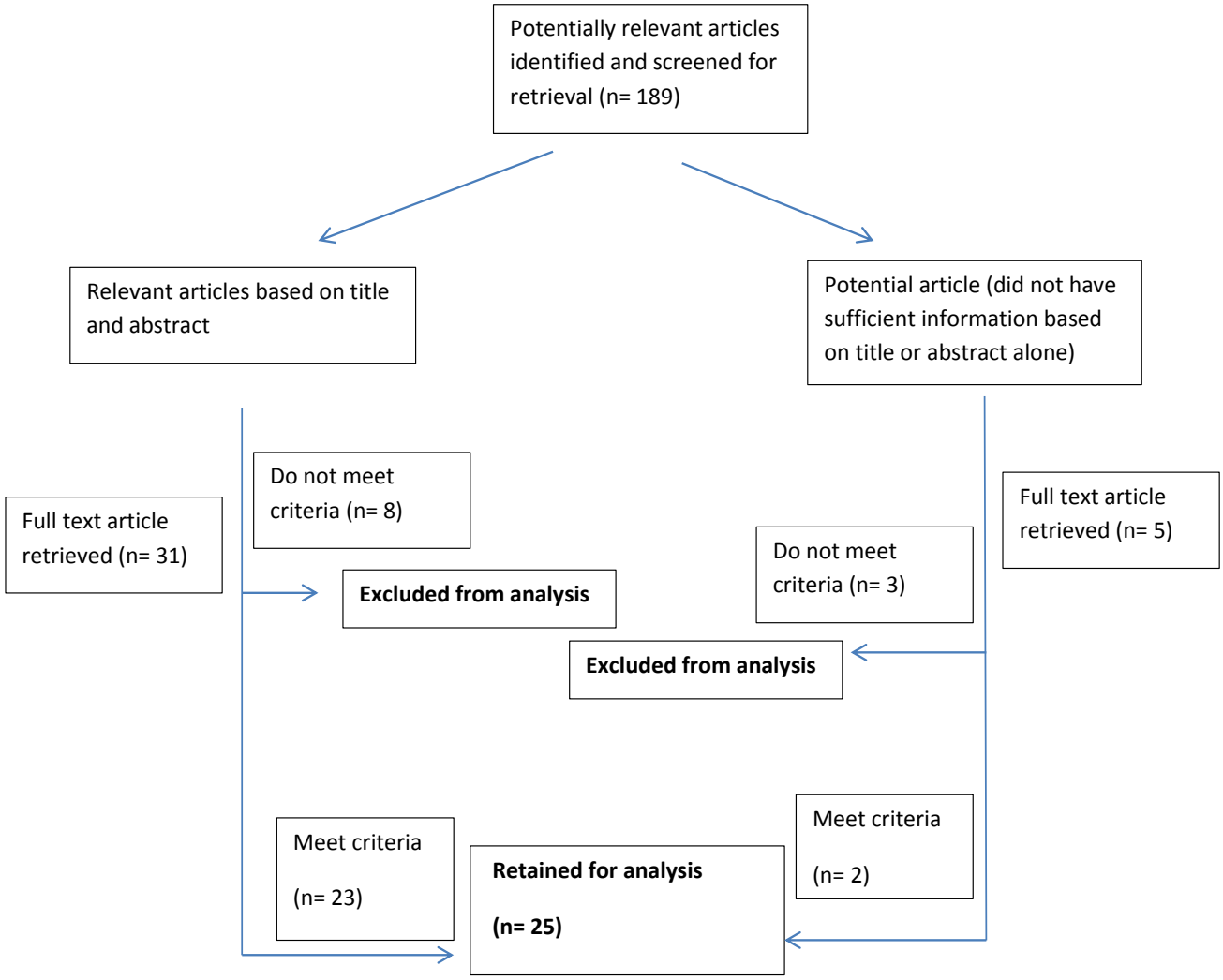

Fig. (1). Flow chart of the results from the literature search.

as well as the description of the program. The acute nature of ICU and the high cost associated with critically ill patients makes the survival rate and the cost saving among the most desirable outcomes measured. Consequently, integration of distance monitoring and observation of intensivists' services to bedside care were significant outcome measures along with the mortality rate and length of stay. The following types of outcomes reported that were of interest for this review were recorded: (1) Clinical process: Outcomes related to service delivery, such as attendance and adherence to programs and recommendations, as well as healthcare provider and staff satisfaction with the program; (2) Healthcare utilization: Events that occur outside the program's scope and that the program may aim to reduce or increase, such as hospitalizations, ICU admissions and average Length of Stay;(3) Costs: From the patient's, provider's or organization's perspective, all costs (savings and/or expenses) associated with the use of Tele-ICU.

RESULTS

As Fig. (**1**) indicates, 25 studies were retained after the initial screening of titles and abstracts and the full-text retrieval of pertinent articles. The results of the clinical process outcomes, healthcare utilization and costs reported in the studies are presented in the following sections.

Clinical Adoption of Tele-ICU

Tele-ICU as a concept is evolving over time; the approach used in the 1970s and later involved a video connection between the bedside care providers and outside consultants without any access to patient monitoring data. The most frequent adopted approach today is the continuous access and monitoring care that focuses on providing supplemental critical care expertise [8-13]. In 2000, Sentara hospital was the first hospital to implement the new Tele-ICU approach. As of 2011, 41 ICU command centers have been installed with a total of 5789 ICU beds being covered throughout 249 hospitals [13]. Even with the early positive impacts of Tel-ICU, there are only 5-7% of adult ICU beds covered by this technology in the USA [13]. Adoption of Tele-ICU is greatly obstructed by the lack of documented outcomes and unproven return on investment (ROI) [13]. Moreover, some Tele-ICU centers have deactivated for reasons like physicians resistance to change in both patient's

management and required sharing control over patient with other off-site physicians. Technical difficulties with lack of training could also be other impediments [13].

Barriers to Tele-ICU

Tele-ICU is relatively new; many bedside doctors and nurses do not understand how the system works. They believe that the eRNs and e-intensivists are watching over them and trying to taking over [1]. In reality, "the purpose of the system is to provide improved safety through redundancy and enhance outcomes through standardization" [2]. The tele-ICU team has a supportive role; they have an overview of what is going on with all the patients in the unit and can alert the bedside staff if any problems occur [14]. "The hospital admitting physician continued to be the attending and was responsible for establishing the care plan," while the TeleICU staff were the primary contact for the on-site nurses [15]. Studies show that the more proactive the Tele-ICU physicians are, "the more improved are the outcomes" [16].

Another barrier to ICU telemedicine is the clinician's acceptance of the technology. This could be one of the reasons that some studies did not show improvement in LOS and mortality in ICU patients. In a study done by Thomas, *et al*. [17], "two-thirds of the patients in our study had physicians who chose minimal delegation to the Tele-ICU." Other clinicians feel that everything is running perfectly and nothing needs to be fixed. Showing these physicians comparative data and the benefits of Tele-ICU may change their mind [4].

The lack of integration was a problem at some hospitals, especially those that did not have electronic records. Thomas, *et al*. [7] observed that although the Tele-ICU team had real time access to most of the patient's information, the monitored unit did not share clinical notes or computerized physician order entry; instead, these notes were faxed daily. Similarly, Berenson *et al*. [18] also noted the limitations related to the lack of interoperability.

Outcome Assessments

With optimizing the telemedicine application in ICU, both the mortality rate and length of stay could influence positively; a 15-60% reduction in the mortality rate along with a 30% reduction in the average length of stay was observed in a hospital with intermittent remote consultation in the delivery of health services to critical care patients. A review of available published articles is presented in Table **1**.

The results from the articles were mixed regarding the mortality rate and LOS in ICU after the adoption of ICU telemedicine. For example, according to Thomas, *et al*. [17] "remote monitoring of ICU patients was not associated with an overall improvement in mortality or LOS." On the other hand, Lilly, *et al*. [19], found that "Tele-ICU intervention was associated with reduced adjusted odds of mortality and reduced hospital length of stay." Young, *et al*. [20] concluded that Tele-ICU was associated with a decrease in mortality and LOS in the ICU but not within the hospital. A study done by Morrison, *et al*. [5] concluded that a difference in mortality could not be determined because the mortality rate at the hospital was already low in the ICU. Lilly, *et al*. [19] found that after the intervention of Tele-ICU, tools were developed for real-time auditing and reconciliation which increased the adherence to best practices. This also led to a decrease in the rates of complications in the ICU.

Telemedicine in the ICU may also prevent intensivist and nurse "burn outs and posttraumatic stress" [3]. Physicians who are tired due to long hours or stress are more prone to making mistakes. "The Tele-ICU is the "second set of eyes" that provide additional clinical surveillance and support" [10]. It has also helped residents that were new to the field [3].

Costs

Adoption of Tele-ICU requires a substantial up-front capital investment with ongoing cost of operation and maintenance. These costs may impede the adoption of this technology especially with lack of reimbursement and uncertainties about return on investment (ROI) calculations. Moreover, the ROI was merely calculated using the indirect clinical effects and the expected length of stay reduction.

Pay-back period or Net Present Value (NPV) are the indictors used for return on investment. More specifically, the equation of financial issue related to tele-ICU is desired to be as the following [15].

[Capital Cost+ Operating Cost] $\leq$ *[Revenue from reimbursement + Cost Saving Attained]*

The cost of Tele-ICU varies depending on the setting, hardware, software, training and compatibility issues with other systems. One study reported a cost of over $2 M to set a command center and its components [15]. In general, an estimation of $ 2-5 million is probably the cost to set up a command center and install the Tele- ICU systems with an operation cost of $600,000-1.5 M per year as an operation cost is reported from different adaptors [15].

On the revenue side, one study indicated that there was a 10% reduction in ICU length of stay with ability to care for one new ICU patient per day which could result in a positive $2.5 M net present value (NPV) [15].

Most studies reviewed, used the LOS and mortality to determine cost savings. For example, according to Rosenfeld, *et al*. [21]. ICU costs decreased between 25% and 31% during the intervention period and hospital costs decreased by 12% to 19%. Breslow, *et al*. [15]. hired an independent consulting firm to determine the financial outcome of the Tele-ICU program. They determined the cost of care per day of service and also included equipment cost, staff cost and other costs associated with having a Tele-ICU system. The report showed that there was a 24.6% decrease in variable costs per case. This decrease is probably due to a shorter LOS in the ICU and improved clinical outcomes [4, 15, 21].

Staff Acceptance of Tele-ICU

Implementation of Tele-ICU encompasses a change in the practice of many health workers. Most studies that measured the acceptance of Tele-ICU showed high acceptance for the increased ICU coverage. Moreover, Tele-ICU has a favorable impact on both patient care and on organizations. Thomas *et al*. [22] conducted a pre/post

Table 1. Study Characteristics

Study	Hospital	ICU Mortality Change	Average Length of Stay(LOS) Change
Rosenfeld *et al*. 2000 [21].	A ten-bed surgical ICU in at Johns Hopkins Medical Institution.	Severity-adjusted Mortality rate in - ICU is decreased by 46% - Hospital by 30%	ICU length of stay decreased by 30%
Breslow *et al*. 2004 [15].	Sentara (VA)	26.4% reduction at the end of first year	Observed 5.6 to 4.8 days decrease in LOS
Shaffer J, *et al*. 2005 [26].	Health First (Integrated network on Florida's East Coast)	Associated with significant decrease in mortality rate Odd ratio of pre to post is 0.72	
Dickhaus D., 2006 [27].	Community Hospital in Weston, WI and Jefferson City hospital	A decrease in mortality is observed	17% decrease in LOS resulted.
Ikeda D, *et al*. 2006 [28].	Sutter health, Sacramento.	Actual ICU mortality rate reduced from 40.07% to 18.86%. Estimated of 56 lives were saved over 30-months period	
Young B, 2006 [29].	Parkview Hospital, Fort Wayne	Cardiac arrest decline from 9 months prior average of 38% to 28%	
Gracias *et al*. 2007 [12].	Surgical intensive care units (SICU) at Pennsylvania Health System	Mortality rate decrease from 5.5% to 2.6%.	
Howell G. *et al*. 2007 [30].	Saint Luke's Health System	Severity-adjusted ICU mortality went from 1.0 to 0.68, Hospital mortality from 0.95 to 0.77,	ICU LOS from 1.18 to 0.96 and hospital LOS from 1.09 to 0.84.
Kohl *et al*. 2007 [9].	University of Pennsylvania Health System	Reduction in ICU mortality rate from 8.4% to 3.1%. (63%) Hospital mortality rate reduced from 11.1% to 6%. (46%).	Decreased between 3.7-4.4 days in average.
Kohl B., 2007 [31].	University of Pennsylvania health institute		10% reduction in LOS in ICU. 20% reduction in Floor stay. (cost saving of $ 700,000 to 2.850,000)
Mora A., 2007 [32].	The University of Texas Medical School at Houston,	Majority of resident's perceived eICU improves patient care (82.3%) and 66.7% of residents expressed a desire to have remote Telemonitoring involved in the care of their patients.	
Rincon T., 2007 [33].	The Bay Area Sacramento		A total estimated savings of $132,859 for 2007.
Rincon T, *et al*. 2007 [34].	Sutter health. Sacramento	Accurate sepsis identification can be achieved from eICU, improved sepsis bundle compliance and reduced mortality observed after using eICU	
Zawada E.,2007 [35].	Avera Health System		Annual reduction in 4146 ICU days and 572 hospital days.
Coletti C., 2008 [36].	Christiana CareHealth System, Newark	77% of surveyed residents reported that the eICU associated with improved patient safety.	
Howell G, *et al*. 2008 [37].	University of Missouri, Kansas City.	Both ICU and hospital mortality improved.	Severity adjusted ICU LOS improved from 0.84 to 0.03. Severity adjusted hospital LOS improved from 0.97 to 0.64.
The New England Healthcare Institute, 2008 [13].	University of Massachusetts Memorial Medical Center	209 lives were saved in 2007	Hospital length of stay reduced by 4 days on average. Cost saving averaged $5000 per patient
Goran SF., *et al.*, 2008 [8].	Maine Medical Center	Estimate of 5-20% reduction in mortality rate. For an estimated 2000 adult ICU admissions/year, 100 additional patients per year survive	

(Table 1) contd…..

Study	Hospital	ICU Mortality Change	Average Length of Stay(LOS) Change
Zawada E., 2008 [11].	Rural center close to Avera Heath system		160 patients were prevented from transfer to a tertiary hospital for a savings of $1,202,379
Thomas, E., *et al.* 2009 [17].	Non-profit health system of gulf coast region	Reduction in mortality by 1.4%-2.1%	No significant differences in LOS pre and post Tele-ICU
Zawada *et al*. 2009 [38].	Conducted in Avera Health System (One large tertiary hospital, three rural hospitals, two community hospitals and 9 critical care centers	Adjusted mortality rate range between unchanged and 29% reduction.	LOS reduction ranged from 45% to 22.5%. (9 sites)
Morrison *et al*. 2010 [15].	two community hospitals in the metropolitan Chicago area	No significant effect on ICU/non-ICU/total mortality	No effect on LOS.
Lilly, C., *et al*. 2011 [19].	University of Massachusetts	2.1% decrease	1.9 days decrease
Young, L., *et al*. 2011 [20].	Review	Odds ratio for pooled data was 0.80 which shows reduction	1.26 days decrease
Willmitch, B., *et al*. 2012 [16].	South Florida		0.55 day decrease

attitude survey for physicians and found that the safety attitudes significantly increased after implementation. Tele-ICU, also increased the confidence that patients were adequately covered. Another study conducted by Kowitlawakul *et al.* [23]. measured the nurse's attitude through a survey; it revealed that Tele-ICU would be beneficial in units without adequate physician coverage. Weininger *et al.* [24] measured the teamwork and safety environment of three ICUs before and after implementation. Their results showed that implementation of a Tele-ICU improved teamwork and the safety climate in some units especially among nurses. As a result, collaboration needed to enhance the value of the Tele-ICU system is acquired through effective implementation of continuous change management plan. With implementing best practice protocols and other quality assurance measures, the scope of Tele-ICU is expected to evolve and extend to other microsystems such as emergency departments, risk delivery unit, long term acute hospital and other departments that are designated to provide immediate response to patients.

DISCUSSION

From the articles reviewed, current studies are early steps but more research needs to be done before Tele-ICU will become more widespread. Some studies did not show any difference pre- and post- adoption because they already had optimal outcomes (see Table **1**). Other studies showed a large decrease in LOS and mortality which could be attributed to the fact that the hospital was an open system (Table **1**). Similarly, Yoo and Dudley [25] also found heterogeneity in Tele-ICU systems and believe that "it is unlikely that any single study can definitely address the benefits of telemedicine for the critically ill." They also mentioned that there is a "lack of consistent reference in the literature to a unifying conceptual framework of what ICU care is and how Tele-ICU could improve it" [25].

Another problem in the studies was the lack of consistent measurement, reporting and adjustment for patient severity [20]. This could have led to inflated results relating to mortality and LOS. One hospital may be a Trauma 1 center and experience many deaths, while another facility could be a smaller hospital that does not typically see those type of patients. Cost-effectiveness is another area that more research needs to be done. While many studies draw conclusions on cost based on the mortality and LOS, actual cost was not reported. This is an important consideration especially for smaller facilities that want to make sure that they will get a return on their investment.

LIMITATIONS OF THIS REVIEW

One of the limitations of this systematic review is that it uses studies published in a peer-reviewed journal. It is well documented that there is a publication bias towards studies that have positive findings [39]. Therefore, studies that do not demonstrate any effect or report a negative effect of Tele-ICU may not carry as much weight in the synthesis of the data because they were not identified through the search. Moreover, this study did not include studies looking at patient assessment as the focus of this review was on Tele - ICU intervention program. This was a first attempt to identify scientifically sound evidence of telemedicine intervention program and synthesize and critically appraise the published literature in this area. In part this also helps identify possible directions for future studies.

CONCLUSION

This systematic review identified a substantial amount of scientific literature in the relatively new area of Tele-ICU. This review showed that although there is heterogeneity between studies in terms of study designs, settings and outcomes measured, there is a consistent trend in the literature supporting the efficacy and effectiveness of Tele-ICU. In conclusion, from the data available, Tele-ICU seems to be a promising path, especially in the United States where there is a limited number of board-certified intensivists.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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