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

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Abstract

Tele-ICU is the use of an off-site command center in which a critical care team (intensivists and critical care nurses) is connected with patients in distant ICUs to exchange health information through real-time audio, visual, and electronic means. The aim of this study is to review the available literature related to the efficacy and cost-effectiveness of tele-ICU applications and to study the possible barriers to broader adoption. While the available studies draw conclusions on cost based on mortality and length of stay, actual costs were not reported. Another problem with the studies is 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 increase with the aging population.[1] As of 2010, less than 15 percent of intensive care units (ICUs) are able to provide intensivist care.[2] There are 6,000 ICUs but only 5,500 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] The complexity of today's ICU services entails the need for sharing health information through off-site ICU centers.[6] Tele-ICU is the use of health information exchanged from a hospital critical care unit to another site via electronic communications.[7] Tele-ICU intensivists provide real-time services to multiple care centers regardless of their locations. Tele-ICU uses an off-site command center in which a critical care team (intensivists and critical care nurses) is connected with patients in distant ICUs through 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 real-time monitoring of patient instability or any abnormality in laboratory results, ordering diagnostic tests, making diagnoses and ordering treatment, and implementing interventions through the control of life-support devices. As a result, tele-ICU holds great promise in improving the quality of critical care given to patients and increasing the productivity of intensivists. This article explores the available studies related to efficacy and cost-effectiveness of tele-ICU applications and outlines possible barriers to broader adoption.

Methods

Electronic databases were searched to identify relevant articles. Searches were limited to the English language and the most recent publication date of March 2012 for each database. PubMed/MEDLINE, Embase, CINAHL (Cumulative Index to Nursing and Allied Health) with full text, PsychINFO, Evidence-Based Medicine 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 Resources 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 did any one of the following:

1. Pertained to uses of telemedicine in the ICU;
2. Assessed the outcome of implementing tele-ICU by measuring its effect on mortality rate and LOS;
3. Explored staff attitudes toward implemented tele-ICU systems.

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 if they were not found to meet the above criteria once the full text was examined (see Figure 1 for a flowchart of article retrieval). 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 record details pertaining to the study quality such as study design, number of subjects, and study population, as well as a description of the program. The following types of outcomes 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 LOS; and/or
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.

Result

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

Clinical Adoption of Tele-ICU

The concept of tele-ICU has evolved 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 continuous access and monitoring care that focuses on providing supplemental critical care expertise.[8–13] In 2000, Sentara Healthcare was the first hospital to implement the new tele-ICU approach. As of 2011, 41 ICU command centers had been installed, with a total of 5,789 ICU beds covered throughout 249 hospitals.[14] Even with the early positive impacts of tele-ICU, only 5 to 7 percent of adult ICU beds are covered by this technology in the United

States.[15] Adoption of tele-ICU is greatly obstructed by the lack of documented outcomes and unproven return on investment (ROI).[16] Moreover, some tele-ICU centers have been deactivated for reasons such as physicians' resistance to change in both patient management and the requirement of sharing control over patient care with other, off-site physicians. Technical difficulties and lack of training could also be other impediments.[17]

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 nurses and intensivists at the tele-ICU command center are watching them and trying to take over.[18] In reality, "the purpose of the system is to provide improved safety through redundancy and enhance outcomes through standardization."[19] The tele-ICU team has a supportive role; they have an overview of all the patients in the unit and can alert the bedside staff if any problems occur.[20] One study noted that "the hospital admitting physician continued to be the attending of record and was responsible for establishing the care plan," while the tele-ICU staff were the primary contact for the on-site nurses.[21] Studies show that the more proactive the tele-ICU physicians are, "the more improved are the outcomes."[22]

Another barrier to ICU telemedicine is the clinician's acceptance of the technology. This could be one reason why some studies did not show improvement in LOS and mortality in tele-ICU patients. In a study done by Thomas et al., "two-thirds of the patients in our study had physicians who chose minimal delegation to the tele-ICU."[23] 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.[24]

The lack of integration was a problem at some hospitals, especially those that did not have electronic records. Thomas et al. 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 provider order entry; instead, these notes were faxed daily.[25] Berenson et al. also noted the limitations related to the lack of interoperability.[26]

Outcome Assessments

The acute nature of ICU patients' healthcare needs and the high cost associated with critically ill patients makes survival rates and cost savings among the most desirable outcomes measured. Consequently, integration of distance monitoring and intensivists' services into bedside care were significantly associated with a decrease in the mortality rate and LOS in hospitals that were early adopters of tele-ICU. By optimizing telemedicine applications in the ICU, both the mortality rate and LOS could be influenced positively. 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 ICUs after the adoption of tele-ICU. For example, according to Thomas et al., "remote monitoring of ICU patients was not associated with an overall improvement in mortality or LOS."[27] On the other hand, Lilly et al. found that "tele-ICU intervention was associated with reduced adjusted odds of mortality and reduced hospital length of stay."[28] Young et al. concluded that tele-ICU was associated with a decrease in mortality and LOS in the ICU but not in the hospital.[29] A study done by Morrison et al. concluded that a difference in mortality could not be determined because the hospital's ICU mortality rate was already low.[30] Lilly et al. found that after the implementation of tele-ICU, tools were developed for real-time auditing and reconciliation, which increased the adherence to best practices and also led to a decrease in the rates of complications in the ICU.[31]

Telemedicine in the ICU may also prevent intensivist and nurse "burn-outs and posttraumatic stress."[32] Physicians who are tired because of long hours or stress are more prone to making mistakes. "The tele-ICU is that 'second set of eyes' that provides additional clinical surveillance and support."[33] It has also helped residents who are new to the field.[34]

Financial Impact of Tele-ICU

The adoption of tele-ICU requires a substantial up-front capital investment with ongoing costs of operation and maintenance. These costs may impede the adoption of this technology, especially with the lack of reimbursement for tele-ICU services and uncertainties about ROI calculations. Moreover, the ROI is merely calculated using indirect clinical effects and the expected LOS reduction.

Payback period or net present value (NPV) are the indictors used for ROI. More specifically, the financial equation related to tele-ICU is desired to be the following.[35]

[Capital Cost + Operating Cost] ≤ [Revenue from Reimbursement + Cost Savings Attained]

The cost of tele-ICU varies depending on the setting, hardware, software, training, and compatibility with other systems. One study reported a cost of more than $2 million to set up a command center and its components.[36] In general, $2 million to $5 million is the estimated cost to set up a command center and install a tele-ICU system, with operating costs ranging from $600,000 to $1.5 million per year, according to costs reported by various adopters.[37]

On the revenue side, one study found a 10 percent reduction in ICU length of stay, creating the ability to care for one new ICU patient per day, which could result in a positive $2.5 million NPV.[38]

Most studies reviewed used LOS and mortality to determine cost savings. For example, according to Rosenfeld et al., ICU costs decreased between 25 percent and 31 percent during the intervention period, and hospital costs decreased by 12 percent to 19 percent.[39] Breslow et al. hired an independent consulting firm to determine the financial outcome of a tele-ICU program.[40] They determined the cost of care per day of service and also included equipment costs, staff costs, and other costs associated with having a tele-ICU system. The report showed a 24.6 percent decrease in variable costs per patient. This decrease is probably due to a shorter LOS in the ICU and improved clinical outcomes.[41–43]

Staff Acceptance of Tele-ICU

Implementation of tele-ICU requires a change in the practices of many health workers. Most studies that measured the acceptance of tele-ICU showed high acceptance of the increased ICU coverage. Moreover, tele-ICU has a favorable impact both on patient care and on organizations. Thomas et al.[44] conducted a pretest-posttest attitude survey for physicians and found that their attitudes regarding safety significantly increased after implementation. Tele-ICU also increased the confidence that patients were adequately covered. Another study, conducted by Kowitlawakul, measured nurses' attitudes through a survey; it revealed that tele-ICU would be beneficial in units without adequate physician coverage.[45] Chu-Weininger et al. measured the teamwork and safety environment of three ICUs before and after implementation.[46] Their results showed that implementation of a tele-ICU system improved teamwork and the safety climate in some units, especially among nurses. As a result, the collaboration needed to enhance the value of the tele-ICU system is acquired through effective implementation of a continuous change management plan. Through implementation of 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, high-risk delivery units, long-term acute care hospitals, and other departments that are designated to provide an immediate response to patients.

Discussion

The current studies in the articles reviewed are early steps, and more research needs to be done before tele-ICU will become more widely adopted. Some studies did not show any difference before and after adoption of tele-ICU because the institutions already had good outcomes (see Table 1). Other studies showed a large decrease in LOS and mortality, which could be attributed to the fact that a hospital is an open system (Table 1). Similarly, Yoo and Dudley 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."[47] 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."[48]

Another problem in the studies was the lack of consistent measurement, reporting, and adjustment for patient severity.[49] This problem could have led to inflated results relating to mortality and LOS. One hospital may be a Level 1 trauma center and experience many deaths, while another facility could be a smaller hospital that does not typically see that type of patients. Cost-effectiveness is another area in which more research is needed. While many studies draw conclusions on cost based on mortality and LOS, actual costs were not reported. This is an important consideration, especially for smaller facilities that want to ensure a return on their investment.

Limitations of this Review

One of the limitations of this systematic review is that it uses studies published in peer-reviewed journals. A publication bias toward studies that have positive findings has been well documented.[50] Therefore, studies that do not demonstrate any effect or report a negative effect of tele-ICU implementation may not carry as much weight in the synthesis of the data because they were not identified through the search. Moreover, this review did not include studies that looked at patient assessment because the focus of this review was on tele-ICU intervention programs. This review was a first attempt to identify scientifically sound evidence on telemedicine intervention programs and synthesize and critically appraise the published literature in this area. In part, this review 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. The review showed that although the published studies differ 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.

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Notes

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Figure 1

Flowchart of the Results from the Literature Search

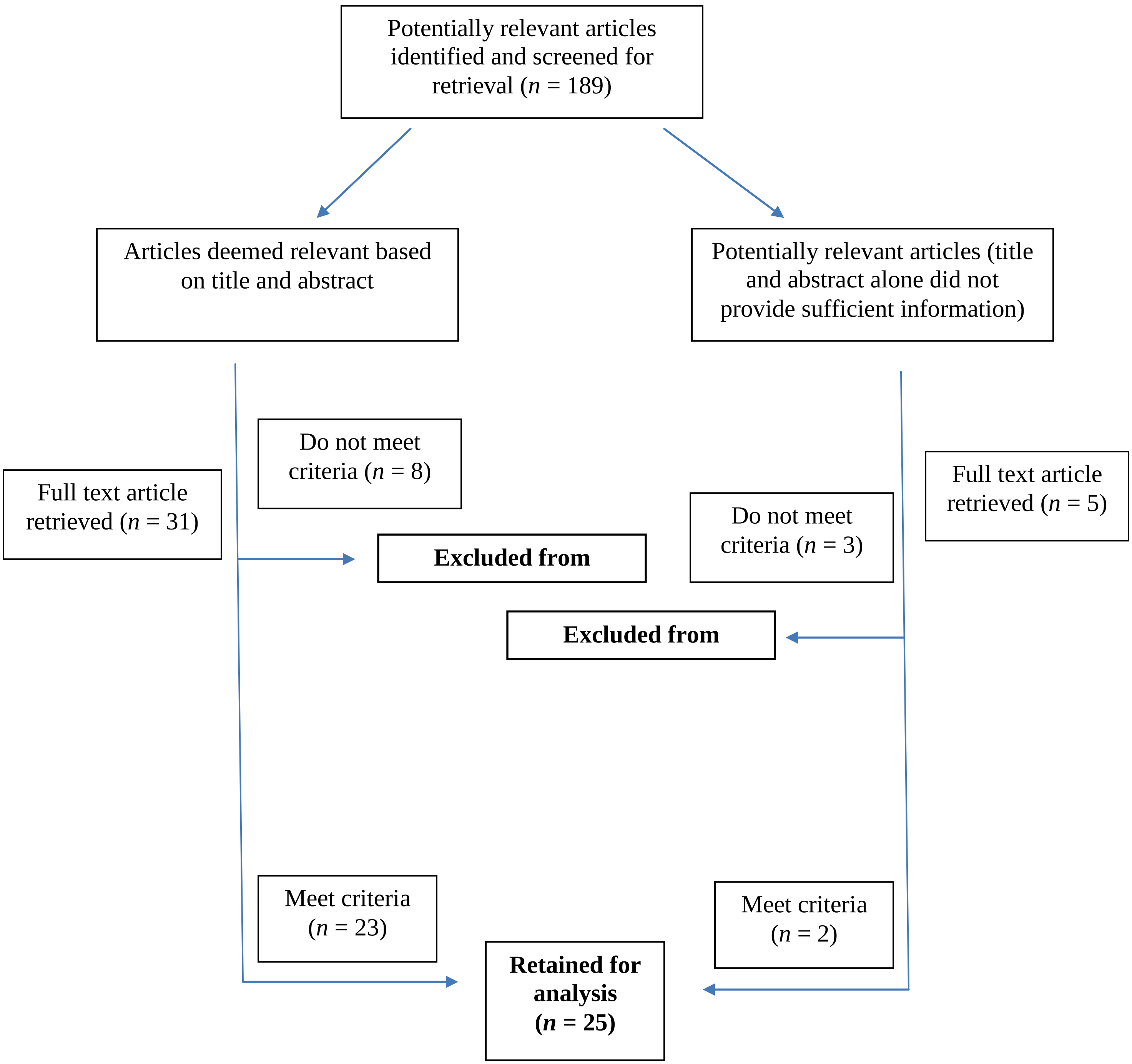

Table 1
Study Characteristics

Study	Hospital	Intensive Care Unit (ICU) Mortality Change	Average Length of Stay (LOS) Change
Rosenfeld et al. (2000)[a]	A 10-bed surgical ICU at Johns Hopkins Medicine	Severity-adjusted mortality rate in ICU decreased by 46%; in hospital, by 30%	ICU length of stay decreased by 30%
Breslow et al. (2004)[b]	Sentara Healthcare (Virginia)	26.4% reduction at the end of first year	Observed decrease in LOS from 5.6 to 4.8 days
Shaffer et al. (2005)[c]	Health First (integrated network on Florida's east coast)	Associated with significant decrease in mortality rate; odds ratio of pre- to postimplementation is 0.72	
Dickhaus (2006)[d]	Community hospital in Weston, Wisconsin, and a hospital in Jefferson City, Wisconsin	A decrease in mortality is observed	17% decrease in LOS resulted
Ikeda et al. (2006)[e]	Sutter Health (Sacramento, California)	Actual ICU mortality rate reduced from 40.07% to 18.86%; an estimated 56 lives were saved over a 30-month period	
Young (2006)[f]	Parkview Hospital (Fort Wayne, Indiana)	Cardiac arrest decline from nine months' prior average of 38% to 28%	
Gracias et al. (2007)[g]	Surgical intensive care units (SICU) at Pennsylvania Health System	Mortality rate decreased from 5.5% to 2.6%	
Howell et al. (2007)[h]	Saint Luke's Health System	Severity-adjusted ICU mortality went from 1.0 to 0.68; hospital mortality, from 0.95 to 0.77 days	ICU LOS decreased from 1.18 to 0.96; hospital LOS decreased from 1.09 to 0.84 days
Kohl et al. (2007)[i]	University of Pennsylvania Health System	Reduction in ICU mortality rate from 8.4% to 3.1% (63% decrease); hospital mortality rate reduced from 11.1% to 6% (46% decrease)	Decreased 3.7 to 4.4 days on average
Kohl et al. (2007)[j]	University of Pennsylvania Health System		10% reduction in LOS in ICU; 20% reduction in floor stay (cost savings of $700,000 to $2,850,000)
Mora et al. (2007)[k]	University of Texas Medical School at Houston	Majority of residents perceived that tele-ICU improves patient care (82.3%); 66.7% of residents expressed a desire to have remote telemonitoring involved in the care of their patients	
Rincon, Welcher,	Sutter Health (Bay Area and		Total estimated savings of

Srikanth, and Seiver (2007)[l]	Sacramento, California)		$132,859 for 2007
Rincon, Bourke, and Ikeda (2007)[m]	Sutter Health (Sacramento, California)	Accurate sepsis identification can be achieved from tele-ICU; improved sepsis bundle compliance and reduced mortality observed after using tele-ICU	
Zawada and Herr (2007)[n]	Avera Health System (Sioux Falls, South Dakota)		Annual reduction of 4,146 ICU days and 572 hospital days
Coletti et al. (2008)[o]	Christiana Care Health System (Newark, Delaware)	77% of surveyed residents reported that tele-ICU was associated with improved patient safety	
Howell et al. (2008)[p]	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)[q]	University of Massachusetts Memorial Medical Center	209 lives were saved in 2007	Hospital length of stay reduced by 4 days on average; cost savings averaged $5,000 per patient
Goran et al. (2008)[r]	Maine Medical Center	Estimate of 5% to 20% reduction in mortality rate; for an estimated 2,000 adult ICU admissions per year, 100 additional patients survive per year	
Zawada and Herr (2008)[s]	Rural center close to Avera Heath System (Sioux Falls, South Dakota)		160 patients were prevented from transfer to a tertiary hospital for a savings of $1,202,379
Thomas et al. (2009)[t]	Nonprofit health system of Gulf Coast region	Reduction in mortality by 1.4% to 2.1%	No significant differences in LOS pre- and postimplementation
Zawada et al. (2009)[u]	Avera Health System (one large tertiary hospital, three rural hospitals, two community hospitals, and nine critical care centers)	Reduction in adjusted mortality rate ranged from 0% to 29%	LOS reduction ranged from 45% to 22.5% (nine sites)
Morrison et al. (2010)[v]	Two community hospitals in the metropolitan Chicago area	No significant effect on ICU, non-ICU, or total mortality	No effect on LOS.
Lilly et al. (2011)[w]	University of Massachusetts	2.1% decrease	1.9-day decrease
Young et al. (2011)[x]	Review	Odds ratio for pooled data was 0.80, which shows reduction	1.26-day decrease
Willmitch et al. (2012)[y]	South Florida		0.55-day decrease

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