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# A Business Case for Tele-Intensive Care Units

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## Abstract

**Objectives:** A tele-intensive care unit (tele-ICU) uses telemedicine in an intensive care unit (ICU) setting, applying technology to provide care to critically ill patients by off-site clinical resources. The purpose of this review was to examine the implementation, adoption, and utilization of tele-ICU systems by hospitals to determine their efficiency and efficacy as identified by cost savings and patient outcomes.

**Methods:** This literature review examined a large number of studies of implementation of tele-ICU systems in hospitals.

**Results:** The evidence supporting cost savings was mixed. Implementation of a tele-ICU system was associated with cost savings, shorter lengths of stay, and decreased mortality. However, two studies suggested increased hospital cost after implementation of tele-ICUs is initially expensive but eventually results in cost savings and better clinical outcomes.

**Conclusions:** Intensivists working these systems are able to more effectively treat ICU patients, providing better clinical outcomes for patients at lower costs compared with hospitals without a tele-ICU.

## Introduction

Telemedicine is the use of medical information exchanged from one site to another via electronic communications to improve a patient's clinical health status. Telemedicine includes a growing variety of applications and services using two-way video, smart phones, wireless tools, and other forms of telecommunications technology.<sup>1</sup> A tele-intensive care unit (tele-ICU) involves the use of telemedicine in an intensive care unit (ICU), using technology to assist in providing care for critically ill patients by off-site clinical resources.<sup>2</sup>

In the US, more than 4 million patients are admitted to ICUs each year; treatment of these critically ill patients has been estimated to account for 30% of costs of acute care hospitals.<sup>3,4</sup> Patient safety concerns persist in the ICU, and serious medication errors account for 78% of all errors in the ICU.<sup>5</sup> Hospital costs for critically ill patients have been estimated to be

about \$67 billion annually, with mortality rates ranging from 10% to 28%, or approximately 540,000 deaths each year.<sup>6-8</sup>

Tele-ICUs may be effective by decreasing costs, decreasing ICU length of stay (LOS), decreasing medication errors, and increasing patient safety when adopted and implemented in hospitals. Two distinct types of tele-ICU have been identified. The *decentralized tele-ICU* is a medical facility or multiple medical facilities that can be accessed from remote sites such as office, home, or mobile. There is no distinct tele-ICU; rather there is a process of care having multiple sites of access to the patient, with intensivists monitoring the patients. A *centralized tele-ICU* program is often the tele-ICU system of choice. In the centralized system, one central ICU provides intensive care via telemedicine and remote monitoring to several satellite ICUs.

In the tele-ICU model, the tele-ICU is a definable entity providing continuous

monitoring to sites with high levels of need via private, dedicated telecommunications lines.<sup>9</sup> Networks of audiovisual communication and computer systems link hospital ICUs to intensivists and other critical care professionals, who are able to access patient data such as medical records, to conduct remote real-time monitoring of vital signs or chronic conditions, or to facilitate staff interactions via video, phone, or online computer. Video cameras located on the ceiling of an ICU patient room are situated to allow telemedicine practitioners to observe equipment and monitors in the patient's room. Cameras often have an alert system to announce that the tele-ICU staff is in visual contact to share observations and care recommendations with bedside caregivers.<sup>10</sup> These devices and elements are vital to the successful application of tele-ICUs. As has been noted, without appropriate electronic medical records and clinical decision support systems, or lacking patient-related data and information, clinicians may make inappropriate treatment recommendations.<sup>11</sup>

Studies have demonstrated both clinical and economic benefits associated with adoption of tele-ICUs, including decreased mortality rate, decreased frequency of ICU complications, decreased ICU LOS and decreased ICU costs after a 16-week implementation of technology-enabled remote care.<sup>12-14</sup> Additionally, it has been found that tele-ICU use can decrease medication errors and improve patient safety.<sup>11</sup> A meta-analysis of non-severity-adjusted data from 11 studies confirmed these results and found the decrease of ICU mortality and ICU LOS, as well as hospital mortality and hospital

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LOS to be statistically significant.<sup>15</sup> These outcomes are particularly important because studies that reported results on the basis of both severity-adjusted data and non-severity-adjusted data have found that the level of statistical significance of these outcome variables when using non-severity-adjusted data was higher than when using severity-adjusted data.<sup>16,17</sup> These findings indicate that the benefits of tele-ICU implementation reach all populations of patients, regardless of severity of illness.

It has been estimated that full implementation of the tele-ICU standard in community hospitals could prevent between 5,400 and 13,400 deaths and could potentially save \$5.4 billion annually.<sup>18,19</sup>

One of the main barriers to adoption of tele-ICUs has been adoption and implementation cost: the cost of construction, installation, and training. The “command center” for a tele-ICU system has been estimated to cost between \$2 and \$5 million, with each additional tele-ICU added to the system costing \$250,000.<sup>20</sup> Such substantial financial outlays can be a challenge for hospitals and health systems that lack significant financial funds or borrowing capacity, especially with annual operating costs of about \$2 million, including maintenance costs, licenses, staffing expenses, and additional upgrades.<sup>21</sup> If the tele-ICU system is not fully compatible with the hardware or software systems of the physical ICU, additional software, hardware, and infrastructure may be required, which would require additional cost to the hospital.

Regardless of the need for upgrades, staff must overcome additional barriers such as computer issues, including difficulty logging on, short battery life, frequent rebooting, and other technical issues with computers or software. Some of the possible solutions for these problems include ensuring computers remain plugged in, confirming that passwords are able to be used in multiple programs, and providing information technology (IT) assistance by phone and on-site as required.<sup>22</sup>

Although tele-ICUs are expensive to implement, with startup costs between \$50,000 and \$100,000 per bed, the benefits of tele-ICU utilization may far outweigh those costs for ICUs. Because ICU patients

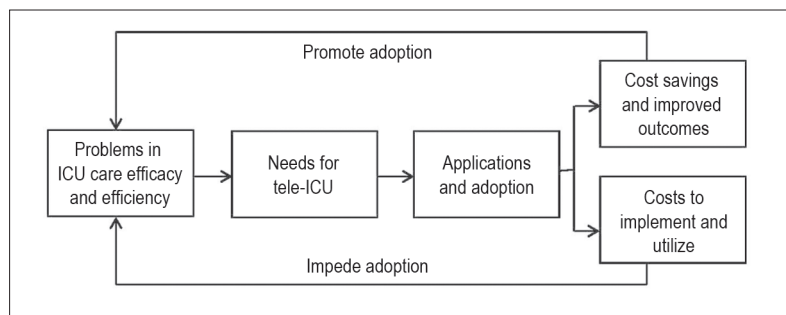


Figure 1. Research framework.

ICU = intensive care unit.

frequently have such complex medical and/or surgical conditions, intensive care provided via a tele-ICU system can provide this care and decrease hospital cost.<sup>23</sup>

The purpose of this review was to examine the implementation, adoption, and utilization of tele-ICU systems by hospitals to determine their efficiency and efficacy as identified by cost savings and patient outcomes.

## Methods

The methods employed for this study were a literature review and a review of case studies. The research approach for the examination of the promotion factors and barriers to adoption of tele-ICUs was customized to this study following the conceptual framework used by Yao et al<sup>24</sup> (Figure 1). Figure 1 depicts the process of IT adoption in health care, in this case, the tele-ICU. To research how tele-ICU can help improve health care practices in the ICU, it is first necessary to recognize the existing problems in the ICU and issues that drive and impede adoption of this technology by the hospital industry; then different applications can be identified to solve or partially unravel these challenges. By analyzing the literature, the benefits and barriers of tele-ICU utilization in health care can be identified (Figure 1). The use of this framework in the current study is appropriate because the focus of this study, as in that by Yao et al,<sup>24</sup> is to show how new technologies and IT systems can be applied to health care settings to enhance the care of patients. In addition, this conceptual approach has been successfully replicated in previous studies, including adoption of tele-ICU, radiofrequency identification, and electronic

prescribing technologies, thus supporting its internal validity.<sup>25-27</sup>

The review was conducted in stages, including: 1) determining the search strategy and establishing inclusion and exclusion criteria, 2) literature analysis, and 3) extracting and categorizing the findings.

## Step 1: Determining the Search Strategy and Establishing Inclusion and Exclusion Criteria

When executing the search, the following terms were used: “tele-ICU” or “telemedicine ICU” or “virtual ICU” and “cost” or “benefits.” A mix of databases and online sources were used to compile a set of references covering both academic peer-reviewed research and practitioner literature. It was believed that this approach would help create the most comprehensive and up-to-date review. The following electronic databases and sources were used: PubMed, Academic Search Premier, Science Direct, ProQuest, and Google Scholar. The Web sites of the Society of Critical Care Medicine and the American Telemedicine Association also were searched.

## Step 2: Literature Analysis

The literature review yielded 76 sources, which were assessed for information pertaining to this research project. Given the technology- and enterprise-oriented nature of the current study, literature was selected for review on the basis of financial, technological, and organizational impacts. References were reviewed and determined to have satisfied the inclusion criteria if the material provided accurate information about the tele-ICU with a particular focus on benefits and barriers

to its implementation. Only articles that were written in English were included for review. Given the rapid changes in technology, studies that were published before 2001 were excluded from the search.

**Step 3: Literature Categorization**

In the third step, selected academic articles and practitioner health IT sources were analyzed, and relevant categories were identified. The findings are presented in the subsequent sections using the categories of cost of telemedicine technology in the ICU and several case studies. The use of brief case studies was thought to illustrate real cases of tele-ICU implementation.

**Results**

**How Tele-ICUs**

**Can Be Cost-Effective**

According to the leading tele-ICU systems vendor, Philips VISICU in Baltimore, MD, tele-ICU implementation costs ranged from about \$50,000 to \$100,000 per bed, and the cost of equipping 100 beds was approximately \$3 to \$5 million.<sup>28,29</sup> Annual operating costs (eg, overhead, maintenance, staffing) were estimated by Philips

VISICU to be approximately 20% of the software costs, or about \$300,000 for 100 beds.<sup>30</sup> Staffing costs depended on hours in use and level of additional staff in the off-site center; typical staffing scenarios added approximately \$1 to \$2 million per year per 100 beds covered.<sup>31</sup>

**Brief Case Study 1: Sentara Healthcare**

Sentara Healthcare in Norfolk, VA, was the nation's first health system to establish a tele-ICU program in 2000 through the vendor VISICU (now Philips VISICU).<sup>32</sup> Implementation of the tele-ICU at Sentara Norfolk General Hospital and Sentara Hampton General Hospital took 5 months and cost more than \$1 million. In 2002, Sentara reported a reduction in hospital mortality of 26%, with a 17% decrease in ICU LOS (Table 1).<sup>33</sup>

Findings from an independent evaluation by Cap Gemini Ernst & Young, London, United Kingdom, suggested a \$2 million tele-ICU cost that was offset by \$3 million in net savings annually.<sup>33</sup> It reported extra revenue, approximately \$460,000 per month, because of increased

patient turnover resulting from decreased LOS.<sup>34</sup> Table 2 displays the findings of the patient cost reduction of \$2150 per stay based on reduced patient expenses and increased ICU capacity as well.

The centralized model has allowed optimization of time and services of intensivists without the requirement of staffing intensivists at multiple locations. The availability of intensivists in a single location also has given patients the opportunity to stay in location, instead of traveling and being transferred to a different hospital.<sup>35</sup> As of 2010, more than 1 million ICU patients had been cared for using the strategy of frequent reassessment, alert-prompted evaluation, and rapid response to clinical needs.<sup>34</sup>

**Brief Case Study 2: University of Massachusetts Memorial Medical Center**

The University of Massachusetts Memorial Medical Center in Worcester, MA, installed a tele-ICU command center in 2005 and extended the tele-ICU coverage to 2 Massachusetts community hospitals in 2007 and 2008. Over 3 years, 1 tele-ICU

**Table 1. Tele-intensive care unit cases studied, implementation costs, and outcomes**

Institution	Setting	Implementation costs (US dollars)	Major results/outcomes
Sentara Healthcare	Sentara Healthcare, <sup>a</sup> academic tertiary care medical center with 5 ICUs, 103 critical care beds	1 million	Decreased ICU LOS by 17%; decreased hospital mortality by 26.4%. <sup>33,36</sup>
New England Healthcare Institute and Massachusetts Technology Collaborative	University of Massachusetts Memorial Medical Center, academic hospital with 5 adult ICUs, 130 beds, 7000 ICU patients	7.12 million	Decreased ICU LOS (from 13.3 to 9.8 days); decreased mortality from 13.6% to 11.8%; recovered costs of implementation; lowered rates of complications <sup>36</sup>
Resurrection Health Care	Community hospitals with 14 ICUs, 182 critical care beds Pre- and postimplementation design; preimplementation: n = 2034 patients; postimplementation: n = 2134	7 million	6 months after implementation: 38% decrease in ICU LOS, approximately \$3 million in cost savings <sup>37,38</sup>

<sup>a</sup> Includes both Sentara Norfolk General Hospital and Sentara Hampton General Hospital. ICU = intensive care unit; LOS = length of stay.

**Table 2. Sentara Healthcare and Resurrection Health Care tele-intensive care unit implementation savings**

Hospital	Cost of implementation (US dollars)	Outcomes	Cost saving
Sentara Healthcare (savings from 2002 to 2010)	1 million	Reduction in mortality by 27%; decreased LOS of 17%	Reduced patient cost of \$2150; average case contribution margin <sup>a</sup> increased by 55.6%. <sup>33,36</sup>
Resurrection Health Care (savings from 2007 to 2011)	7 million	Decreased LOS of 38%	7% reduction in blood transfusions (\$11,200 in savings); estimated total cost savings of \$11.5 million <sup>37,38</sup>

<sup>a</sup> Average case contribution margin is the selling price per unit minus cost per unit. Contribution represents the portion of sales revenue that is not consumed by variable costs and so contributes to the coverage of fixed costs. LOS = length of stay.

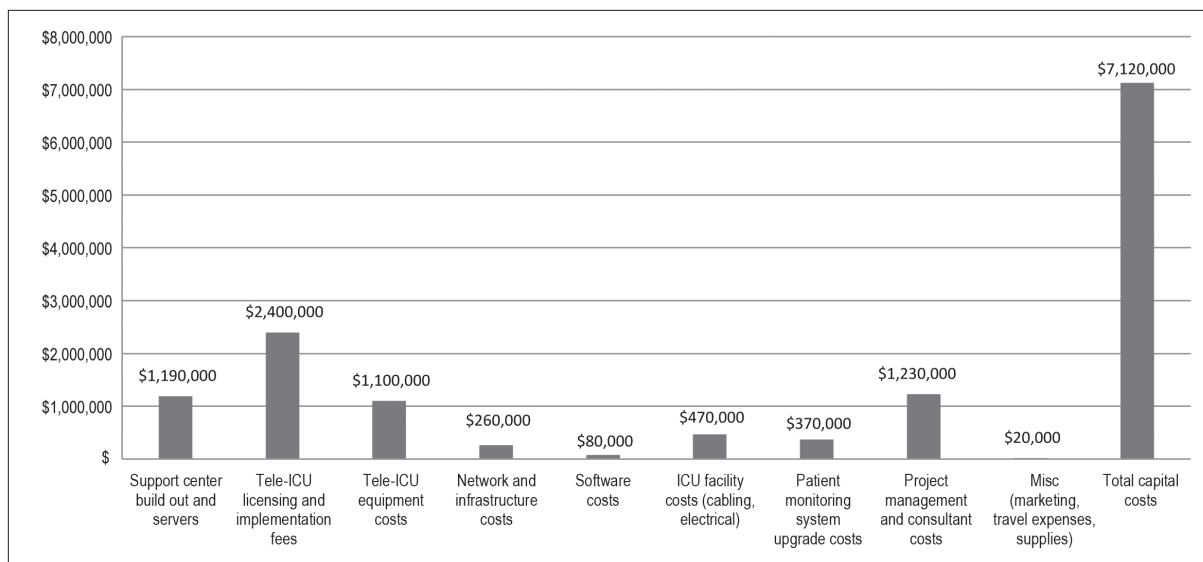


Figure 2. University of Massachusetts Memorial Medical Center: one-time costs for tele-intensive care unit implementation, 2010.<sup>36</sup> ICU = intensive care unit; Misc = miscellaneous.

command center extended coverage to 9 adult ICUs covering 116 ICU beds in central Massachusetts.<sup>36</sup>

Figure 2 shows the initial expenses of implementation of a tele-ICU at the medical center. The total operating costs of \$7.12 million also required an increment of annual operating cost of \$3.15 million. Licensing and implementation fees accounted for 34% of the total expenses. Tele-ICU equipment costs and support center and servers accounted for \$1.1 million and \$1.19 million, respectively (Figure 2).

Figure 3 shows the operating costs and the continuous ongoing costs for the tele-ICU. The main ongoing cost was clinical salaries and benefits accounting for 72% or \$2.27 million, followed by nonclinical salaries at 20% or \$630,000 (Figure 3). The centralized tele-ICU program has been one of the most beneficial programs to the medical center. The positive net revenue produced a rapid payback such that total costs of implementation were recovered within 1 year.<sup>36</sup>

**Brief Case Study 3: Resurrection Health Care**

Covering 7 acute care hospitals and a long-term care facility, Resurrection Health Care in Des Plaines, IL (now part of Presence Health), introduced telemedi-

cine into its 14 ICUs in 2007. The tele-ICU command center in Resurrection's Holy Family Medical Center (now Presence Holy Family Medical Center) promoted proactive intervention, including trended alerts, which showed incremental changes in such factors as blood pressure, oxygen levels, and drip rates.<sup>37</sup>

In the first 6 months after installation in 2007, a cost savings of \$3 million was

reported, including \$11,200 from a 7% reduction in blood transfusions. The hospital found a 38% decrease in ICU LOS in 6 months, which totaled to approximately \$3 million in savings (Table 2).

Resurrection Health Care leadership wanted to know how the system was going to prove its return on investment on the \$7 million spent to set up all 14 ICU systems simultaneously. In 2011, it

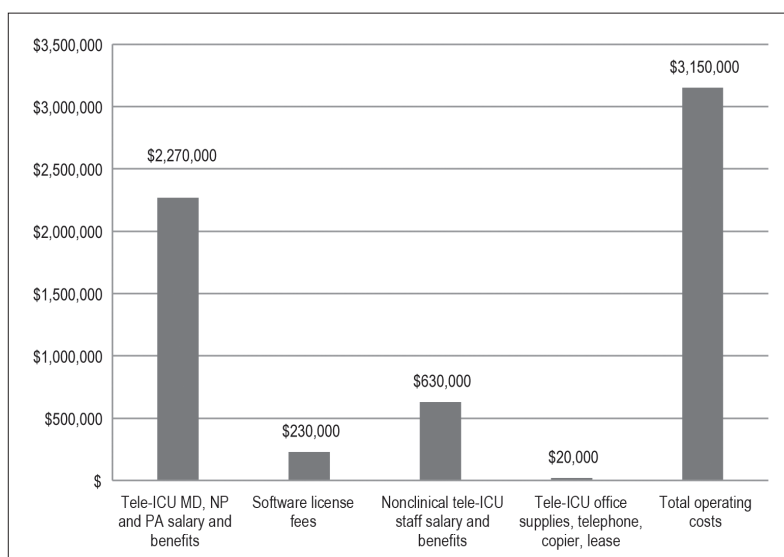


Figure 3. University of Massachusetts Memorial Medical Center ongoing operating costs, 2010.<sup>36</sup>

ICU = intensive care unit; MD = physician; NP = nurse practitioner; PA = physician assistant.

was reported that it had a \$387,000 financial benefit: tele-ICU support for ICU patients across the health care system resulted in 9000 ICU days saved, for an estimated cost savings of \$11.5 million. Also, it was reported that the reengineering of the existing tele-ICU infrastructure was expanded to support telestroke, telepsychiatry, telemedicine with skilled nursing facilities, and sepsis management initiatives.<sup>38</sup>

**Brief Case Study 4:  
Six Intensive Care Units  
in Five Large Hospitals**

A study by Franzini et al<sup>39</sup> was conducted to determine the costs and cost-effectiveness of 6 ICUs in 5 large hospitals in the Gulf Coast region after the installation of a tele-ICU program. The sample included 4142 patients in the 6 different ICUs: 2034 patients were from the pretest period and 2108 were from the posttest period. Table 3 shows the ICU average daily cost before and after the tele-ICUs were implemented. The average daily costs and costs per case increased in all 6 ICUs after implementation (posttest period) from the period before implementation of the tele-ICU (pretest period). Overall, the daily average ICU cost increased from \$2851 to \$3653, or a 28% increase after tele-ICUs were installed, which was statistically significant. Two hospitals experienced cost increases greater than 30% (Table 3).<sup>39</sup>

The floor daily average costs increased 16%, from \$1451 to \$1687, after tele-ICUs were installed. The overall ICU costs per

case increased from \$13,029 to \$19,324 after tele-ICU installation.<sup>39</sup>

Costs per patient for hospitals increased, but the patient out-of-pocket expenses remained the same, causing the hospitals to need to find some way to absorb the financial losses of tele-ICU implementation. Average ICU hospital cost per patient was \$20,231 in the pretest period and \$25,846 in the posttest period, which was financially and statistically significant (Table 4). Overall, the installation of the tele-ICU programs in the 6 ICUs was associated with higher costs not attributable to medical inflation. These researchers did note that sicker patients exhibited lower mortality; thus ICUs with high volumes of severely ill patients may gain more financial benefit with the utilization of tele-ICU technology. The researchers also noted that about two-thirds of ICU physicians in the study chose only minimal participation in the tele-ICU intervention.

**Positive Outcomes of  
Tele-ICU Implementation**

In terms of effectiveness, the literature on tele-ICUs demonstrated improved hospital financial performance, improved ICU financial performance, improved teamwork climate and safety climate, and improved patient care (Table 5).<sup>40-66</sup> A tele-ICU program enhanced compliance to evidence-based practice bundles for severe sepsis. Between January 1, 2006, and December 31, 2008, antibiotic administration increased from 55% to 74%, serum lactate measurement increased from 50% to 66%, the initial fluid bolus of 20 mL/kg

or greater increased from 23% to 70%, and central line placements increased from 33% to 50%.<sup>53</sup> Higher rates of ICU staff adherence to critical care best practices, reduction of ICU LOS, and improved patient care were found in several studies (Table 5). Quality improvement and patient care have been improved by the implementation of the tele-ICU by increasing the use of evidence-based protocols for sepsis, ventilator-associated pneumonia, and blood transfusion (Table 5).<sup>67-70</sup>

In 2013, Kumar et al<sup>71</sup> combined a systematic review with cost data from the implementation of a tele-ICU program in 7 ICUs (74 beds) in the Veterans Health Administration to measure the cost of tele-ICU programs. According to the authors, it was estimated that the first-year costs of implementation ranged between \$70,000 and \$87,000 per ICU bed. The Veterans Health Administration also projected cost for staffing and operating the monitoring site for the first year as \$3300 or 27% of total cost. The researchers also reported that tele-ICU studies with vendor association presented cost savings of \$2600 to \$3000 per patient, whereas studies without vendor association suggested increased hospital cost after implementation. Hospital cost per patient ranged from a reduction of \$3000 to an increase of \$5600.<sup>71</sup>

**Discussion**

This research study has examined potential benefits of implementing a centralized tele-ICU system. The evidence supporting cost savings is mixed. The

**Table 3. Average daily costs (US dollars) before and after tele-ICU installation in six intensive care units in 2010<sup>39</sup>**

Costs	Overall	ICU 1	ICU 2	ICU 3	ICU 4	ICU 5	ICU 6
Before tele-ICU period	2851	2586	3647	4248	3155	2355	2370
After tele-ICU period	3653	3272	4307	4252	4131	3275	2746
Change (%)	802 (28)	686 (27)	660 (18)	4 (0)	976 (31)	920 (39)	376 (16)

ICU = intensive care unit.

**Table 4. Intensive care unit costs per case (US dollars) before and after tele-ICU installation in six intensive care units in 2010<sup>39</sup>**

Costs	Overall	ICU 1	ICU 2	ICU 3	ICU 4	ICU 5	ICU 6
Before tele-ICU period	13,029	7422	12,912	26,296	8770	13,328	15,167
After tele-ICU period	19,324	10,797	18,519	33,594	19,002	15,392	18,947
Change (%)	6295 (48)	3374 (45)	5608 (43)	7298 (28)	10,232 (117)	2065 (15)	3780 (25)
Average cost: before tele-ICU period vs after tele-ICU period	20,231 vs 25,846						

ICU = intensive care unit.



Table 5. Studies addressing tele-ICU implementation and utilization		
Author, year	Study design	Outcome
Aaronson et al, 2006 <sup>40</sup>	Literature review	Higher rates of ICU staff adherence to critical care best practices
Badawi et al, 2010 <sup>41</sup>	Pre/posttest of tele-ICU implementation	Higher rates of ICU staff adherence to critical care best practices
Badawi and Shemmeri, 2006 <sup>42</sup>	Pre/posttest of tele-ICU implementation	Higher rates of ICU staff adherence to critical care best practices
Berenson et al, 2009 <sup>31</sup>	Literature review	Improved patient care
Breslow et al, 2004 <sup>12</sup>	Pre/posttest of tele-ICU implementation across several hospitals	Improved hospital financial performance, improved ICU financial performance, improved patient care
Chu-Weininger et al, 2010 <sup>43</sup>	Pre/posttest of tele-ICU implementation and utilization in 3 ICUs	Improved teamwork and/or safety climate
Coletti et al, 2008 <sup>44</sup>	Cross-sectional survey of residents in ICU and tele-ICUs	Improved teamwork and/or safety climate
Dickhaus, 2006 <sup>45</sup>	Pre/posttest of tele-ICU implementation and utilization in a multistate hospital system	Lower ICU LOS
Giessel and Leedom, 2007 <sup>46</sup>	Pre/posttest of tele-ICU implementation and utilization	Higher rates of ICU staff adherence to critical care best practices
Groves et al, 2008 <sup>13</sup>	Literature review	Lower ICU LOS
Howell et al, 2007 <sup>47</sup>	Pre/posttest of tele-ICU implementation and utilization	Lower ICU LOS
Howell et al, 2008 <sup>48</sup>	Pre/posttest of tele-ICU implementation and utilization	Lower ICU LOS
Ikeda et al, 2009 <sup>67</sup>	Pre/posttest of tele-ICU implementation and utilization	Lower ICU LOS
Kohl et al, 2007 <sup>49</sup>	Pre/posttest of tele-ICU implementation and utilization	Lower ICU LOS
Kohl et al, 2007 <sup>50</sup>	Pre/posttest of tele-ICU implementation and utilization	Improved ICU financial performance, lower ICU LOS
Kohl et al, 2012 <sup>16</sup>	Pre/posttest of tele-ICU implementation and utilization	Lower ICU LOS
Kumar et al, 2013 <sup>51</sup>	Literature review	Improved ICU financial performance
Khunlerkit and Carayon, 2013 <sup>11</sup>	Qualitative study with semistructured interview of tele-ICU staff	Improved ICU staff adherence to evidence-based protocols for sepsis, ventilator-associated pneumonia, and blood transfusion
Lilly et al, 2011 <sup>17</sup>	Pre/posttest of tele-ICU implementation and utilization	Higher rates of ICU staff adherence to critical care best practices, lower ICU LOS, improved patient care
Mora et al, 2007 <sup>52</sup>	Survey of residents practicing in tele-ICUs	Improved patient care
Norman et al, 2009 <sup>53</sup>	Literature review and meta-analysis	Improved ICU financial performance
Patel et al, 2007 <sup>54</sup>	Pre/posttest of tele-ICU implementation and utilization of 6 tele-ICUs	Higher rates of ICU staff adherence to critical care best practices, lower ICU LOS
Rincon et al, 2007 <sup>55</sup>	Pre/posttest of tele-ICU utilization in prevention of sepsis	Higher rates of ICU staff adherence to critical care best practices: <ul style="list-style-type: none"> <li>• Antibiotic administration increased from 55% to 74%</li> <li>• Serum lactate measurement increased from 50% to 66%</li> <li>• Central line placements increased from 33% to 50%</li> </ul>
Scales et al, 2011 <sup>56</sup>	Literature review	Higher rates of ICU staff adherence to critical care best practices
Thomas et al, 2007 <sup>57</sup>	Pre/posttest of tele-ICU implementation and utilization	Improved teamwork and/or safety climate
Vespa et al, 2007 <sup>58</sup>	Pre/posttest of tele-ICU implementation and utilization	Improved ICU financial performance, lower ICU LOS, improved patient care
Wilcox and Adhikari, 2012 <sup>15</sup>	Meta-analysis of 11 studies	Lower ICU LOS
Willmitch et al, 2012 <sup>59</sup>	Pre/posttest of tele-ICU implementation and utilization over 3 years	Lower ICU LOS
Youn, 2006 <sup>60</sup>	Literature review and meta-analysis	Higher rates of ICU staff adherence to critical care best practices
Young et al, 2011 <sup>61</sup>	Meta-analysis of 11 studies	Lower ICU LOS
Zawada et al, 2006 <sup>62</sup>	Survey of physicians practicing in remote areas using tele-ICU	Higher rates of ICU staff adherence to critical care best practices, lower ICU LOS
Zawada et al, 2007 <sup>63</sup>	Pre/posttest of tele-ICU implementation and utilization	Improved ICU financial performance, lower ICU LOS
Zawada et al, 2008 <sup>64</sup>	Pre/posttest of tele-ICU implementation and utilization in a rural health care system	Higher rates of ICU staff adherence to critical care best practices, improved ICU financial performance
Zawada and Herr, 2008 <sup>65</sup>	Pre/posttest of tele-ICU implementation and utilization	Improved patient care
Zawada et al, 2009 <sup>66</sup>	Pre/posttest of tele-ICU implementation and utilization	Improved hospital financial performance

ICU = intensive care unit; LOS = length of stay.

hospitals in the first three cases experienced some benefit in terms of cost reduction, a decreased ICU LOS, or an overall improved efficiency.

The return on investment for hospitals implementing a tele-ICU system depends on how the system is used, as well as the number of patients the hospital ICU treats. If a hospital system wants to use a tele-ICU system for safety reasons or to make their workforce more efficient, the tele-ICU is a tool that could help. Another benefit of tele-ICU implementation has been an expansion of markets; the tele-ICU allows health care facilities to take care of more patients, which decreases geographic barriers and allows the provision of ICU services into previously inaccessible markets, such as those in rural areas.

In hospital tele-ICU systems examined by Franzini et al<sup>39</sup> and Morrison et al,<sup>72</sup> hospital costs rose after implementation. Both studies noted that costs associated with physicians choosing a low or nonexistent involvement with tele-intensivists rose more quickly than those costs associated with physicians choosing a higher level of tele-intensivist involvement. Additionally, Franzini et al<sup>39</sup> noted that the tele-ICU system used in their study was not fully integrated with the hospitals' electronic health record system, which may also have contributed to increased cost.

The LOS decreased because intensivists had more time to spend with the patient and were able to provide adequate intensive care. Franzini et al<sup>39</sup> and Morrison et al<sup>72</sup> noticed patients were being served more effectively than before the implementation of a tele-ICU system.

The large range of hospital costs per bed reported by Kumar et al<sup>71</sup> stresses that each health care institution must do a careful cost-benefit analysis and should include vendors in the implementation process from the beginning. Many hospitals have demonstrated that a strong tele-ICU program can find payback in about a year, according to the New England Healthcare Institute (now the Network for Excellence in Health Innovation) in Cambridge, MA.<sup>36</sup> In another study, with 10,000 patients, Advanced ICU Care in St Louis, MO, achieved a 40% reduction of mortality and a 25% reduction of ICU LOS.<sup>73</sup> This finding concurred also with a study by Lilly et al<sup>74,75</sup> of 28,000 patients

across 8 states, supporting decreasing mortality and shorter LOS with increased cost savings for the hospitals implementing the tele-ICU programs.

Overall, hospitals have few research findings to help guide them when making a decision about whether to adopt and to use a tele-ICU program. The findings of this literature search suggest that the implementation of a centralized tele-ICU system can be cost-effective and can result in more efficient use of the hospital's ICU staff, improvement in the quality of care provided, and a financial positive impact by the reduction of ICU LOS.

There were several limitations of this study review. Many articles documented the benefits of tele-ICUs but contained limited data on the actual financial savings or cost of implementing a tele-ICU. Other articles had cost data about the savings but did not have data on how much ICUs were costing them before a tele-ICU implementation. In addition, the excessively high fees presented may be peculiar to the location and hospital size, and so may not be as large elsewhere. This study also was limited by restrictions in the search strategy used, and publication and researcher's bias may have limited the availability and quality of the research identified for review. Additionally, the review was limited to hospital organizations in the US, thus excluding many international providers of tele-ICU care.

The implication of this study is that the implementation of tele-ICU systems can be cost-effective and can improve patient outcomes. Future research should examine the results attributable to the implementation of a tele-ICU. A meta-analysis should be performed to have a more precise measurement of the effects (ie, cost and savings) of the implementation of a tele-ICU in practice. Other areas for study include how tele-ICUs affect different types of ICUs such as surgical vs nonsurgical ICUs, including tele-ICU vs a 24/7 in-house pulmonary model, and whether similar findings can be achieved in small and rural hospitals.

## Conclusion

Although mixed results were found in the literature in terms of cost savings, the findings suggest that the implementation of tele-ICU systems have the potential

to produce organizational change, with clinical and nonclinical ICU staff becoming more efficient and effective, and to decrease ICU LOS, hospital costs, and ICU mortality. ♦

## Disclosure Statement

The author(s) have no conflicts of interest to disclose.

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## Structure and Ability

The tasks assigned [to the physician] ... are determined primarily by the social and economic structure of society and by the technical and scientific means available to medicine at the time.

— *Medicine and Human Welfare*, Henry E Sigerist, 1891-1957, Swiss medical historian