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Impact of Tele-ICU Coverage on Patient Outcomes: A Systematic Review and Meta-Analysis

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Introduction

Staffing intensive care units (ICUs) with physicians specially trained in caring for critically ill patients (i.e., intensivists) is associated with improved survival. [1-3] Because many hospitals lack the patient volume or financial resources to justify hiring dedicated intensivists and because of a shortage of trained intensivists, hospitals are increasingly adopting tele-ICU coverage to compensate for a lack of on-site intensivist expertise.

Tele-ICU coverage typically utilizes a combination of technologies (i.e., videoconferencing, telemetry, electronic medical records) to allow off-site intensivists and/or critical care nurses to assist in the management of critically ill patients.[4] While robust evidence supports the benefits of on-site intensivist staffing, the impact of tele-ICU coverage is less clear. Thorough evaluation of the impact of tele-ICU coverage is important given that installation of these systems can cost hospitals millions of dollars in installation and ongoing maintenance expenses.[5]

Key Findings

- A systematic literature review and meta-analysis of 13 studies encompassing more than 41,000 patients indicated that tele-ICU coverage was associated with a significant reduction in both ICU mortality and length-of-stay (LOS) but did not significantly reduce in-hospital mortality or hospital LOS.
- These analyses also revealed a striking degree of variation in how tele-ICU coverage was defined, the hospitals where it was evaluated and the impact that tele-ICU coverage appeared to have.
- The results highlight the need for more rigorous evaluation of tele-ICU coverage.

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This Rural Health Brief summarizes the findings reported in the article, "Impact of Tele-ICU Coverage on Patient Outcomes: A Systematic Review and Meta-analysis" published in the *Archives of Internal Medicine*[6].

Tele-ICU coverage holds the potential to extend specialist services to hospitals and patients who otherwise would have limited access to intensivists and nurses certified in critical care. Rural hospitals are particularly vulnerable to the shortage of critical care specialists. As a result, patients, their families, and their primary care providers often face a tradeoff: recover near home with fewer specialists, or risk transferring to an ICU, often a long distance away, with more critical care resources. Not only does tele-ICU hold the potential to better identify cases for transfer, but it also promises better care for those who remain. These analyses sought to determine whether this potential is supported by the research to date.

Accordingly, a systematic review and meta-analysis was conducted of the published and unpublished literature with the primary objective of examining the impact of tele-ICU coverage on both ICU and in-hospital mortality. A second objective was to evaluate the impact of these systems on ICU and in-hospital length of stay (LOS). Key hospital, ICU, and patient factors were examined as potential mediators and/or modifiers of the effectiveness of tele-ICU coverage.

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Methods

Study Inclusion Criteria and Outcome Measures

We conducted a systematic literature review in accordance with published guidelines.[7-8] For this review, tele-ICU coverage was defined as the application of telemedicine to hospital critical care units. This included any tele-communication system installed in the ICU to facilitate real-time access to critical care specialists (e.g., intensivists or critical care nurses) located elsewhere.

This definition covers a variety of tele-ICU models ranging from exclusively reactive systems, where tele-ICU staff was available via telecommunication technology on an as-needed consultative basis,[9] to the more commonly used proactive systems where patients were continuously monitored in real-time via videoconferencing, telemetry, and access to the electronic medical record. [10-11]

Data Sources and Search Strategy

A thorough search was conducted for relevant studies published between January 1, 1950, and September 30, 2010 using PubMed, CINAHL, Global Health, Web of Science, and Cochrane Library. The initial search yielded 721 articles.

A keyword search of abstracts and presentations from relevant major scientific conferences between 2006 and 2010 was conducted to identify unpublished studies. The keyword search yielded an additional 2,683 abstracts or presentations that were potentially relevant to our study.

Study Selection

Removal of duplicate reports resulted in the identification of 3,133 unique studies of potential relevance. A large number of studies (N=2,957) were eliminated as they did not pertain to tele-ICU coverage as defined above or did not report original research (e.g., case reports and commentaries).

The remaining 176 studies (59 articles and 117 abstracts) were considered potentially eligible and reviewed in-full. Studies were included if: 1) they evaluated tele-ICU coverage; 2) they reported ICU or in-hospital mortality in a manner that allowed us to abstract both the number of deaths and number of patients at-risk for death; and 3) they provided mortality data for an ICU under tele-ICU coverage and for a control. Ultimately, 13 studies that met the inclusion criteria were included in this analysis (Table 1).

Data Synthesis and Analysis

We examined four distinct study outcomes: ICU mortality, in-hospital mortality, ICU length of stay (LOS), and in-hospital LOS.

Table 1. Characteristics of Studies Included in Meta-Analysis of Tele-ICU Mortality and Length of Stay

Article	# ICUs	Data Presented at ICU-Level?	# Baseline ICU Patients	# Tele-ICU Patients	Authors Affiliated with Tele-ICU Vendor	Newcastle-Ottawa Quality Score
Breslow 2004	2	Yes	1,396	744	Yes	9
Howell 2008	3	No	700	4,647	*	6
Kohl 2007	1	Yes	189	2,622	*	5
Marcin 2004	1	Yes	116	47	*	7
McCambridge 2010	3	No	954	959	No	9
Morrison 2010	4	No	1,371	1,430	No	9
Norman 2009	1	Yes	356	477	Yes	5
Rosenfeld 2000	1	Yes	225	201	Yes	9
Shaffer 2005	6	No	6,205	3,954	Yes	4
Siek 2009	2	No	148	128	*	3
Thomas 2009	6	Yes	2,034	2,107	No	9
Van der Kloot 2009	1	Yes	1,277	2,012	Yes	5
Zawada 2009	4	No	696	6,379	No	6
Total:	35		15,667	25,707		

* = not reported

Findings

Data Synthesis and Analysis

A total of 13 studies encompassing 35 ICUs (9 medical, 8 surgical, 8 mixed, 7 other, and 3 not specified) from 27 hospitals were included in this study. [9-11, 12, 14, 15-19, 20-22] These studies included a total of 41,374 ICU patients (15,667 pre-intervention and 25,707 post-intervention).

There were notable differences in the settings where the studies were conducted and the manner in which remote monitoring was implemented. For example, of 35 individual ICUs examined in these 13 studies, 9 ICUs were within or affiliated with academic medical centers, 18 were in community hospitals, and studies for the remaining 8 ICUs did not report presence/absence of academic affiliation. Additionally, 16 ICUs were reported as open, 8 were either closed or mixed, and the remaining 11 were not categorized.

There were important differences in how tele-ICU monitoring was used. Thirteen ICUs received around-the-clock monitoring, 11 were monitored primarily during evenings and weekends, and one used remote monitoring on an “as needed” basis. The remaining ICUs did not report the hours for the tele-ICU monitoring.

Mortality

Twelve of the 13 studies encompassing 34 ICUs reported ICU mortality among 40,541 patients (15,311 pre-intervention and 25,230 post-intervention). Collectively, implementation of tele-ICU coverage was associated with a significant reduction in ICU mortality (pooled OR, 0.80; 95% CI, 0.66 to 0.97; p=0.025).

Table 2: Impact of Tele-ICU on Mortality

Study Subgroup	ICU Mortality Odds Ratio (95% CI)	Studies Included	Hospital Mortality Odds Ratio (95% CI)	Studies Included
Overall	0.80 (0.66, 0.97)	9-11, 12, 13, 15, 17-19, 20-22	0.82 (0.65, 1.03)	10-11, 12, 15-18, 20-22
Higher quality study	0.77 (0.58, 1.01)	9-11, 20-22	0.74 (0.60, 0.92)	10-11, 20-22
Lower quality study	0.84 (0.64, 1.10)	12, 13, 15, 17-19	0.92 (0.61, 1.37)	12, 15-18
Studies with vendor affiliation	0.79 (0.55, 1.15)	10, 17, 19, 20	0.77 (0.53, 1.13)	10, 16-17, 20
Studies without vendor affiliation	0.87 (0.70, 1.08)	11, 12, 21-22	0.98 (0.67, 1.43)	11, 12, 21-22

There were 10 studies encompassing 30 ICUs that reported data on in-hospital mortality among 32,575 patients (13,574 pre-intervention and 19,001 post-intervention). Pooled analysis revealed that tele-ICU monitoring was not associated with reduced hospital mortality for patients admitted to an ICU (pooled OR, 0.82; 95% CI, 0.65 to 1.03; P=0.081). (Table 2).

Length of Stay

Of the 13 studies included in our analysis, ICU LOS was reported for seven studies (18 ICUs) representing 14,395 patients and hospital LOS was examined in six studies (17 ICUs) representing 14,232 patients. Implementation of tele-ICU coverage was associated with a significant reduction in ICU LOS (mean reduction of 1.26 days; 95% CI, -2.21 to –0.30 days; P=0.01), but was not associated with a significant reduction in hospital LOS (mean reduction of 0.64 days; 95% CI, -1.52 to +0.25 days; P=0.16).

Conclusion

A number of findings merit further discussion. First, tele-ICU care was associated with a significant reduction in ICU mortality, but not in-hospital mortality. Tele-ICU care is typically a multifaceted intervention that includes upgrades to electronic health records (EHRs), enhanced quality improvement programs, and monitoring of patients by off-site intensivists with a focus on the patients, staff, and technology of the ICU.

Thus, it is possible that tele-ICU care might reduce the mortality for ICU patients while the patients are in the ICU, but that this benefit could be eroded once patients are transferred to the floor.

It is also possible that a portion or all of the reduction in mortality observed with tele-ICU care results from changes in triage and medical decision making and thus the severity and acuity of the patients that were treated in the ICU before and after tele-ICU implementation. In particular, implementation of tele-ICU care may lead to changes in decision making about which patients should and should not be admitted to the ICU in the first place. Specifically, tele-ICU care may lead to more judicious decisions about which patients are likely to benefit from ICU admission and which patients should immediately be made palliative. Finally, the statistically significant reduction in ICU mortality but not in-hospital mortality may reflect the fact that more studies reported ICU mortality than in-hospital mortality.

It is also important to consider the finding that tele-ICU care was associated with a 1.2 day reduction in ICU LOS but no reduction in hospital LOS. In particular, if this addition of tele-ICU care leads to more consistent attempts at ventilator weaning, this might reduce both ICU LOS and ventilator days. If the availability of 24-7 intensivist oversight leads to a greater willingness to transfer patients out of the ICU on weekends and evenings, this too could contribute to reductions in ICU LOS.

Third, the benefit of tele-ICU on both mortality and LOS appeared moderately greater in studies that were published by authors associated with tele-ICU vendors such as VISICU. While these interaction effects were not statistically significant, the point estimates alone are cause for concern and highlight the importance of independent research. Future studies involving tele-ICU should consistently disclose potential financial conflicts of interest and funding sources.

Fourth, it is necessary to point out the high degree of heterogeneity in the studies included in this analysis. Specifically these analyses included evaluations of tele-ICU coverage that were implemented in both open and closed ICUs despite evidence that closed ICUs with dedicated intensivist staffing typically have much better outcomes. Additionally the current analysis incorporated few studies that presented data on important confounders (i.e., baseline ICU mortality, patient severity, underlying diagnosis) in a consistent and transparent enough way to allow for more detailed analyses at the ICU level. The heterogeneity observed in the design of the underlying studies included in this analysis contributed to the wide confidence intervals for all four of the study endpoints (ICU and in-hospital mortality and ICU and in-hospital LOS).

The implications of this analysis for rural veterans are unclear. With tele-ICU coverage, patients are more likely to survive the ICU, but the hospital mortality data allow for the possibility of dying patients being identified more efficiently and being moved quickly out of critical care. Alternatively, additional data may confirm that the reduction in ICU mortality carries through to an overall reduction in hospital mortality. In 2011, ICUs in VISN-23 will receive tele-ICU, providing the opportunity for a natural experiment to directly compare risk-adjusted mortality between rural and urban medical centers.

In conclusion, while tele-ICU coverage was associated with significant reductions in ICU mortality and LOS, we found no improvement in hospital mortality or hospital LOS. Several factors likely to mediate the effectiveness of tele-ICU coverage were identified but there exists little definitive data as to which patients, ICUs and hospitals are most likely to benefit from this technology. Given the significant resources required for tele-ICU implementation, further evaluation is clearly needed.

Impact

- Tele-ICU coverage is very expensive, but holds the potential to extend resources to rural hospitals with limited access to critical care specialists.
- Tele-ICU coverage reduces ICU mortality and length-of-stay, but the hospital-level data do not indicate whether more patients are surviving or whether triage is simply more efficient.
- The pending implementation of tele-ICU in VISN-23 promises adequate data to determine the conditions under which tele-ICU is most effective.

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