

# Tele-ICU: Experience To Date

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## Abstract

Tele-intensive care unit (ICU) is a care provided to critically ill patients by off-site clinicians using audio, video, and electronic links to leverage technical, informational, and clinical resources. Providing care includes the ability to detect patient's instability or laboratory abnormalities in real-time, collect additional clinical information from or about the patient, order diagnostic testing, make diagnoses, implement treatment, render other forms of intensive care such as managing life-support devices, and communicate with patients and bedside providers. This review summarizes how tele-ICU services are delivered, the alternative approaches that have been used, and summarizes published reports of its effects on patient-focused outcomes. Tele-ICU is thought to have great promise to support critically ill adults.

## Keywords

telemedicine, critical care, adult, monitoring, health information system

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Telemedicine is defined as the practice of medicine when the doctor and patient are widely separated using a 2-way voice and visual communication (as by satellite or computer).<sup>1</sup> It follows that tele-ICU is a care provided to critically ill patients by off-site clinicians using audio, video, and electronic links to leverage technical, informational, and clinical resources. Tele-ICU care includes the ability to detect patient's instability or laboratory abnormalities in real-time, collect additional clinical information from or about the patient, order diagnostic testing, make diagnoses, implement treatment, render other forms of intensive care such as managing life-support devices, and communicate with patients and bedside providers. The application of telecommunications technology to the intensive care setting has been evolving over a surprisingly long interval in parallel with advances in the extent and detail of clinical information that can be effectively communicated. Advances in the application of tele-ICU tools to intensive care medicine have been closely linked to advances in the supporting technologies. Models that relied on bedside provider descriptions of patient information to off-site clinicians<sup>2</sup> or pager notification of bedside alarms have been supplanted by systems that collect, organize, and analyze patient-derived information and alert off-site providers of nascent problems and abnormal laboratory findings.<sup>3</sup> Not surprisingly, the commercial availability of tele-ICU systems has been associated with a rapid increase in the number of patients being supported using this technology. In 2009, there are approximately 4900 US adult ICU beds being supported by comprehensive or high availability tele-ICU programs and more than 1 million patients have been monitored by these programs. A smaller number of

patients are being supported by episodically available programs using webcams or robots (Figure 1).

## The Evolution of Tele-ICU

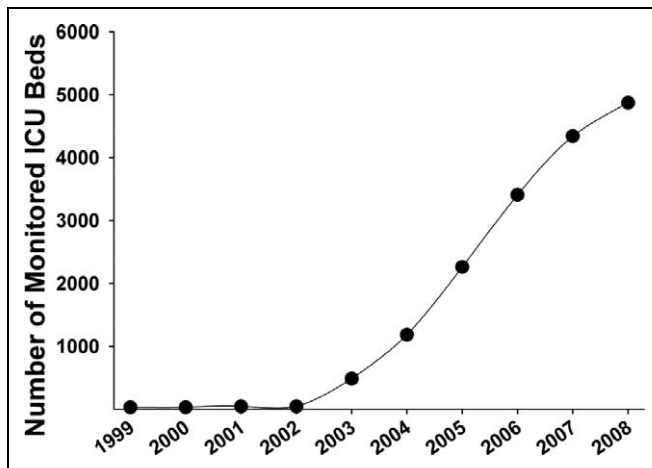
The concept of tele-ICU has evolved overtime and has a number of alternative forms. Tele-ICU systems described in the 1970s video-linked on-site providers with off-site consultants in a manner that did not provide direct access to patients or bedside monitor information.<sup>2,4</sup> One recent approach involves video-cam access to patients without a dedicated off-site monitoring team. This approach often does not involve continuous monitoring but episodic access at the discretion of a provider. This "episodically available" approach using secure web-based audio and video access to providers relies primarily on bedside providers to detect the patient's needs rather than on system-generated alerts. These systems can work well to

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**Figure 1.** Growth in the number of beds monitored by a tele-ICU technology. Most tele-ICU programs serve 100 to 200 patients with a range of 50 to 400 patients for comprehensive programs.

extend the reach of bedside providers who are away from the ICU but are expected to be less efficient for detecting evolving physiological instability compared to comprehensive high availability systems with continuous oversight and alerting functions. Another approach that is rapidly expanding involves robotic devices that can move from patient to patient. These systems have the advantage of lower equipment costs per patient but can be limited by wireless connectivity issues and often have a lower profile for obtaining video images than wall-mounted cameras. This approach has been helpful for allowing more team members to be “on rounds” when space is limited because several providers or learners can observe rounds through the robot from a conference room or even from an off-unit location. Tele-ICU programs using remote monitoring by critical care specialists have now spread across the globe.<sup>5,6</sup>

### **Comprehensive “High Availability” Tele-ICU Programs**

The most frequently adopted approach focuses on providing supplemental critical care expertise when and where it is needed. Comprehensive programs monitor patients from a dedicated off-site center using tele-ICU workstations. These workstations have several functions including the efficient display of clinical information, the reporting of changes in signals from bedside physiological monitors that indicate instability, alerts for abnormal laboratory values, audio and video links to patients and their bedside caregivers, and tools that allow off-site ICU team members to create patient care notes and provider orders. The layout of the workstations and the processes by which information is acquired have important implications for how efficiently and effectively patients can be evaluated and monitored.<sup>7</sup> It is thought that the electronic capture of accurate clinical information is a key element contributing to the benefits that this technology brings to patients, providers, and payers.

### **Off-Site Support Team—Clinical Staff**

The off-site support center is staffed by a team including both clinical and nonclinical members. The Clinical Support Team includes at least one physician that specializes in critical care, as well as ICU-qualified nurses or affiliate practitioners and, in some programs, an ICU pharmacist. The off-site Clinical Support Team has primary functions that can be divided into 2 main categories. The first category involves the detection and response to evolving physiological instability. The tone and processes of communication with bedside providers including the physician-of-record are major determinants of how effectively episodes of instability can be resolved to the satisfaction of all. The early detection and effective resolution of evolving physiological instability are thought to be a major driver of improved severity-adjusted mortality. The second category involves screening the monitored patients for preventable events and adherence to best practice guidelines and reconciling discrepancies between actual and best practice. Improved detection and action on preventive opportunities is thought to be an important driver of improved cost structure when improved adherence to preventive practices lowers the rates of preventable complications and their associated costs. The ability of this technology to allow one clinician to follow many more patients than is possible from the bedside allows comprehensive tele-ICU programs to provide real-time oversight for populations of critically ill patients. Program integration allows patient-level care to be supplemented by population-level management tools and a means to provide meaningful benchmarks of program performance. The efficiency of the team is directly related to the time and expertise required to detect and to work with bedside providers to reconcile care improvement opportunities.

The focus is on 2-way communication with both a bedside and an off-site clinical support team vigilant of and responding to patient needs. How this off-site clinical support team interacts with bedside providers can influence program satisfaction and acceptance. There is no single approach that will result in optimal leveraging of tele-ICU resources for every ICU community, but there are important lessons from focus-of-change and self-efficacy theory that appear to be relevant.<sup>8,9</sup> One approach to integration is to have the same individuals that work at the bedside also provide the off-site support. Most comprehensive tele-ICU programs have found that including seasoned and respected bedside nurses in the support center facilitates acceptance and more effective usage of tele-ICU resources by bedside nurses. Programs that have not been well accepted or have closed have provided support, at least in part, with clinicians still in training programs or off-site intensivists that were not from the community of bedside providers. Another model, which is designed for areas where intensivist care is in short supply, exclusively provides off-site services and leverages access to specialist critical care physicians to drive acceptance by bedside clinicians. Program introduction that includes meaningful input from current program insiders and their active participation in the governance of the program

**Table 1.** Tele-ICU Interventions

Intervention group	Intervention type	Number of interventions (%)
Clinically significant <sup>a</sup>		6468 (57%)
	Best practice adherence	1625 (14%)
	Comprehensive admission reviews	1134 (10%)
	Response to physiological instability	760 (7%)
	Alteration of mechanical ventilation	723 (6%)
	Intervention to prevent instability	679 (6%)
	Other alteration of diagnosis or care plan	570 (5%)
	Sensitivity targeted alteration of antimicrobial coverage	556 (5%)
	Medication administration-related	203 (2%)
	Allergy-related	149 (1%)
	Directly life saving	69 (0.6%)
Communication based		4848 (43%)
	Educational	1531 (14%)
	Communication with bedside physician	1247 (11%)
	Communication with bedside nurses	906 (8%)
	Technical or system issues	604 (5%)
Communication with referring provider	560 (5%)	
All interventions		11 316 (100%)

<sup>a</sup> Interventions were considered clinically significant when they altered the care plan.

is thought to be important for brokering impactful change. While reported experience remains limited, it appears that a careful consideration of local factors and a thoughtful approach to integration lead to greater program impact that occurs earlier. Because the effect of tele-ICU on medicolegal risk has not yet been defined at the level of case law, assessments in this area have been derived from legal opinion from those with insurance and risk management experience. Current opinions tend toward reduced risk. This has been ascribed to shorter times to recognition and response of patient instability, more comprehensive documentation of critical events, and better documentation of concordance among providers with regard to the care plan.<sup>10</sup>

The primary function of off-site clinical providers is to intervene for the benefit of patients. They also function to provide information, reassurance, and education. To better understand tele-ICU transactions, we recorded 400 events that were directly observed. A review of the descriptions of these transactions revealed that nearly all interactions not focused on technical issues could be classified either as involving the sharing of information or as discussing alterations in the care plan.

Transactions involving communication were parsed based on the recipient of the information, and transactions affecting care were classified as “clinically significant interventions” even when they also included information sharing or education. Based on these initial observations, we developed an electronic tool to record the number and types of interventions that occurred in the tele-ICU support center of a large tertiary referral academic medical center. Using this tool, 11 316 interventions were recorded over 6 months of observation (Table 1). Eighty percent of these interventions occurred at times when the ICU team was not on the unit and 20% occurred at times when the bedside team was on the unit but was focused on other patients at the time the instability was recognized by off-site team members.

The recording of tele-ICU interventions has provided new insights into the nature of the opportunities made possible by more vigilant systems and supplemental resources. Interventions involve the ordering of medications, diagnostic tests, and therapeutic interventions such as managing mechanical ventilation or dialysis. It is worth emphasizing that current approaches are not a substitute for bedside providers. Bedside providers are essential because not all interventions that are necessary can be performed remotely; examples include the administration of medications, placement of endotracheal tubes, performance of procedures, and movement or manipulation of the patient.

One key issue involves what clinical information will be available to clinicians providing both bedside and off-site support. The quality of the off-site support depends, in part, on how clinical information is captured and how it is prioritized, displayed, shared among caregivers, and acted on. There was a fundamental trade-off made at the time that many of the currently available clinical information systems were being designed. The essence of this trade-off is that it can take less time and effort to record a minimal amount of clinical information or more time and effort to record information that is accurate and complete enough to be useful for managing patients. These trade-offs are also part of how tele-ICU systems are integrated into existing ICU work flows. In the context of tele-ICU implementation, approaches to this trade-off can be summarized in 3 alternative paradigms of data acquisition. (1) Bedside providers document in a paper system, and the resulting output is translated (eg, via FAX) into the tele-ICU system. (2) The bedside provider documents in an electronic system other than the tele-ICU system, and the documentation is interfaced into the tele-ICU system. (3) Bedside providers document directly into the tele-ICU system. These alternative approaches have stepwise differences in transcriptional errors, completeness of information, and clarity of the intent of the care plan to off-site providers that have important implications for how efficiently the information can be used to assess and respond to unstable patients.

In addition to the efficiency of the tele-ICU system for detecting and responding to patient needs, the operational costs of the system depend largely on staffing intensity. In staffing models where off-site intensivist support is strictly supplemental to that of bedside providers, some centers have elected not to have an intensivist present in the off-site center when the

bedside providers are present on the unit. The availability of the off-site team to take sign-out at a time that is convenient for the bedside team also appears to be of value. There is little comparative data regarding optimal staffing models.

The introduction of many comprehensive tele-ICU programs has accompanied the introduction of electronic documentation for bedside provider services. Critical care documentation software can be leveraged to better capture critical care services and time spent serving critically ill patients. Bedside provider charges have been reported to increase by 31% before and after the introduction of one tele-ICU program,<sup>11</sup> and in another program the percentage of surgical ICU encounters that could support first-hour critical care billing increased from 55% to 77% and the actual number of these charges increased by 71%.<sup>12</sup>

There are also potential educational benefits for residents' and fellows' training in adult ICUs supported by off-site intensivists. The immediate availability of an awake critical care specialist who has full electronic access to the patient records, studies, laboratory values, bedside monitor information, and real-time visual images of the patient has been perceived by residents to enhance training and improve patient care.<sup>13</sup> The inclusion of tele-ICU experience in a fellowship program was perceived as valuable, and those surveyed would prefer working in an ICU with tele-ICU support.<sup>14</sup>

### *Off-Site Support Team—Nonclinical Staff*

Maximizing the effectiveness of tele-ICU nonclinical staff is one method of controlling the operational costs and is an important aspect of bedside provider acceptance of a tele-ICU intervention. One of the important benefits of a comprehensive tele-ICU program is access to performance, process, and outcomes data that are benchmarked to other similar units or centers. The integrity of data collection depends on the timely and accurate recording of ICU admissions and discharges. Discussions at conferences and meetings among clinical, operational, technical, and executive leaders of tele-ICU programs have led to several practical observations that we included based on their potential usefulness (personal communication—William Hanson, M.D, Robert Groves, M.D). Virtually, all programs have found that well-trained, service-oriented clerical personnel are essential. The nature of current electronic systems that interact through interfaces with other hospital information systems makes information system's technical support an important part of a successful program. Most programs have found that bedside providers have a low tolerance for technical issues such as difficulty accessing the system, system downtime, and unexpected service interruptions. Program acceptance by bedside providers is greatly enhanced by information system support that can support real-time over the phone resolution of system access issues and can achieve a greater than 99.97% uptime characteristic.

### *Tele-ICU Workstations*

Early tele-ICU systems displayed patient information on a single screen, and this is often the case for episodic programs that

allow clinicians secure web-based video access from personal computers and the attendant freedom of the site of access. Programs providing continuous off-site support now use dedicated workstations equipped with multiple screens supported by processors that can simultaneously display information from several different applications or health information systems. This approach enables the simultaneous display of the same physiological signals from bedside monitors, laboratory, radiographic, flow sheet, and provider note information that is available at the bedside. The ability of both groups of providers to use the same information in a similar format is thought to be important for increasing concordance of opinion regarding patient care plans. The number of separate systems that must be accessed to display all the data for a single patient will determine the number of software sessions that must be run to support the displays. This makes switching among patients supported by different hospital information systems more complex. Off-site support center personnel that can do this efficiently can support more monitored beds. The limits to the number of beds that can be monitored depend on several factors including how clinical information is organized and displayed, the skill of the provider team, the ability to leverage each other's resources, the accuracy of the information available in the system, and the quality of bedside provider to off-site team sign-out.

### *Program Integration and Acceptance*

Integration and acceptance of a tele-ICU program appears to be greater when the monitored units have established standards for sign-out, collaborative rounding models, and agreement on standard best practice approaches to the management of common issues (eg, sepsis bundles). The ability of the off-site and bedside team members to cooperate and communicate with each other is central to both efficiency and acceptance. The nature of the relationship between integration of the bedside and off-site providers to program outcomes is an area of active research interest. Social learning theory<sup>9</sup> predicts that program introduction that includes bedside providers will be better accepted than approaches that are perceived as coming from outside the group of providers.<sup>15</sup> There are several ways to measure the integration of the off-site providers including the presence and form of patient sign-out at the time that bedside providers leave the hospital, the types of interventions that the off-site team is allowed to make when the bedside team is not available, the level of decision making authority assigned to off-site providers, the methods of review of after-hours admissions, and whether the off-site clinical staff also work at the bedside. Increased partnership has been reported to correlate with better adherence to best practice guidelines for the prevention of venous thrombosis and improved glycemic control.<sup>16</sup> Increased partnership has also been associated with larger reductions in days of mechanical ventilation in a study where acceptance of off-site support varied across hospitals supported by the same tele-ICU program.<sup>17</sup>

## Program Impact on Outcomes

The keystone issue for tele-ICU programs is the nature and extent of the value that they bring to the patients they serve and the institutions that implement them. It is evident from the well-established principals of care improvement<sup>18</sup> that it is not the electronic equipment but how it is used to change processes of care that determine program impact on outcomes. The effects of implementing a tele-ICU program are of particular interest because using the introduction of this technology to reengineer care processes has the ability to simultaneously improve mortality and reduce cost. There are 2 reported methods for assessing program outcomes. The more rigorous is to measure the effects of introducing a tele-ICU program to compare acuity-adjusted hospital and ICU mortality (standardized mortality ratios) or length of stay before and after the introduction of the program. The less rigorous approach is to compare postimplementation standardized ratios overtime or to those of a reference population.

To date, many of the reports of program outcomes have appeared in abstract form with relatively few appearing in peer-reviewed literature. The field of tele-ICU was advanced by 2 seminal studies published in the peer-reviewed critical care literature. The first study performed in a single, 10-bed community hospital found that a surgery/trauma ICU reported a 45% reduction in severity-adjusted ICU mortality, 30% reductions in hospital mortality and length of stay, and a 16% reduction in cost.<sup>3</sup> A follow-up study in 2 Sentara Health Care System ICUs reported significant reductions in ICU (odds ratio [OR] 0.72, 95% confidence interval [CI] 0.55-0.95;  $P < .05$ ) and hospital mortality, a 16% reduction in ICU length of stay, and a 25% reduction in variable costs per case.<sup>33</sup> These studies have been followed by a before and after study performed in a surgical ICU of an academic medical center reporting a 5% absolute reduction in actual hospital mortality that was statically significant before and after acuity adjustment.<sup>19</sup> Intensive care unit and hospital length of stay were also significantly reduced with a clinically meaningful reduction in median length of hospital stay of 1.8 days with financial benefits that exceeded program costs.<sup>20</sup> A progressive reduction in both hospital and ICU standardized mortality rates was reported by a program from a 7-hospital system that covers 84 ICU beds that performed a before and after study. The ICU-standardized mortality rate went from 1.0 to 0.68, and the hospital rate went from 0.95 to 0.77. The standardized rate for hospital length of stay went from 1.09 to 0.84 and the ICU rate went from 1.18 to 0.96.<sup>21</sup> These changes were clinically and financially important and statistically significant in appropriate nonparametric analyses. Clinically significant and financially meaningful reductions in length of stay of 47% have been reported for a tertiary community teaching hospital and 35% for 3 supported rural hospitals.<sup>22</sup> Another study of tele-ICU support for a community hospital reported reduced mortality and a 17% reduction in length of stay.<sup>23</sup>

Tele-ICU programs have also reported the ability to support interventions targeted to specific groups of patients. Significant reductions in mortality of patients with an Acute Physiology

and Chronic Health Evaluation (APACHE) admission diagnosis of sepsis were reported when remote providers facilitated the use of a system-wide best practices bundle for the management of patients with sepsis.<sup>24</sup> Integration of a tele-ICU team into the management work flow of patients with sepsis was reported to improve adherence to all protocol elements in a single-center<sup>25</sup> and multi-center study of 8 hospitals.<sup>26</sup> Tele-ICU monitoring and reporting have enabled the improvement of adherence to best practice guidelines to near perfect levels for pneumonia, deep venous thrombosis, and stress ulcer prevention<sup>27</sup> and facilitated more modest improvements in glycemic control.<sup>28</sup> A parallel group study found adherence to best practice guidelines for the prevention of venous thrombosis in a monitored cohort of 202 patients at risk (95%;  $P < .0001$ ) was significantly better than in an unmonitored group of 220 patients (75% adherence).<sup>29</sup>

Several studies have focused on identifying the mechanisms or aspects of the interventions that can account for improved outcomes. A study of the frequency of cardiorespiratory arrests from a health system on the east coast of Florida reported significant reductions with OR (0.61, 95% CI 0.47-0.79) in arrests per patient per day after a tele-ICU intervention.<sup>30</sup> This suggests that early detection of physiological instability and intervention can reduce cardiorespiratory arrests and increase survival rates. In rural hospitals where intensivists resources were described as scarce, ICUs with more tele-ICU authority for case management had better observed to predicted postprogram implementation ratios than tele-ICU supported ICUs that limited off-site interventions.<sup>31</sup>

To provide a more complete picture of what is known about tele-ICU, we have attempted to include information from evolving studies or “gray” literature that is not represented in published reports including those with unfavorable results. This discussion is limited to comments on evolving knowledge in the field and not as rigorous methodological presentation or meta-analysis. At the time of this review, we identified 26 ICUs that have performed before and after outcome studies. Of these ICUs, 12 were described as tertiary referral hospitals, 11 as community hospitals, and 3 as rural or regional hospitals. Standardized mortality rates are calculated for each ICU using APACHE III or APACHE III-J acuity scores to derive mortality and length-of-stay predictions. A percentage change was calculated using the equation pre-post/pre  $\times 100$ . These studies include 4874 pre-tele-ICU patients and 23 555 tele-ICU intervention patients for a total of 28 429 patients. The distribution of changes in standardized hospital mortality and ICU length-of-stay ratios is presented in Table 2. Analyses of mortality benefit by strata of APACHE III predicted mortality risk have suggested that improved mortality for ICUs with higher standardized mortality rates before the implementation of a tele-ICU program tends to come relatively proportionally from all severity strata while improvements for ICUs with low severity-adjusted mortality tend to come disproportionately from low-risk strata patients.

These studies also report significant improvements in APACHE III adjusted length of stay. Improved length of stay

**Table 2.** Number of ICUs in strata of observed to APACHE III predicted outcome.

Outcome	Strata of percentage (pre-post/pre)	Number of ICUs
Hospital SMR	SMR increased > 10%	3
	SMR unchanged or increased by 10% or less	2
	SMR up to 10% lower	2
	SMR > 10% and up to 20% lower	7
	SMR > 20% and up to 30% lower	2
	SMR > 30% and up to 40% lower	3
	SMR > 40% lower	7
ICU-LOS ratio <sup>a</sup>	LOS Unchanged or increased by 10% or less	3
	LOS up to 10% lower	2
	LOS > 10% and up to 20% lower	6
	LOS > 20% and up to 30% lower	6
	LOS > 30% and up to 40% lower	6
	LOS > 40% lower	3
Total ICUs		26

NOTES: APACHE = Acute Physiology and Chronic Health Evaluation; ICU = intensive care unit; SMR = standardized mortality ratio; LOS = length of stay. <sup>a</sup> ICU-LOS ratio is the standardized ICU length of stay ratio; actual value over APACHE III predicted value.

was detected in 23 of 26 or 88% of tele-ICU intervention studies. On average, a 23% reduction in length of stay was observed with a range of 49% shorter to 4% longer. There is a consistency of experience among these studies associating improved mortality and length-of-stay metrics with tele-ICU-associated reengineering of critical care processes. However, it is also clear that the introduction of a tele-ICU program does not have mortality or length-of-stay benefits for every patient in every ICU.<sup>32</sup> One of the most important questions for the field of tele-ICU medicine is to understand why most programs see benefits and others do not. One hypothesis is that the degree of benefit is related to the extent to which program acceptance leads to durable change in the processes of care delivery.

## Summary

Maturation of supporting technologies has fostered rapid growth in the number of patients supported by tele-ICU programs. There has been substantial variation in program structure with significant differences among programs including whether patients are continuously or episodically monitored. The advent of hospital information systems that support tele-ICU functions has led to more robust off-site support for critically ill patients. There are an increasing number of studies of the effects of using the implementation of comprehensive tele-ICU programs to reengineer critical care delivery. As a group, these studies report substantial improvements in mortality and lower costs, but improvements are not universal and many of

the studies have yet to be published in peer-reviewed journals. The reasons why most tele-ICU programs derive improvements and some do not are important questions for the field of tele-ICU medicine.

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## Declaration of Conflicting Interest

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