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Telemedicine for Trauma and Emergency: the eICU

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Abstract
Purpose of Review The purpose of this study was to describe the current use of telemedicine in the intensive care units (ICUs), particularly as it relates to trauma and emergency.
Recent Findings Telemedicine in the ICU has been validated through several large before-after studies with positive effects on mortality, morbidity, and length of stay. New research agendas looking at how best to utilize it and to prove efficacy are required.
Summary The USA and most of the Western world face several major healthcare challenges including an aging population, lack of critical care physicians, and importantly a lack of financial resources. Telemedicine in the ICU makes possible to use intensivists from major medical centers to provide critical care services in small hospitals in remote areas that otherwise will not be able to care for their sick and injured patients.

Keywords Telemedicine · eICU · Patient safety · Trauma · Emergency

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Introduction

The US healthcare system, like many other international healthcare systems, faces significant challenges in the coming years. The first challenge is an ever-increasing aging population that will need critical resources and professionals at much higher rates than seen in previous years. The percentage of the population older than 65 years will increase by 50 % by 2020 and 100 % by 2030 [1]. This has troubling consequences for critical care, given that as patients age their need for critical care resources increases exponentially, with a transition point above 64 years of age [2]. This is particularly important in trauma as injury is now the seventh leading cause of death for individuals 65 years of age and over [3].

The second challenge is a lack of critical care professionals, particularly critical care physicians. Evidence of this shortage is found in the original Committee on Manpower for Pulmonary and Critical Care Societies (COMPACCS) study, in which only one out of every three intensive care unit (ICU) patients received care from a dedicated intensivist [4, 5]. When looking at the supply of critical care physicians, one finds that many trainees simply lack interest in critical care, an important data point for the future [6, 7]. The most common reasons cited are lack of personal and family time and stress among faculty. Furthermore, many practicing critical care physicians seek early retirement or face burnout, leading to shorter careers and further truncating the supply of intensivists [8]. Exacerbating this supply/demand mismatch is the uneven geographical distribution of healthcare professionals relative to our elderly population [3]. Healthcare professionals are clustered in major metropolitan areas. However, a recent troubling statistic shows that the elderly population, which is in most need of trauma and highly specialized ICU resources, is growing disproportionately in underserved rural areas [9]. To make things worse, many of these elderly patients are triaged to lower level or non-trauma centers without specific geriatric protocols or order sets [10•].

Compounding all of this, the US government has a high ratio of debt to gross domestic product, placing increasing restraints on financial resources. Healthcare in the USA, including critical care, is the most expensive in the world. In 2005, critical care costs in the USA were estimated at $81.7 billion per year. This represents 0.66 % of the gross domestic product, more than 10 % of hospital costs, and approximately 4 % of national healthcare expenditures [11].

The Origin of Telemedicine

Telemedicine is defined at that time as “applying the use of modern information and communications technologies for the delivery of health services” [12]. Its name is derived from the Latin word “medicus” and the Greek “tele” literally meaning to “heal at a distance.” Telemedicine has now been transformed into an integrated system of two-way audio and video capabilities often combined with prediction analytics and auditing systems to help healthcare professionals treat patients at a distance in nearly all specialties, not just in the ICU.

The most common types of tele-ICUs exist in centers that house healthcare professionals and provide continuous monitoring as well as the ability to audit best practices, intervene when patients experience physiological instability, identify early deterioration in syndromes like sepsis, and serve as a “second set of eyes” in the treatment of critically ill patients. This remote monitoring can be done in a 24/7 fashion or just at nights/weekends when fewer staff are available. The nighttime support is particularly important to preserve our limited number of critical care physicians and nurses as night work has been highly correlated with burnout [8].

Growth of Telemedicine in the ICU

The modern tele-ICU (i.e., the 24/7 continuous monitoring center), which we so commonly think of today, is a phenomenon of the first decade of this century. This was an explosive period for growth of tele-ICUs, which increased in number by a factor of 10 and came to occupy approximately 4 % of all hospitals in the USA [13•]. Importantly, this increase had little geographic variation, with all parts of the USA experiencing growth. When looking at common unifying themes in hospitals adopting tele-ICUs, most of the hospitals were medium size (100 to 400 beds) and 91 % were not-for-profit [13•].

To help explain and understand the growth of telemedicine in the ICU, many have made the argument to apply Roger’s model of diffusion of innovation (Fig. 1) [13•]. Roger’s model is a hallmark of any marketing class in business school since it was first published in 1962 [14]. It is typically used to describe

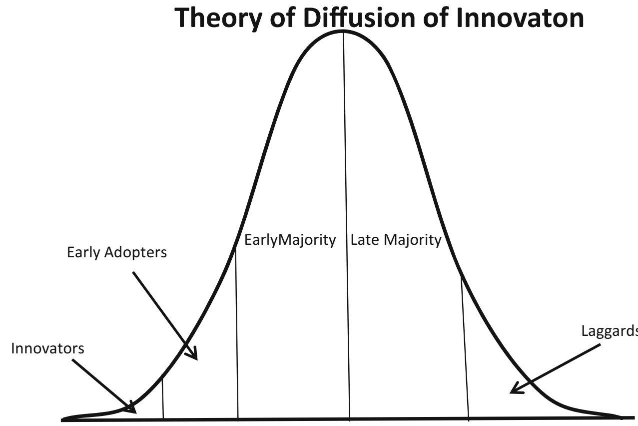

Fig. 1 Theory of the diffusion of innovation

the phases that a typical technology or product passes through as it finds its ultimate role in society. There is however, some argument as to where telemedicine in the ICU or telemedicine overall lies along this curve [13•]. Most would reason that telemedicine in the ICU today has moved beyond the *Early Adopter* phase and is currently positioned somewhere in the larger *Early Majority* segment of this curve.

Data Regarding Telemedicine in the ICU

It is now widely recognized that a high-intensity staffing model, as recommended by the Leapfrog group in 2000, is associated with improvements in ICU quality and reductions in patient mortality [15•]. This was seen recently in a meta-analysis of 52 studies analyzing high-intensity versus low-intensity staffing models. In 34 of the studies, mortality was significantly lower in the high-intensity group (risk ratio = 0.83; 95 % confidence interval [CI] 0.70–0.99) [15•]. Further, another meta-analysis has yielded similar results associated with high-intensity staffing models (risk ratio = 0.71; 95 % CI, 0.62–0.82) [16]. However, studies of nighttime intensivists have reported mixed results, potentially helping in low-intensity (resource-poor) units and without this same effect in high-intensity (resource-rich) units [17, 18]. Importantly, none of these studies looked directly at the effect of telemedicine in the ICU and none specifically examined the effect in a community setting where tele-ICUs are most commonly implemented.

The most promising study to look at the effect of a tele-ICU is a before-after study from the University of Massachusetts published in 2011 [19]. This single-center trial was specifically powered to detect a 3.5 % improvement in mortality. The novel aspect of this study was that it focused on care processes after implementation of telemedicine in the ICU. Limitations of this study included that it was a single-center investigation and was not blinded. After implementation of the tele-ICU, mortality in the ICU decreased from 10.7 to 8.6 %, with an odds ratio of 0.37 (95 % CI, 0.28–0.49; $P = 0.003$). The average ICU length of stay was also reduced by approximately 2 days ($P < 0.001$). The authors suggested that these results were due to a coalescence of factors such as improvements in best practice compliance, alerting mechanisms, predictive analytics, and the eICU serving as a "second set of eyes." Importantly, these improvements in care were independent of time of day: similar benefits were noted in patients admitted during the day with the academic team present as well as in patients admitted after hours.

In a larger before and after implementing tele-ICUs study, these same authors analyzed 118,990 ICU patients across 56 ICUs, 32 hospitals, and 19 US healthcare systems [20•]. Many of the same results were found as in the single-center trial, with significant reductions in ICU mortality (hazard ratio = 0.74, 95 % CI, 0.68–0.79; $P < 0.01$) and reductions in length of stay of approximately one ICU day. In addition, there seemed to be a dose-dependent effect of the tele-ICU, with longer-stay patients benefitting the most from tele-ICU involvement. However, the most important findings of the study were the specific care processes affected by tele-ICUs that were most strongly associated with improved outcomes (Table 1). Importantly, but perhaps not surprisingly, many of these revolve around data review, collaboration, and communication, key components of tele-ICU programs. These should serve as a road map and guide for the successful implementation of a tele-ICU.

A more recent study of tele-ICUs was again an observational before/after study looking at the effects of implementing a tele-ICU across eight separate ICUs in the Veteran Affairs Health System [21•]. There were a variety of ICUs monitored, ranging from medical to surgical to mixed medical-surgical units. On matching these tele-ICUs to controls, there was no significant difference in ICU, hospital, or 30-day mortality or length of stay. When examining this study with a discerning eye, one finds several questionable details:

- Many of the patients in either arm of the study were not mechanically ventilated.
- Severity of illness scores for individual patients was low, in both the control and intervention groups, making it difficult to show the impact of the tele-ICU.
- Mortality rates in both groups were very low, making it difficult to distinguish a difference.

Table 1 Specific care processes affected by tele-ICUs most strongly associated with improved outcomes

1. ICU physicians reviewing the care plan within 1 h of admission
2. Collaborative and frequent review of performance data
3. Increases in adherence of best practices after implementation
4. Shortened response times to laboratory alerts and alarms for physiological instability
5. The performance of interdisciplinary rounds
6. The presence of an effective ICU committee

At this point, the literature has been mixed in regard to outcomes associated with tele-ICU use, although multiple, well-conducted studies have shown improved outcomes while others have revealed little benefit. Furthermore, the implementation of tele-ICUs can entail multiple barriers, including cultural, financial, and organizational factors which vary between different implementation scenarios and thus can be difficult to study. What is needed now in the literature is to shift our thinking on tele-ICU from studies trying to prove efficacy to instead studying what locations and processes make it work the best.

Keys to Success

Nursing Acceptance

To implement and maintain a tele-ICU program, it is of utmost importance to understand local—that is, institutional—culture, care preferences, and referral patterns. The statement "All politics are local" could not be truer than in the world of telemedicine, and it is apt in all other clinical work areas as well. Human relations and buy-in play a very important role in the success of any new technology. Evidence of the importance of trust and collegiality can be seen in a nursing study in which 72 experienced ICU nurses were surveyed on their feelings regarding working alongside a tele-ICU in their hospital. A majority of the nurses felt that it was important to have a personal relationship with the tele-ICU doctor [22]. More than 70 % of those same nurses felt that the tele-ICU improved patient survival, yet less than half actually followed the tele-ICU recommendations and orders. Clearly, personal relationships are key drivers in developing a partnership with a tele-ICU.

Physician Acceptance

Due to proximity and the ease of study, most investigations of tele-ICU acceptance have been performed with medical residents working in large urban teaching institutions. Most of these studies have yielded overall positive results, as summarized in a recent meta-analysis [23]. Recently, a study comparing rural hospitals with urban centers reported that tele-ICUs were generally well accepted and overall reviews by physicians in both settings were generally positive [24•]. Interestingly, there were very little differences between urban and rural settings. However, respondents at hospitals with more tele-ICU use generally became more positive at a faster rate. Due to size alone, this happened more readily in large urban hospitals. This study also found improved acceptance when critical access hospitals were able to retain critically ill patients. In addition, both physicians and nurses felt that the tele-ICU provided relief in terms of the care of critically ill patients. In a Veterans Affairs study that predominantly included hospitals in the Midwest, the main predictors of acceptance of tele-ICUs were perceived need by the staff and the amount of time spent on tele-ICU training for the bedside staff [25•]. Given these findings, it is imperative that one focus on the following when implementing a tele-ICU:

- Communication patterns among clinicians
- Educational methods so that bedside and tele-ICU staff understand the strengths and weaknesses of the tele-ICU
- An agreement on best practices

It is only through developing a consensus on these issues that local clinician acceptance is improved and optimal working relationships between the tele-ICU and the local bedside team are achieved.

Driving Process Improvement

Tele-ICUs, as well as ICUs in general, are rich operational environments with time-stamped data resulting in a high potential for process improvement applications. Many tele-ICU systems include severity of illness scoring systems and alerting mechanisms around syndromes like severe sepsis. In addition, through automation, tele-ICU systems can provide real-time feedback for best practice compliance, medication safety, and medical error reduction, thus driving patient safety. This gives partner ICUs recurrent and frequent actionable data to improve the quality of care in their local environment. Given that medical error is the third leading cause of death in the USA, following only heart disease and cancer, it seems that any system that can reduce error would be of value not only in improving quality but also in reducing cost [26•].

New Areas of Exploration

Remote Education

Telemedicine has recently gained broader acceptance as a medium for long distance learning and teaching in resource-restricted areas [27, 28]. Since its inception in the early 1970s, the Advanced Trauma Life Support (ATLS) course has become the standard for teaching trauma resuscitation skills. However, travel costs, faculty time, and large underserved rural populations can make the uniform teaching of this course difficult. In a recent study comparing teaching ATLS to first-year family practice residents either on site or remotely through telemedicine, there were no differences in pass rates for the students (89.69 vs. 85.89 %), nor were there differences in student feedback on lectures or instructor evaluations of participants [29•]. In addition, the telemedicine students showed greater interactivity than the on-site students did. This novel way of educating larger cohorts of individuals in remote areas may be an area worth further study and replication particularly when dealing with emergencies and trauma.

Remote Triage

It has been well documented in the literature that children admitted to pediatric intensive care units (PICUs) from remote emergency departments (EDs) have higher severity of illness on arrival than children admitted directly to a PICU from an ED within the same hospital [30, 31]. This difference can be explained to some extent by lack of pediatric expertise, equipment, and experience in the referring EDs [32, 33]. A recent retrospective cohort study looked at severity of illness scores in children admitted from referring EDs with and without access to pediatric telemedicine [34•]. Not surprisingly, they found that children from referring EDs with telemedicine had lower severity of illness scores on arrival (Pediatric Risk of Mortality Ill score, 3.2 vs. 4.0; $P < 0.05$). Furthermore, when looking specifically at EDs that implemented telemedicine during the study period, children also arrived significantly less sick (mean Pediatric Risk of Mortality Ill score 1.2 units lower; $P = 0.03$). This seems to indicate that having a pediatric intensive care specialist assist in the care in a referring ED and providing appropriate care early in the course of illness could result in improved outcomes.

Conclusion

Critical care medicine is at a crossroads. The lack of financial resources, uneven population growth, and, most importantly, limited numbers of healthcare professionals to deal with these changes have forced the medical community to look at alternative methods to care for the critically ill.

Telemedicine in the ICU, which leverages technology and conglomerates of intensivist populations, is one of the methods used to meet this mismatch of supply and demand. This is a novel field with many unanswered questions. Further studies that are based on a standardized and mutually agreed upon research agenda and that examine processes of implementation and maintenance of tele-ICUs are needed to continue to improve outcomes. Many of these studies will need to focus on methods for improving physician and nurse acceptance of this technology as well as elucidate how to break down cultural barriers and prejudices.

A careful review of the literature reveals that, for the most part, tele-ICUs have a positive impact on mortality and length of stay, and many of the keys to success for a tele-ICU revolve around communication, data review, and collaboration between teams. These tenets of connection between the two teams are keys to allowing the tele-ICU to thrive and reach its full potential.

Compliance with Ethical Standards

Conflict of Interest Drs. Scurlock and Becker declare no conflict of interest relevant to this manuscript.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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