Telemedicine in the Pediatric Intensive Care Unit

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Abstract

Telemedicine technologies involve real-time, live interactive high-definition video and audio communication that allow pediatric critical care physicians to have a virtual presence at the bedside of any critically ill child. Telemedicine use has been increasing and is expected to become a common tool in remote emergency departments, inpatient wards, and Intensive Care Units for pediatric care. There is increasing data to support new care models that incorporate telemedicine technologies result in higher care quality, more efficient resource use with improved cost-effectiveness, and higher patient, parent and remote provider satisfaction. As more research is conducted, the best use of these technologies will be better defined, and result in increased access to pediatric critical care expertise to a larger population of children in need of Pediatric Intensive Care Unit (PICU) services.

Keywords

Telemedicine • Tele-ICU • eICU • Pediatric critical care • Healthcare disparities • Quality of care

Introduction

The annual number of patients admitted to Intensive Care Units (ICUs) in the United States (US) is approximately five million and is increasing each year. Patient acuity, reflected by comorbid medical conditions, technology dependence, and severity of illness, is also on the rise. The care provided in the ICU is increasingly complex and requires state-of-the-art facilities, the most modern technologies, and a comprehensive team of specially trained multidisciplinary providers and ancillary personnel. As a result, care of ICU patients has become more complicated, and patients are increasingly exposed to failures in the care delivery that result in mistakes, complications, and even death. In fact, it is estimated that on average, every patient admitted to an average US ICU experiences 1.7 potentially life threatening errors each day, and each year some 50,000 patients die from preventable deaths [1].

In the past two decades, two major health system factors have been identified that maximize the chances of high care quality and minimize risks of mistakes and complications in the ICU. The first factor is the regionalization of specialty ICU services. ICU regionalization is a means of concentrating medical expertise and increasing patient volumes at designated referral and tertiary care hospitals. Higher patient volumes often result in increased care efficiency and improved patient outcomes. Well known examples include the regionalization of trauma, specialty surgical procedures, adult critical care, as well as neonatal and pediatric intensive care [2–8]. The second factor shown to improve outcomes and quality of care in the ICU is to ensure that all patients are actively cared for by critical care physicians. In both adult and pediatric ICUs, research demonstrates that critically ill patients have a lower risk of death, shorter ICU and hospital length of stay, and receive higher care quality when critical care physicians are involved in their management [9–12].

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D.S. Wheeler et al. (eds.), *Pediatric Critical Care Medicine*,
DOI 10.1007/978-1-4471-6362-6_8, © Springer-Verlag London 2014

In fact, researchers estimate that ICU mortality is reduced by some 10–25 % when critical care physicians direct patient care compared to ICUs where critical care physicians have little to no involvement in patient care [9, 10].

Unfortunately, not all critically ill patients are cared for in regionalized ICUs, nor are they uniformly treated by critical care physicians. While regionalization improves patient care, by its design, it also creates disparities in access. Acutely ill patients living in non-urban areas, are by necessity treated and cared for in hospitals that lack full PICU services and critical care expertise [13], resulting in risk of both delays in care and inappropriate care [14, 15]. Magnifying this problem is the continued shortages of critical care physicians, for both adult and PICUs, which is expected to worsen in future years [16, 17].

Telemedicine is defined as the provision of health care over a distance using telecommunications technologies. It can be used to supplement efforts to both maintain the regionalization of ICU services as well as help specially trained critical care physicians participate in the care of critically ill patients in other locations. Telemedicine technologies can be used to more efficiently increase access to specialty care services, including critical care physicians, to patients living in underserved and remote communities and in community hospitals where the full spectrum of ICU and critical care services is not available [18, 19]. By importing specialty expertise using telemedicine, emergency departments, inpatient wards and intensive care units are given the means to increase their capacity to provide higher quality of care to critically ill patients. Critical care physicians can also increase their efficiency with these technologies so that their expertise can be shared with more patients at more than one ICU or hospital at a time. In addition, telemedicine use can potentially reduce patient transfers of less severely ill and injured children to referral centers, thus reserving limited ICU beds to those most in need of care at a regionalized center [20, 21]. For these reasons, the use of telemedicine in critical care is increasing, and is expected to become a technology that most centers will use in their future practice.

Although telemedicine can be part of the solution to disparities in access to critical care physicians and specialized care, it is not meant to obviate the transfer of critically ill patients in need of services at a regional ICU, nor is it meant to replace an on-site critical care physician. Instead, as numerous clinical programs across the country have demonstrated, telemedicine and remote monitoring technologies can be used by critical care providers to immediately share their expertise in a variety of clinical scenarios. In this chapter, we review how telemedicine can be used by pediatric critical care physicians. Specifically, we review how telemedicine can be used in remote hospital emergency departments, during the transport of critically ill children, in hospital inpatient wards, and in remote ICUs where pediatric critical care specialists are not immediately available.

The Use of Telemedicine in Emergency Departments

Past studies demonstrate shortcomings in care quality for acutely ill and injured children treated in EDs without pediatric expertise [14, 22–24]. These EDs are, at times, inadequately equipped to care for pediatric emergencies [22, 23, 25–27]. Further, personnel working in rural EDs, including physicians, nurses, pharmacists and support staff are often less experienced in caring for critically ill children. The relative lack of equipment, infrastructure and personnel experienced in delivering specialty care to children may result in delayed or incorrect diagnoses, suboptimal therapies, and imperfect medical management [3, 11, 28, 29]. As a consequence, acutely ill or injured children receive lower quality of care than children presenting to EDs in regionalized children's hospitals [14, 30–33].

Telemedicine is a practical means of delivering expertise to remote EDs where specialists are not otherwise available [34–40]. The benefit of this technology is that it provides the consultant (i.e., the pediatric critical care physician) the ability to see what is happening in the remote ED as if they were physically present. The consultant has access to high-definition patient views, the treating providers, the family, as well as monitors and equipment. Several controlled trials have compared the diagnostic accuracy, planned treatment and disposition plans of patients seen and treated in the ED supported with telemedicine compared to conventional ED care. In general, studies demonstrate equivalent results, supporting the concept that telemedicine can be used by emergency and critical care physicians to provide expert advice to remote EDs [35, 36, 41]. Specifically, in some clinical scenarios, it has been shown that patients treated over telemedicine have similar outcomes, including the need for diagnostic studies, the need for medical interventions, the frequency of return ED visits, and overall patient satisfaction compared to patients treated by in-person physicians [35, 41].

Two current examples where telemedicine has been successfully implemented in clinical ED programs are adult stroke care and to support physician extenders working in remote EDs. In several studies, neurologists providing telemedicine consultations in the evaluation and treatment of stroke patients have similar outcomes to neurologists providing consultations in-person [42–44]. This care model allows hospitals without around-the-clock access to neurologists to have immediate expert care. While this is one of the fastest growing applications of telemedicine in the ED, other specialists can similarly provide consultations from remote sites to various patient groups that need specialty care.

Telemedicine is also effective when used by emergency medicine and critical care physicians to supervise the care of other non-physician clinicians working in remote EDs [45, 46]. Galli et al., reported their experience with a care

model where physician assistants staff several rural EDs, with an emergency medicine physician available for consultation using telemedicine from a university hospital [45]. In this model, where tens of thousands of patients have been treated in the rural EDs by the on-site physician assistants, patient outcomes and provider satisfaction are similar to the care provided when emergency medicine physicians staffed each of the rural EDs. In addition, this model of ED care resulted in lower total healthcare costs [47, 48].

Telemedicine use to provide immediate specialty consultations to pediatric patients in the ED has also been shown to improve the quality of care and increase provider, patient, and parent-guardian satisfaction [46, 49]. Two studies describe how pediatric critical care physicians use telemedicine to provide consultations to critically ill children presenting to several rural EDs [46, 49]. Heath et al., at the University of Vermont concluded that use of telemedicine was associated with improved patient care and was superior to telephone consultations [46, 50]. In another study by Dharmar et al., the overall care quality, measured using a previously validated implicit-review instrument [51], was higher for patients receiving telemedicine consultations in remote EDs than for patients who received telephone consultations and for patients who received no consultations [49]. These researchers also found that referring ED physicians reported that consultations more frequently prompted a change in diagnosis or therapeutic interventions than when consultations were provided by telephone. Finally, parent-guardian satisfaction and perceived quality of care were significantly higher when telemedicine was used compared to telephone for consultations obtained by the referring ED [49].

The Use of Telemedicine During Transport of Critically Ill Children

There are currently only a handful of US programs using telemedicine technologies during the transport of critically ill patients. The transport program goals are to use telecommunications technologies to transmit data, including electrocardiac and laboratory data, as well as video of the patient during transport. Unfortunately, this model is typically limited by inadequate mobile telecommunication services to provide adequate bandwidth for continuous data and video transmission. Currently, there are two primary methods of providing continuous telecommunication services: the first uses combined cell-phone services and the second uses internet connectivity with city-wide Wi-Fi or satellite services [52, 53]. While a few programs document anecdotal success with their transport telemedicine programs, researchers have yet to produce data documenting improved clinical outcomes with this telemedicine application.

In a recent study, the outcomes of simulated adult trauma patients were compared among scenarios using telemedicine and scenarios using telephone communications during transport [54]. The researchers found that use of telemedicine resulted in improved clinical outcomes including fewer episodes of desaturation, hypotension, and less tachycardia compared to identical simulated patients without telemedicine use. In addition, the researchers found that recognition rates for key physiological signs and the need for critical interventions were higher in the transport simulations with access to telemedicine [54].

Such data support the feasibility of using telemedicine during patient transport and raises possibilities that telemedicine can improve this phase of care. However, until more reliable and affordable telecommunications are available to evaluate telemedicine in transport, the effectiveness and/or benefit remain undetermined.

The Use of Telemedicine for Children Hospitalized in Intensive Care Units

PICUs are more regionalized and fewer in number than adult ICUs because children require critical care services less frequently than adults. As a result, acutely ill and injured children living in non-urban communities frequently require a medically complicated, expensive, and sometimes lengthy and risky transport in order to access specialty services. Despite the risks and potential for complications, lengthy transports are most often in the patient's best interest, given the expertise of the regionalized PICU. However, under some circumstances, transporting a pediatric patient a long distance may not be necessary if there is a close by facility with intermediate capabilities, such as a Level II PICU or adult ICU with pediatric capabilities [55]. In addition, children hospitalized at regional hospitals experience longer length of stays, greater resource utilization, and higher costs than similar children cared for at non-Children's hospitals [56–58]. Therefore, it is logical that some "mildly" or "moderately" ill children (e.g., a child with asthma who requires continuous albuterol or a child with known diabetes and mild diabetic ketoacidosis) can be cared for in a Level II PICU or other non-Children's hospital's ICU under the care of nurses and physicians competent in the care of such children with supervision from a pediatric critical care physician or pediatric critical care team using telemedicine and remote monitoring.

Telemedicine can be used by pediatric critical care physicians in a variety of clinical scenarios and for a broad range of applications [59]. Consultations, remote monitoring, and nurse-physician oversight can range from a model of intermittent, need-based consultations (the consultative model), to a bundled continuous monitoring and active involvement

model (the continuous oversight model). In a consultative model, a pediatric critical care physician can provide bedside telemedicine consultations to a patient in a remote inpatient ward or ICU. Such consultations could prompt a variety of clinical interventions, including recommendations on diagnostic studies, medications, and/or other therapies. The consultation may also recommend transport to the regional PICU. This type of model could result in a one-time consultation and recommendations or lead to multiple videoconferencing interactions during the day or hospital stay [60, 61].

In the continuous oversight model, telemedicine can be used in combination with comprehensive remote monitoring by a critical care physician and nurse(s). In such a model, a remote team of physician(s) and nurse(s) are able to monitor many patient beds in sometimes several different ICUs. This care model could be more pro-active in implementing evidence-based guidelines and intervening prior to worsening care status or development of complications. This ICU telemedicine model can be created by centralizing existing ICU monitoring technologies and electronic health records, or can be contracted out to a third party specializing in remote ICU monitoring services.

Consultative Model

A pediatric critical care telemedicine program based on the consultative model has been successfully used in caring for mildly to moderately ill children in remote ICUs in Northern California [60]. In one model, pediatric critical care physicians from a regional PICU connect to the telemedicine unit at the bedside for consultations to a referring neonatologist, general pediatrician, adult critical care physician, and/or surgeon caring for an infant, child or adolescent in a combined Pediatric-Adult ICU. The bedside nurses also can initiate a request for assistance from either the physician or pediatric critical care nurse at the regional PICU. While the remote ICU does not have pediatric critical care physicians on staff, it does have a neonatal ICU, a pediatric service, a pediatric inpatient ward, and the nurses are required to maintain training in pediatric critical care nursing [60].

In this program, telemedicine consultations from pediatric critical care physicians are available 24 h per day, 7 days per week. Consultations consist of a full history (with referring physician, nurse, and/or parent-guardian) and physical exam which may require the use of telemedicine peripheral devices (such as a stethoscope, otoscope, ophthalmoscope and/or general exam camera) or reported physical findings from the bedside nurse or physician. The history and physical also includes the review of pertinent radiographs, medical records, and laboratories. Follow-up consultations can be conducted at the discretion of the consulting critical care physician or as requested by the referring physician or bedside nurse. At any time after the initial or follow-up consultation, the patient can be transported to the regional PICU based on the specialty needs of the patient, patient stability, and at the discretion of the referring or consulting physicians, with consideration to nurse and physician comfort and parental preference.

Published data from this telemedicine program demonstrate clinical outcomes, including mortality and length of stay, similar to severity adjusted benchmark data from a set of national PICUs [60, 61]. This program resulted in a high degree of satisfaction among remote providers and parents-guardians, and allowed patients to remain in their local community, lessening the stress among family members. Consultations using this model also provide clinical expertise for patients requiring evaluation from other specialty services, including cardiology and ethics [62, 63]. Data from this program also demonstrated an overall reduction in healthcare costs due to more appropriate transport utilization and decreased utilization of the more costly, regional PICU [64].

Continuous Oversight Model

When telemedicine and videoconferencing is bundled with a remote monitoring or "tele-presence" ICU system, a more proactive care model involving critical care physicians and nurses can be used. In this model of care, the specialist may act as a consultant responsible for continuous patient monitoring but may also actively participate in patient management, including addition and titration of therapies, championing compliance with critical care best practices, and active communication with health care team members. Using this model, the initial research studies comparing pre-intervention to post-intervention outcomes suggested a non-statistically significant reduction in severity-adjusted ICU mortality, severity adjusted-hospital mortality, the incidence of some ICU complications, and decreased ICU length of stay [65, 66]. However, the studies found no overall reduction in hospital length of stay.

There have been several subsequent studies evaluating the impact of the continuous oversight ICU model of care in a variety of adult ICU settings. In a large study conducted at six ICUs in a large US health care system, a similar pre-intervention versus post-intervention study found that implementation of an integrated telemedicine and remote monitoring program did not have a large impact on evaluated care [67]. This study reported no difference in ICU mortality, hospital mortality, ICU length of stay or hospital length of stay. However, the researchers found that among the subset of patients with higher involvement of remote telemedicine

providers, outcomes including survival, were improved [67]. Using the data from this study, another group of investigators researched the costs and cost-effectiveness of the tele-ICU program [68]. They found that daily average ICU and hospital costs after the implementation of the program increased by 28 % and 34 %, respectively. The investigators concluded that the cost-effectiveness of the continuous oversight program was limited to the most severely ill patients [68].

However, two more recent studies in smaller hospital settings found conflicting results. In one study, investigators conducted a pre-intervention versus post-intervention study and found no reduction in ICU mortality, hospital mortality, ICU length of stay, or hospital length of stay when the same continuous oversight model was implemented in four ICUs in two community hospitals [69]. In the same year in a similarly designed study of a single academic community hospital, the continuous oversight telemedicine program was associated with a statistically significant reduction in mortality from 21.4 % at baseline to 14.7 %. The investigators also found a significant reduction in ICU length of stay from 4.06 days at baseline to 3.77 days, which remained significant even after adjustment for case-mix and severity of illness [70].

There has been one meta-analysis that combined published data evaluating ICU telemedicine impact on patient outcomes. These researchers found that among 13 eligible studies involving 35 ICUs, there was a significant reduction in ICU mortality (pooled odds ratio, 0.80), but found no impact on in-hospital mortality for patients admitted to the ICU [71]. They also found that remote ICU telemedicine coverage was associated with a reduction in ICU length of stay by 1.3 days, but found no statistically significant reduction in hospital length of stay [71]. All studies included in this meta-analysis were assessments that compared pre-telemedicine measures to post-telemedicine measures. This study design is not ideal and subject to many biases. In addition, the meta-analysis contained a heterogeneous group of studies conducted on heterogeneous populations resulting in wide confidence intervals [72, 73].

Subsequent to the publication of this meta-analysis, researchers evaluated seven adult ICUs on two campuses of a single academic medical center where a similar continuous oversight ICU telemedicine program were implemented. These researchers found that the telemedicine program was associated with significant improvements in several clinical outcomes [74]. The adherence to critical care best practices, including guidelines for prevention of deep vein thrombosis, stress ulcers, ventilator-associated pneumonia, catheter-related bloodstream infections, and guidelines for cardiovascular protection all significantly improved. In addition, there was a relative reduction in unadjusted and risk-adjusted ICU mortality by 13 % and 20 %, respectively. Further, both risk-adjusted hospital mortality ICU and hospital length of stay were significantly decreased [74, 75].

The reasons why some continuous oversight telemedicine programs have resulted in significantly improved outcomes while others have not is likely multifactorial and related to how the programs were implemented and supported. In studies that found improved clinical outcomes, the remote critical care teams seemed to work more proactively and were involved in care of a greater proportion of patients. The studies that found no improvements in clinical outcomes tended to use telemedicine and remote monitoring technologies in a more reactive manner where the primary physicians limited participation of the remote critical care physicians to fewer patients. In addition, the studies that did not find improved outcomes with telemedicine did not have an ongoing clinical improvement program. In other words, the degree of benefit seems to be related to the extent to which the telemedicine and remote monitoring is accepted by the medical staff and whether the program is actively used to create sustainable ICU care changes [74].

Telemedicine Technologies

Telemedicine ICU consultations involve real time, live interactive high-definition video and audio communication between the specialist at the regional PICU and health care provider at the remote hospital. Therefore, in developing a telemedicine program that originates from a PICU, there are many technical challenges to address, considering the goal is to provide 24 h per day immediate assistance to critically ill infants and children. It is a requirement to have on-call systems for both clinicians, as well as the technical personnel at both remote hospitals and regional PICUs.

Telecommunication lines need to be reliable and have adequate bandwidth to maintain quality of service. This may require use of dedicated telecommunication lines, such as complete or fractionated T1 lines, Integrated Services Digital Network (ISDN), or some other private networking telecommunication systems. If the internet is used, connection speeds can vary, and resulting audio-video quality can be unreliable. Further, modifications to allow encryption must be made so that the communications are compliant with the Health Insurance Portability and Accountability Act (HIPAA). A common solution to this is built-in videoconferencing unit encryption and/or establishing a virtual private network (VPN) tunnel.

Careful consideration of the telemedicine imaging equipment is also needed. Remotely controlled videoconferencing devices offer a range of quality and can be wall mounted, pole mounted, or even mounted on mobile robotic platforms. Peripheral devices, such as high-resolution exam cameras, stethoscopes, and oto-ophthalmoscopes are available;

however, it may be easier to have the remote physician or nurse describe physical findings, such as pupillary responses, than to have a remote operator use the camera. In the continuous oversight telemedicine models, the connections for live feeds of cardiorespiratory and pressure monitors are needed, with the option for live feeds of ventilators or other monitoring devices. In some cases where these monitoring systems are not used, as in the consultative model, a remotely controlled video camera can be directed for close-up real-time monitor visualization and other equipment with interpretations similar to physical bedside interpretations.

The Future of Telemedicine in the PICU

It is expected that telemedicine use in pediatric critical care will increase. These technologies allow subspecialists to extend their expertise more quickly and further than could be done in the past. The potential advantages are numerous. Pediatric critical care physicians will be able to provide better consultations to remote locations, resulting in higher quality of care. The transport of children to the regional PICU may become more efficient and appropriate. Referring hospitals and physicians will ideally be supported to care for less ill patients that previously were referred to urban tertiary care centers. All of these goals are to the advantage of the patient, the patient's family, the remote physician, the local hospital, regional health care systems as well as the payers.

Relationships between remote and regionalized PICUs may be enhanced, as subspecialists can provide the latest information to their remote peers, and these peers can educate their urban peers about the practice of medicine in a non-regionalized, non-children's Hospital. We expect that telemedicine technologies will become more integrated into our daily care, just as computerized physician order entry and the electronic health records are becoming. Different models of care using different technologies will be used depending upon the needs of the patients, the remote hospitals, and the regional PICUs. Data will continue to be evaluated and updated to better understand telemedicine's impact on efficiency, clinical outcomes, and cost-effectiveness, to better define where, when and for whom the technologies are most clinically and economically effective.

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