Telemedicine in the Pediatric Intensive Care Unit

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INTRODUCTION

In the past 2 decades, it has become increasingly evident that the quality of care provided in the pediatric intensive care unit (ICU) is improved when patients are actively cared for by pediatric critical care physicians. Research has demonstrated in both adult and pediatric ICUs 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.1–5 Specifically, researchers estimate that ICU mortality can be reduced by some 10% to 25% when critical care physicians direct patient care compared with ICUs whereby critical care physicians have little to no involvement in patient care.1,2,6

Unfortunately, not all critically ill children are cared for in regionalized pediatric ICUs and they are not uniformly treated by pediatric critical care physicians. This circumstance is in part explained by the fact that regionalization of pediatric ICUs, although increasing quality and efficiencies of care, by its design, also creates disparities in access. Critically ill children from nonurban areas are frequently treated and cared for, by necessity, in hospitals that may lack the full spectrum of pediatric ICU services and/or pediatric critical care expertise.7,8 Magnifying this problem is the continued...

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shortages of critical care physicians, for both adult and pediatric ICUs, which is expected to worsen in future years. Combined, regionalization and physician shortages make it difficult to guarantee that all critically ill patients are treated in a timely manner by qualified physicians in an appropriate full-service ICU.

Telemedicine, defined as the provision of health care over a distance using telecommunications technologies, can enable specially trained critical care physicians’ participation in the care of critically ill patients in remote locations while simultaneously maintaining the regionalization of ICU services. This model of care, referred to as Tele-ICU, 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. By importing specialty expertise using telemedicine, emergency departments (EDs), inpatient wards, and nonspecialty ICUs 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 disseminated to more patients at more than one ICU or hospital at a time. The use of telemedicine technologies can also reduce the need to transfer less ill children to referral centers, reserving the limited pediatric ICU beds to those most in need of a regionalized center. For these reasons, the use of telemedicine by hospitals and physicians providing critical care services will continue to increase and be individualized to best fit the needs of the patients that they serve.

Although the use of Tele-ICU can help providers of critical care services address disparities in access to care, improve quality of care, and reduce overall health care costs, it will never replace the bedside pediatric critical care physician or eliminate the need to transfer critically ill children to regional pediatric ICUs. Instead, pediatric critical care physicians can use telemedicine and telehealth technologies as a tool to assist in the remote monitoring and treatment of patients where their services may not otherwise be immediately available. Herein, the author reviews how telemedicine can be used by pediatric critical care physicians and pediatric ICUs, focusing particularly on the delivery of care in remote hospital EDs, in critical care transport, in remote hospital inpatient wards, and in remote ICUs where pediatric critical care specialists are not immediately available.

TELEMEDICINE FOR CRITICALLY ILL CHILDREN IN REMOTE EDs

It is well documented that without pediatric expertise, critically ill children presenting to EDs receive poorer quality of care compared with the care provided in EDs with pediatric expertise. These EDs are also, at times, inadequately equipped to care for pediatric emergencies. In addition, the staff working in smaller, general EDs, including physicians, nurses, pharmacists, and support staff, are often less experienced in caring for critically ill children. Combined, the relative lack of equipment, infrastructure and experienced personnel can result in delayed or incorrect diagnoses, suboptimal therapies, and imperfect medical management. As a consequence, acutely ill or injured children receive lower quality of care than children presenting to EDs in regionalized children’s hospitals.

The use of telemedicine technologies for disaster victims or in remote or underserved EDs can be a means of obtaining subspecialty expertise by consultation. The benefit of using this technology as opposed to using the telephone (the current standard of care) is that the consultant (ie, the pediatric critical care physician) has the ability to have a virtual presence at the patients’ bedside. The consultant has access to high-definition patient views, the treating providers, the family, as well as monitors...
and equipment. Previous studies have demonstrated that the use of telemedicine in the ED to deliver consultations is similar to in-person consultations when comparing diagnostic accuracy, treatment plans, and plans for disposition. The use of telemedicine to urgently obtain a consultation from a neurologist in the ED to treat patients with an acute stroke is now common practice. Similarly, telemedicine is used to provide emergency medicine consultations to critical access hospitals, which are staffed by physician assistants. Both of these examples have been shown to result in high-quality, cost-effective care.

With regard to providing pediatric critical care consultations to remote EDs for critically ill children, there is increasing acceptance and evidence that this model of care can improve the quality of care and increase provider, patient, and parent-guardian satisfaction. Two studies have describe how pediatric critical care physicians use telemedicine to provide consultations to critically ill children presenting to rural EDs. Heath and colleagues, at the University of Vermont, concluded that the use of telemedicine was associated with improved patient care and was superior to telephone consultations. In another study by Dharmar and colleagues, it was shown that patients receiving telemedicine consultations in remote EDs received higher overall care quality when compared with similar patients receiving telephone consultations. Both of these programs also reported that referring ED physicians more frequently changed their diagnosis and/or therapeutic interventions compared with when consultations were provided by telephone. Finally, the use of telemedicine to provide critical care consultations has also been shown to result in significantly higher parent-guardian satisfaction and perceived quality when compared with telephone consultations.

Overall, although more research is needed, there is mounting evidence that pediatric critical care consultations to rural and underserved EDs using telemedicine can be used to help address disparities in access to specialists and, in doing so, improve the overall quality of care. It is also likely that because of better care and the reduction in unnecessary transports, telemedicine consultations to rural and underserved EDs can be provided in a cost-efficient manner that reduces the health care costs that would otherwise be encumbered if telemedicine were not used.

TELEMEDICINE DURING TRANSPORT OF CRITICALLY ILL PEDIATRIC PATIENTS

The use of telemedicine by physicians to assist in the care of critically ill patients during transport could have the potential to improve processes of care at several levels. For example, telemedicine could allow physicians to be an immediate part of the monitoring, identification, and management of changes in the patients’ status that occur during transport. With more immediate physician supervision using telemedicine, medical decisions, including new medication orders, have the potential to occur more rapidly and efficiently than without direct physician supervision.

Currently, mobile telephone technologies are used to transmit 2-way audio as well as data, including electrocardiogram data. However, to create a model of care that uses telemedicine during transport, much more robust, mobile broadband telecommunications are needed. Only a handful of transport programs in the United States use these technologies because high-quality broadband mobile telecommunications is expensive and not always or easily available. This circumstance is particularly true if continuous video transmission or large data streaming is desired. Two common methods of transmitting video include the use of high-fidelity cell-phone service (sometimes combining several cell-phone lines) and the use of the Internet that can be available with citywide Wi-Fi or satellite services. Although satellite
technologies can be used to provide mobile telemedicine connections, this technology is most often prohibitively expensive.

There have been anecdotal reports documenting the feasibility of cell-phone and Wi-Fi transmitted telemedicine consultations during transport. In one study, the outcomes of simulated adult trauma patients were compared among scenarios that used telemedicine and scenarios that used telephone communications during transport. The researchers found that use of telemedicine resulted in a reduction in adverse clinical events, including fewer episodes of desaturation, hypotension, and less tachycardia compared with identical simulated patients without telemedicine use. In addition, the researchers found that recognition rates for key physiologic signs and the need for critical interventions were higher in the transport simulations that used telemedicine. These data are encouraging and support the possibility that telemedicine can be used during patient transport. However, until more reliable and affordable mobile telecommunications are available to implement telemedicine during transport and more research is conducted on the impact that telemedicine has during transport, the effectiveness and benefit of this technology remain undetermined.

CRITICAL CARE TELEMEDICINE CONSULTATIONS FOR HOSPITALIZED CHILDREN

Pediatric critical care services are more regionalized and fewer than adult critical care services. As a result, children living in nonurban communities that may need critical care services have to be transferred a sometimes lengthy and risky transport to a pediatric ICU. Often, pediatric patients that are not critically ill are overtriaged and transferred to the regional center because there may be the potential for needing the specialty services provided by the pediatric ICU. This practice is particularly inefficient given the fact that regionalized quaternary pediatric ICUs are frequently running at full capacity. In fact, the transfer of some pediatric patients to a quaternary pediatric referral center is often not necessary if there is a closer hospital with adequate pediatric capabilities, such as a level II or community pediatric ICU, an intermediate or step-down pediatric care unit, or general ICU with pediatric expertise.

Admitting some of the less-ill children to hospitals other than regional, quaternary referral centers can result in high quality of care provided with similar length of stays, less resource use, and lower costs. It is, therefore, logical that some mildly or moderately ill children (eg, 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 or community pediatric ICU or other non–children’s hospital’s ICU under the care of pediatric nurses and physicians with supervision from a regional children’s hospital pediatric critical care team using telemedicine and remote monitoring.

Telemedicine can be used by pediatric critical care clinicians using a broad range of applications to assist in the care of hospitalized children in a variety of clinical scenarios. Physician consultations, nurse and physician monitoring, and medical oversight can range from a simple model of intermittent, need-based consultations (consultative model) to a model that integrates continuous monitoring and proactive medical decision making (continuous care model). In a consultative model, a pediatric critical care physician can provide bedside telemedicine consultations to patients in a remote inpatient ward, high-acuity unit, or ICU. Such consultations could prompt a variety of clinical interventions, including recommendations on diagnostic studies, medications, or other therapies. The consultation may also conclude that the patient should be transported to the regional pediatric ICU. This type of model could result in a range of interventions from a one-time consultation to multiple videoconferencing interactions during the course of the day or hospital stay.
In the continuous care model, telemedicine can be used in combination with comprehensive electronic remote monitoring as well as oversight by critical care physicians and nurses. In such a model, a remote team of physicians and nurses are able to monitor many patient beds, sometimes several ICUs. This continuous care model of telemedicine is more proactive with medical interventions and can involve nontelemedicine guidelines, such as the implementation of evidence-based standards. This Tele-ICU model is created by centralizing electronic health records, ICU monitoring technologies and nurse/physician video oversight. Continuous care Tele-ICUs can be created internally by a large health system, or can be contracted out to a third party technology and physician organizations that specialize 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 by several programs. One such model could involve pediatric critical care physicians from a regional pediatric ICU connecting to 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 community or combined pediatric-adult ICU. The bedside nurse or physician could initiate a request for consultation either from the regional pediatric critical care nurse or physician. Such a model would also require compliance with critical care best practices and maintenance of pediatric critical care training, advanced life support certifications, and participation in quality-assurance programs.61,62

In this model of care, telemedicine consultations from pediatric critical care physicians should be available 24 hours per day, 7 days per week. Consultations should consist of a full history (with referring physician, nurse, and/or parent-guardian) and physical examination, which may require the use of telemedicine peripheral devices (such as a stethoscope, otoscope, ophthalmoscope, and/or general examination camera) or reported physical findings from the bedside clinical staff. The consultation should include 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, patients can be transported to the regional pediatric ICU based on the specialty needs of the patients, the discretion of the referring or consulting physicians with considerations to nurse and physician comfort, and/or parental preference.

Published data from a consultative telemedicine program demonstrates excellent clinical outcomes, including mortality and length of stay, similar to severity-adjusted benchmark data from a set of national pediatric ICUs.61,62 This program has reported a high degree of satisfaction among remote providers and parents-guardians and has allowed patients to remain in their local community, which lessens the burden of family members. In addition, implementation of this consultative telemedicine model resulted in an overall reduction in health care costs because of more appropriate transport use and the decreased use of the more costly, regional pediatric ICU.63 This consultative telemedicine model has also been reported by other specialists to provide inpatient consultations, including cardiology consultations and ethics consultations.64,65

Continuous Care Model

When telemedicine is integrated with continuous remote electronic monitoring and electronic health records, the result is a tele-presence ICU system. This model is
a more comprehensive and proactive care model that involves around-the-clock monitoring by critical care nurses and physicians. In this model of care, the role of the critical care specialist can range from involvement only during patient emergencies to more active involvement, including ongoing communication with remote providers directing changes in care and therapies. Using this continuous care model, initial research studies comparing preintervention to postintervention outcomes suggested a nonstatistically significant reduction in severity-adjusted ICU mortality, severity-adjusted hospital mortality, incidence of some ICU complications, and decreased ICU length of stay.\textsuperscript{66,67} However, the studies found no significant reduction in overall hospital length of stay and were conducted by teams of investigators affiliated with the proprietary remote ICU telemedicine company used in the investigations.

There have been several subsequent studies evaluating the impact of the continuous care Tele-ICU model in a variety of adult ICU settings. In a large study conducted at 6 ICUs in a large US health care system, a similar preintervention versus postintervention study found that the implementation of an integrated telemedicine and remote monitoring program did not have a large impact on evaluated care.\textsuperscript{68} 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.\textsuperscript{68} Using the data from this study, another group of investigators researched the costs and cost-effectiveness of the tele-ICU program.\textsuperscript{69} They found that the 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 care program was limited to the most severely ill patients.\textsuperscript{69}

Several more recent studies in smaller hospital settings found conflicting results.\textsuperscript{70–72} In one report whereby the Tele-ICU was used to monitor 4 ICUs in 2 community hospitals, investigators found no reduction in ICU mortality, hospital mortality, ICU length of stay, or hospital length of stay.\textsuperscript{72} In the same year, in a similar designed study of a single academic community hospital, the continuous remote oversight ICU telemedicine model resulted in a statistically significant reduction in mortality from 21.4% at baseline to 14.7%. These 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.\textsuperscript{71}

In one of the largest studies to date, researchers evaluated 7 adult ICUs on 2 campuses of a single academic medical center where a similar continuous care telemedicine program was implemented. These researchers found that the Tele-ICU program was associated with significant improvements in several clinical outcomes.\textsuperscript{73} The adherence to critical care best practices, including guidelines for the 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.\textsuperscript{73,74}

There have been at least 2 meta-analyses that have combined published data evaluating ICU telemedicine impact on patient outcomes. In one meta-analysis, 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.\textsuperscript{75} 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. In another, researchers reviewed 11 eligible studies and found that the continuous care telemedicine model resulted in statistically significant reductions in ICU and hospital mortality (pooled risk ratio, 0.79 and 0.89, respectively) as well as ICU and hospital length of stay. All studies included in both of these meta-analyses were combined assessments that compared pretelemedicine outcomes to post-telemedicine outcomes, which are subject to significant bias. As demonstrated by the fact that inconsistent conclusions were made by 2 different meta-analyses that analyzed virtually identical data, there is the real need to conduct more rigorous studies whereby timelines are concurrent and/or patients and ICUs are randomized as part of a larger trial. 

The reasons why some continuous care telemedicine programs have resulted in significantly improved outcomes and others have not is likely multifactorial and related to how the programs were implemented and supported. In general, when ICUs experienced improvements in clinical outcomes, the centralized monitoring critical care teams seemed to work more proactively and were involved in the care of a greater proportion of patients. On the other hand, when ICUs did not experience improvements in clinical outcomes, the ICUs often limited the participation of the centralized monitoring critical care teams. In addition, some studies that did not find improvements in clinical outcomes often did not simultaneously implement clinical improvement programs. In other words, the degree of benefit seems to be related to the extent to which the telemedicine, remote monitoring, and collaboration between the monitoring and monitored teams are mutually embraced and whether the program is supported as a means of creating sustainable improvements in ICU care.

Collectively, the studies suggest that the utility of a care model that uses telemedicine to assist in the treatment of infants and children hospitalized in remote hospitals or ICUs is promising but remains controversial because of a lack of evidence. It is known that telemedicine technologies, in and of itself, will not result in improved care. Rather, telemedicine is a technological tool that can enable providers to provide better care. Telemedicine needs to be thoughtfully integrated into partnering institutions in a well-defined and collaborative effort; in these cases, it can result in improvements in access and quality for mildly or moderately ill children. Similar to other quality improvement efforts, for the success of a telemedicine partnership, there must be firm support from administrators, physicians, nurses, and other clinical providers on both sides of telemedicine.

THE FUTURE OF TELLEDICINE IN THE PEDIATRIC ICU

It is very likely that the use of telemedicine in pediatric critical care and in the pediatric ICU will increase. Telehealth technologies can allow specialists, including pediatric critical care physicians, to extend their expertise more quickly and easily to locations in need of their service more than ever before. The potential advantages are numerous and include improved access, improved efficiencies, improved quality, and more cost-effective care. All of these work to the advantage of our patients, our patients’ families, remote clinicians, and regional health care systems.

In addition, telemedicine connections between remote hospitals and regionalized pediatric ICUs can be enhanced because pediatric critical care physicians can better educate remote providers in the care of critically ill children. Telemedicine technologies will become more integrated into our practice of medicine, similar to computerized physician order entry and the electronic health record. Different models of care will require different technologies depending on the needs of the patients, the remote
hospitals, and the regional pediatric ICUs. More data will help us determine where, when, and for whom the telemedicine technologies are most clinically and economically effective.

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