Chapter 17
Telemedicine Consultation to the General ICU

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Introduction

When the concepts and technology of telemedicine are applied to the aspects of remote care in the ICU, it is called tele-ICU. The idea of using telemedicine to improve the care of critically ill patients was clearly stated as early as 1982 [1]. Arguably, the first major tele-ICU intervention to use modern technology, research design, and demonstrate effectiveness did not take place until 1997 [2]. The results of this study, conducted at a community hospital affiliate of Johns Hopkins, were published by Rosenfeld and colleagues in 2000 and showed reductions in mortality and costs of care [2]. It is clear even in this earliest telemedicine work that tele-ICU care is largely consultative. By using the word consultative, we mean that the tele-ICU is supportive of the work that is performed in the physical ICU. This contrasts with active management of critically ill patients. Indeed, one of the rationales of creating tele-ICU systems is to provide consultative intensivist staffing to understaffed ICUs. It is the nature of critical care that active management requires

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frequent and high-intensity physical interactions. These interactions require the on-site presence of highly trained and experienced nurses and other medical professionals who have the skills and judgment to perform physical exams and procedures. It is possible for tele-ICU clinicians to perform some elements of active management such as documentation, provider safety double checks, family meetings, and order entry. However, the vast majority of activities are consultative in that they require the tele-ICU clinicians to communicate with the ICU team to provide or alter care.

As indicated above, the idea of a tele-ICU consultation is somewhat amorphous and can be a place holder for a large variety of interactions. It is also true that tele-ICU systems are not uniquely defined. However, it is clear that the best functioning of tele-ICU systems manage technology, processes of care, and culture in an established and engineered framework (see, e.g., [3, 4]). It is also clear that in order to provide any sort of telemedicine consultations to critically ill patients, a mature and reliable system must be established. In the current era of telemedicine, it seems unlikely that such a system will be used exclusively for critical care consultations.

There are numerous telemedicine models and almost any of them could be applied to tele-ICU consultation. The gold standard for tele-ICU care is a dedicated in-room audiovisual system with continuous, around-the-clock coverage staffed by physicians and nurses. In contrast, because many highly staffed ICUs have physicians on-site during working hours, they choose to provide tele-ICU services during just the nighttime hours. In these models, the tele-ICU team is dedicated exclusively to the care of ICU patients. Robotic or mobile audiovisual carts are used to provide telemedicine service in units (or locations) where fixed camera installations are impractical or too costly (Fig. 17.1). These mobile solutions are well established as working models for telemedicine consultations [5, 6]. Finally, with the nearly universal deployment of electronic medical records (EMRs), it is possible for a remote intensivist to conduct telephone consultations with on-site providers. This telephone model is not even as robust as the long-standing model of the on-call intensivist, and we will not consider it further in our discussions. We will assume that any meaningful, real-time consultation of critically ill patients will include both audio and visual channels of communication.

The value a tele-ICU system brings to hospital operations is highly dependent on the anticipated use cases for the implementation. Intensivist staffing has been associated with lower general ICU patient mortality [7]. Based on these and other data, it was suggested that tele-ICU should be a standard, when needed, to bolster ICU staffing and improve clinical outcomes [8]. When tele-ICU was implemented for a 16-week period in a surgical ICU, the mortality rate, complication rate, length of stay, and ICU costs all improved [2]. This ICU was considered to be staffed at a low-intensity, as there were no on-site intensivists, and it is unclear if adding tele-ICU to an ICU that is already highly staffed would result in the same reduction in complications. The case for consultative critical care has not been teased out of the complex models that currently exist for tele-ICU.

Fig. 17.1 RP-7 Robot (InTouch HealthSanta Barbara, CA). Self-propelled robot with bidirectional audiovisual communication is one method of engaging with patients in tele-ICUs

How Can Telemedicine Facilitate Consultation to Improve Patient Care?

Triage Decisions

Triage decisions can be facilitated and improved using telemedicine when highly specialized care is required. Examples of this exist in neonatology [9], pediatric ICU [10, 11], burn care [12, 13] (where 84% reported using some form of telemedicine usually to improve burn care or triage decisions), and neurology [14]. The body of evidence for using telemedicine in consultation for stroke diagnosis and therapy is the most robust [15].

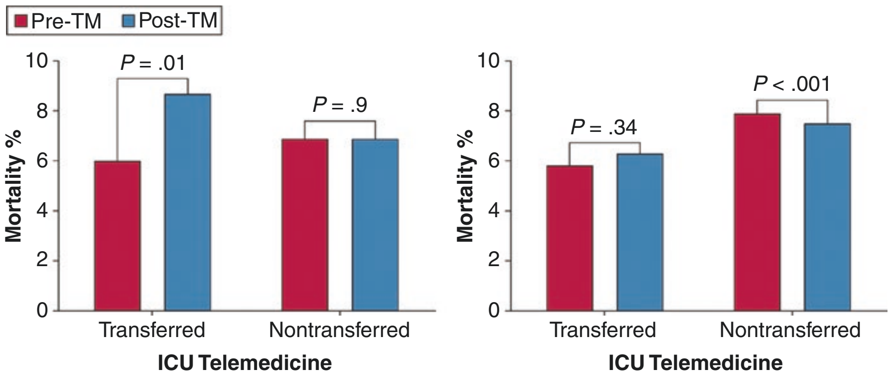

Fig. 17.2 Thirty-day unadjusted mortality in transferred and non-transferred patients in the TM ICU and non-TM ICUs. The comparison between pre-TM and post-TM periods was performed using $\chi 2$ analysis. TM telemedicine. (Reprinted with permission from Fortis et al. [16]. Copyright 2018 by the Elsevier Inc.)

Unnecessary inter-hospital transfers waste healthcare resources, jeopardize patient safety, and may be burdensome to families. Telemedicine deployed across a hospital system or geographic region may give referral centers a means to evaluate patients prior to transfer. Of these patients, a subset may be identified which do not require intensivist care, and thus transfer. Likewise, telemedicine can bring intensivist expertise to the bedside and thus obviate the need for transfer. The Veterans Administration deployed a telemedicine system to provide remote access to patients in 52 small, community, regional ICUs [16]. Over a 4 year period, 97,256 were admitted to these ICUs, and they experienced a reduction in the rate of transfers to their tertiary care center from 3.46% to 1.99% [17]. This reduction was not associated with an increased risk of mortality (Fig. 17.2).

Specialist Consultation

Telemedicine has also been considered as a tool to improve access to subspecialty care in the ICU. Remote neurology consultation and tele-stroke care is a well-established practice to improve the delivery of time-sensitive therapies associated with improved stroke outcomes [15]. This topic is covered in depth in Chap. 12. Infectious disease specialty consultation is common in the ICU, and telemedicine may have a role in improving the access to infectious disease consultation particularly in low-resource environments [18]. The Infectious Disease Society of America supports the use of telemedicine to improve access to infectious disease providers; however there has been no research specifically examining the impact of infectious disease teleconsultation on ICU outcomes [19].

The consultative model of telemedicine is well established at Johns Hopkins through the efforts of Johns Hopkins Medicine International (JHI). JHI focuses on the global expansion of Johns Hopkins Medicine to support care and improvement globally. Using this platform, we have been able to provide specialist consultations to external critical care units across a wide array of disciplines. Typically, a patient has an unexplained clinical condition or is not responding to therapy and is located at an outside ICU that has a relationship with a telemedicine center. In these situations, the background case information is usually transmitted asynchronously to an expert intensivist, surgeon, or medical specialist. This allows the specialist consultant at Johns Hopkins to review the patient's history in detail prior to the actual teleconsultation. With this preparation, the consultant conducts a consultative meeting with the remote team. Traditionally, this sort of consultation was performed over the phone. However, with improved technology, shared medical records platforms, and healthcare systems integration, these consultations can now be performed with synchronous, real-time review of patient data including lab data, radiographic images, and video linkage of physical exams (Fig. 17.3). There is no doubt that this kind of interaction provides a deeper shared understanding of the patient and helps the consultant and ICU team to develop a care plan. While exact data for the Johns Hopkins International experience is not yet published, a survey of activities shows that the majority of consultations are conducted in oncology and a significant fraction take place for neurosurgical or neurological diagnoses (personal communica-

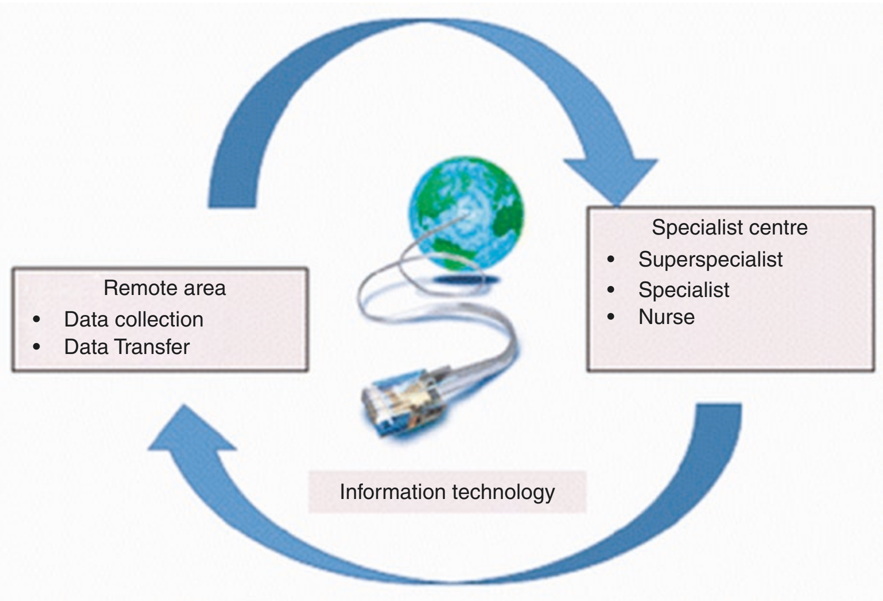

Fig. 17.3 Basic concept of telemedicine: transmitting and receiving data in a healthcare environment. (Reprinted with permission from Hao et al. [45]. Copyright 2014 by the Springer International Publishing.)

tions RD). Other specialty consultations by the Johns Hopkins program include allergy and immunology, endocrinology, dermatology, cardiology, infectious disease, gastroenterology, nephrology, rheumatology, psychiatry, and pulmonology. All of the surgical subspecialties have been able to use this platform to provide consultative care. While JHI consultations are provided on an ad hoc basis, it is important to note the emerging trend of establishing tele-ICU centers that are geographically time shifted from the target ICUs. This allows the tele-ICUs to monitor the remote ICUs at night while it is daytime locally [20].

Bedside psychiatric evaluation of the critically ill patient is challenging. Patients often experience cognitive and behavioral symptoms due to their disease process, such as delirium or traumatic brain injury. Likewise, sedation and analgesic medication regimens can limit the effectiveness of a psychiatric evaluation. These issues are unlikely to be any less of confounders when telemedicine is introduced. The value of telepsychiatry itself remains in question, and the advent of new mobile mental health applications is further challenging this approach [21]. In our opinion, it is unclear whether the telepsychiatry model can or should be translated to the patient in the ICU setting.

Tele-ICU nursing is not generally considered a consultative service because the most common application of a tele-ICU system is to add an additional level of monitoring for all patients within the ICU. Nurses are essential telemedicine staff in this model and clearly function as specialists in the intricacies of critical care nursing. In such a setting, tele-ICU nurses may also provide the most important role in consultative care. These nurses continuously perform virtual rounds for a set of patients, typically 30–35 in number [22]. In addition to monitoring the alerts generated by the tele-ICU system, tele-ICU nurses may monitor compliance with care pathways and quality indicators. Perhaps even more important is the potential of an experienced tele-ICU nurse to provide nursing consultations to the bedside nursing team [23]. As the average experience of a bedside critical care nurse continues to decrease, the value of a nursing consultation is likely to increase over time and could have major impacts on quality of care, nursing satisfaction, and burnout [24, 25]. There is evidence suggesting that bedside critical care nurses feel less anxiety when they have the ability to consult with an experienced tele-ICU nurse, and we will discuss this in greater detail below.

Tele-sitting

The incidence of agitated delirium in the ICU is very high and has a major impact not only on patient outcomes but also ICU operations. The current approach to care of delirious patients is to minimize sedatives and maintain a high nurse-to-patient staffing ratio or employ a bedside sitter to prevent an agitated patient from self-harm. In situations where sitters are not available, patients may be cared for in the ICU setting simply by using a nurse to monitor and intervene during periods of agitation. There is now a growing use of virtual or tele-sitters to remotely monitor multiple, at-risk patients. This simple application of telemedicine systems may have profound impact on ICU throughput and manpower costs [26].

Best Practices Oversight

Failure to provide evidence-based best care practices is a significant contributor to morbidity and mortality in the ICU [27]. Improving the reliable delivery of the processes of care aimed at reducing preventable harm can improve patient morbidity and mortality. Telemedicine may have a role in improving process compliance for best care practices in the ICU. We performed a study of a purely consultative telemedicine care model using an audiovisual tele-ICU implementation. In this study, the tele-ICU team communicated deficiencies in best care practices to the ICU team but did not perform documentation or write any orders. We examined compliance with best practice care processes before and after implementation [28]. The majority of care processes showed a positive trend toward compliance with many reaching statistical significance. Compliance with both mechanical (93.6% to 98.2%) and pharmacologic (80.8% to 88.8%) deep vein thrombosis prophylaxis improved significantly. Daily sedation interruption improved from 69.7% to 85.5% and compliance with an oral care regimen improved from 69.7% to 90.9%, both of which were statistically significant (Fig. 17.4). Most striking, compliance with Joint Commission guidelines for restraints improved significantly from 38.7% to 82.7%. Interestingly, during this same time period, compliance with the head of the bed greater than 30 degrees, regular repositioning, and gastrointestinal ulcer prophylaxis trended down, although this was not significant. This study was performed in a highly staffed ICU

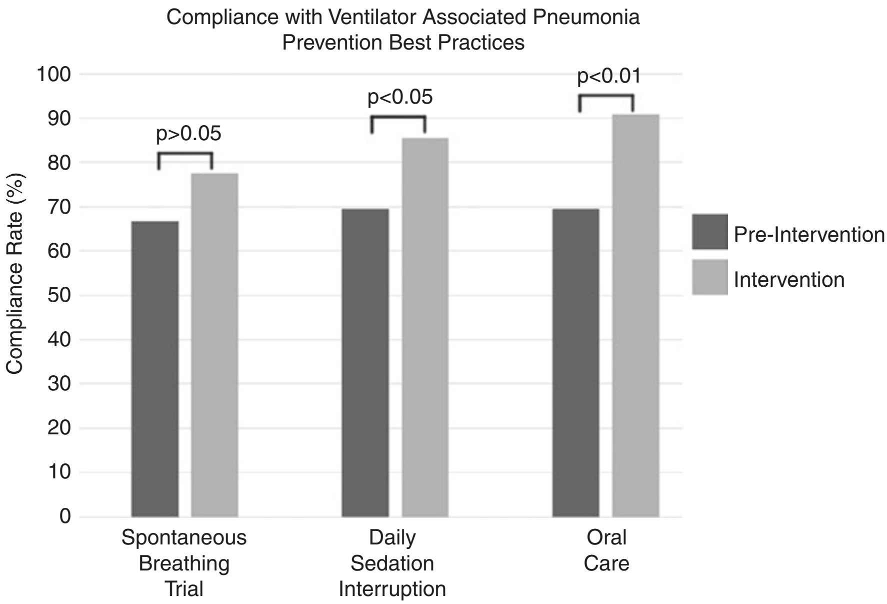

Fig. 17.4 Compliance with Ventilator Associated Pneumonia Prevention Best Practices. Tele-ICU significantly improves compliance with daily sedation interruption (69.7% vs 85.5%, $p < 0.05$) and oral care (69.7% vs 90.9%, $p < 0.01$). The trend toward improvement in daily spontaneous breathing trials was not significant (66.7% vs 77.6%, $p > 0.05$) (unpublished data)

in an academic tertiary center, and we expect the magnitude of these improvements would be even greater in a lower resourced ICU.

The effects of adhering to best practices may be profound in terms of patient outcomes and care efficiency. ICU telemedicine appears to benefit hospital throughput by decreasing length of stay. In a 1 year study, seven academic ICUs were examined using a stepped-wedge design [29]. Patients were allocated to either a pre- or post-tele-ICU intervention group, based on the rollout of the tele-ICU intervention in their ICU. Length of stay was decreased from 13.3 to 9.8 days per patient after the initiation of tele-ICU. Likewise, the mortality rate in this period decreased significantly from 13.6% to 11.8%. These improvements may be the result of improvement in processes of care. Adherence to best practices such as deep vein thrombosis prevention and stress ulcer prophylaxis were improved during this period, which may be the underlying driver for the improvements in length of stay and mortality. The authors of this study also make the case that a proper tele-ICU implementation requires "reengineering" the process of ICU care. This reengineered ICU may lead to improvements that cannot be attributed to any one specific intervention or consultation [29].

Value and Costs of Tele-ICU Implementation and Impact on Consultations

Typically, tele-ICU systems are implemented "on top of" current ICU resources. They require significant capital and operational expenditures which are not offset by a reduction in other fixed costs. Therefore, the economic goal of tele-ICU systems is to achieve a return on investment through reduction of marginal costs by improving patient outcomes and more efficient resource utilization. Improvements in metrics such as length of stay and readmission rates may be associated with significant costs savings to a hospital system. Several research studies have tried to evaluate the savings that may be elicited from a tele-ICU system by extrapolating the deferred costs from a reduced length of stay. One study reported a 10% reduction in length of stay which was extrapolated to a $2.5 million value [30]. Another study employed an independent consulting firm to estimate that their 30–34% ICU length of stay reduction was comparable to a 25–31% reduction in ICU costs and a 12–19% reduction in hospital costs [2]. These cost savings, however, are difficult to generalize as they are financial extrapolations on clinical data and costs may vary across geographic regions. It is important to note that all of the financial analyses of tele-ICU were conducted at a time when there was essentially no reimbursement for telemedicine services. Over recent years, the value of telemedicine consultation is increasingly recognized by insurers, and this appears to be spurring implementation of telemedicine systems and their utilization [31, 32]. Therefore, if current trends in reimbursement continue, we expect that tele-ICUs may be able to provide value not only through cost avoidance but also through recovering costs with billing. The path to billing for specialty consultation appears to be much more clear now.

The costs to start-up a tele-ICU have previously been evaluated in a number of studies and are consistently found between $50 and 100,000 per ICU bed in a closed tele-ICU model with proactive monitoring [33]. The University of Massachusetts Medical Center System has one of the largest and best researched tele-ICU systems. This group provided a detailed cost accounting for both the one-time costs associated with starting a ~ 100-bed tele-ICU and annualized estimate of the recurring costs for maintaining tele-ICU activities [34]. The initial implementation costs were about $7 million, of which approximately 40% were used for physical capital costs. The remainder of the costs can be categorized as software licensing, project management, and consulting fees. These costs are reflective of an era in which integrated EMRs were not typical. Currently, EMR adoption is near universal, and most major EMR vendors are embedding telemedicine capabilities within their systems. These capabilities can be used as part of a tele-ICU system. Thus, in the present day, we expect that some of the software licensing, consulting, and network costs will be reduced by adopting telemedicine components of an existing EMR. Cost accounting based on these new assumptions has not been published and may be difficult to disambiguate from the bundled costs of maintaining multifaceted medical records systems.

However, staffing costs remain the largest component of the ongoing costs of any telemedicine system. The same University of Massachusetts group determined these costs were about 90% of system sustainment. Unlike capital costs, staffing costs are likely to have increased since these estimates were made. Indeed, using the University of Massachusetts data, we estimate that in 2010, each tele-ICU bed will cost approximately $25,000 per year. If the goal of the tele-ICU system is to provide specialist consultation, this will require an additional cost for access and time for specialists.

Barriers to Tele-ICU Consultation

Since the earliest implementation of tele-ICUs, bedside nurses and physicians have demonstrated reluctance to accept the advice of or ask for consultation with tele-ICU clinicians. For example, in a large, comprehensive trial conducted in five different hospitals, physicians granted treatment authority to the tele-ICU for only ~ 30% of the ICU patients [35]. However, this same group compared safety attitudes before and after tele-ICU implementation and found that it improved teamwork and safety climate in some ICUs, especially among nurses [36]. Technology assessment tools have been used to determine the drivers of both physicians' and nurses' attitudes toward the use of tele-ICU. Nurses were influenced by the perceived ease of system use and felt that tele-ICU could be beneficial in ICUs without high levels of physician staffing [37], while physicians were not concerned with ease of use but had attitudes that were driven by their perceptions of the usefulness of the system [38]. These staff perceptions regarding telemedicine implementations may have a number of impacts on successful tele-ICU adoption and staff satisfaction. In a survey of 93 nurses from 3 academic ICUs, 72% of nurses felt that a nocturnal tele-ICU implementation improved patient survival, but only 47% believed that tele-ICU reduced medical errors [39]. A small percentage had concerns that tele-ICU was intrusive (11%) and left staff feeling as if they were being spied on (13%). Most interesting, 61% of nurses reported being more likely to contact the tele-ICU physician if they knew that physician, and 79% felt that it was important to personally know the tele-ICU physician.

Nursing perceptions of the impact of tele-ICU on quality of care and staff satisfaction have also been studied with a prospective, controlled method [40]. Nursing staff in a surgical ICU were surveyed prior to and after a 2-month tele-ICU implementation and found to have improved perceptions of effectiveness, communication, relations, job satisfaction, and burnout. In the same institution, another surgical ICU that was used as a control and completed the survey tool without any intervention did not show the same improvements in perceptions as the study ICU. In this implementation, the tele-ICU was staffed by clinicians that already worked within that ICU and were familiar to the bedside staff.

Job satisfaction and reduced burnout is strongly correlated with improvements in staff retention. Thus, tele-ICU has the potential to indirectly reduce costs associated with staff turnover such as recruitment and training; however, this effect has not been directly studied. It is notable that, in both of these studies, either the bedside staff was familiar with the tele-ICU staff or felt that such a relationship was an important factor in their decision to engage with the tele-ICU. This relationship may be an important and unrecognized factor in successful tele-ICU implementation but has not yet been studied in a controlled manner.

Discussion

There are many factors that are leading inexorably to the expansive development of telemedicine systems. These factors include the adoption of EMRs and the ability to integrate population-based monitoring into this platform, the decreasing costs of hardware for implementation, the building evidence that telemedicine adds value and should be directly compensated by insurers, and the acceptance of extended multidisciplinary care teams for the care of the critically ill patient. Leaders in critical care have recently pronounced that telemedicine will become universally available in the ICU [41].

We can anticipate that, as technical capabilities advance, there will be an associated increase in the demands for critical care telemedicine. These demands are likely to take on forms that are distinct from the customary models of the tele-ICU. It is interesting to consider that the driving force behind the original development of the tele-ICU was that it could mitigate ICU staffing shortages. Over recent years, there is a growing awareness that certain diseases may be detected and treated before they rise to the level of critical illness. Evidence of this phenomenon is seen in the early detection and treatment of sepsis using predictive analytics [42]. Coupled with the awareness that early intervention may forestall the need for ICU admission is the increasing array of remote sensor systems. These systems provide high-fidelity, continuous patient monitoring without the requirement for ICU admission. Thus, we are close to achieving the ability to provide meaningful, routine critical care consultation beyond the ICU. This ability can be used to improve early intervention, limit geographic disparity, and react to disaster situations. The ability to use telemedicine to prevent the need for ICU admissions may be extrapolated from improved outcomes when telemedicine was used in a progressive care unit [43].

Defining the roles and organizational structure for using telemedicine to provide critical care consultation is essential in extending the expertise of the critical care clinicians beyond the walls of the ICU. Technology and telemedicine services can provide consultative care almost anywhere, but alone, they cannot provide critical care. It is important to emphasize the distinction between critical care delivery and critical care consultation. There are essential features of an ICU that are required to provide critical care, and these include a dedicated physical space [44]. We believe that a robust tele-ICU system, staffed by ICU clinicians and overseeing care in the ICU, is needed for the most responsive and impactful telemedicine critical care consult service. Only such a system can assure the full spectrum of consultative activities that we have described. Indeed, this system will be able to leverage investments in telemedicine so that consultations are used to assure timely therapy, appropriate triage, and use of the physical ICU to its maximal capabilities.

References

1. Grundy BL, Jones PK, Lovitt A. Telemedicine in critical care: problems in design, implementation, and assessment. Crit Care Med. 1982;10(7):471–5.
2. Rosenfeld BA, Dorman T, Breslow MJ, Pronovost P, Jenckes M, Zhang N, et al. Intensive care unit telemedicine: alternate paradigm for providing continuous intensivist care. Crit Care Med. 2000;28(12):3925–31.
3. Irwin RS, Flaherty HM, French CT, Cody S, Chandler MW, Connolly A, et al. Interdisciplinary collaboration: the slogan that must be achieved for models of delivering critical care to be successful. Chest. 2012;142(6):1611–9.
4. Lilly CM, McLaughlin JM, Zhao H, Baker SP, Cody S, Irwin RS. A multicenter study of ICU telemedicine reengineering of adult critical care. Chest. 2014;145(3):500–7.
5. Wood D. No longer rocket science: robots have found their place in healthcare. Telemed J E Health. 2011;17(6):409–14.
6. Becevic M, Clarke MA, Alnijoumi MM, Sohal HS, Boren SA, Kim MS, et al. Robotic Telepresence in a Medical Intensive Care Unit – Clinicians' Perceptions. Perspect Health Inf Manag. 2015;1c:12.
7. Pronovost PJ, Angus DC, Dorman T, Robinson KA, Dremsizov TT, Young TL. Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. JAMA. 2002;288(17):2151–62.
8. Gasperino J. The leapfrog initiative for intensive care unit physician staffing and its impact on intensive care unit performance: a narrative review. Health Policy. 2011;102(2–3):223–8.
9. Fang JL, Collura CA, Johnson RV, Asay GF, Carey WA, Derleth DP, et al. Emergency video telemedicine consultation for newborn resuscitations: The Mayo Clinic Experience. Mayo Clin Proc. 2016;91(12):1735–43.

10. Ellenby MS, Marcin JP. The role of telemedicine in pediatric critical care. Crit Care Clin. 2015;31(2):275–90.
11. Dayal P, Hojman NM, Kissee JL, Evans J, Natale JE, Huang Y, et al. Impact of telemedicine on severity of illness and outcomes among children transferred from Referring Emergency Departments to a Children's Hospital PICU. Pediatr Crit Care Med. 2016;17(6):516–21.
12. Theurer L, Bashshur R, Bernard J, Brewer T, Busch J, Caruso D, et al. American telemedicine association guidelines for Teleburn. Telemed J E Health. 2017;23(5):365–75.
13. Wallace DL, Hussain A, Khan N, Wilson YT. A systematic review of the evidence for telemedicine in burn care: with a UK perspective. Burns. 2012;38(4):465–80.
14. Holt B, Faraklas I, Theurer L, Cochran A, Saffle JR. Telemedicine use among burn centers in the United States: a survey. J Burn Care Res. 2012;33(1):157–62.
15. Ali SF, Hubert GJ, Switzer JA, Majersik JJ, Backhaus R, Shepard LW, et al. Validating the teleStroke mimic score: a prediction rule for identifying stroke mimics evaluated over telestroke networks. Stroke. 2018;49(3):688–92.
16. Fortis S, Sarrazin MV, Beck BF, Panos RJ, Reisinger HS. ICU telemedicine reduces interhospital ICU transfers in the veterans health administration. Chest. 2018;154(1):69–76.
17. Fortis S, Weinert C, Bushinski R, Koehler AG, Beilman G. A health system-based critical care program with a novel tele-ICU: implementation, cost, and structure details. J Am Coll Surg. 2014;219(4):676–83.
18. Parmar P, Mackie D, Varghese S, Cooper C. Use of telemedicine technologies in the management of infectious diseases: a review. Clin Infect Dis. 2015;60(7):1084–94.
19. Siddiqui J, Herchline T, Kahlon S, Moyer KJ, Scott JD, Wood BR, et al. Infectious Diseases Society of America position statement on telehealth and telemedicine as applied to the practice of infectious diseases. Clin Infect Dis. 2017;64(3):237–42.
20. Christenbury J. Emory cares for ICU patients remotely, turning 'night into day' from Australia: Emory University Media Relations; 2018. Available from: https://news.emory.edu/stories/2018/05/buchman-hiddleson_eicu_perth_australia/index.html. Accessed Sept 2018.
21. Hubley S, Lynch SB, Schneck C, Thomas M, Shore J. Review of key telepsychiatry outcomes. World J Psychiatry. 2016;6(2):269–82.
22. American Telemedicine Association TeleICU Practice Guidelines Work Group. Guidelines for TeleICU operations. 2014.
23. Hoonakker PLT, Pecanac KE, Brown RL, Carayon P. Virtual collaboration, satisfaction, and trust between nurses in the tele-ICU and ICUs: results of a multilevel analysis. J Crit Care. 2017;37:224–9.
24. Siffleet J, Williams AM, Rapley P, Slatyer S. Delivering best care and maintaining emotional wellbeing in the intensive care unit: the perspective of experienced nurses. Appl Nurs Res. 2015;28(4):305–10.
25. Khan N, Jackson D, Stayt L, Walthall H. Factors influencing nurses' intentions to leave adult critical care settings. Nurs Crit Care. 2019;24(1):24–32.
26. Kensley A. Patient sitter, meet telesitter [internet]. 2016. Available from: https://www.uchealth.org/today/2016/02/17/patient-sitter-meet-telesitter/. Accessed Sept 2018.
27. Hayward RA, Asch SM, Hogan MM, Hofer TP, Kerr EA. Sins of omission: getting too little medical care may be the greatest threat to patient safety. J Gen Intern Med. 2005;20(8):686–91.
28. Latif A, Romig M, Pronovost P, Sapirstein A. A consultative telemedicine service improves compliance with best practice guidelines in a highly staffed intensive care unit. Crit Care Med. 2010;38(12):U180.
29. Lilly CM, Cody S, Zhao H, Landry K, Baker SP, McIlwaine J, et al. Hospital mortality, length of stay, and preventable complications among critically ill patients before and after tele-ICU reengineering of critical care processes. JAMA. 2011;305(21):2175–83.
30. Breslow MJ, Rosenfeld BA, Doerfler M, Burke G, Yates G, Stone DJ, et al. Effect of a multiple-site intensive care unit telemedicine program on clinical and economic outcomes: an alternative paradigm for intensivist staffing. Crit Care Med. 2004;32(1):31–8.
31. State Telehealth Laws and Reimbursement Policies Report: The Center for Connected Health Polic; 2018. Available from: http://www.cchpca.org/state-telehealth-laws-and-reimbursement-policies-report. Accessed Sept 2018.

32. Neufeld JD, Doarn CR, Aly R. State Policies Influence Medicare Telemedicine Utilization. Telemed J E Health. 2016;22(1):70–4.
33. Chen J, Sun D, Yang W, Liu M, Zhang S, Peng J, et al. Clinical and economic outcomes of telemedicine programs in the intensive care unit: a systematic review and meta-analysis. J Intensive Care Med. 2018;33(7):383–93.
34. New England Health Care Institute. Critical care, critical choices: the case for tele-ICUs in intensive care. Cambridge: New England Healthcare Institute; 2010.
35. Thomas EJ, Lucke JF, Wueste L, Weavind L, Patel B. Association of telemedicine for remote monitoring of intensive care patients with mortality, complications, and length of stay. JAMA. 2009;302(24):2671–8.
36. Chu-Weininger MY, Wueste L, Lucke JF, Weavind L, Mazabob J, Thomas EJ. The impact of a tele-ICU on provider attitudes about teamwork and safety climate. Qual Saf Health Care. 2010;19(6):e39.
37. Kowitlawakul Y. The technology acceptance model: predicting nurses' intention to use telemedicine technology (eICU). Comput Inform Nurs. 2011;29(7):411–8.
38. Hu PJ, Chau PY. Physician acceptance of telemedicine technology: an empirical investigation. Top Health Inf Manag. 1999;19(4):20–35.
39. Mullen-Fortino M, DiMartino J, Entrikin L, Mulliner S, Hanson CW, Kahn JM. Bedside nurses' perceptions of intensive care unit telemedicine. Am J Crit Care. 2012;21(1):24–32.
40. Romig MC, Latif A, Gill RS, Pronovost PJ, Sapirstein A. Perceived benefit of a telemedicine consultative service in a highly staffed intensive care unit. J Crit Care. 2012;27(4):426.e9–16.
41. Vincent JL, Creteur J. The hospital of tomorrow in 10 points. Crit Care. 2017;21(1):93.
42. Taylor RA, Pare JR, Venkatesh AK, Mowafi H, Melnick ER, Fleischman W, et al. Prediction of in-hospital mortality in emergency department patients with sepsis: a local big data-driven, machine learning approach. Acad Emerg Med. 2016;23(3):269–78.
43. Armaignac DL, Saxena A, Rubens M, Valle CA, Williams LS, Veledar E, et al. Impact of telemedicine on mortality, length of stay, and cost among patients in progressive care units: experience from a large healthcare system. Crit Care Med. 2018;46(5):728–35.
44. Marshall JC, Bosco L, Adhikari NK, Connolly B, Diaz JV, Dorman T, et al. What is an intensive care unit? A report of the task force of the World Federation of Societies of Intensive and Critical Care Medicine. J Crit Care. 2017;37:270–6.
45. Hao J, et al. Tele-ICU: the way forward in geriatric care? Aging Clin Exp Res. 2014;26(6):575–82.