Telemedicine to Expand Access to Critical Care Around the World

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KEYWORDS

- Tele-intensive care • Tele-critical care • Tele-ICU • COVID and tele-critical care
- Disasters and tele-critical care • India and cross-border tele-critical care
- Telemedicine and critical care • Telemedicine and intensive care

KEY POINTS

- Tele-critical care makes available remote, rapid, cost-effective technology-enabled intensive care in deprived areas. International, cross-border tele-critical care bridging time zones with the assured standard of care is now commonplace.
- COVID-19 pandemic, natural disasters, and wars have resulted in widespread adoption of tele-critical care.
- Tele-critical care requires transparent communication with hardware, software, and connectivity as three important components.
- Barriers in implementing tele-critical care solutions include regulatory policies, compensation structures, network infrastructure costs, and cybersecurity vulnerabilities.
- More research on Tele-Critical implementation and outcomes is required to develop best-practice guidelines, certification, standardization of processes, and clinical training paradigms.

INTRODUCTION

Tele-intensive care units (T-ICU) aim at making available critical care capabilities remotely, using technology. Worldwide, there is an acute shortage of intensivists.

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Crit Care Clin 38 (2022) 809–826
https://doi.org/10.1016/j.ccc.2022.06.007
criticalcare.theclinics.com

Concurrently there has been an unprecedented, exponential growth of audio-visual communication and monitoring systems. Distance has become meaningless. The COVID pandemic has demonstrated that bridging the urban–rural health divide in critical care is eminently doable. With 15% of ICU beds in the United States participating in telemedicine programs, tele-critical care (TCC) seems to have come of age.[1–3] Global TeleICU market will reach USD 7.39 billion by 2027.[4] An intensivist in a Telemedicine-enabled "command center" can remotely monitor patients in smaller suburban or rural areas.[5] Tele-intensivists providing care from points of convenience (eg, home, office mobile devices), rather than from a centralized hub, have the highest impact.[6] T-ICU's have reduced expenditure, ICU/ventilator days, and mortality, improving care, quality, and safety.[7] Reports from India demonstrate that T-ICU is no longer confined to developed countries.[8–10]

HISTORY

As early as 1977, Grundy reported using Telemedicine in critical care.[11] In 1982 Grundy reported on 1548 Telemedicine "visits" made to 395 patients physically located in various states.[12] In 2000, investigators at Johns Hopkins, during a 16-week trial of 24-h remote ICU care showed a reduction in ICU and hospital mortality by 60 and 30%.[13] Stimulus for growth of T-ICU in United States was the Leapfrog Group recommendations in 2000. From 2003 to 2010, hospitals using ICU telemedicine increased from 16 to 213 (0.4% to 4.6% of total) and "Tele ICU beds" from 598 to 5799 (7.9% of total beds). In 2004, 20% of 5 million Americans admitted annually to ICUs died.[14] During the pandemic, Karnataka a state in India established a dedicated command center for critical care support, linking ICUs of COVID-19 hospitals on to a single platform.[15] The first international T-ICU service for hospitals in the United States, from Chennai, India was established in 2010.32,000 h of remote monitoring and consultative services covering 50 hospitals have been carried out.[7]

TELE-CRITICAL CARE SET UP

The key to effective TCC is transparent communication as in aviation practices. This requires state-of-the-art hardware, effective software, and ancillary devices, ensuring seamless transfer of patient data from bedside to provider. Various models have evolved, with advances in telecommunications technology. Legacy systems using dial-up modems have given way to wireless, high-speed two-way audio and video interfaces. The components of a basic T-ICU are given in **Table 1**.

Hardware is a major component, hosting equipment to communicate, enter, retrieve information, and perform audiovisual interaction. Software operates medical, logistic, and communication components. The third constituent is a connectivity network for broadband through an intranet/VPN or the internet. There is a need for data storage in physical or cloud format, power systems with backup power, and disaster mode requirements for downtime procedures and business continuity. Most TCC systems are now real time, enabling subspecialty teleconsultations. Remotely located data are reviewed by the teleconsultant at a convenient time.

T-ICU systems need patient data interfaces, including manually bedside-measured vital signs, and automated transfer of physiologic parameters to Electronic Medical Records. This information is securely visible to the remote command center provider. Electrocardiograms and other physiological waveforms are visible using a direct interface to the central monitor. Web-based systems also allow access to individual monitors eg the General Electric MUSE software. Bandwidth, earlier a challenge is now available inexpensively. 4 Mbps can handle most system requirements. Ensuring

Table 1
Components for a basic or advanced tele-critical care system

Component	Hardware	Software	Connectivity
Essential	• Computer systems (Desktop/laptop/tablet/ mobile device) • AV devices including traditional phones/ internet telephones/ headphones/fixed cameras or cart based cameras	• Proprietary/legacy hospital electronic medical record • Alert systems • Data storage on site/ cloud based • Firewall/cybersecurity	• Redundant systems • At least 4 Mbps bandwidth • Virtual Private Network
Optional	• On site servers • Remote monitoring devices linked to command center directly	Newer modular options for analytics	• Always-on video systems
Future Trends	• Minimal footprint computer systems • Contactless monitoring devices	• Open source software • Advanced artificial intelligence/machine learning • Metaverse	• 5G • IOT-based systems • Virtual presence

network speeds implies planning for increased capacity. A redundant access system used for connectivity increases system reliability.

Newer TCC systems simplify processes by using *off-the-shelf* components like webcams, tablet-based AV connectivity, and video-based monitor review. These systems, though lacking the safety and security of traditional hard-wired enclosed networks, were more deployable during the pandemic. The National Emergency TeleCritical Care Network (NETCCN) system in the United States was developed for rapid deployment during times of disaster and has been used for patient care.[16] Examples of a typical T-ICU setup are shown in **Figs. 1–4**.

Use of Emerging Technologies in Tele-Critical Care

As chips are getting smaller, faster, and more efficient there is great excitement and optimism. Fiberoptic cables and 5G technology have increased the possibility of providing advanced critical care in real time. Interfaces like FaceTime display reasonable fidelity of ultrasound images, with rapidly-trained bedside providers performing an acceptable study.[17] The ubiquitous nature of artificial intelligence (AI) applications has impacted health care. Algorithms identify and label endotracheal tubes on chest x-ray images and predict COVID 19 mortality.[18] Multiple early warning scores of patient deterioration generate automated alerts and trigger a rapid response.

Computer vision and contactless monitoring simplifies patient physical interaction. Using photo-plethysmography, oxygen saturation can be measured. Small wearables to collect cardiac rhythms and other vitals have been developed. Processing terabytes of data generated from the ICU is an active research area. AI has been used to troubleshoot ventilator waveform graphics.

The future of critical care is without boundaries—real and figurative. Patients can become critically ill in any location. TCC can be instantaneously deployed due to its virtual nature. There are anecdotal illustrations of remote domiciliary critical care

Fig. 1. A typical setup for a tele-critical care command center at eACCESS, Apollo Hospitals, Hyderabad, India. (*Courtesy* of Sai Haranath, MBBS, MPH, FCCP, Telangana, India.)

with remote home monitoring from a command center. The overarching principle of avoiding harm and maximizing benefit has driven innovation to expand the breadth and scope of remote critical care. The process is in its infancy from a global perspective but will remove inequity existing in critical care expertise availability.

Training and Retraining of Consultants, Residents, and Nurses for Running a Tele Intensive Care Unit

Despite agreement that TCC is most effective when clinicians have specific training and competencies, in use of virtual technologies, there is little published research on this topic.[19,20] Descriptions of clinical training in TCC originate primarily from nursing literature. In a 2011 survey of T-ICU programs, Goran[21] found that 85% of those surveyed were using a formal process for orientation, training, and ongoing assessment of core competencies in TCC nursing. This was despite the paucity of professional practice guidelines available at the time. Communication skills,

Fig. 2. Viewing remote ultrasound. (*From* Haranath SP, Ganapathy K, Kesavarapu SR, Kuragayala SD. eNeuroIntensive Care in India: The Need of the Hour. Neurol India. 2021;69(2):245–251. doi:10.4103/0028-3886.314591; with permission.)

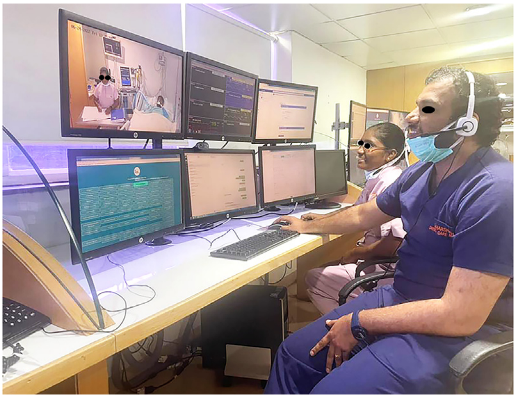

Fig. 3. Interacting with remote ICU from command center. (*Courtesy of* Sai Haranath, MBBS, MPH, FCCP, Telangana, India.)

collaborative decision-making, and effective use of telemedicine tools and technologies were considered. The American Association of Critical Care Nurses created the CCRN-E, a specialty nursing certification for nurses providing TCC.[22] Certification requires a clinical practice component and a certifying examination. As of January 2022, nearly 500 registered nurses have been certified through this pathway in the United States.[23]

For physicians, training is likely to be *ad hoc* and on-the-job. In 2021 the Association of American Medical Colleges released a report describing “Telehealth Competencies Across the Learning Continuum”.[24] In both the United States and United Kingdom, several groups have reported successful implementation of structured telemedicine skills curricula.[25,26]

For those in practice, the American Telemedicine Association offers certificate training in Telehealth (https://www.americantelemed.org/resource).[27] The National Consortium of Telehealth Resource Centers (https://telehealthresourcecenter.org)[28] and professional societies such as The Society of Critical Care Medicine (SCCM; https://www.sccm.org/Clinical-Resources/Disaster/COVID19/Telemedicine-and-COVID-19)[29] offer informal guidance and educational resources but more formal practice guidelines and assessment strategies are needed.

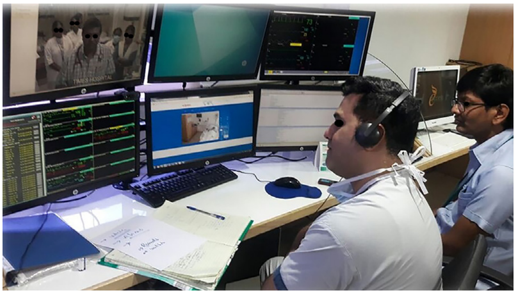

Fig. 4. Interacting with remote ICU. (*From* Haranath SP, Ganapathy K, Kesavarapu SR, Kuragayala SD. eNeuroIntensive Care in India: The Need of the Hour. Neurol India. 2021;69(2):245–251. doi:10.4103/0028-3886.314591; with permission.)

Policy and Regulatory Challenges in Interstate and International Deployment of Tele-Crictical Care Services

COVID-19 has necessitated the acceptance and utilization of telemedicine.[30] However, existing policy, regulatory, and financial barriers have proven challenging due to the paucity of well-established definitions, practice guidelines, and standards of care. In the United States, medical licensing and legal liability are regulated by state governments. Medical privileging and credentialing are administered at the local level. The US Centers for Medicare and Medicaid Services, which sets standards recognized by private insurance companies and health systems, requires that medical professionals be licensed and credentialed to practice at a physician's physical location. Limited opportunities exist for credentialling-by-proxy arrangements between health systems. Interstate medical licensing compacts have been adopted by only half of all states. Legal precedents to guide TCC services are limited. Obtaining malpractice coverage remains a significant obstacle to providing interstate TCC.[31]

Despite significant cost reductions in technology and tools required, provision of TCC services, parallelly using large centralized hub-and-spoke care-delivery models, remains expensive.[32,33] In the United States, no specific billing codes are available to offset TCC services. Fees for critical care services still require physical presence. TCC programs have demonstrated labor-savings compared with in-person coverage. Improvements in quality, safety, and efficiency of care have been documented.[34] Many services charge what amounts to a subscription fee for coverage, but alternative compensation strategies would improve uptake.

During the pandemic, emergency waivers were granted, allowing billing of critical care codes using telemedicine. Many states and localities simplified and expedited licensing and credentialing processes. Many TCC programs initially elected to defer billing for their expanded services, in part due to pervasive uncertainty about the duration of the emergency conditions.[35–37]

International delivery of TCC is complicated. Although the World Health Organization and the United Nations' International Telecommunications Union have made efforts to improve interoperability and access to mobile health, little formal guidance or international law is available regarding TCC.[38] Licensing, credentialing, and compensation are generally dependent on ad-hoc arrangements. Most deployments have involved either circadian-concordant ICU coverage by US-trained physicians living abroad, or limited volunteer services provided during disasters.[9,39] Pandemic-induced temporary volunteer deployments could weaken foundations for future necessary regulations.

International Cross Border Tele-Critical Care: a Perspective from India

Cross-border remote critical care was an uncommon use of technology in critical care, until 2010. The United States has a large requirement for critical care, as many institutions followed the Leapfrog group recommendations for staffing.[40] Commencing in Baltimore,[41] the concept expanded, necessitating the need for after-hours coverage and expanded resources.[42] Simultaneously another social factor was in a play where critical care providers trained, licensed, board-certified, and credentialed in various US states, were moving back to their home countries-primarily Israel and India. Entrepreneurs in both countries quickly designed safe, secure, and profitable businesses that provided remote critical care to the United States, in the same manner as a TCC provider in the United States would function. Different time zones created a workforce primarily working during *their* daytime. *On-call* provider shortages have been a long-standing problem. This virtual model overcomes supply problems as well as issues of night, weekend, and holiday coverage. 5000 ICU patients are probably being monitored nightly from overseas. These systems should be studied to understand logistics, challenges, and opportunities.

CASE STUDIES—ILLUSTRATIONS

It has been the experience of the authors from India that many ICU emergencies and management dealt with remotely are not reported. These include post-cardiac arrest resuscitation, management of sepsis, septic shock, hemorrhagic shock, respiratory failure, cardiac emergencies, postoperative care as well as clinical trials.

ILLUSTRATIONS

A 79-year-old woman was admitted with pancreatitis in a small suburban hospital with limited services in India. She was revived following a cardiac arrest and was subsequently evaluated remotely. A diagnosis of hemorrhagic conversion of pancreatitis was made. Immediate lab work confirmed severe anemia and blood product resuscitation advised. Transfer to an advanced center was initiated. Communication with bedside teams at both locations, close follow-up of pending tests and regular updates ensured advanced level care, even before being shifted. At the same time, a call was received from another ICU discussing arterial blood gas values in a patient with acute respiratory failure, secondary to pneumonia. Adjustment of the noninvasive ventilator was viewed on camera and immediate feedback was obtained on the changes made. In a typical 12-h shift, a teleconsultant may have 30 interactions. This varies widely depending on day, time, unit capacity, hospital features, and staff engagement with the Tele-ICU.

DOMINICAN REPUBLIC COVID-19 TELE-INTENSIVE CARE UNIT—ILLUSTRATIONS

On March 31, 2020, the Dominican presidency (Decree 140–20) created the Presidential COVID-19 Committee and tasked it with creating public–private partnerships (PPP) as well as developing public policy, strategies, and operations to combat COVID-19 at a national level. The committee, on April 5, 2020, presented a comprehensive technology utilization, hospital capacity augmentation, and test–trace–treat strategy with a focus on strengthening local government capacities via PPP including ICU capacity augmentation *via* use of telematic technologies.[43]

The Tele-ICU Project was developed as a capacity-building and force-multiplying effort to support hospitals with basic ICUs but lacked human resources. An initial data-driven needs assessment noted that access gaps existed in health services outside of Santo Domingo (the capital) and Santiago (second largest city). Rural municipalities referred patients to these two cities, creating an unwanted additional surge that overwhelmed care services. Referrals could have been handled in a regional hospital, with a simplified training solution and TCC provided by urban intensivists. The Dominican Republic Tele-ICU Project sought to improve the quality, diagnosis, and treatment of COVID-19, by connecting subject matter experts in provincial hospitals to medical centers having advanced ICUs. The Dominican health system improved the reference pathway and flow of COVID-19 patients to health care centers of higher levels. Through this first-of-a-kind initiative, doctors were able to share *via* teleconference, best practices proving their effectiveness. A total of 2500 nurses and general/primary care physicians were trained in principles of critical care, via a 10-h, 3-day program using the Society for Critical Care Medicine COVID-19 resources.

In September 2020 the first Dominican TeleICU project was launched using a crowdfunding model. This comprised 14 donors, belonging to the Council of Directors of the Dominican Republic American Chamber of Commerce who contributed to the development of the Project. This was the first example of effective health-related crowdfunding. Private sector support guaranteed the care continuum for patients requiring medical specialists expanding their coverage virtually, facilitating the second opinion for difficult cases. This pilot project is led by the Ministry of Public Health, National Health Service (SNS), and the Emergency and Sanitary Management Committee for the fight against COVID-19. This T-ICU project demonstrated the effectiveness of PPP with alliances between local government and private entities. Working from a local perspective, entrepreneurs worked to control the pandemic and keep their employees healthy.

Illustrations from Haiti: On August 14, 2021, a 7.2 magnitude earthquake rattled the nation, killing 2200 and leaving thousands of Haitians injured, in need of assistance. In addition to casualties, 66 health facilities were damaged or destroyed, placing an impossible burden on an already fragile health care system.[44] Haiti is the poorest country in the Western Hemisphere. Even before the earthquake, there were drastic health inequities, limited access to care, and a shortage of physicians and nurses. Further impediments included the assassination of Haiti's President Jovenel Moïse before the earthquake, civil unrest, government instability, and the pandemic. Parts of Haiti are still recovering from the 2010 earthquake (250,000 deaths).[45]

With the Society for Critical Care Medicine, an ICU capacity-building program was developed for Haiti. The goals of the project were to (a) optimize human resources in acute and critical care, responding to patients affected by the earthquake directly or indirectly (b) improve referral system to higher-level care centers to decongest the existing health system. This pilot, included implementation of a virtual Fundamental Critical Care Support course (16 h) directed to general nursing staff and nonintensivist physicians, thus providing working ICU knowledge. This program empowered the University Hospital in Mirebalais to care for critically ill patients remotely, limiting patients sent to bigger referral hospitals in Port-au-Prince. Using an inexpensive web-based Health Insurance Portability and Accountability Act (HIPAA) compliant platform, Haiti-National ICU physicians living outside of Haiti provided T-ICU support to their compatriots remotely.

Earthquakes are catalysts for technological solutions.[46] Before the earthquake, Haiti needed this project. During the pandemic, critically ill patients needed a higher level of care. This project is catalyzing change based on immediate needs. Developing nations like Haiti, with inadequate critical care services, can use this model.

CASE STUDY: UNITED STATES AND INTERNATIONAL TELE-CRITICAL CARE

In the early months of the pandemic, in response to unprecedented strain on critical care resources, the Army's Center for Telemedicine and Advanced Technology Research partnered with the Society of Critical Care Medicine (SCCM), the office of the Assistant Secretary for Preparedness and Response (ASPR) and the Medical Technology Enterprise Consortium (MTEC) to develop an all-hazards NETCCN. Through a competitive funding process, multi-organizational teams were asked to design and build a lightweight, rapidly deployable platform for the delivery of TCC services to any bedside, temporary hospital, or home, using any web-enabled device at the point of care. The minimum viable product would meet cybersecurity and patient privacy standards, and provide synchronous and asynchronous communication tools, a basic electronic medical record system, and a patient cohorting and triage system for the creation of scalable virtual wards. Three teams were then selected for clinical pilot deployments and an additional team to provide logistics and dashboarding support. Over the next year, in response to successive regional COVID surges, NETCCN provided care to hundreds of patients in 61 sites across 18 US states and one US territory, including many critical access hospitals without local critical care capability. Results are being analyzed. Future directions for the program include participation in a national disaster medicine data commons, incorporation of autonomous and remotely controlled medical devices through the Technology in Disaster Environments program, and potential integration with other emergency systems such as the Regional Disaster Health Response System and the National Disaster Medical System.[47]

INDIA AND INTERNATIONAL TELE-CRITICAL CARE

India and Israel were the initial hubs for international TCC. With more intensivists moving out of the United States, this has expanded to other countries. India has a unique time-zone advantage. The high-intensity work of TCC requires strict standards of quality, safety, and system security. In an analogous fashion, a few providers in India began TCC. Initially, these included monitoring of distant hospitals in their own health system. Subsequently, pilot programs and, later, commercial contracts with smaller hospitals in near and distant locations, were initiated. Difficulty in convincing hospitals to adopt a TCC program and making it a viable business proposition remain the biggest barriers to widespread adoption.

The pandemic has allowed many models of TCC to be used. Expansion of existing systems to cover broader geography, as well as a greater range of serious clinical conditions, was noted. As hospitals increased bed capacity, TCC programs adapted, by simplifying documentation requirements, to focus on patient care. As patients increased, complexity of care also rose. Managing critically ill COVID patients with ARDS is time-consuming requiring a considerable degree of coordination with bedside teams. The benefit of remote connectivity was seen in virtual *rounding*, a form of “near” tele-CC though beneficiaries were physically distanced.

India now has multiple organizations providing TCC in various formats. Some are focused on, higher volume public sector hospitals; some are focused on internal patients and others are reaching out to remote locations, with overlapping strategies. Given the as yet niche market, processes and protocols are evolving. Effective use of TCC during the pandemic in India showed its doability.[48] eNeurointensive care has also been documented.[6] Traction and calls to action are building, given the clear utility of TCC in resource-constrained settings.[8] In the TELESCOPE trial in Brazil, TCC-based rounding and outcomes are being studied in a cluster-randomized manner.[49] Increased confidence in handling COVID patients using a hybrid model in a US–Mexico set of border hospitals has been documented.[9]

Tele-Critical Care in Disasters

The first large-scale attempt to provide international telemedicine support to disaster victims was in 1989, in the aftermath of the devastating Spitak earthquake in Russian Armenia. A pioneering National Aeronautics and Space Administration-supported “Spacebridge to Armenia” provided telemedicine consultation using a combination of facsimile, two-way audio, and one-way video.[50] In the subsequent decades, a number of programs have provided support for victims of earthquakes, hurricanes, and other disasters using large, centralized command centers, and lightweight distributed mobile health technologies.[51,52]

Continuous growth in computing power, network coverage, and communications bandwidth has normalized transmission of near real-time monitor and electronic health record data and two-way high-fidelity audiovisual communications platforms. These TCC technologies promise rapid, cost-effective, and scalable support, particularly in unexpected resource-strained disaster areas.[53–56] Systems utilizing existing commercially available communications software and web-based or downloadable applications, working on personal devices of any clinician, caregiver, or patient are necessary.[57] These ad-hoc approaches proliferated in response to the pandemic[58–61] and subsequently in response to Russia's 2022 invasion of Ukraine.[62]

As communications tools, TCC programs are well-positioned to provide logistical support before disasters occur. A logical framework for the coordination of disaster simulation exercises, development of formal disaster contingency plans, and establishment of higher-level networking functions between local entities are provided. TCC networks facilitate large-scale training simulations and monitor resource allocation and strategic medical stockpiles. Real-time surveys are done regarding clinical and material resource strains. This information could be combined with other data streams to help predict clinical surges, and rapidly mobilize or shift resources to the point of need, ensuring early dissemination of clinical information. Lessons learned are likely to benefit future patients and care teams.[63]

In addition, TCC support, while focused primarily on managing critically ill or injured patients, helps mitigate numerous knock-on effects that accumulate in the aftermath of a disaster. Tele-triage supports help identify patients, who could be managed at home. This reduces unnecessary transfers, saving hospital beds. During the pandemic, numerous TCC programs participated in home monitoring of infected and chronically ill patients, minimizing patient transfer.[64–67]

Excepting pandemics, most large-scale disasters are likely to disrupt the communications infrastructure basis of TCC platforms. Allocating bandwidth for emergency response systems and design of drop-in mobile ad-hoc networks and satellite-based internet systems reduce the impact of legacy communications disruptions.[68–71] A second looming threat involves the weaponization of information technologies and increased risks to patient privacy and cybersecurity. This accompanies moves toward distributed systems–especially in the context of war or disaster. Block-chain or other encryption technologies may provide adequate information security.[72,73]

How COVID-19 Changed the Role of Telemedicine in Critical Care

T-ICU is a telemedicine application that has gained strength recently. The objective is to integrate critical care units with intensivists providing highly specialized remote services to centers without trained personnel.[74–77] The main driver for T-ICU is evidence supporting the positive impact of the "intensivist" model. T-ICU is a cost-effective tool that successfully addresses access and level of care opportunities, through efficient resource allocation.[78,79] Telemedicine enables the exchange of knowledge between teams, as well as the training and education of multidisciplinary teams. With advances in medical care, the number of critical patients has been increasing significantly. This affects day-bed occupancy in critical care units.[47,80–82] Despite the use of digital technology, telemedicine deployment had been low before the pandemic. Benefits for institutions implementing a care system based on T-ICU is shown in **Box 1**.

The pandemic has had a devastating impact on global health. Traditionally, public health emergencies expose health system challenges and opportunities. Telehealth has been proposed and utilized as a solution in various health specialties. It is particularly suited for scenarios in which access to care is challenging, such as in rural areas with limited resources. Telehealth can help manage the surge in various conditions

Box 1
Benefits of tele-intensive care unit

- Increased survival indicators
- Decrease in referrals
- Efficient bed rotation/utilization, ensuring greater coverage
- Caring for a greater number of patients
- Significant cost reduction

and help improve the quality diagnosis and treatment of COVID-19. T-ICU can ensure retention with remote support and help triage appropriate patients to higher levels of care.

Hospitals had to address various multiple components of critical care capacity. Significant disparities already existed in the distribution of access to critical care expertise across the world. In developing countries, patients far exceeded available ICU beds.[83–87] This surge required hospitals to expand capacity and implement tiered staffing models. Physicians without formal critical care training were often caring for severely ill patients, including those mechanically ventilated. For COVID-19, telemedicine has been utilized for same-site care to conserve health care resources such as personal protective equipment. Same-site telemedicine ensured safe and high-quality patient care while maintaining social distancing to minimize virus spread. For remote site care, T-ICU has been utilized to augment the workforce, reducing unnecessary referrals and optimizing level of care in underserved areas as shown in **Table 2**.[88–92]

With telemedicine, physicians and nurses can maintain continuity of patient care, simultaneously triaging patients preparing for an anticipated case backlog, after crisis abatement. From a pandemic perspective, T-ICU programs have been implemented to appropriately allocate resources and prevent virus exposure while maintaining safe and effective patient care. In disasters and large emergency scenarios, from a utilitarian perspective for COVID-19 and non-COVID 19 cases, T-ICU can be used for ethical/triage decisions. When there is a high probability of morbidity, a T-ICU consult can be used for resource allocation and palliative care decision-making. Resource utilization could be optimized favoring patients with a higher probability of survival.[93]

Table 2
Tele-ICU Applications during the pandemic

Same Site Applications	Remote Site Applications	Remote Site Applications
1. Personal Protective Equipment Conservation	1. Human Capacity Force Multiplier	2. Intensive Care Specialist Availability
2. Physical Distancing tool	3. Other Specialist Consultant availability	4. Rural/Resource Limited Hospital Support
3. Family Access/ Consultation	5. Tele-Education/Quality Assurance (QA)/Quality Improvement (QI)	6. Health System Triage/ Transfer tool
4. Specialist Consultant Protection	7. ICU Resource Conservation	8. Triage at initial remote site
	9. Dissemination of information to health care teams, and to the general population	10. From triage to Providing patient care

The pandemic has provided immense opportunities for telehealth and telemedicine solutions. Telemedicine services have become a critical asset, with important implications across the whole health care delivery continuum. Telemedicine offers several advantages, especially in nonurgent/routine care and situations where services do not require direct provider-patient interaction. This reduces resource use, improves access to care, and minimizes risk of person-to-person transmission of the infectious agent. In addition, telemedicine solution providers can remotely identify patients requiring further care, using tailored approaches. Telemedicine is a powerful monitoring and coordinating tool ensuring appropriate use of provider facilities. It covers a greater number of patients in remote areas who have no access to specialists or ICU beds. Telemedicine is a safe and efficient care modality with levels of acceptance and improvement of quality of care, now proven worldwide.

SUMMARY

COVID-19 has turned the world upside down. The exponential deployment of communication technology in making available critical care is a global phenomenon. Wireless miniaturization of equipment and real-time remote monitoring has significantly reduced the time for clinical decisions. Training, retraining, and relearning for nurses, residents, and consultants working in T-ICUs have started. Interstate and international deployment of TCC services has led to policy, regulatory, and reimbursement challenges. Interestingly, TCC is an organizational innovation rather than a clinical or technological advance.[94] Resource-intensive and expensive critical care accounts for 15% of hospital costs in the United States (1% of US gross domestic product).[95] Hopefully with TCC, this will significantly come down. The optimal “dose” of remote providers appears to be one nurse per 30 to 35 ICU beds and one intensivist for 100 to 130 patients.[96]

THE FUTURE

With Telehealth eventually becoming the new normal, smart hospitals of the future will be restricted to carrying out complex procedures and handling serious trauma. Specialized ICU’s may constitute 40 to 50% of standalone beds in single-specialty hospitals. Alternatively, with location becoming irrelevant, any bed may be converted into a virtual critical care bed. Multispecialty teleconsultants will be virtually available 24/7. A “lab/doctor” in your pocket will be a reality. Noninvasive sensors and breath analysis will simplify wireless telemonitoring. Miniaturized extracorporeal membrane oxygenation and extracorporeal CO_2 removal devices will reduce the need for mechanical ventilation.[97] Personalized, patient-centric, technology-enabled, remote intensive care will be commonplace. The T-ICU market in 2028 is expected to reach USD 5 billion with a compound annual growth rate of 17.64% over the previous years.[98] With a manned mission to Mars possibly occurring by the end of the decade, extending TCC to space may not be science fiction.[99,100]

CLINICS CARE POINTS

- Lung dynamics such as plateau pressure and evaluation of autoPEEP using ventilator graphics is preferably evaluated with a respiratory therapist As in face-to-face care, the bedside team verbally repeating the order given by the remote teleconsultant will ensure accuracy.
- Time zone differences is helpful in utilizing remote critical care services. Formally ending a shift and starting shift handover is helpful.

- Immediate communication between the bedside team and the remote monitoring team is critical, whenever there is a change in clinical condition or parameters monitored.
- Sepsis reassessment and evaluation of perfusion parameters like lactic acid can be done through remote care assistance.
- Evidence based best practices including DVT (deep venous thrombosis) prophylaxis, stress ulcer prophylaxis, early appropriate antibiotic use when indicated and head of bed elevation. These can be remotely instituted and monitored.

ACKNOWLEDGMENTS

Ms. Lakshmi rendered secretarial assistance

DISCLOSURE

The authors confirm that no competing financial interests exist and there are nil source(s) of support in the form of grants, equipment, etc.

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