COVID-19 and the Transformation of Intensive Care Unit Telemedicine

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KEY POINTS

- ICU telemedicine center critical care specialists played an important role in the expansion of critical care services during the COVID-19 pandemic.
- Off-hours oversight of noncritical care prescribing providers allowed a sudden and substantial transformation of the existing hospital workforce to serve critically ill patients without delay for training those who did not care for the critically ill before the pandemic.
- Bedside providers used the telemedicine system to increase their efficiency and combat the effects of COVID-19 isolation.
- New models of reimbursement for ICU telemedicine services and monitoring and more efficient telemedicine tools became available during the pandemic.

INTRODUCTION

COVID-19, caused by the SARS-COV-2 RNA virus,[1,2] reshaped our everyday way of life.[3] At the time of writing, there have been more than 100 million cases worldwide and more than 3 million deaths[4] despite recommendations from the Center for Disease Control (CDC) to stay 6 feet apart, avoid crowds, avoid poorly ventilated indoor spaces,[5] and limit travel.[6] The COVID-19 pandemic has infiltrated so deeply into our society that it has changed the very way we communicate with one another. According to the US Bureau of Labor Statistics, between 25% and 35% of the US workforce was working remotely between May and August 2020.[7] The change in communication strategies seen in the public sector has also impacted how health care is delivered, and support for the critically ill has been no exception.

Expanding Access to Critical Care Specialist-Directed Management Using Telemedicine

It has been accepted by medical professionals since the time of Machiavelli that early recognition and prompt action for battlefield injuries and medical conditions, including hectic fever (sepsis), allow the application of treatments and techniques that become less effective if delayed.[8] The concept of time windows for interventions is now well-recognized and has shaped life-saving early recognition programs for thrombotic disorders including myocardial infarction and stroke. The value of ICU telemedicine specialist support for

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less common, high mortality-risk conditions is highlighted by the following case example.

A 45-year-old asthmatic mother of 4 presented to an otolaryngologist with progressive nasal occlusion. For many years she had noted episodes of wheezing and nasal congestion after exposure to ibuprofen and reported no other medical conditions. Examination of her nasal mucosa revealed bilateral near occlusion with nasal polyps. After testing negative for COVID-19 nucleic acid secretion she underwent removal of the polyps from her left nare. The next morning, she noted worsening left facial pain and swelling. She presented the following evening to the Emergency Department of her local hospital with a temperature of 101° F, a 0.25 cm blister on her upper lip, and hoarseness. Laboratory evaluation revealed a WBC of 12×10^9/L, lactate level of 8 mmol/L, and a clear chest radiograph with an elevated L hemidiaphragm. Blood cultures were obtained, piperacillin-tazobactam and vancomycin administered, and 25 mL/Kg isotonic crystalloid was administered when sinus tachycardia and hypotension were identified.

Hoarseness was evaluated by a covering otolaryngologist who noted nasal and pharyngeal soft tissue edema and recommended transfer to an operating room for airway assessment and control. Laryngoscopy revealed edema that extended to her vocal cords and endotracheal intubation was performed. Norepinephrine was administered for hypotension. Examination of the operative site was unremarkable and debridement was deemed not to be indicated. After the operation, the patient was transported to her local hospital ICU whereby central and arterial lines were inserted and CT scans of the neck, head, and chest were ordered by an ICU nurse practitioner. Scans demonstrated small pockets of air adjacent to the platysma muscle and were interpreted as not demonstrating convincing evidence of necrotizing fasciitis. Vasopressin and phenylephrine were prescribed for progressive hypotension. The ICU nurse practitioner contacted the otolaryngologist who was unable to offer an off-hours source control procedure. The laboratory reported that blood cultures were growing gram-positive cocci in chains and clusters and the patient was noted to be oliguric and progressively acidemic. On the arrival of the morning shift physician's assistant the blood culture isolate had been identified as beta-hemolytic *Streptococcus*; the otolaryngologist was contacted and recommended the evacuation of the patient to an academic medical center for a source control procedure. On arrival at the academic medical center, the patient was rushed to an operating theater and pronounced dead of a cardiac arrest that occurred during the resection of necrotic neck tissue. Necrotizing fasciitis was confirmed at autopsy.

It is notable that the ICU telemedicine program that would have provided critical care specialist oversight to the affiliate practitioners was terminated several years prior when its financial support was redirected to a lucrative specialty surgery program.

DISCUSSION
Intensive Care Unit Telemedicine Support Models: the Emergent Expansion of Our Critical Care Workforce During the COVID-19 Pandemic

The COVID-19 pandemic provided insights into how the traditional critical care consultative and hub-and-spoke models of critical care support performed during the first influx and were modified and made sustainable for the second influx of patients with COVID-19. The recognition of evolving respiratory failure and controlled, elective, protocol-adherent rather than reactive, emergent, less-controlled care was a central change.

Telemedicine support models are best compared by their key activation, reporting, and efficiency of care delivery characteristics that affect their ability to support the rapid expansion of service delivery. The ability of the hub-and-spoke model to connect new "spokes" to existing infrastructure was leveraged during the pandemic to increase critical care capacity (Fig. 1). The consultative model is activated when the clinical skill, availability, and priorities of a bedside provider allow the recognition of evolving physiologic instability and specialist assistance is needed. In practice, the costs of this determination include time, effort, and vigilance by bedside providers who, when in crisis, have compelling competing demands for their time and energy. The extent to which recognition, prioritization, and costs of intervention inhibit the activation of ICU telemedicine services is larger than most clinicians suspect. It has been reported that only 1 in 50 emergent tele-ICU interventions are initiated by a bedside provider before a telemedicine clinician had determined that an emergent intervention was required.[9] The case presented above provides a clear example of the safety advantages of automated event warning systems that are independent of bedside provider judgment and vigilance.

The hub-and-spoke model of tele-ICU support differs from the consultative model in several aspects that affect the efficiency of service delivery (Fig. 2). The hub-and-spoke model monitors patients with advanced analyses of monitor-
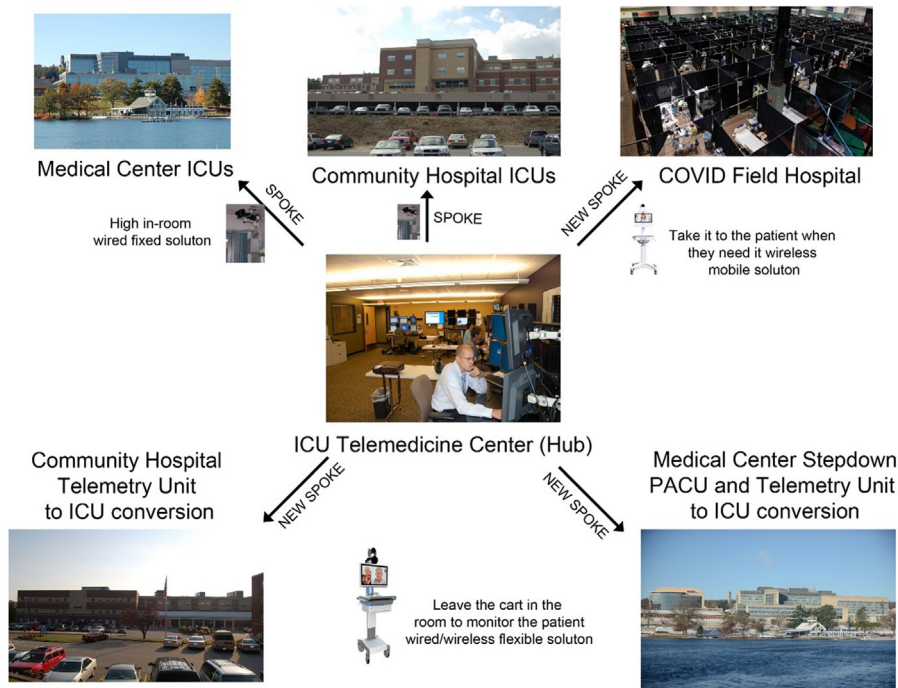
Fig. 1. The expansion of existing tele-ICU infrastructure by adding spokes to established ICU telemedicine centers to expand the medical center and community hospital ICU capacity and provide safe care at field hospital sites that did not exist before the pandemic. During the COVID-19 pandemic, the hub-and-spoke model deployed telemedicine carts with monitoring capability to direct off-site critical care clinicians to at-risk patients, often before physiologic instability and organ failure had occurred. This allowed an approximate 15% increase in bed ICU capacity by conversion of telemetry beds and intensivist support of care by bedside staff who did not work in an ICU before the pandemic. This was conducted without additional telemedicine center staffing.

generated vital sign signals that identify nearly all, and predict some, episodes of hemodynamic instability or respiratory failure. The ability of these predictions to direct critical care specialist reviews to patients who can benefit allows for better and more timely matching of patient need with specialist services than the consultative model. The ability to exchange health information from electronic records and to interact with patients, family members, and bedside caregivers using real-time, audiovisual links[10,11] allow the delivery of care by off-site specialists over wide geographic areas using a leveraged workforce service delivery model (see **Fig. 1**).
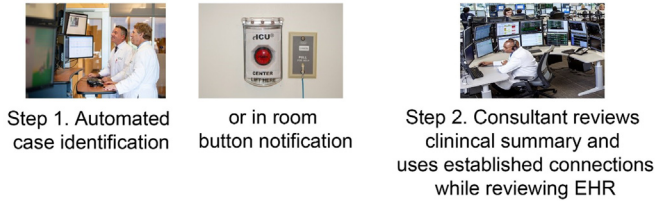
Indeed, it has been estimated that the integration of tele-communication and information systems allows a 10- or more-fold increase in access to ICU specialist care. A specialist that would cover a 15-bed ICU can provide direction using physician extenders for the patients of 150 telemedicine-monitored ICU beds.[12] The higher negative predictive value of telemedicine system alerts than biomedical monitor alarms more efficiently targets specialist attention to patients with evolving hemodynamic instability and respiratory failure than

central monitor station alarms and traditional care models. The hub-and-spoke monitoring model also uses electronic detection that allows an off-site support center to encourage adherence to evidence-based ICU best practices. In addition to improved best practice adherence, a large multi-center study of ICU telemedicine processes and outcomes associated with critical care specialist case review in the first hours after ICU admission[13] and less than 3-min response times to alerts for physiologic instability with more improved outcomes after an ICU telemedicine intervention.[12]

In the case of our 45 year old with life-threatening septic shock from a surgical site infection, critical care specialist case review from the Emergency Department likely would not have produced early surgical debridement but would have facilitated transfer before she was moribund. In addition, a workflow-integrated specialist case review would have enabled a critical care specialist-to-otolaryngologist discussion regarding a diagnosis of necrotizing fasciitis and the role of timely source control.

This event occurred despite the fact that her local hospital used a Leapfrog[14] compliant

2-Step Hub and Spoke Connection

Step 1. Automated case identification

or in room button notification

Step 2. Consultant reviews clinical summary and uses established connections while reviewing EHR

6-Step Consultation Connection

Step 1. Recogniton of instability

Step 2. Request for consultation

Step 3. Available consultant is notifiied

Manual solution   Robotic solution

Step 4. Transport and connect mobile device

Step 5. Consultant connects to mobile cart

Step 6. Consultant securely connects to and reviews EHR

Fig. 2. Lateral expansion of existing infrastructure was 50-fold more effective than the deployment of the consultative model. This is due, in part, to the more efficient 2-step activation characteristics of the hub-and-spoke infrastructure (*top*) compared with the 6-step activation process for arranging telemedicine intensivist consultations (*bottom*). Expansion of the consultative model also requires the resolution of crediting, privileging, privacy, connectivity, and security barriers before being deployed.

consultative model of critical care delivery. After-hours critical care specialist involvement was at the discretion of FCCS-certified prescribers who briefed the specialist about the events of the night only after transfer to the referral center.

The Role of the Tele-Intensive Care Unit Critical Care Specialist in a Leveraged Workforce Environment

One strategy for increasing access to ICU care is to use telemedicine critical care specialist oversight of physician extenders and physicians who have not met critical care specialty board training requirements to provide intensivist curated critical care. Providing critical care training and ICU telemedicine oversight of physician extenders, including nurse practitioners and physician assistants, is associated with lower societal critical care costs and reduced usage of postacute care among Medicare beneficiaries.[15]

Comparative Effectiveness of Intensive Care Unit Telemedicine Center and Specialist Network Consultative Models of Intensive Care Unit Workforce Expansion During the Pandemic

The "Network of Networks" model, in which resources of under-used centers are diverted to

centers that are overwhelmed, played a much smaller role than the lateral growth of existing ICU telemedicine centers during the pandemic. The within-network hub-and-spoke model leveraged existing licensed, privileged and credentialed, critical care providers and used telemedicine cart technologies to increase ICU bed capacity by 15% to 20% (approximately 1500 nonfederal ICU beds).[16,17] ICU telemedicine center professionals supported bedside nurses, physicians, physician assistants, and nurse practitioners who cared for patients in telemetry-equipped spaces that did not house critically ill patients before the pandemic (see **Fig. 1**). In addition, when elective surgical volume decreased during the pandemic, telemedicine critical care specialists were able to help ICU staff who had not routinely cared for acute hypoxemic respiratory failure before the pandemic to support patients with COVID-19 associated critical illness. The outcomes of the patients managed in these transformed and monitored spaces did not differ significantly from those of patients housed in pre-epidemic respiratory ICU beds. The in-hospital mortality among 547 patients admitted to a pre-pandemic ICU bed of 22% was not significantly different than the rate of 26% observed for 223 surge space ICU admitted patients (chi-square test; $P = .24$). In the context of the national

emergency, this expansion from 250,000 to 280,000 monitored patient hours per day was accomplished nearly completely without increasing the ICU telemedicine center workforce. The large geographic scope of the pandemic effectively prevented ICU telemedicine centers from serving patients beyond their system because all centers experienced nearly simultaneous overwhelming local demand.

In addition to increasing medical center COVID-19 capacity, the hub-and-spoke model allowed patients with high-acuity COVID-19 to be cared for in community hospital ICU beds that were vacant when elective surgical volume declined during the pandemic. The critical care specialists of supporting telemedicine centers were able to apply validated, standardized protocols for severe hypoxemia, implement ventilation strategies not routinely before the pandemic, and implement and supervise rescue protocols such as prone ventilation.

A recent report from the National Emergency Critical Care Telemedicine Network allows comparison of the timeliness and effectiveness of expansion of hub-and-spoke model centers with a volunteer consultative model of tele-critical care.[18] A cadre of 248 remote experts provided advice to 260 bedside caregivers, equating to190 hours of clinician interactions and a maximum of 4560 hours of patient stay coverage per day. From a service point of view, the comparative effectiveness of the consultative model to the hub-and-spoke model is 4560/280,000 or 1.6%. Comparison of effectiveness from a workforce size perspective reveals that the consultative model required 248 trained and credentialed specialists to cover 190 patients, or 1.3 specialists per patient served. The hub-and-spoke model used 78 critical care specialists to serve 11,825 patients, or 1 specialist to 150 patients covered. Hub-and-spoke was several-fold more efficient than the consultative model. The time to credentialing for the consultative model was 28 days while hub-and-spoke specialists were credentialed at the time of pandemic onset.

The more favorable service characteristics of hub-and-spoke account for the fact that lateral expansion of telemedicine center support was the dominant form of ICU telemedicine support used during the pandemic (see **Fig. 2**). It is notable that none of the medical centers experiencing a surge of patients with COVID-19 elected to use the services of the National Emergency Critical Care Telemedicine Network.[18]

Key limitations of both models include the availability of functional telecommunication equipment, bedside monitoring equipment, and access to electronic health records. ICU telemedicine centers with established connectivity, network security clearances, and technical support resources were better positioned than volunteer network consultants to provide additional network-connected telemedicine equipment and nursing and pharmacy support services. ICU telemedicine centers were able to add spokes to their hubs by rapidly connecting new devices to their established networks (see **Fig. 1**).

In addition, ICU telemedicine center health informatics professionals connected off-the-shelf telecommunications equipment when it was available and transformed EHR documentation carts into both mobile (wireless) and fixed (wired) ICU telemedicine carts when preassembled carts were no longer available (**Fig. 3**). One specialist could assemble a telemedicine cart every 4 hours. The ability to securely connect these devices to an existing network allowed rapid deployment and testing. Patients were more reliably monitored and rescue interventions were more rapidly made using grid-powered, wired carts than by battery-powered, wireless devices that were powered upon demand. This ability to use the widely available essential components listed in **Fig. 3** to create and connect ICU telemedicine equipment, not existing prepandemic, allowed a rapid 10% to 25% increase in ICU bed capacity by transforming telemetry beds (see **Fig. 1**). This approach also allowed support and oversight of nurses that were not caring for ICU patients before the pandemic by experienced, telemedicine center nurses who had CCRN-E training[19] as well as tele-pharmacist review of orders.[20]

Telemedicine Center Support for Hospital Overflow Patients with COVID-19

In addition to critically ill patients with COVID-19, many hospitals were flooded with patients with noncritically ill COVID-19 pneumonia who were at high risk for respiratory failure. During the height of the pandemic, it became necessary to monitor lower-risk patients in non–telemetry-equipped hospital locations and in field hospitals. Because monitor feed data were not available for these patients, telemedicine center personnel could not use automated detection methods. As an alternative, they used daily visual inspection of hospital vital sign flowsheet data to perform binary risk stratification. Patients with an oxygen prescription of 4 L/min or an increment of 2 or more liters/min in the prior 12 hours, an increase from baseline to a persistent respiratory rate (RR) greater than 25/min, or a notation indicating respiratory distress were classified as high risk. All others were

ICU Telemedicine Cart Component Parts

Pan-Tilt-Zoom Camera and wireless antena

Microphone and Speaker

Telemedicine Help Button

Power Supply, Network and Sound Cards

Cabels and connections

Monitor

Surge Protected Power Supply and Battery

Fig. 3. When off-the-shelf devices were no longer available, telemedicine team information systems professionals continued to expand ICU capacity by cobbling together the camera, microphone, speaker, help button, power supply, sound and network cards, cables, connections, power supply, battery, and antenna (for wireless carts) into a functional telemedicine cart from spare or parts that were commercially available or could be scavenged from out of service devices or carts originally designed for EHR documentation or other nontelemedicine uses. One skilled professional was able to build a cart every 4 hours.

classified as low-risk for hypoxemic respiratory failure in the subsequent 24 hours. Telemedicine clinicians contacted the bedside providers of high-risk patients and offered ICU transfer for life support.

High-risk and low-risk patients were demographically similar, but high-risk patients had higher oxygen flow rate prescriptions and creatinine levels. Telemedicine center risk stratification had 91% sensitivity and 90% specificity for detecting hypoxemic respiratory failure during the subsequent 24 hours. The negative predictive value (NPV) was 0.991 and the positive predictive value (PPV) was 0.348. None of the low-risk patients who did not have care limitations required rescue. The 3 rapid response events among 127 risk-stratified patients with COVID-19 were significantly fewer than the 42 events observed among 265 COVID-19 negative, unscreened, adult inpatients who were hospitalized during the study period ($P < .001$). The in-hospital mortality of high-risk patients who elected rescue was significantly lower than that of those who declined ICU transfer for life support (22% vs 65%, $P < .001$).

Bedside Provider Usage of Telemedicine System Resources

Early in the COVID-19 pandemic in the setting of national and local patient volume surges[21] there

were limits to the amount of personal protective equipment (PPE) available at the bedside.[22] The specter of running out of PPE generated interest in using tele-ICU system resources to reduce room entry events to limit the consumption of PPE. Bedside providers were enthusiastic about their use of audio–video tools and the number of telemedicine interactions by bedside providers dramatically increased near the time they were granted camera access (Fig. 4). As the use of the ICU telemedicine became part of bedside provider practice, aggregate bedside camera usage exceeded tele-ICU team usage, and there was an increase in the number of bedside nurse requests for assistance from off-site team members (see Fig. 4).

Telemedicine System Support for Severe Hypoxemic Respiratory Failure Procedures

The management of COVID-19 associated, refractory, severe hypoxemia with prone ventilation spurred the development of protocol-driven proning teams. The position of the camera and microphone high in the room allowed monitoring members of the team to assure protocol adherence and patient safety. This method of monitoring was perceived by proning team members to be safer and more efficient than in-room monitoring. Telemedicine care delivery became standard ICU work.
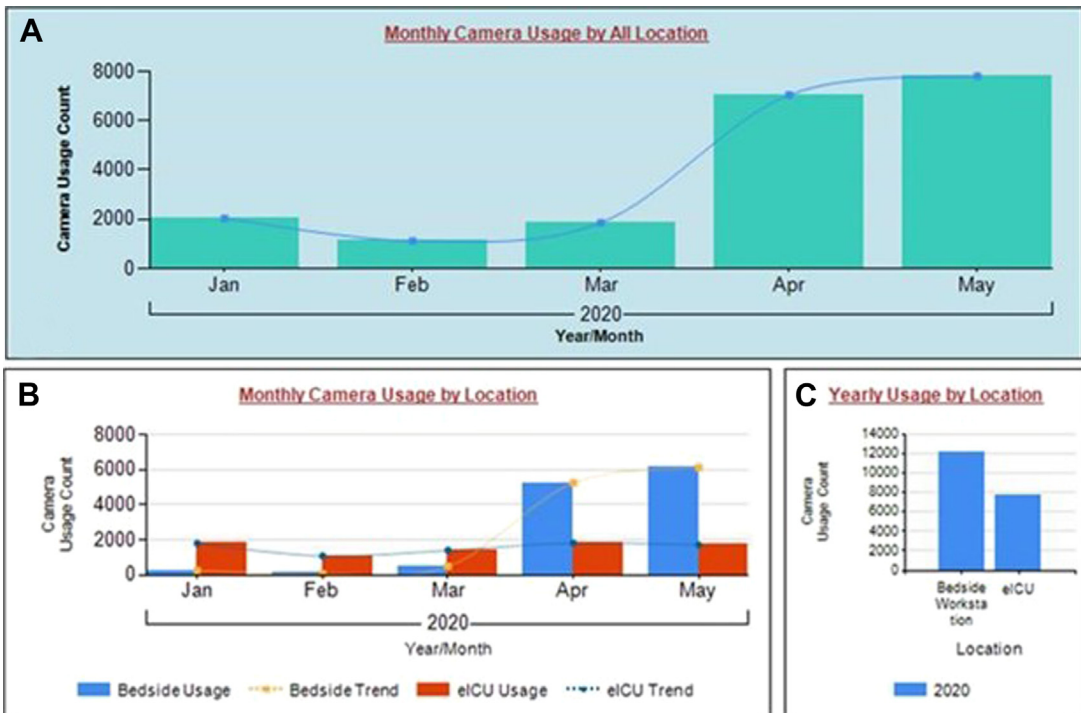
Fig. 4. Wired ICU in room camera usage episodes increased at the time of COVID-19 ICU caseload increased during the pandemic (*A*). The increase in camera usage by off-site usage (*B*; *red bars*) was in proportion to the ICU telemedicine-supported ICU bed expansion. A more than 10-fold increase in camera usage by bedside providers occurred at the time that access was granted (*B*; *blue bars*). Camera usage by bedside ICU providers exceeded, in aggregate, telemedicine provider usage (*C*).

Intensive Care Unit Telemedicine Support for Patients in COVID-19 Isolation

Unintended consequences of COVID-19 visitation policies were barriers to patient–family interaction and emotional support. These well-intentioned measures resulted in isolation and loneliness with their adverse effects on mood and well-being.[23] The importance of physical proximity of family and friends, deeply needed at the time of an unplanned critical care crisis, became even more evident. Moreover, visitation policies disrupted interactions of providers with families and medical decision makers that had formerly fostered trusting relationships. Telecommunication connections were used to provide emotional support by connecting patients to their loved one's mobile devices and allowing them to interact with support center nurses and intensivists. ICU telemedicine systems were also used to support family-inclusive ICU rounding.

COVID-19 Intensive Care Unit Telemedicine Service Reimbursement

Before 2020, Centers for Medicare and Medicaid Services provided reimbursement for some telehealth service transactions on a limited basis.[24] The January 27, 2020 declaration of a Public Health Emergency (PHE) for 2019 Novel Coronavirus (2019-nCoV)[25] enacted Social Security Act (SSA) Section 1135 authority to waive reimbursement requirements during a national emergency.[26] CMS allowed temporary changes in transactional restrictions after the declaration of PHE, the SSA 1135 waiver, and the Coronavirus Preparedness and Response Supplemental Appropriations Act.[27,28] The changes made by CMS rules combined with the many provisions to states laws mandating that commercial payors[29] restore access to health care by reimbursing telemedicine-based transactions.

There is increasing evidence that these policy changes dramatically increased the volume of telemedicine transactions. Koonin and colleagues found that, in the first quarter of 2020, the number of telehealth visits increased by 50% compared with the same period of 2019.[30] The Centers for Medicare and Medicaid Services (CMS) also reported that the volume of telemedicine transactions increased. Before the PHE, there were 15,000 Medicare fee-for-service beneficiary claims

every week for telemedicine services. At the start of the PHE, CMS added 144 telehealth codes which are reimbursable until the end of the PHE. Between mid-March and mid-October 2020, there were more than 24.5 million beneficiaries who received a Medicare telemedicine service; this accounted for 38% of all Medicare beneficiaries.[31]

The transactional approach and other requirements for reimbursement for critical care services largely excluded tele-ICU center-based specialists from being reimbursed for their services because efficient gathering and organization of the clinical facts required for critical care decision making were performed by team members other than the critical care specialist. Accordingly, the most efficient specialists in our critical care workforce were not paid for their services because they could not meet inappropriately lengthy time requirements for transactional critical care CPT codes. Increased efficiency and access to the specialist care that beneficiaries demand are convincing drivers for the development of telemedicine service reimbursement strategies that are appropriate for leveraged workforce-delivered services. The practical obstacles to expanding services using transactional reimbursement were well-appreciated by the leaders of the Department of Veterans Affairs who are expanding ICU telemedicine services for the federal hospital system by funding regional programs for the services that they provide using a subscription model.

A subscriptional reimbursement approach on a per monitored bed day-basis is an attractive option for expanding ICU telemedicine in nonfederal hospital systems because it delivers the right combination of critical care specialist, subspecialty nursing, pharmacy, and technical support personnel as a package. Bundling these services over large geographic areas better aligns service provider available with the need for critical care services than the current transaction-based system. The financial benefits of ICU workforce leveraging have been shown to exceed the costs of privileging and credentialing off-site providers.[32,33] Importantly, this model removes the lack of locally available personnel as a barrier to the delivery of critical care services.

Predictive Analytics for Early Intervention

Hub-and-spoke centers with continuously available personnel are able to leverage increasingly sophisticated event prediction and early warning software to target evaluation and management services. This software is designed to reduce time-to-event recognition and increase the amount of preevent time off-site specialists have

to formulate countermeasures and communicate with bedside providers. Effective systems are transformative because they predict future events and enable preventive countermeasures more frequently than bedside alarms that identify physiologic instability only once it occurs.

SUMMARY

Before the pandemic, ICU telemedicine centers evolved to remove barriers to critical care specialist-directed care, support critical care delivery by providers who are not critical care specialists and respond promptly to alerts for evolving physiologic instability. These activities have been associated with improved hospital and ICU mortality and length of stay in before-and-after tele-ICU studies,[9,34,35] encourage higher rates of adherence to ICU best practices,[9,13] increase access to critical care services, and generate favorable financial outcomes.[32] Their ability to provide a leveraged workforce solution allowed lateral growth and expansion of services to help broker the influx of patients with acute hypoxemic respiratory failure during the COVID-19 pandemic. Health care systems with ICU telemedicine centers were able to more rapidly and robustly expand their delivery of high-quality critical care evaluation and management services than those deploying consultative telemedicine models.

The pandemic also encouraged the use of ICU telemedicine tools by bedside providers to reduce room entry events that consumed PPE, combat COVID-19 isolation and loneliness, and supervise prone ventilation teams. The pandemic brought new methods for reimbursing ICU telemedicine monitoring and service delivery and encouraged the development of improved predictive analytics.

CLINICS CARE POINTS

- COVID-19 associated rapid increases in critical care volume encouraged the lateral growth of hub-and-spoke tele-ICU programs.
- ICU telemedicine critical care specialists supported a safe and rapid expansion of the delivery of effective critical care services by noncritical care providers during the pandemic.
- ICU telemedicine tools were incorporated by rapid response and prone ventilation teams, but also by patients and families, more readily than before the pandemic.

- The value of telemedicine support is more widely accepted by patients, families, and providers and novel reimbursement strategies are making ICU telemedicine the standard of care in the federal hospital system.

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DISCLOSURE

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