In the US, the Health Information Technology for Economic and Clinical Health (HITECH) Act in 2009 stimulated the adoption of electronic health records (EHRs) and promoted health information technology (HIT), including the secure exchange of electronic health information. The American Telemedicine Association (ATA) defines telemedicine as "the use of medical information exchanged from one site to another via electronic communications to improve a patient’s clinical health status." The coronavirus disease 2019 (COVID-19) pandemic accelerated the adoption of telemedicine across the US. Even prior to the pandemic, however, telestroke initiatives were leading the way in improving access to acute stroke triage and management in the US. Telestroke has quickly spread, with at least 56 networks in 27 states linking a stroke center with local hospitals in the US that lack around-the-clock stroke expertise. Similarly, the adoption of telecritical care (TCC) has increased from 0.9% in 2003 to approximately 10% in 2016. During the pandemic, programs have harnessed existing telehealth programs while creating new infrastructure for telehealth to reduce risks for infectious transmission and meet growing demands due to surges of critically ill patients and staff shortages. This article reviews recent advances in telestroke and TCC and how COVID-19 has affected these services.

**Telestroke**

Stroke remains a high priority public health problem. Despite clear evidence for improved outcomes, including reduced mortality, with timely use of recombinant tissue plasminogen activator (rtPA) and endovascular thrombectomy for emergent large vessel occlusion (ELVO), access to rtPA is not yet universally available. Only 55% of people in the US have a primary stroke center within a 1-hour drive, and approximately half of these hospitals do not have staff neurologists. Individuals with acute ischemic stroke who present to rural emergency departments are approximately 10 times less likely to receive rtPA than those presenting to urban primary stroke centers. The field of telestroke developed in the 1990s with the advent of rtPA and a goal of overcoming some of the challenges created by health inequities and geographic disparities. An acute ischemic stroke encounter is particularly suited to telestroke interventions (Box, Table 1).

Patients with a severe acute ischemic stroke and an ELVO may need to undergo interfacility transfers for thrombectomy for a higher level of care in a critical care unit.

**Acute Care**

Although overall outcomes of stroke patients are dependent on stroke systems of care, telestroke programs can be instrumental in providing neurologic assessment, triage, and decision-making related to rtPA administration. The 2019 American Stroke Association (ASA) policy statement on interactions within stroke systems of care recommends telemedicine assessment with the National Institutes of Health Stroke Scale (NIHSS) score. This recommendation has the same level of evidence as inpatient assessment (Class I recommendation; level of evidence A).

**Box: Acute Ischemic Stroke Characteristics Suitable for Telemedicine**

- A wide geographic and population distribution of disease
- Clearly visible clinical findings, often readily identifiable on video
- A narrow therapeutic window
- An existing, proven therapy that is predominantly intravenous and therefore can be administered in any facility with basic infrastructure
- Limited specialist availability
Technology and Guidelines

Mobile stroke care capabilities have expanded with access to smartphones, tablets, and laptops and can be conducted via a mobile console, computer cart, or remotely driven robot. Advanced telestroke applications can provide users with an easy-to-use interface, picture archiving, communication systems imaging, and clinical notes within a single software program integrated with EHRs for documentation and billing. The ATA guidelines include recommendations on providing assessments, diagnosis, management, documentation, technologic support, and training among other key aspects for a telestroke program and network.

Although technologic advances have made the adoption and dissemination of telestroke services easier, the widespread adoption of telestroke has been impeded by licensing, credentialing, reimbursement, and liability issues. Statutory and regulatory requirements vary from state to state.

Table 1. Service Models for Telestroke Care

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
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<tbody>
<tr>
<td>Tele-Consultation</td>
<td>Remote neurologist makes recommendations; referring hospital maintains responsibility and liability for patient</td>
</tr>
<tr>
<td>Tele-thrombolysis</td>
<td>Remote neurologist takes decision-making role regarding thrombolysis and is responsible to varying degrees for patient; typically in context of preexisting agreements between hospitals; patients may be admitted to referring hospital (drip-and-keep model) or transferred (drip-and-ship model)</td>
</tr>
<tr>
<td>Integrated telehealth system</td>
<td>Different centers within single health system share information to facilitate decision making and transfers, often with disseminated responsibilities and no clearly dominant hub</td>
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Telerehabilitation

Telerehabilitation is a promising area for poststroke recovery. A recent Cochrane database systematic review included 22 trials (n=1,937 total participants) of telerehabilitation for stroke, although it was difficult to draw conclusions about efficacy because the interventions and comparators varied greatly across studies. Nevertheless, there is at least low- or moderate-level evidence suggesting telerehabilitation is as or more effective as in-person rehabilitation.

TCC Models

There are several different types of models of TCC, for which comparative effectiveness data are not yet available (Table 2). The centralized hub-and-spoke model is also termed the continuous care model by the ATA. In this model, a single hub provides TCC to multiple localities simultaneously. A variant of this model is the hub-node-spoke structure used by the Veterans Affairs (VA) Administration, the Military Health System, and some large civilian TCC programs. The hub has dedicated staff with only occasional or no staffing responsibilities at the spokes. Patients are monitored continuously by the intensivist. Software programs generate notifications and include clin-
Both centralized critical care and telecritical care (TCC) to multiple locations simultaneously may experience a mortality benefit with telecritical care, but those with observed-to-expected mortality rates greater than 1 may not experience mortality benefit from TCC, shown divergent results.

### TCC Outcomes

Studies evaluating telemedicine and patient outcomes (eg, length of stay, mortality, transfers, and complications) have shown divergent results.

**Mortality.** ICUs with observed-to-expected mortality ratio of less than 1 may not experience mortality benefit from TCC, but those with observed-to-expected mortality rates greater than 1 may experience a mortality benefit with telecritical care. This association could be due to TCC-mediated performance improvement, increased access to physician or nursing support, or standardization of processes. Hospitals that adopted TCC vs those that had not been shown to have a small but statistically significant reduction in 90-day mortality odds (odds ratio OR, 0.96; 95% CI: 0.95, 0.98; P<0.001). However, only 12% of hospitals experienced significant mortality reduction, and these were urban hospitals with high admission volumes (>1,000/year). This finding is counterintuitive to the expectation that TCC mostly benefits small rural hospitals where critical care expertise is limited or absent.

**Hospital Transfers.** Telemedicine has the potential to enhance emergency medical services by expediting triage, helping initiate management prior to transfer, expediting urgent patient transfers, improving the quality and accuracy of remote consultation, and enhancing the supervision of paramedics and nurses.

**Rapid Response Teams (RRTs).** The purpose of both TCC and RRT is to improve care, identify high-risk patients and prevent deterioration of their conditions, and decrease ICU utilization and cost. In a retrospective observational study, TCC was used to support RRT and found to be cost-effective.

**Performance Improvement.** A key purpose of TCC is to help standardize practices, making it well suited to quality improvement projects. Studies have evaluated how TCC can improve adherence to evidence-based medical guidelines lung-protective ventilation, ordering deep venous thrombosis prophylaxis in all appropriate patients, and evaluating the need for continued use of restraints.

**Cost.** The cost of setting up a TCC program can range from $1 to $7 million dollars. Annual operating costs range from $3 to $3.5 million dollars. There are challenges in reimbursing for TCC services, but several studies have shown cost savings from TCC.

**Barriers to Use.** Widespread adoption of TCC has similar barriers as telestroke, including cost, variable licensure, credentialing and privileging requirements governed by inconsistent federal and state laws, medical staff bylaws, and the American Medical Association. Technologic acceptance by the frontline staff particularly nursing may be challenging, and some may perceive TCC to be intrusive or an invasion of privacy.

### TCC and COVID-19

The COVID-19 pandemic and rapid increase in the number of critically ill individuals overwhelmed ICU resources at several hospitals and health systems. Critical care teams were augmented with noncritical care-trained team members. TCC provided promising avenues for oversight of tiered team models. The Centers for Medicare and Medicaid Services (CMS) expanded access to telehealth services, and states relaxed licensing and credentialing requirements. These changes facilitated expansion of TCC services from rural or underserved areas to more widespread areas to fill gaps in the critical care workforce.

Family visitation had to be limited for safety reasons, and several hospitals resorted to virtual platforms for conducting family meetings. TCC resources were used for consultants from palliative care. TCC was leveraged for pandemic surge planning and redefining typical ICU staffing models in a design.

### Table 2. Service Models for Telecritical Care

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
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<tbody>
<tr>
<td>Centralized hub and spoke</td>
<td>A single hub provides telecritical care (TCC) to multiple locations simultaneously</td>
</tr>
<tr>
<td>Hub-node-spoke</td>
<td>Hub with dedicated staff and only occasional or no responsibility to staff spoke</td>
</tr>
<tr>
<td>Decentralized (point-to-point)</td>
<td>Remote intensivist virtually reviews a single patient at a time who may be in any of the served locations; the remote intensivist may also connect from any convenient location</td>
</tr>
<tr>
<td>Hybrid</td>
<td>Both centralized critical care and decentralized subspecialty consultation</td>
</tr>
<tr>
<td>Reactive (responsive)</td>
<td>Virtual visits prompted by alerts (page, telephone call, or monitoring platform)</td>
</tr>
</tbody>
</table>
meant to improve workforce efficiencies and conserve personal protective equipment (PPE) by augmenting in-person critical care teams with a TCC-based intensivist leader. During the pandemic, makeshift TCC platforms were rapidly set up to help with surge planning. If TCC is deployed systematically, it can continue to promote adherence to best practices, improve ICU throughput, and improve communication. Poor implementation, however, could lead to breakdown in communication in a rapidly changing care environment.

The burden of post-intensive care syndrome (PICS), defined as the unintended consequences of critical care in the physical, cognitive, and behavioral domains in COVID-19 survivors is expected to be tremendous. Post-ICU recovery clinics and dedicated COVID-19 centers with multidisciplinary team members such as intensivists, internists, neurologists, pulmonologists, physical and occupational therapists, neuropsychologists, cardiologists, and immunologists among others have also adapted their care delivery models to include in-person as well as telehealth visits.

Conclusion

Telestroke and TCC are promising avenues for improving access to timely care and overcoming geographic disparities. In the midst of a global pandemic, access to telestroke and TCC has proven invaluable for acute care to fill workforce shortages. Potential solutions for overcoming barriers to improve access to these services include support from regulatory bodies, streamlined credentialing and licensing, cost-effective technologies, and streamlined reimbursement for hospitals deploying these services. Future studies should be designed to understand the comparative effectiveness for different models of telestroke and TCC services and for understanding which telehealth models can be implemented effectively during a pandemic.

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