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Telemedicine across the continuum of neonatal-perinatal care

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1. Introduction

Telemedicine has become a significant modality of care delivery during the COVID-19 pandemic [1]. Within a short time, the medical community learned about its potential benefits, applicability, and limitations. A nation of over 332 million people successfully changed how patients were managed in a matter of weeks - from a traditional in-person healthcare practice to substantially virtual delivery. When compared with the same period in 2019, the number of telehealth visits increased by 50%–154% during January to March of 2020 [2]. Sensible laws, regulations, and practice policies at the federal, state, and local levels were enacted with remarkable speed to reduce reimbursement and licensure barriers, drive the needed change, and overcome adoption inertia.

1.1. What is telemedicine?

Telehealth has been defined as the use of electronic information and telecommunication technologies to support and promote long-distance clinical healthcare, patient and professional health-related education, public health and health administration [3] - which includes telemedicine, telenursing, remote patient monitoring and m-Health. Telemedicine is a subset of telehealth that involves real time or asynchronous communication between healthcare providers, patients, and the patients’ families (Fig. 1).

Perhaps the earliest record of telemedicine use in neonatology was reported by Grundy et al., in 1977 where neonatologists at Case Western University Hospital provided newborn nursery rounds remotely to Forrest City Hospital [4]. They concluded that, although telemedicine was feasible and offered value, the technology was too expensive. Technological advances in cell phones, mobile tablets, and miniaturized high-definition cameras coupled with availability of high-speed broadband and cellular data services have improved the transmission of high-quality video/audio. These advances have made the use of telemedicine more affordable and reachable, especially in rural areas where healthcare is most scarce [5]. The 2020 COVID-19 pandemic became a great change catalyst that accelerated adoption in all sectors of the economy, but particularly in healthcare. While this transformation is occurring most notably in ambulatory settings, the current evolution of telemedicine use in neonatal and perinatal medicine has highlighted potential ways that this mode of healthcare delivery can optimize care and health outcomes for infants and their families in the entire spectrum of maternal, fetal, and neonatal care [6, 7].

1.2. Telemedicine across the care continuum

Telemedicine can benefit neonatal and perinatal care across the care continuum, starting from the fetus and moving to delivery room resuscitation, acute neonatal intensive care unit (NICU) care, and follow up after discharge (Table 1).

Telemedicine has been tailored to the changing needs of neonates and families at each stage of these transitions. This chapter summarizes telemedicine use and early data regarding its impact on health outcomes, quality and cost of healthcare delivery, and individual personal experiences, and provides practical steps for using quality improvement (QI) principles to implement telemedicine [47].

1.2.1. Prenatal period

Mothers with medically complex pregnancies may have difficulty traveling long distances to fetal centers and benefit from the ability of their local care systems to access perinatologists, neonatologists, and other subspecialists in telemedicine-capable quaternary centers [8]. Capabilities, including transmission and review of diagnostic studies such as fetal echocardiograms, ultrasounds and other imaging, and
provider-to-provider and provider-to-patient teleconsultations, have improved triage and timing for referrals and transfers of care, with positive impact on perinatal regionalization [48]. Faced with restrictions on in-person visits during the pandemic, fetal centers rapidly adopted telemedicine as a reliable way to continue providing care to expectant mothers. A High-Risk Program at the University of Arkansas for Medical Sciences focused on the management of diabetes during pregnancy recently reported significantly fewer inpatient admissions and fewer maternal care expenditures in the telemedicine group compared with an in-person care group [49]. Rapid implementation of prenatal virtual consultation programs with mothers with fetal anomalies during the pandemic has allowed care to continue, where the providers could explain the fetal defect and formulate a care plan for the delivery room and NICU [50]. A recently conducted study showed high levels of physician and patient satisfaction with telemedicine to provide prenatal consultation during the COVID-19 pandemic, demonstrating feasibility and effectiveness for this application [51]. However, while access to care and travel burden for patients improved, issues with connectivity and video/audio quality persisted [50].

1.2.2. Neonatal resuscitation and training

Delayed initiation and improper execution of neonatal resuscitation is associated with poor cardiopulmonary and neurological outcomes. Erdal et al. showed a 16% increase in the risk for death or prolonged admission for every 30-s delay in initiating face mask ventilation [52]. In the U.S., 15–20% of very low birth weight neonates and 45–60% of term neonates with hypoxic ischemic encephalopathy are born in hospitals without a NICU [10]. Enabling neonatologists to guide neonatal resuscitations using telemedicine can improve the quality of care and patient safety [11–13]. Teleresuscitation programs require judicious selection of technology, implementation with validated frameworks, understanding factors that support or hinder adoption and utilization, and strategies for monitoring and evaluation [10,14]. In addition to consultation for live resuscitations, real time video coaching in simulated neonatal resuscitation improves performance of community hospital staff [12]. Studies of teleresuscitation across an expansive network of hospitals demonstrated a reduction in unnecessary medical transport to higher levels of neonatal care, a finding that persists after risk adjustment for Apgar scores, birthweight, gestational age, and TRIPS (Transport Risk Index of Physiologic Stability) scores [31,53]. Installation of low-cost, effective telemedicine systems have helped local birth centers triage newborns who can safely stay at the local centers or be transferred to appropriate tertiary centers [12]. Studies of tele-education programs have also demonstrated comparable results of knowledge acquisition and skills, compared with in-person teaching [15].

1.2.3. Neonatal teletransport

A critical moment in managing ill neonates is transport to a tertiary or quaternary neonatal care center. A recent prospective study looking at the use of telemedicine during pediatric and neonatal transport suggested that visual findings via telemedicine can influence care management, particularly for complex cases [16]. Physicians are more inclined to use telemedicine for assessment, as it adds a virtual component to assessment, whereas transport team members find it less useful [16]. One reason could be that transport teams are already highly trained and skilled at managing difficult situations – the need for a second set of eyes could be perceived as time consuming (especially when the team needs to troubleshoot at times of poor connection), and an infringement on their autonomy. While video can be helpful in certain cases, video technology has not been simple and intuitive enough to allow teletransport use in situations where the transport teams are not able to troubleshoot the technology, and therefore they abandon its use altogether. Efforts to identify and measure the value of teletransport use under specific conditions is critical and will likely require input from key stakeholders from both referring and receiving centers with transport capabilities.

1.2.4. Telemedicine support for clinical management in NICUs

Over the last several years, clinical support for community NICUs from remote neonatologists and pediatric subspecialists in neurology, medical genetics, cardiology, ophthalmology, and surgery have increased [19].

Neonatology support at community nurseries. Community nurseries in medically underserved areas may benefit from using telemedicine with neonatologists at tertiary NICUs [28]. Telerounding allows neonatologists to participate remotely in multidisciplinary rounds at lower-level NICUs to support the local advanced practice provider, family, and nurse. The remote provider can observe a physical examination performed by the in-person team and/or use remote diagnostic tools, such as stethoscopes and other peripheral devices, to examine the patient themselves. Physical examinations performed using telemedicine are highly reliable, with some exceptions such as skin findings [54], and when used carefully can be cost effective by avoiding unnecessary transports to referral centers [53]. Hybrid telemedicine models in which neonatal specialists provide in-person care a few days a week and tele-rounding for the remaining days have also demonstrated success [55,56]. In a prospective study of this care model, Makkar et al. demonstrated non-inferior patient outcomes in a satellite Level II NICU compared with a regional Level IV NICU for a similar patient cohort [29]. Parents reported a high level of satisfaction with care provided through telemedicine. Furthermore, families spent more time with their infants and had fewer travel difficulties when their babies were able to stay at the local hospital closer to home and this approach prevented
Cardiology. Cardiologists have been one of the biggest adopters of telemedicine. Remote fetal echocardiography has facilitated the diagnosis of congenital heart defects and is feasible, cost-effective, and results in the delivery of such infants at appropriately equipped and staffed fetal centers [9]. For infants who fail the CCHD pulse oximetry screening, remote tele-echocardiography and pediatric cardiology consultation can effectively identify undiagnosed ductal-dependent cyanotic congenital heart disease and neonatal arrhythmias [24]. Additionally, tele-echocardiography with remote interpretation can be an effective option for determining which neonates require urgent transfer to tertiary care centers. This service can be provided in real time or using store-forward mechanisms [58,59]. Real-time tele-echocardiography also has the advantage of providing training to community ultra-sonographers. Alternatively, store-forward modalities allow cardiologists a more flexible schedule to review images, although this approach carries the risk of needing to repeat a suboptimal exam and could delay diagnosis. Success has varied depending on the skill of local ultra-sonographers [60]. The lack of digital stethoscopes that can transmit heart sounds with high fidelity and quality has limited the auscultative exam of some remote cardiologists. A recently conducted study showed the feasibility of tele-echocardiography for congenital heart disease (CHD) screening in a Level II NICU. These authors demonstrated that tele-echocardiography can be safe and effective in CHD screening and can prevent unnecessary transfer of infants to regional level III/IV NICUs, thus saving on transfer costs [59]. Feasibility of remote cardiac intensive care unit rounds, especially in the international setting, is beginning to be studied [25].

Retinopathy Of Prematurity (ROP). Remote ROP examination and image analysis are effective and valuable if done with well-trained retinography technicians and readers. The SUNDROP study demonstrated that retinal images from infants with verified treatment-warranted ROP can be obtained, transmitted, and interpreted with high accuracy (99.8% sensitivity, 100% specificity) [22]. A 2015 joint technical report from the American Academy of Pediatrics, the American Academy of Ophthalmology, and the American Association of Certified Orthoptists discussed the current literature on remote digital fundus imaging evaluation techniques, practices, and risk considerations [61]. Further, their most recent guidelines recommend performing screening ROP examinations using digital wide-angle ocular fundus photography, followed by remote interpretation for infants who are admitted to a NICU without an on-site qualified pediatric ophthalmologist [62]. Although feasible, evidence for effective remote monitoring of infants after ROP therapy remains unclear [23].

1.2.5. Telemedicine and family-centered care

Lactation. Telelactation programs can give access to board-certified lactation consultants whose babies are in NICUs lacking such support. Early studies suggest that mothers enrolled in a telelactation program found it to be helpful [36]. Larger multicenter studies examining whether telelactation improves initiation and sustainability rates of breastfeeding are needed.

NICU cameras. Visitation restrictions due to the COVID pandemic have promoted the use of bedside web cameras by parents so they might see their babies from home. This ability provides reassurance, decreases anxiety and stress [63]; in some reports, this approach also makes pumping easier [64]. However, since lactation support is typically a predominantly nurse-led effort, implementation success relies on careful consideration of nursing buy-in [65,66].

Family education. Educational opportunities within the NICU can be optimized with the use of telemedicine. The use of web-based or mobile applications provides both asynchronous and synchronous avenues for caregiver education. These strategies decrease parental stress and anxiety, and potentially increase caregiver discharge “readiness” and decrease patient length of stay [18,64,67].

Telemental health. Addressing the mother’s mental health needs has been a growing priority in fetal centers and NICUs. Rates of perinatal

### Table 1

| NICU Journey Stage | Telehealth Clinical Activities |
|--------------------|--------------------------------|
| Prenatal           | • Maternal-Fetal Medicine consultation for high-risk pregnancies, abnormal fetal imaging, and pregnancies complicated with fetal anomalies |
|                    | • Remote monitoring for high-risk conditions |
|                    | • Neonatology, pediatric, and surgical subspecialty consultation for pregnancies complicated with fetal anomalies [8,9] |
|                    | • Renutrition support for high-risk deliveries to primary care providers in the community [10-14] |
|                    | • Renutrition simulation education [15] |
| Perinatal          | • Teletransport support to referring hospital for stabilization of the infant before transport team arrival |
|                    | • Teletransport support to transport team members for stabilization of the infant in transit to referal NICU [16] |
| Transfer           | • Family-centered care initiatives [18] |
|                    | • Teleconsults or E-consults from subspecialists (medical or surgical) [19] |
| NICU Admission     | • Common described subspecialties: |
|                    | • Neurology [20,21] |
|                    | • Tele-ROP [22,23] |
|                    | • Cardiology [9,24,25] |
|                    | • Surgery [26] |
|                    | • Genetics [27] |
|                    | • Virtual rounding |
|                    | • Hybrid Telemedicine to support lower level NICUs in the community [28,29] |
|                    | • Interprofessional teлерounding [30] |
|                    | • ECMO Rounds |
|                    | • OnDemand neonatology consults [31,32] |
|                    | • Inpatient therapy services |
| Discharge Transition| • Lactation support [36] |
| Neonatal Follow-up | • Discharge communication (Provider-to-Provider) [37] |
| Medical Home       | • Home Care [38] |
| and Medical Home   | • Ambulatory follow-up visits for NICU graduates [39] |
|                    | • Medical Home for infants with complex medical issues: |
|                    | • Home care for infants with complex medical and surgical conditions transition [40] |
|                    | • Home ventilator management program [41] |
|                    | • Supplemental NG feeding program [42] |
|                    | • Home Supportive Programs: |
|                    | • Home care [43] |
|                    | • Teletherapies [34,35,43] |
|                    | • Telelactation [44-46] |

unnecessary transfers to a regional Level IV NICU. Use of teleconsultation via video rather than telephone also decreased patient transfer rates between rural community hospitals and neonatal providers at a tertiary NICU [32]. Haynes et al. found that 64% of newborns who had a video consultation were transferred to a higher level NICU vs. 82% of those who had a telephone consultation. Although the study was not designed to show prevention of “avoidable” transfers, it does demonstrate a potential benefit of neonatal teleconsultation use for regionalization [32].

Neurology. Provision of clinical neurology subspecialty services via telemedicine dates to the 1950s, when teletask programs were established for adult populations in rural communities where early recognition and treatment improved patient outcomes [20]. Advances in video resolution and broadband technology have allowed providers to perform genetic and neurological examinations with acceptable accuracy [57]. In a recent pilot study, remote neurologists were able to observe and advise local providers performing the modified Sarnat examination on infants with suspected neonatal encephalopathy [21].
mood anxiety disorders (PMADS) in pregnant women are becoming more prevalent during the COVID-19 pandemic, making telemental health essential. Cognitive Behavioral Therapy and Interpersonal Psychotherapy are evidence-based treatments for PMADS that can be transferred to a virtual platform [68]. The Stafford Disaster Relief and Emergency Assistance Act of 2020 has allowed more psychologists and licensed clinical social workers to deliver telemental health to anxious parents processing unexpected and worrisome news about their pregnancy. Following birth, the psychologist can provide important counseling to parents. The efficacy of telemental health in the NICU is largely unknown and must be studied. During the pandemic, a recent survey of NICU psychologists reported that 46% of providers found the teledicine technology easy to use, while 23% found it difficult. Despite limitations such as the ability to observe certain activities such as parent-infant interactions, accessibility of psychologists to parents, even if virtually, is better than no access at all.

1.2.6. Transition of care and post-discharge follow up

Ensuring a safe and effective transition from the NICU to home is critical, especially for technology-dependent infants. [38,410,51] Televisits conducted with caregivers in their homes shortly after NICU discharge have uncovered practice and knowledge gaps, as well as care coordination inefficiencies. Televisits offer a safety net to close such gaps and reinforce the highlights of the tremendous amount of education caregivers receive in the short time before discharge. A prospective cohort study by Willard et al. gave examples where 78 post-discharge issues, mostly minor related to feeding and surgical site concerns, were identified in 98 patient telemedicine visits [40]. About 50% of caregivers reported that telemedicine visits prevented an additional call or visit to a clinician, while 12% prompted an earlier visit. Caregiver satisfaction rating was high. Median estimation of total mileage saved by respondents was 1755 miles.

Telemedicine Assisted Neonatal Homecare (TANH) is a service where qualified nurses support parents at home in the management of tube feeding and breast/bottle routines via telemedicine. A 2019 observational study comparing TANH with historical controls of premature infants receiving standard education/support in NICU care found no significant difference in exclusive breastfeeding rates [69]. The authors suggested that comparable breastfeeding rates can be achieved through telehealth support for families at home instead of in the NICU, but warned that larger multicenter trials are necessary to validate efficacy.

1.3. Implementing telemicine using a QI lens

We offer a practical approach for deciding whether telemedicine can be helpful at each stage of an infant’s and their family’s perinatal and neonatal journey that is rooted in the SPROUT (Supporting Pediatric Research in Outcomes and Utilization of Telehealth) Framework for Evaluating Telehealth [57].

Step 1. What physical or mental health outcomes are affected by such improvements? While these outcomes often “lag” behind process measures, they are essential to define early in these projects to move towards outcomes-focused improvement work.

Step 2. Determine opportunities for delivering better healthcare (independent of telemedicine) at each stage of the journey, as described below. These opportunities measure the quality (effectiveness, equity, efficiency, safety, timeliness, patient centeredness) [70] and cost-effectiveness of healthcare delivery.

- Prenatal care – Improve glucose management in gestational diabetes, increase the percentage of expectant mothers within a community who receive adequate prenatal care.

- Peripartum care – Improve performance of neonatal resuscitation protocols in the delivery room, reduce transportation time to tertiary centers, improve TRIPS scores.

- NICU – Reduce parental anxiety and stress; expedite access to subspecialty consultation; improve teamwork and collaboration amongst NICU providers, various subspecialties, and support services; improve caregiver and family experience and inclusion; reduce avoidable hospital stay; avoid patient harm.

- Transition to home – Make the discharge process more efficient, improve post-discharge care coordination, ensure care plan alignment with primary care pediatricians, ensure a safe discharge, reduce avoidable readmissions and health care utilization.

Step 3. Identify 3–5 key drivers that are critical for successful and sustainable improvement. Broadly speaking, these key drivers are typically aimed at changing some part of the current care system at the people, process, or tool level. For example, getting buy-in from leaders, managers, and frontline staff and making workflow more efficient or easier to do are often cited. Many brainstorming techniques, such as affinity diagrams, can be used by the team to identify key drivers.

Step 4. How can video/audio technology (if any) support one or more of the drivers identified in Step 3? If so, what is the technology and how should it be used? If not, end here.

Step 5. For each technology supporting the drivers: What value does the technology offer and at what cost? Is the value qualitative or quantitative? Such estimates can be obtained through published evidence, group consensus, or personal experience. For example, tele-education would increase the knowledge and skills of NICU parents who cannot come to the NICU to take in-person classes. Tele-resuscitation can improve adherence to CPR protocols. How disruptive is the technology to the current workflow? Say estimates to estimate this disruption using, for example, a 9–5 Likert scale (5 being very, and 0 being not at all). What is the staffing cost (provider, frontline, staff)? Will existing staff be reassigned to other responsibilities or new staff hired? How much will the technology cost the NICU? (Table 2)

Critical steps for a successful program include establishing realistic goals and timelines, anticipating potential barriers, and identifying an implementation team composed of key stakeholders. Additionally,

Table 2

| Step | Description |
|------|-------------|
| Step 1 | What physical or mental health outcomes are you trying to improve? Improve TRIPS (Transport Risk Index for Physiologic Stability) score. Ensure baby’s safe transfer to the transport ventilator, maintain eutermia, identify and treat risk factors for hypotension and hypothermia. Situational awareness of baby’s conditions and risk for hypotension, hypothermia, and respiratory decompensation, effective teamwork and communication, rapid response and stabilization, minimal safe transport time. Telemedicine huddle between transport team, referring team, and medical command team at receiving hospital. Telemedicine huddle value - increase situational awareness and sharing of the same mental model of the patient, allow for communication and clarification, assumption checking, catch safety risk factors that can be mitigated immediately. Cost - estimated 5-10 min per huddle, team distraction, workflow rework required. |
| Step 2 | Determine opportunities for delivering better healthcare (independent of telemedicine) |
| Step 3 | Identify 3–5 key drivers that are critical for successful and sustainable improvement. |
| Step 4 | How can video/audio technology (if any) support one or more of the drivers identified in Step 3? |
| Step 5 | What value does the technology offer in support of the drivers, and at what cost? |


deploying more expensive technologies that are simpler to use and HIPAA-compliant (despite relaxation of security regulations during the pandemic), and providing succinct but effective education to providers and patients, will help with success and longevity down the road.

1.4. Policy and reimbursement

Current regulations and payment for telenoneonatology depend on the specific rendered service, state-specific policies on licensure, and reimbursement parity for telemedicine. The Center for Connected Health Policy offers helpful information on state-by-state payment policies [71]. In many states, public health emergency (PHE) waivers have temporarily lifted geographic restrictions and expanded coverage for video-based telehealth care, store-forward services, and remote monitoring to continue care provisions for children and pregnant women during the pandemic. Currently, at least 42 states require commercial insurers to cover telehealth services, although not necessarily at parity with in-person care [72,73]. Additionally, the Office of Civil Rights issued more permissive guidance on using non-HIPAA (Health Insurance Portability and Accountability Act) compliant video-conferencing and data sharing technology, resulting in quicker and broader adoption of telemedicine [74,75].

While reimbursement for telenoneonatology service varies across the many use cases, payment for subspecialty and/or support tele-consultations and remote patient monitoring is better reimbursed than teletransport and NICU cameras. Temporarily expanded coverage for telemedicine could become restricted after the emergency subsides, unless there are supporting data demonstrating its value.

2. Conclusion

Moving forward, it is imperative to build on the progress made in the field of telemedicine. The COVID-19 pandemic has awakened the medical community to the potential uses and benefits of telemedicine in neonatal and perinatal care. Retreating to pre-pandemic use would be an unfortunate lost opportunity to improve delivery of perinatal and neonatal care. With reliable and systematic monitoring of quality, effectiveness, and outcomes, current and future neonatal telemedicine programs can be even more impactful on healthcare with wider accessibility, more appropriate targeted utilization, and potential systematic cost-effectiveness.

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