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Scope of telemedicine in neonatology

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Abstract: There is a widespread shortage of physicians worldwide, especially in rural areas. This shortage is more prevalent when it comes to subspecialty care, even in developed countries. One way to provide access to specialty care is using technology via telemedicine. Telemedicine has evolved over the last two decades, and its use is becoming widespread in developed countries. However, its use in the neonatal population is still limited and practiced only in some centers. It is now apparent that telemedicine can be successfully used in the neonatal population for screening premature infants for retinopathy of prematurity, congenital heart disease, bedside clinical rounds, neonatal resuscitation with the support of a tertiary care hospital, and family support. This avoids unnecessary transfer and appears to provide the same quality of care that the baby would have received at the tertiary care facility. This approach also improves family satisfaction, as the baby and the mother are kept together, and reduces the cost of care. This review focuses on the use of telemedicine in neonatal care, concentrating on the main areas where telemedicine has been shown to be successful and effective, including the status of telemedicine in China. **[Chin J Contemp Pediatr, 2020, 22(5): 396-408]**

Key words: Telemedicine; Neonatal intensive care unit; Neonatology; Newborn

Physician shortage is a worldwide concern due to a growing demand for physicians that outmatches the supply. Recently, the World Health Organization (WHO) reported a global shortage of 4.3 million physicians, nurses, and other healthcare professionals. The shortage is worse in developing nations due to the limited number and capacity of medical schools. Many developed nations, including the United States, Canada, New Zealand, United Kingdom, Australia, and Germany, report similar problems[1].

The Association of American Medical Colleges estimates that demand for physicians in the United States will exceed supply anywhere from 46 900 to 121 900 by the year 2032[2]. This shortage will result in both urban and rural areas being underserved with physician support. Currently, there are two times the numbers of physicians per ten thousand in urban areas compared with rural areas. For subspecialty care, there are nine times more physicians per 10 000 population in urban areas than in rural areas[3]. At present, we utilize available resources based on regionalized health care, with the goal to improve patient outcomes by directing patients to facilities with expertise for a given type of illness. The major disadvantage of this necessity is that it involves the transfer of patients away from home to obtain required care. In addition, this approach can overwhelm the resources at the specialty hospitals.

One of the most prominent alternatives to patient transfer can be use of technology, such as telemedicine to deliver the physician, albeit virtually, to the patient, especially when the reason for transfer is a lack of subspecialists at the local hospital. Telemedicine has evolved from an initial definition as healing at a distance to the current definition of remote delivery of health care services and clinical information using telecommunications technology[4-5]. Telemedicine is considered to occur in “real time” when there is live

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interaction between the patient and the provider at a remote end, whereas the "store and forward" type of telemedicine involves acquiring medical data and then transmitting this data to a physician at another site for assessment[4]. Since the year 2000, telemedicine has gained popularity, with more than 50% of US hospitals now using some form of telemedicine; there are about 200 telemedicine programs serving 3 000 sites[5]. Telemedicine has been utilized in adult and pediatric populations for the last few decades to extend health care to medically underserved areas. The use of telemedicine in the neonatal population is relatively new and is understudied. During the last decade, telemedicine has been increasingly used in the neonatal population to provide consultation, tele-echocardiography, retinopathy of prematurity screening, neonatal resuscitation program (NRP) education, post-discharge follow-up, and care at neonatal intensive care units (NICUs)[6]. The growing need for telemedicine use in neonatal and pediatric populations has created an opportunity for the American Academy of Pediatrics to create guidelines and promote research through a group called Supporting Pediatric Research on Outcomes and Utilization of Telehealth (SPROUT)[7].

In this review, we discuss the evidence behind the five most common applications of telemedicine in neonatology as follows: tele-retinopathy of prematurity screening; tele-echocardiography; tele-resuscitation; tele-rounding; and family support.

1 Retinopathy of prematurity screening

There are several factors that have converged to place telemedicine at the forefront of evaluation of infants to detect retinopathy of prematurity (ROP). The increasing survival of extremely low birth weight infants has led to an increase in the incidence and severity of this disease. Currently, ROP screening requires a real-time fundus examination by a qualified pediatric ophthalmologist. At the same time, the increasing medicolegal burden and psychological stress on physicians who diagnose and treat ROP has led to a decrease in trained providers who are willing to keep this service among their clinical duties. Finally, the success of telemedicine in diagnosing diabetic retinopathy and the advent of computer analysis of retinal vascular characteristics has become much more sophisticated over the past several decades.

Although both are retinal diseases, there are important differences in the use of telemedicine for ROP vs. diabetic retinopathy. The temporal profile of ROP is much more compressed and the treatment window to prevent poor visual outcomes is measured in days rather than months. In addition, different equipment and higher levels of technical expertise are required to image the fundus of premature infants to obtain images for accurate reading by either trained humans or computer analysis. Given the high stakes of the potential outcome of a blind infant from inadequately diagnosed or treated ROP, the use of telemedicine for ROP requires substantial and rigorous scientific study.

Although a number of studies have evaluated the use of telemedicine in ROP, the Evaluating Acute-Phase Retinopathy of Prematurity Study (eROP study) is considered the landmark work[8-9]. This multi-center collaborative effort developed the concept of Referral-Warranted ROP (RW-ROP), based on the fact that fewer than 10% of infants who undergo ophthalmic evaluations for disease require treatment to prevent poor visual outcomes. Thus, in a highly functioning telemedicine system, only a clear minority of infants would require an *in vivo* exam with indirect ophthalmoscopy by a trained ophthalmologist. In the eROP study, only 9.4% of 1 257 infants developed RW-ROP. When both of the infant's eyes were considered for the diagnosis or RW-ROP, as would occur in a clinical setting, a negative predictive value of 97.3% was obtained.

The eROP study demonstrated the feasibility of a number of entities required for a successful telemedicine program. First, high image reading accuracy could be obtained from trained non-

physician graders[8-9]. Second, previously naïve imagers could be trained to obtain high-quality, readable images[8-9]. Third, reading results could be returned to physicians within 24 hours in over 95% of cases[10]. Other developments since completion of the eROP study also support continued development of telemedicine systems for ROP. Coupling the eROP findings with computer analysis of retinal images, as well as tiering of infants selected for evaluation based on the Postnatal Growth and Retinopathy of Prematurity Study, could further reduce the number of infants screened while still maintaining high-quality safety parameters[11]. In addition, the development of more user-friendly cameras, identification of specific high-risk fundus imaging findings, and more targeted algorithms for image grading could move us closer to a consistent diagnostic accuracy of RW-ROP of near 100%[12-13].

Finally, preliminary studies have demonstrated the potential for notable cost savings from implementation of a telemedicine system for ROP [14]. Much of the savings results from removal of a need to hold infants in or transfer infants to higher level NICUs solely for ROP exams. Daily cost savings in such instances may be several hundred dollars. Of course, there are notable startup costs in developing a new system, including training and validating imagers, purchasing a fundus camera, developing IT systems and protocols, compensation for imagers and image readers, and potentially higher malpractice coverage costs. Nevertheless, great potential exists.

At the University of Oklahoma Health Sciences Center, we have demonstrated that telemedicine can be safely utilized for ROP examination in a Level II NICU. No case of worsening ROP was missed, and this approach allowed more infants to get intensive care closer to home[15-16].

In summary, the last decade has seen tremendous advances in the use of telemedicine for ROP. It is likely that telemedicine use will continue to increase, and that it will become a standard of care over the next two decades. Telemedicine will move us closer to the goal that no infant, anywhere in the world, should become blind from undiagnosed or untreated ROP.

2 Tele-echocardiography

The prevalence of congenital heart disease (CHD) has increased significantly over the last decade[17]. The current prevalence estimate for CHD is 9.410/1 000 live births. American Heart Association (AHA) and American Academy of Pediatrics (AAP) guidelines recommend routine neonatal pulse oximetry to rule out CHD prior to discharge[18]. Research has shown that one-year survival rates of neonates with CHD significantly increase with early diagnosis[19]. When CHD is suspected, echocardiography is immediately needed on both asymptomatic newborns and those with respiratory symptoms or heart murmurs. Unfortunately, this procedure typically requires transfer to a tertiary care center.

Telemedicine use has grown significantly in recent years, particularly among cardiologists[20]. Though initially adopted as a way of extending pediatric emergency care to rural hospitals, the value of telemedicine in assessing cardiac conditions in Level II NICUs quickly became evident. Echocardiography (store and forward and real-time) is among the top five most common uses of pediatric telemedicine[6]. This technology is increasingly being used to evaluate neonatal CHD without transferring the patients to better-equipped tertiary care centers located in distant cities.

A review of 60 echocardiography sessions on 48 patients, done in real-time using teleconferencing software, found that interpretations and diagnoses performed by pediatric cardiologists who were not present were accurate, as confirmed by critically reviewing video recordings of the procedures[21]. This early study was later replicated with a much larger population of neonates (n=364) residing in rural hospitals. The researchers utilized more advanced sonographic and teleconferencing equipment and found that not only were diagnoses

and recommendations as accurate as in-person echocardiography, but the approach also resulted in significantly improved patient care. Increased patient referrals, fewer patient transfers, and better utilization of medical staff and hospital resources were observed [22].

Similar results were reported by Grant et al[23], who found that real-time tele-echocardiography performed on 124 infants in the United Kingdom achieved 96% accuracy and reduced medically unnecessary transfers by 75%. In 2013, Webb et al[24] conducted a 36-month prospective multi-center trial of infants identified as needing echocardiography. Infants received this procedure with either in-person or remote administration, depending on whether cardiologists were available at the institution. The findings demonstrated, again, that telemedicine use reduced time to diagnosis and reduced transfer rates. Moreover, the use of this technology reduced length of hospitalization, use of indomethacin, and length of NICU stay.

In the roughly 19 years since these studies were undertaken, improvements in telecommunication infrastructure (i.e., high-speed internet, wireless communication networks), higher resolution and faster imaging technologies, and improved hardware and software systems have made the use of telemedicine both more reliable and better accepted by medical providers[6]. Currently, real-time telemedicine is the preferred modality for conducting echocardiographic evaluations. Cardiologists able to interpret the results of these tests are rarely available at regional medical centers. This technology allows them to not only request additional viewings in real-time, but it also allows these regional centers to provide quality service despite increased difficulties in hiring and maintaining medical staff who are trained and experienced in using this equipment. At the University of Oklahoma Health Sciences Center, we have been performing this modality and have been very successful in safely screening infants for CHD at a Level II NICU, resulting in reducing the number of unnecessary transfers to a regional Level IV NICU[25].

Recently, another technology has evolved using tele-echocardiography with a portable hand-held device, such as a tablet (iPad). Colombo et al[26] compared 50 studies performed with both modalities and found a high correlation, making this alternative a promising option to reduce costs and increase portability.

3 Telemedicine use in newborn resuscitation

A few decades ago, perinatal regionalization was introduced. The goal was to provide high-quality, risk-appropriate care to the mother-infant dyad. Several studies have demonstrated decreased mortality rates among very low birth weight infants who are delivered and treated at centers with higher levels of neonatal care[27-28]. Therefore, the American Academy of Pediatrics has recommended that infants <32 weeks of gestation should be delivered at Level III NICUs[29]. Despite strong evidence, there is regional variation across the U.S. in the delivery location of high-risk infants. In certain cases, maternal transfer to a facility with expertise in neonatal care is not safe, perhaps due to maternal medical conditions making the mother not stable for transport or mothers who are in an advanced stage of labor. In these cases, infants who require advanced resuscitation have poorer outcomes when delivered at hospitals with lower levels of neonatal care[30]. Lack of exposure to high-risk deliveries by providers at community hospital settings could explain this outcome disparity. Unfortunately, there are a large number of U.S. states in which less than 80% of women of reproductive age have easy access, defined as living within 50 miles of the facility, to a NICU[31]. The unavailability of neonatologists in medically underserved areas has prompted an innovative solution to address this problem. The use of technology, like telemedicine, can address the rural-urban disparity in access to subspecialty care by providing patients at less specialized centers with access to a physician with subspecialty expertise.

Telemedicine has been shown to decrease

the time needed to establish effective ventilation in simulation settings[32]. This simple finding could have great impact, as the neonatal resuscitation program identifies ventilation as the most effective intervention in most neonatal resuscitations. Although most providers at community settings are Neonatal Resuscitation Program (NRP) certified, the lack of continued exposure to newborn resuscitation could lead to a decay in the knowledge and skills needed to provide effective newborn resuscitation. A recent study demonstrated the feasibility and safety of a newborn resuscitation telemedicine program (NRTP) to remotely support local providers with resuscitation[33]. Fang et al[33] compared the outcomes of infants who received a consultation using telemedicine during resuscitation with controls who did not. A two-person expert panel blinded to intervention assigned a resuscitation quality rating using a descriptive rating scale. Neonates who received a tele-neonatology consult had a higher median quality rating of 7 compared with a median quality rating of 4 for the control group. Albritton et al[34] reported that access to a specialist via telemedicine improves the quality of resuscitation and creates educational opportunities that generate a halo effect that improves overall care quality. In addition, the author reported that implementation of telemedicine resulted in significant cost savings by preventing the unnecessary transfer of patients to higher level NICUs.

One of the basic requirements to implement a telemedicine program is the equipment that is utilized for the audio-visual connection between the consultant at the remote site and the local provider. Both wired and wireless devices have been tested in emergency telemedicine clinical settings. There are pros and cons associated with both of these options. Wireless devices, such as tablets, have the advantages of being mobile, readily available, and affordable. However, video and audio connectivity can deteriorate when mobilizing these devices. In comparison, wired devices have more reliable audio and visual connections, but restrict mobility and are expensive. A recent study reported a comparison between the two technologies. The NRP algorithm contains assessments and interventions to be performed at 30-to-60-second intervals during resuscitation. Therefore, a highly reliable connection is key for NRTP. A wired connection device may be considered the more reliable option to safely provide consultation in emergent settings[35]. Another recently conducted study comparing two technologies demonstrated improved audio quality and reliability with wireless connections in comparison to wired cart. Therefore, each program should consider connection reliability and available infrastructure before selecting a NRTP technology[36].

NRTP implementation could have some challenges, as it is quite different from the conventional method of providing neonatal resuscitation[37]. Further, inclusion of local stakeholders in planning clinical workflow is vital to successful implementation of telemedicine. The workflows must include technology that is rapid, reliable, and simple to use. Clear guidelines regarding indications for service activation and the process to communicate with remote neonatologists should be defined. Establishing and maintaining a professional relationship with team members is crucial; in particular, the remote neonatologist should be calm and supportive during consultation. Additionally, regular NRP education and periodic mock codes utilizing telemedicine are key supportive tools for maintaining successful NRTP.

4 Tele-rounding in neonatal intensive care unit

Use of telemedicine in intensive care settings is mostly limited to pediatric and adult populations[38]. Nadar et al[39] recently published a meta-analysis on the use of telemedicine in pediatric acute care settings. About 24 studies were included in final analysis. Of those, 11 took place in emergency department settings, 7 took place in pediatric ICU, 2 took place in trauma ICU, and only 4 were conducted in neonatal ICU settings. Two of those studies addressed tele-rounding

in the NICU[40-41].

Garingo et al[42] demonstrated the feasibility of using a tele-rounding model in an academic hospital's Level IV NICU. The researchers demonstrated that physical examination done using telemedicine is quite reliable, as excellent or intermediate-to-good agreements were noted for all but a few physical examination assessments between both the on-site neonatologist and off-site neonatologists and the two on-site neonatologists. In 2013, McCoy et al[43] demonstrated the use of an innovative telemedicine model, "hybrid telemedicine," in Level II settings. This hybrid telemedicine model consists of 24/7 neonatal nurse practitioner (NNP) coverage with neonatologists physically present three days a week, and use of telemedicine to round for the remaining four days. Since then, Makkar et al[41,44]. have evaluated the use of hybrid telemedicine in Level II NICU settings through a retrospective study and a prospective study. In the retrospective study, patient outcome measures, such as hospital length of stay, time to full enteral feeds, days on oxygen and noninvasive ventilation for premature infants (32-35 weeks), managed by the hybrid telemedicine system at a satellite Level II NICU were not inferior to conventional management provided to similar infants at a referral Level IV NICU. Some of the patient outcome measures were even better for infants who were managed at the satellite Level II NICU utilizing telemedicine.

Higher family participation and prevention of stress due to avoiding transport could be one possible reason for favorable outcomes in infants who received telemedicine[41]. In 2019, Makkar et al[44] reported similar favorable patient outcome measures from patients in a prospective study with telemedicine use. This study also evaluated parental satisfaction with telemedicine use. Parents reported a high level of satisfaction with the technical aspects of telemedicine. There were no differences noted in the degree of parental satisfaction with the other aspects of care when the care was provided using telemedicine versus conventional care. This telemedicine model is feasible and safe in Level 2 NICU settings, in which patient acuity is usually low.

The potential use of telemedicine in Level III/IV NICUs needs evaluation, as the current evidence only supports its feasibility based on a research study by Garingo et al[40]. This study was conducted at an academic institution where there was 24/7 access to a resident and neonatologist, if needed. This feasibility study demonstrated that telemedicine rounds are effective. There were no significant differences in outcome measures when telemedicine care was utilized instead of conventional care. The authors concluded that although they do not envision the use of this system in academic settings where neonatologists are present 24/7, the technology has clear potential in settings where there is a lack of access to neonatologists in person.

In summary, the use of innovative models, such as hybrid telemedicine, appears to be a promising solution for providing intensive care in late premature infants in Level II NICUs, thus allowing for more infants to get intensive care closer to home. Initial research has shown some promise for this technology even in Level IV settings, but the use of telemedicine in high-acuity patients' needs further evaluation.

5 Family support

Telemedicine has been successfully utilized to support parents of high-risk newborns[45]. Gray et al[46] compared the use of telemedicine (Baby Carelink) for families of infants in the NICU with a control group without access to telemedicine, and assessed the length of hospital stay for the infants and family satisfaction in multiple components of infant care. The researchers demonstrated that telemedicine use significantly improved family satisfaction with the care of inpatient very low birth weight infants and lowered costs associated with hospital to hospital transfer.

Additionally, telemedicine has been

demonstrated as an alternative means to provide in-home care in preterm infants. Neonatal tele-homecare allowed parents of clinically stable preterm infants to manage tube feeding and establish oral feeding at home[47]. This study showed that neonatal tele-homecare is an alternative model for the management of preterm infants outside of the hospital environment, with the added benefit of higher rates of breastfeeding at the time of discharge for very preterm infants. Garne Holm et al[48] recently published a qualitative study to share parents' perspectives about neonatal tele-homecare. Parents of premature infants had a very positive experience with telemedicine use for in-home care. They felt it was a personalized method for linking to specialist staff in the NICU and enhanced their role as the primary care provider, thus strengthening the parent-infant relationship.

6 Telemedicine use in the neonatal population: Chinese experience

Telemedicine implementation in China began in the 1980 s, when most applications were based on the store and forward technique, as the telecommunication infrastructure required for live telemedicine was not available[49]. Telemedicine use in China has been rapidly developing in last decade. Currently, China has three major telemedicine networks: the Golden Health Network (GHN), the People's Liberation Army (PLA) telemedicine network, and the International MedioNet of China (IMNC) network. However, research and applications of telemedicine are at a fairly early stage[50]. Telemedicine applications in China are mostly limited to adult and pediatric populations.

The use of telemedicine in the neonatal population in China is understudied. Pan et al[51] showed the value of using long-distance fetal heart rate monitoring in reducing neonatal asphyxia and the outside hospital fetal death rate, without increasing the incidence of caesarean section. Similar findings were reported in other studies[52-53].

Telemedicine can be especially impactful in areas where expertise in subspecialty care, such as ophthalmologists with ROP screening expertise, is lacking. In 2018, Xu et al[54] conducted a systematic study to report current ROP screening practices. The researchers reported that ROP screening in China has obvious regional specificity, with better implementation in the eastern region due to the uneven distribution of medical resources in China. Telemedicine was identified as a potential solution to expand ROP prevention and management platforms in areas with limited resources. Zhang et al[55] reported on the utility of telemedicine in evaluation of ROP. Telemedicine was instrumental in accurate diagnosis of ROP, where it was a supplemental tool to provide support to less experienced and professionally isolated ROP examiners. This study reported that expert support through telemedicine changed or corrected diagnosis in 4/21 (19%) of ROP cases that was previously diagnosed clinically. Despite some of the encouraging results reported with telemedicine applications, it is evident that telemedicine research and applications of telemedicine are at a relatively early stage in China, and are potential areas of growth.

7 Summary

Recent advances in technology and the shortage of healthcare providers has resulted in increasing uses of telemedicine in neonatology. Telemedicine implementation is instrumental in reducing rural urban disparity to health care access without compromising quality of care, reducing unnecessary patient transport and allowing more infants to get needed care closer to home. Current evidence in support of telemedicine is mostly based on case-control studies, but development of networks, such as SPROUT, will promote multicenter trials in order to strengthen research-based evidence in favor of telemedicine use. Additionally, barriers like high equipment costs and poor reimbursement rates for services provided through telemedicine may prohibit widespread use of telemedicine.

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Author's contribution:

All authors equally contributed in the preparation of this manuscript. Kris Sekar edited and revised the manuscript. All authors approved the final manuscript submission.

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[References]

[1] Aluttis C, Bishaw T, Frank MW. The workforce for health in a globalized context - global shortages and international migration[J]. Glob Health Action, 2014, 7: 23611.

[2] Association of American Medical Colleges. 2019 update: the complexities of physician supply and demand: projections from 2017 to 2032[EB/OL]. [March 13, 2020]. https://aamc-black.global.ssl.fastly.net/production/media/filer_public/31/13/3113ee5c-a038-4c16-89af-294a69826650/2019_update_-_the_complexities_of_physician_supply_and_demand_-_projections_from_2017-2032.pdf.

[3] Association NRH. About rural health care[EB/OL]. [March 13, 2020]. https://www.ruralhealthweb.org/about-nrha/about-rural-health-care#_ftn1.

[4] Health C. Types of telemedicine[EB/OL]. [March 13, 2020]. https://chironhealth.com/definitive-guide-to-telemedicine/about-telemedicine/types-of-telemedicine/.

[5] Association AT. Telehealth basics[EB/OL]. [March 13, 2020]. https://www.americantelemed.org/resource/why-telemedicine/.

[6] Hoffman AM, Lapcharoensap W, Huynh T, et al. Historical perspectives: telemedicine in neonatology[J]. Neoreviews, 2019, 20(3): e113-e123.

[7] Olson CA, McSwain SD, Curfman AL, et al. The current pediatric telehealth landscape[J]. Pediatrics, 2018, 141(3). pii: e20172334.

[8] Graham E Quinn; e-ROP Cooperative Group. Telemedicine approaches to evaluating acute-phase retinopathy of prematurity: study design[J]. Ophthalmic Epidemiol, 2014, 21(4): 256-267.

[9] Quinn GE, Ying GS, Daniel E, et al. Validity of a telemedicine system for the evaluation of acute-phase retinopathy of prematurity[J]. JAMA Ophthalmol, 2014, 132(10): 1178-1184.

[10] Quinn GE, Ying GS, Repka MX, et al. Timely implementation of a retinopathy of prematurity telemedicine system[J]. J AAPOS, 2016, 20(5): 425-430.e1.

[11] Binenbaum G, Tomlinson LA, de Alba Campomanes AG, et al. Validation of the postnatal growth and retinopathy of prematurity screening criteria[J]. JAMA Ophthalmol, 2019, 138(1): 31-37.

[12] Quinn GE, Vinekar A. The role of retinal photography and telemedicine in ROP screening[J]. Semin Perinatol, 2019, 43(6): 367-374.

[13] Quinn GE, Ying GS, Pan W, et al. Detection of potentially severe retinopathy of prematurity by remote image grading[J]. JAMA Ophthalmol, 2017, 135(9): 982-986.

[14] Isaac M, Isaranuwatchai W, Tehrani N. Cost analysis of remote telemedicine screening for retinopathy of prematurity[J]. Can J Ophthalmol, 2018, 53(2): 162-167.

[15] Makkar A, McCoy M, Sekar K, et al. Utility of telemedicine for retinopathy of prematurity examination in level II NICU[J]. J Okla State Med Assoc, 2018, 111(5): 610-613.

[16] Makkar A, McCoy M, Siatkowski M. Use of telemedicine for retinopathy of prematurity examination in a level II NICU[J]. J Investig Med, 2020, 68(2): 435-710.

[17] Liu Y, Chen S, Zühlke L, et al. Global birth prevalence of congenital heart defects 1970-2017: updated systematic review and meta-analysis of 260 studies[J]. Int J Epidemiol, 2019, 48(2): 455-463.

[18] Mahle WT, Newburger JW, Matherne GP, et al. Role of pulse oximetry in examining newborns for congenital heart disease: a scientific statement from the AHA and AAP[J]. Pediatrics, 2009, 124(2): 823-836.

[19] Oster ME, Lee KA, Honein MA, et al. Temporal trends in survival among infants with critical congenital heart defects[J]. Pediatrics, 2013, 131(5): e1502-e1508.

[20] Sable C. Digital echocardiography and telemedicine applications in pediatric cardiology[J]. Pediatr Cardiol, 2002, 23(3): 358-369.

[21] Sable C, Roca T, Gold J, et al. Live transmission of neonatal echocardiograms from underserved areas: accuracy, patient care, and cost[J]. Telemed J, 1999, 5(4): 339-347.

[22] Sable CA, Cummings SD, Pearson GD, et al. Impact of telemedicine on the practice of pediatric cardiology in community hospitals[J]. Pediatrics, 2002, 109(1): E3.

[23] Grant B, Morgan GJ, McCrossan BA, et al. Remote diagnosis of congenital heart disease: the impact of telemedicine[J]. Arch Dis Child, 2010, 95(4): 276-280.

[24] Webb CL, Waugh CL, Grigsby J, et al. Impact of telemedicine on hospital transport, length of stay, and medical outcomes in infants with suspected heart disease: a multicenter study[J]. J Am Soc Echocardiogr, 2013, 26(9): 1090-1098.

[25] Milsten JPK, McCoy M, Makkar A. Utility of telemedicine for screening congenital heart disease in a level II NICU[J]. J Investig Med, 2020, 68(2): 435-710.

[26] Colombo JN, Seckeler MD, Barber BJ, et al. Application and utility of iPads in pediatric tele-echocardiography[J]. Telemed J E Health, 2016, 22(5): 429-433.

[27] Dooley SL, Freels SA, Turnock BJ. Quality assessment of perinatal regionalization by multivariate analysis: Illinois, 1991-1993[J]. Obstet Gynecol, 1997, 89(2): 193-198.

[28] Gortmaker S, Sobol A, Clark C, et al. The survival of very low-birth weight infants by level of hospital of birth: a population study of perinatal systems in four states[J]. Am J Obstet Gynecol, 1985, 152(5): 517-524.

[29] American Academy of Pediatrics Committee on Fetus and Newborn. Levels of neonatal care[J]. Pediatrics, 2012, 130(3): 587-597.

[30] Lorch SA, Baiocchi M, Ahlberg CE, et al. The differential impact of delivery hospital on the outcomes of premature

infants[J]. Pediatrics, 2012, 130(2): 270-278.
[31] Brantley MD, Davis NL, Goodman DA, et al. Perinatal regionalization: a geospatial view of perinatal critical care, United States, 2010-2013[J]. Am J Obstet Gynecol, 2017, 216(2): 185.e1-185.e10.
[32] Fang JL, Carey WA, Lang TR, et al. Real-time video communication improves provider performance in a simulated neonatal resuscitation[J]. Resuscitation, 2014, 85(11): 1518-1522.
[33] Fang JL, Campbell MS, Weaver AL, et al. The impact of telemedicine on the quality of newborn resuscitation: a retrospective study[J]. Resuscitation, 2018, 125: 48-55.
[34] Albritton J, Maddox L, Dalto J, et al. The effect of A newborn telehealth program on transfers avoided: a multiple-baseline study[J]. Health Aff (Millwood), 2018, 37(12): 1990-1996.
[35] Beck JA, Jensen JA, Putzier RF, et al. Developing a newborn resuscitation telemedicine program: a comparison of two technologies[J]. Telemed J E Health, 2018, 24(7): 481-488.
[36] McCauley K, Kreofsky BL, Suhr T, et al. Developing a newborn resuscitation telemedicine program: a follow-up study comparing two technologies[J]. Telemed J E Health, 2019, 14. DOI: 10.1089/tmj.2018.0319. Epub ahead of print.
[37] Fang JL, Asiedu GB, Harris AM, et al. A mixed-methods study on the barriers and facilitators of telemedicine for newborn resuscitation[J]. Telemed J E Health, 2018, 24(10): 811-817.
[38] Rosenfeld BA, Dorman T, Breslow MJ, et al. Intensive care unit telemedicine: alternate paradigm for providing continuous intensivist care[J]. Crit Care Med, 2000, 28(12): 3925-3931.
[39] Nadar M, Jouvet P, Tucci M, et al. Impact of synchronous telemedicine models on clinical outcomes in pediatric acute care settings: a systematic review[J]. Pediatr Crit Care Med, 2018, 19(12): e662-e671.
[40] Garingo A, Friedlich P, Chavez T, et al. "Tele-rounding" with a remotely controlled mobile robot in the neonatal intensive care unit[J]. J Telemed Telecare, 2016, 22(2): 132-138.
[41] Makkar A, McCoy M, Hallford G, et al. A hybrid form of telemedicine: a unique way to extend intensive care service to neonates in medically underserved areas[J]. Telemed J E Health, 2018, 24(9): 717-721.
[42] Garingo A, Friedlich P, Tesoriero L, et al. The use of mobile robotic telemedicine technology in the neonatal intensive care unit[J]. J Perinatol, 2012, 32(1): 55-63.
[43] McCoy M, Makkar A, Foulks A, et al. Establishing level II neonatal services in southwestern Oklahoma[J]. J Okla State Med Assoc, 2014, 107(9-10): 493-496.
[44] Makkar A, McCoy M, Hallford G, et al. Evaluation of neonatal services provided in a level II NICU utilizing hybrid telemedicine: a prospective study[J]. Telemed J E Health, 2020, 26(2): 176-183.
[45] Gray J, Pompilio-Weitzner G, Jones PC, et al. Baby CareLink: development and implementation of a WWW-based system for neonatal home telemedicine[J]. Proc AMIA Symp, 1998: 351-355.
[46] Gray JE, Safran C, Davis RB, et al. Baby CareLink: using the internet and telemedicine to improve care for high-risk infants[J]. Pediatrics, 2000, 106(6): 1318-1324.
[47] Holm KG, Clemensen J, Brødsgaard A, et al. Growth and breastfeeding of preterm infants receiving neonatal tele-homecare compared to hospital-based care[J]. J Neonatal Perinatal Med, 2019, 12(3): 277-284.
[48] Garne Holm K, Brødsgaard A, Zachariassen G, et al. Parent perspectives of neonatal tele-homecare: a qualitative study[J]. J Telemed Telecare, 2019, 25(4): 221-229.
[49] Wang Z, Gu H. A review of telemedicine in China[J]. J Telemed Telecare, 2009, 15(1): 23-27.
[50] Xue Y, Liang H. Analysis of telemedicine diffusion: the case of China[J]. IEEE Trans Inf Technol Biomed, 2007, 11(2): 231-233.
[51] Pan J, Lu Y, Pan L, et al. Value of long-distance fetal heart rate monitoring on the pre-partum health care of the pregnant woman with umbilical cord loops[J]. Zhonghua Fu Chan Ke Za Zhi, 2002, 37(8): 451-454.
[52] Qi H, Sun J, Liu J, et al. Clinical value of remote fetal monitoring network in high-risk pregnancy[J]. Zhonghua Fu Chan Ke Za Zhi, 2002, 37(8): 455-458.
[53] Su F, Guo X. Clinical application of the expert type terminal of remote electronic fetal heart rate home monitoring system[J]. Zhonghua Fu Chan Ke Za Zhi, 2002, 37(8): 459-461.
[54] Xu S, Liang Z, Du Q, et al. A systematic study on the prevention and treatment of retinopathy of prematurity in China[J]. BMC Ophthalmol, 2018, 18(1): 44.
[55] Zhang X, Wang Y, Ulrich JN, et al. Evaluation of retinopathy of prematurity incidence with telemedicine confirmation in Gansu, China: a pilot study[J]. Ophthalmic Epidemiol, 2018, 25(2): 120-125.

The following is the Chinese translation of this paper, translated by associated professor YU Xiao-He (Department of Neonatology, Xiangya Hospital, CSU). 以下是本文的中文摘译。

新生儿远程医疗

医生短缺是一个世界性的问题。最近，世界卫生组织（WHO）报告全球短缺 430 万名医生、护士和其他卫生保健专业人员。在发展中国家，由于医学院的数量和能力有限，这种短缺更加严重。包括美国、加拿大、新西兰、英国、澳大利亚和德国在内的许多发达国家都报告了类似的问题[1]。

美国医学院协会估计，到 2032 年，美国医生缺口将达到 46 900~121 900 人[2]。医生短缺将导致城市和农村地区都得不到足够的医疗。目前，城市地区每万名居民医生的数量是农村地区的两倍。在亚专科医

疗方面，城市地区每万居民拥有的医生数量是农村地区的 9 倍 [3]。目前，我们基于区域化医疗，利用现有资源，将患者引导到具有专科医疗机构诊治来改善患者的预后。这样做的主要缺点是要将患者从家中转运到专科医疗机构。此外，这样做可能会占用专科医院的资源。

远程医疗技术可以实现医生为病人进行远程诊治，特别是在当地医院缺乏专科医生的情况下，可充分发挥远程医疗的作用。远程医疗已从最初的“远程治疗”发展到“使用通信技术远程提供医疗服务和临床信息”[4-5]。远程医疗是“实时”进行的，即患者和工作人员在远程端进行实时交流，“存储和转发”需要的医疗数据，然后将这些数据传输给另一个站点的医生进行评估。自 2000 年以来，远程医疗越来越受欢迎，超过 50% 的美国医院均使用某种形式的远程医疗；在美国大约有 3 000 个站点，约 200 个远程医疗项目 [5]。远程医疗已被广泛用于成人和儿童，以便将卫生保健扩展到医疗服务不足的地区。在新生儿群体中使用远程医疗相对较少，而且还没有充分的研究。在过去 10 年中，在新生儿科领域，远程医疗越来越多地应用于提供咨询、远程超声心动图检查、早产儿视网膜病变（retinopathy of prematurity, ROP）筛查、新生儿复苏计划（neonatal resuscitation program, NRP）培训、出院后随访和 NICU 护理等 [6]。新生儿和儿童对远程医疗的需求日益增长。美国儿科学会通过一个名为“支持对儿科远程医疗的结果和应用研究”（Supporting Pediatric Research on Outcomes and Utilization of Telehealth, SPROUT）的组织，来制订指导方针和促进远程医疗的研究 [7]。

在本综述中，我们讨论了 5 种新生儿医学中最常见的远程医疗的应用及研究，包括 ROP 的远程筛查、远程超声心动图检查、远程医疗在新生儿复苏中的应用、远程新生儿查房及新生儿家庭支持。

1　ROP 的远程筛查

随着极低出生体重儿救治存活率的增加，ROP 的发生率及严重 ROP 的发生率均明显增加。目前，ROP 筛查需要儿童眼科医生进行实时眼底检查。但近年来，在成人糖尿病视网膜病变领域，计算机技术广泛用于分析视网膜复杂血管病变，远程医疗已成功用于糖尿病视网膜病变的诊断。因此，远程医疗技术在早产儿 ROP 的应用也有广泛前景。

虽然糖尿病视网膜病变和早产儿 ROP 两者都是视网膜疾病，但二者还是有着重大的区别。早产儿 ROP 远比糖尿病视网膜病变进展快，防止视力不良的治疗窗口常常是以天计算，而不是以月来计算。此外，早产儿的 ROP 还需要不同的设备和更高水平的技术专长来筛查，以获得眼底图像，最后由受过训练的人员经计算机分析进行准确阅读。如果 ROP 患儿未能及时诊断、治疗，将会具有很高的失明风险，因此，远程医疗对早产儿 ROP 的应用需要大量和严格的科学研究。

许多研究评估了远程医疗在 ROP 中的应用，其中“评估急性期早产儿视网膜病变研究”，即“eROP 研究”，被认为是具有里程碑意义的一项研究 [8-9]。这项多中心合作研究提出了“保荐 ROP”（referral-warranted ROP, RW-ROP）的概念。这是基于这样一个事实：接受眼底筛查的所有婴儿中，只有不到 10% 的人需要治疗。因此，在远程医疗系统中，只有极少数的婴儿需要由训练有素的眼科医生进行间接检眼镜检查。在 “eROP 研究”中，1 257 名婴儿中只有 9.4% 出现了 RW-ROP；所有眼底筛查阴性预测值为 97.3%[8-9]。

eROP 的研究表明，一个成功的远程医疗计划实施需要许多可行性。首先，训练有素的非医务工作者可采集到高精度的图像 [8-9]。其次，不熟练的员工可通过训练，也可采集到高质量、可读的图像 [8-9]。第三，95% 以上的病例图像阅读结果可在 24 h 内返回给医生 [10]。此外，还有一些研究也支持 ROP 远程医疗的发展。将 eROP 的发现与视网膜图像的计算机分析相结合，并根据早产儿生后具体情况，评估早产儿 ROP 风险，可以减少筛查的婴儿数量，同时保持高质量的安全参数 [11]。此外，更加人性化的摄像机的开发，特定的高危眼底成像结果的识别，以及更有针对性的图像分级算法，可以使 RW-ROP 诊断准确性接近 100%[12-13]。

研究表明，实施 ROP 远程筛查可以显著节约成本 [14]。婴儿不再仅仅因为需要进行 ROP 检查而收入 NICU 住院。这样每天可以节省几百美元的花费。当然，开发新系统的成本也很高，包括员工培训、购买眼底照相机、开发 IT 系统以及可能更高的医疗事故成本等。尽管如此，实施 ROP 远程筛查仍然存在巨大的潜力。

我们健康科学中心已经证明，可以安全地在Ⅱ级 NICU 进行 ROP 远程筛查。没有一例 ROP 恶化的病例被遗漏，这种方法使更多的婴儿可以在离家更近的重症监护室得到救治 [15-16]。

总之，在过去的 10 年里，远程医疗在 ROP 中的应用取得了巨大的进步。远程 ROP 筛查的使用可能会继续增加，并有可能在未来 20 年成为早产儿 ROP 筛查的常规。远程医疗将使我们实现这样一个目标：世界上任何地方的婴儿都不会因未及时诊断或治疗的 ROP 而失明。

2 远程超声心动图

先天性心脏病（CHD）的患病率在过去 10 年中显著增加 [17]。目前估计的 CHD 患病率为 9.41/1 000。美国心脏协会和美国儿科学会建议新生儿出院前常规进行脉搏血氧饱和度测定以排除 CHD[18]。研究表明，CHD 新生儿如果能够早期诊断，其 1 年生存率显著提高 [19]。当怀疑有 CHD 时，新生儿可能无症状，或有呼吸道症状，或出现心脏杂音，这样的新生儿应该进行超声心动图检查。但新生儿超声心动图检查通常需要转诊到Ⅲ级医院才能进行。

近年来，远程医疗的使用有了显著的增长，尤其是在心脏病学中 [20]。远程超声心动图检查在Ⅱ级 NICU 中也用于评估新生儿心脏问题。超声心动图（存储、转发和实时监测）是儿科远程医疗的五大最常见应用之一。这项技术越来越多地用于评估新生儿 CHD，而无需将患者转运到设备更好的Ⅲ级医院。

通过使用电话会议软件对 48 例患者进行的 60 次超声心动图会诊进行回顾，发现由不在场的儿科心脏病学家进行的诊断是准确的，这一点可通过严格审查会诊过程的视频记录得到证实 [21]。类似的一项研究是针对农村地区的 364 例新生儿，研究人员使用了更先进的超声和电话会议设备，发现远程的诊断与实地超声心动图检测一样准确，而远程超声心动图检查可以减少病人转诊，医院资源得到更好地利用 [22]。Grant 等 [23] 也报告了类似的结果。他们对英国 124 名婴儿进行实时远程超声心动图检查，准确率达到 96%，病人转诊率降低了 75%。2013 年，Webb 等 [24] 对需要超声心动图检查的婴儿进行了一项为期 36 个月的多中心前瞻性试验，研究结果再次表明，远程医疗的使用缩短了诊断时间，降低了转诊率。此外，该技术的使用缩短了住院时间、减少了消炎痛的使用。

在进行这些研究之后的大约 19 年里，电信基础设施的改善（更高的分辨率和更快的成像技术）以及硬件和软件系统改进，使得远程医疗更加可靠，也更容易被医生所接受。目前，实时远程医疗是进行超声心动图评估的首选方式。在基层医院，心脏病专家很少。这项远程技术尽管需要培训维护超声心动图设备人员，但心脏病专家可以远程实时为患者检查心脏情况，可以提高基层医院的医疗质量。我们健康科学中心一直在实施这一模式，并在医疗服务不足的州非常成功地减少了不必要的转运 [25]。

最近，远程超声心动图与便携式手持设备（如平板电脑）可结合使用。Colombo 等 [26] 比较了 50 项用这种方式进行的研究，发现这种结合可进一步降低成本，值得推广应用。

3 远程医疗在新生儿复苏中的应用

几十年前，分级诊疗开始实施，其目的是为母婴提供高质量、风险适当的诊疗。有研究表明，在新生儿专科水平较高的中心分娩和治疗的极低出生体重儿的病死率较低 [27-28]。因此，美国儿科学会建议，小于 32 孕周婴儿应在Ⅲ级 NICU 分娩 [29]。在某些情况下，因母亲病情而无法转运，这时，就只有在基层医院分娩，但基层医院对高危新生儿救治能力不足，易导致新生儿预后较差 [30]。不幸的是，在美国的很多州，只有居住在离医院 50 英里以内的妇女（不到 80% 的育龄妇女）可以在专科医院分娩，20% 的育龄妇女分娩的新生儿可能得不到专科医疗 [31]。新生儿专家的不足促使人们提出了创新的解决方案。与其他远程医疗一样，技术的使用可以为非专科医院的患者提供具有专科专业知识的医生，从而解决在基层医院不能获得专科医疗的问题。

远程医疗已被证明可以减少在模拟新生儿窒息情况下建立有效通气所需的时间 [32]。这个简单的发现可能会有很大的影响，因为新生儿复苏中，通气是最有效的干预措施。虽然社区中的大多数医护人员都通过了 NRP 认证，但由于平常工作中较少进行新生儿复苏，可能会导致其复苏知识和技能的衰退。最近的一项研究证明了新生儿复苏远程医疗计划（newborn resuscitation telemedicine program, NRTP）的可行性和安全性 [33]。在这项研究中，作者比较了在复苏过程

中接受远程医疗咨询的复苏婴儿和未接受远程医疗咨询的复苏婴儿的结果。由双盲的两名专家使用描述性评分表对复苏质量进行评分。结果显示，接受远程咨询组的新生儿的中位质量评分为 7 分，高于对照组的中位质量评分 4 分。Albritton 等[34]报告，通过远程医疗获得专家指导的复苏组可以提高复苏的质量，并提高整体医疗质量。此外，远程医疗的实施通过减少不必要的转运，节省了大量成本。

实施远程医疗计划的基本要求之一是利用远程设备在当地医务人员和咨询专家之间进行视听联系。在紧急远程医疗操作中，可以选择有线或无线设备。两种选择各有利弊，像平板电脑这样的无线设备具有可移动、容易获得和价格低廉的优点。然而，这些移动设备，视频和音频效果可能不稳定。相比之下，有线设备有更可靠的音频和可视连接，但移动性差而且价格昂贵。最近的一项研究对这两种技术进行了比较，显示在紧急情况下，有线连接设备是更可靠的选择[35]。但另一项研究对两种技术进行了比较，结果表明，与有线设备相比，无线设备连接提高了音频质量和可靠性[36]。

NRTP 的实施也会面临一些挑战，因为它与传统的新生儿复苏有很大的不同[37]。当地工作人员参与到 NRTP 工作流程中对 NRTP 的成功实施至关重要。工作流程必须快速、可靠和易于实施。对于需远程服务的适应证以及如何与远程新生儿医生沟通，都应该有明确的指南。团队成员建立并保持联系至关重要；远程新生儿医生在会诊期间应保持镇静并及时指导。此外，定期的 NRP 教育是维持 NRTP 成功的关键。

4　新生儿重症监护病房远程查房

在重症监护病房中使用远程医疗，目前多局限于儿童和成人[38]。Nadar 等[39]最近发表了一篇关于远程医疗在儿科急诊中的应用荟萃分析。该文纳入了 24 项研究。其中 11 例在急诊科，7 例在儿科 ICU，2 例在创伤 ICU，只有 4 例在 NICU。其中两项研究涉及 NICU 中的远程查房[40-41]。Garingo 等[42]证明了在教学医院的Ⅳ级 NICU 中使用远程查房的可行性。该研究表明使用远程医疗进行的体格检查是相当可靠的，现场新生儿专家和非现场新生儿专家之间的体格检查评估结果显示了良好的一致性。2013 年，McCoy 等[43]报告了一种在Ⅱ级医院中使用的创新的远程医疗模型，即“混合远程医疗”（hybrid telemedicine）：在每天 24 h 有新生儿护师查房的情况下，实施每周 3 d 新生儿专科医生现场查房，余下的 4 d 则使用远程医疗查房。Makkar 等[41,44]通过回顾性研究和前瞻性研究，评估了混合远程医疗模式在Ⅱ级 NICU 中的应用。在其中这项回顾性研究中[41]，研究对象为 32~35 周的早产儿。患儿预后评估指标包括住院时间、达全肠内喂养时间、氧疗时间、无创通气时间等。结果显示，在Ⅱ级 NICU 中接受混合远程医疗模式的患儿预后与在Ⅳ级 NICU 接受传统管理的患儿比较无明显差异，部分患儿的评估结果甚至比在Ⅳ级 NICU 接受传统医疗的患儿更好。

较高的家庭参与度和避免交通带来的压力可能是接受远程医疗的婴儿获得良好结果的一个可能原因[41]。在 2019 年，Makkar 等[44]在一项使用远程医疗的前瞻性研究中报告了类似良好的结局。本研究也评估了患儿父母对远程医疗的使用满意度。结果显示，患儿父母对远程医疗非常满意。与传统医疗比较，父母满意度没有差异。基层病人病情比较轻，因此远程医疗模式在Ⅱ级 NICU 中是可行和安全的。但在Ⅲ / Ⅳ级 NICU 中的远程医疗能否应用仍需要评估，目前仅有 Garingo 等[40]的一项研究支持其可行性。这项研究是在一个大学附属医院进行的，那里每天有 24 h 值班的住院医师和新生儿科专家。这项研究表明远程查房是有效的。远程查房和传统查房的病人结局没有显著差异。该研究的结论是，如果在新生儿科专家不足的情况下，远程查房具有明显的潜力。

总之，创新模式的使用，如混合远程医疗查房，可为Ⅱ级 NICU 的晚期早产儿提供重症监护，从而使更多的婴儿离家更近获得治疗。初步研究表明，远程医疗即使在Ⅳ级 NICU 也有一定的应用前景，但在病情重的患者中使用还需要进一步的评估。

5　家庭支持

远程医疗已成功用于帮助高危新生儿的父母[45]。Gray 等[46]比较了 NICU 中使用远程医疗的婴儿家庭与未使用远程医疗的对照组的婴儿家庭，评估了婴儿住院时间长短和家庭满意度。结果显示，远程医疗的使用显著提高了家庭对极低出生体重婴儿诊疗的满意度，并降低了转诊费用。

此外，远程医疗已被证实可为早产儿父母提供

家庭护理指导。临床情况稳定的早产儿出院后，患儿父母在家中根据远程指导管饲喂养婴儿并逐渐建立经口喂养[47]。该研究表明，新生儿远程家庭护理指导是在医院之外管理早产儿的另一种模式，对提高早产儿母乳喂养率也有好处。Garne Holm 等[48]最近发表了一项研究，目的是分享父母对新生儿远程护理指导的看法。结果显示，早产儿的父母对远程医疗在家庭护理中的应用有非常积极的体验。他们认为这是一种个性化的方法，可以将他们与 NICU 的专业人员联系起来，增强他们在照顾新生儿中的作用，加强亲子关系。

6 新生儿远程医疗的应用：中国的经验

远程医疗在中国的实施始于 20 世纪 80 年代，当时大多数应用都基于存储和转发技术，因为当时没有实时远程医疗所需的电信基础设施[49]。近 10 年来，远程医疗在中国得到了迅速的发展。目前，中国有三大远程医疗网络：金卫网络（Golden Health Network）、解放军远程医疗网络、中国国际媒体网（International MedioNet of China）。在中国，远程医疗的研究和应用还处于相当早期的阶段[50]。目前远程医疗的应用主要局限于成人和儿童。

远程医疗在中国新生儿群体中的应用研究尚处于起步阶段。Pan 等[51]的研究显示了远程胎心监测在降低新生儿窒息和院外胎儿病死率方面的价值，并且未增加剖宫产的发生。在其他研究中也有类似的发现[52-53]。

远程医疗在亚专科领域，如缺乏 ROP 筛查的眼科医生，可以发挥特别大的作用。2018 年，Xu 等[54]报道，中国 ROP 筛查具有明显的区域特异性，由于中国医疗资源分布不均，在东部地区实施效果更好。该作者认为，远程医疗是在资源有限的地区扩大 ROP 预防和管理平台的一个潜在解决方案。Zhang 等[55]报道了远程医疗在 ROP 评估中的应用。远程医疗在 ROP 的准确诊断中起到了重要作用，它是一种辅助工具，可为缺乏经验和专业知识的 ROP 检查人员提供帮助。该研究显示，原临床诊断为 ROP 的部分病例（19%，4/21）通过远程医疗专家会诊纠正了诊断。尽管远程医疗在中国的应用取得了一些令人鼓舞的成果，但很明显，远程医疗的研究和应用在中国还处于相对早期的阶段，是很有发展潜力的领域。

7 总结

科学技术进步和医护人员的短缺导致远程医疗在新生儿专科的应用越来越多。远程医疗的实施有助于在保证医疗质量的情况下缩小农村和城市在获得医疗服务方面的差距，减少不必要的病人转运，让更多的新生儿在离家更近的地方获得所需的医疗服务。目前支持远程医疗的证据大多基于病例对照研究，但网络的发展将促进关于远程医疗使用的多中心研究。但是，远程医疗设备成本高、医疗补助津贴低可能阻碍远程医疗的广泛实施。

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