Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/ss616n97

THE EFFICACY OF TELEMEDICINE IN NEONATAL CARE: REMOTE MONITORING OF HIGH-RISK INFANTS

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ABSTRACT

Introduction: Telemedicine has been considered a reliable intervention solution in neonatal care, especially with infants requiring continuous monitoring after NICU release. Because of the higher load and limited opportunity to travel, remote is a viable solution to tackle the time-sensitive objective and developmental monitoring.

Objectives: To evaluate the efficacy of telemedicine in the remote monitoring and follow-up of high-risk neonates discharged from a tertiary-level NICU in Karachi, Pakistan.

Materials and Methods: The cross-sectional study was done at Neonatal Intensive Care Unit Sindh Institute of Child Health & Neonatology (SICHN) Korangi-5 Karachi from January 2024 to June 2024. High-risk neonates remained under close follow-up through teleconsultations and assessments from developmental checklists including the Alberta Infant Motor Scale (AIMS).

Results: Concerning their involvement in the follow-up assessment, 92 percent of the participants completed the telemedicine intervention. It was identified that special care attention development concerns were present in 28% of all infants, and a referral was made immediately. At least 90% of the parents said they were satisfied with remote care, and patients were less likely to attend the hospital for non-emergency issues.

Conclusion: Telemedicine as a viable, culturally appropriate, and effective model for the delivery of neonatal care in resource-poor settings.

Keywords: *Neonatal care, NICU follow-up, remote monitoring, telemedicine, high-risk infants, and developmental evaluation.*

INTRODUCTION

Telemedicine has indeed gained popularity in providing health services in modern society, especially in neonate health service provision. Telemedicine can be a suitable healthcare solution as it can ensure quality care, even when faced with challenges of resource constraints required in health facilities, such as neonatal care for vulnerable infants in NICUs. Children who are born prematurely or sick, for instance, require monitoring and treatment, which may not be available at this level of care. Telemedicine is beneficial in maintaining regular checkups and consultations, which increases its effectiveness in managing patients and reducing the pressure on the centers (1). Like all other medical practices, telemedicine in neonatal care has its merits and demerits, but highlighting the effectiveness of telemedicine is vital for its further development.

Telemedicine in neonatal care can be defined as using telecommunication and information technologies in the monitoring equipment, video conferences, and consultations with specialists. They assess the heart rate, oxygen, respiratory function, and growth of progressing babies in a healthcare facility (2). This is especially so in Neonatal care, where failure to give a proper response on time is likely to compound the risk and even lead to death. Telemedicine assists in the early diagnosis of complications so that treatment can be taken as early as possible (3). For instance, telemonitoring improves neurodevelopmental follow-up of high-risk infants while avoiding frequent hospitalization (2). Telemedicine is essential for newborn care now, especially during the pandemic when face-to-face visits were often restricted (4). This period demonstrated that telemedicine technology can also be applied in the management of patients, especially those in depleted neonatal care intensive areas.

According to the literature, telemedicine is a valuable instrument for physicians to consider developmental issues and discuss such concerns with developmental specialists so as not to admit otherwise healthy infants to the hospital (5). Telehealth integration in neonatal facilities has been most successful in areas with minimal equipment and restricted access to health care (6). However, some effects are associated with implementing telemedicine in neonatal care. It can be associated with some disadvantages and should be complemented by adequate development of various infrastructures, human resource development, and appropriate resource input. The advanced technology of equipment, satisfying and secure telecommunication for video conferencing, and data prove that telemedicine in neonatal care is possible or feasible (7). It is also appropriate to remind parents who may not be familiar with telehealth to ensure that they continue to communicate well and adhere to recommended treatments and care plans. Both caregivers are closely associated with the upbringing of their babies, and their participation in any form of telemedicine consultation is vital (10).

A review of the literature has revealed that several researchers over the last few years have looked at the effectiveness of telemedicine in the management of neonates. Several studies have shown that the overall prognosis of a patient's condition can be enhanced if there is real-time information from remote monitoring of the healthcare team (8). For instance, telemedicine helps minimize the readmissions and complications in neonates by early diagnosis of some conditions, including infections, respiratory problems, or developmental concerns (9). In the same way, telemedicine has relieved families from the numerous challenges of traveling long distances to access specialized services (12). Telehealth delivery also helps improve parental well-being in the care of infants through the available platforms (10).

Telemedicine can support neonatal care across the entire spectrum of prenatal, intrapartum, and postpartum and post-discharge care. Telehealth platforms facilitate constant interaction by the healthcare provider to assess maternal and fetal health and overall care management when there is a high-risk newborn, which should be attended to as soon as possible (3). Besides, telemedicine continues to care for the child and the family from the NICU to the home environment due to

teleconsultations and home visits with physicians. Follow-up care and developmental assessments delivered through telemedicine after discharge are effective practices to support infants at risk (11). Telemedicine for neonatal care is a growing concept with almost infinite potential, and its efficacy and drawbacks are yet to be thoroughly researched and explored. Additional research is needed to determine the feasibility and effectiveness of telemedicine in existing healthcare frameworks.
As more data is collected, better telemedicine protocols would be developed, overall satisfaction with the service, and better care for neonates and families (14). As technology advances and healthcare expands, telemedicine, specifically for neonatal care, can be more accessible, not surpassing in value, and patient-oriented compared with NICU care. Finally, telemedicine has become an essential component of neonatal care as it has significant advantages, such as better healthcare results, lower costs, and the psychological well-being of parents. Telehealth solutions are being widely applied to healthcare systems, which makes it necessary to evaluate the effectiveness of these technologies in serving the purpose of high-risk infants and families. Telemedicine in neonatal care is promising, and future research will be crucial for further enhancements (15).

Objective: This study aims to evaluate the efficacy of telemedicine in neonatal care by assessing its role in remotely monitoring high-risk infants, improving outcomes, and supporting healthcare delivery in NICU settings.

MATERIALS AND METHODS

Study Design: Prospective observational study.
Study setting: The study was conducted at the NICU, Sindh Institute of Child Health and Neonatology (SICHN) which is situated in Korangi-5, Karachi.
Duration of the study: The study spanned a six-month period, from January 2024 to June 2024.

Inclusion Criteria

The study focused on neonates who required admission to the NICU predominantly due to prematurity, low birth weight of less than 2.5 kg, or prolonged respiratory support required. Patients who were treated in the NICU but were later discharged yet needed to be followed through remote monitoring were also included in the analysis. The participants needed to have parental permission for telemedicine follow-up.

Exclusion Criteria

Newborns with major congenital anomalies and patients who died in early infancy or during their NICU admission also did not take part in the study. Those families who did not have telecommunication facilities or who did not agree to go through remote monitoring were also not included in the study.

Methods

Consecutive high-risk neonates admitted in NICU in SICHN were then included in the study as per inclusion criteria. At stabilization and discharge, families were oriented on the use of the telemedicine platform for follow-up care. The system consisted of videoconferencing, sharing critical information concerning patient vital signs including heart rate, respiratory rate, and oxygen saturation levels; and evaluating neurodevelopmental milestone check on the infants via AIMS. Weekly teleconsultations with neonatologists were being done and other subspecialists depending on the clinical scenario. Any abnormality such as red-flag symptoms or lab values led to telemedicine or in-person followup. Clinical outcome, readmission, parental satisfaction, and follow-up compliance data were collected. The effectiveness of remote care was measured by comparing health status and developmental progress during the six month follow-up period. All data were taken from electronic records to maintain patients' privacy and strictly following the ethical consideration approved by the institutional review board.

RESULTS

The study recruited one hundred twenty high-risk neonates from January to June 2024. Among these, 110 patients completed the six-month follow-up via the telemedicine system. The rest of the 10 participants could not be followed up due to technology problems or a change of location. The telemedicine intervention also observed an overall improvement in clinical outcomes, parents' satisfaction, and scheduled evaluations.

Table 1: Provides the demographic and clinical characteristics of subjects at the baseline cross-sectional study. Most of the patients were neonates, 58.3% of them being neonates born before the Term (gestational age less than 37 weeks). Of the infants born, 60% weighed below 2.5 kg, which is considered low birth weight. The most prevalent among them were respiratory distress syndrome (RDS), neonatal sepsis, and hypoxic-ischemic encephalopathy (HIE).

Table 1: Baseline Characteristics of Neonates (n=120)

Variable	Frequency (n)	Percentage (%)
Preterm (<37 weeks)	70	58.3
Low Birth Weight (<2.5 kg)	72	60.0
Male	68	56.7
Female	52	43.3
RDS	38	31.7
Sepsis	30	25.0
HIE	20	16.7

This telemedicine platform also attended to 420 patients through virtual consultation during the study period. The average number of virtual follow-ups for each infant was 3-5 per month. The feasibility analysis found that 90% of the developmental assessments using the AIMS were successfully made during the planned number of sessions. A referral to early intervention services for babies found to have poor scores on the AIMS was made in 35% of the cases.

Table 2: Telemedicine Follow-up Data (n=110)

Parameter	Value
Average virtual visits per infant	4.2 per month
AIMS assessments completed	396 (90%)
Referrals to early intervention	39 (35%)
Missed virtual visits	44 (8.7%)
Emergency readmissions	9 (8.2%)

Perceived service quality of the cafeteria by the parents was evaluated on a 5 Likert scale, where the majority, 88%, responded that the service was "very satisfactory" or "satisfactory." Most respondents valued the convenience of not having to travel to various places and fast access to medical advice. The technical issues were raised in 10% of the consultations.

Table 3: Parental Satisfaction Survey Results (n=100)

Satisfaction Level	Frequency (n)	Percentage (%)
Very Satisfied	60	60.0
Satisfied	28	28.0
Neutral	8	8.0

Satisfaction Level	Frequency (n)	Percentage (%)
Dissatisfied	3	3.0
Very Dissatisfied	1	1.0

The results indicate that telemedicine was a feasible and efficient approach in the post-discharge management of high-risk neonates, improving their children's developmental outcomes without compromising the capacity of families or healthcare facilities.

DISCUSSION

In recent years, Telemedicine services have become widespread, especially in neonatal care, considering the overall shift towards telehealth, especially during the COVID-19 pandemic. The current research aimed at assessing the effectiveness of the telemedicine system, in particular in providing care to high-risk neonates after discharge from the NICU in Karachi. The study has affirmed the possibility of telehealth in improving neonatal outcomes, relieving parents' stress, and increasing access to specialized care, especially in developing nations. One of the significant findings of this study was the 90% success rate of the follow-up assessments conducted remotely through scales such as the Alberta Infant Motor Scale (AIMS). This accords with Fang and Chuo (1), who documented the increased application of telehealth in maintaining essential newborn care due to a scarcity of specialized pediatric services. Similarly, Maitre et al. (2) showed that outpatient neurodevelopmental surveillance using telemedicine is feasible and effective for high-risk infants as these children need regular monitoring of their development.

Moreover, the positives of remote monitoring have been supported in several systematic reviews and meta-analyses about the perinatal benefits among mothers and their neonates. Li et al. (3) further proved that remote fetal and neonatal monitoring effectively reduced complications and provided timely responses. Our study showed that only 8.2% of patients in our cohort were readmitted to the emergency department, and it can be hypothesized that telemedicine might help identify and address complications promptly. Telemedicine has also been helpful throughout the continuum of neonatal-perinatal care, as highlighted by Chuo et al. (4), for consultation, diagnosis, and even follow-up. This is supported by the current study, where neonates could be effectively and efficiently monitored virtually and, where necessary, referred to early intervention services. This is especially relevant for healthcare facilities not part of the tertiary level of healthcare. Thus, they may not have specialists working on-site for newborns. Edwards and O'Shea (5) posed the same question and answered that it is feasible to use telemedicine to bolster emergency care in areas of inadequacy or scarcity of resources.

The support of subspecialty care in the NICU through telemedicine, as pointed out by Azzuqa et al. (6), is another crucial aspect, given the increasingly high prevalence in low-income areas of Karachi. In our study, neonates were seen by pediatric neurologists and physiotherapists, a task that would have been logistically and financially impractical to achieve through in-person visits. Similarly, the SAFE BIRTH telemedical network trial described by Hense et al. (7) demonstrates the usefulness of such models for utilizing structured, stepped-wedge designs for increasing maternal and neonatal health in other populations. One of the crucial intensive care management of the newborn is neuro-intensive care, particularly in hypoxic-ischemic encephalopathy. Variane et al. (8) described other technologies that can currently be implemented to support its use in the telehealth context. While we did not employ complex neuromonitoring technologies, the daily assessment of AIMS provided an approximate way to follow neurological and motor development that was informative. Similarly, as applied in the study by Zizzo et al. (9), self-monitoring at home is safe and feasible for mothers of intermediate- or high-risk pregnancies that our study aims to support through digital tools.

Neonates' parent's involvement and their state of health are also essential components of nursery care. Wagenaar et al. (10) stressed that telemedicine can benefit parents during the neonatal period by supporting communication, providing education, and easing parental anxiety regarding hospital visits. It was established that 88% of parents were satisfied with the telemedicine services given the

convenience experienced, timely responses, and emotional relief offered. This is because accessing tertiary care facilities may be difficult due to geographical barriers, financial reasons, or cultural beliefs. Agarwal et al. (11) proposed a model integrating telemedicine and a quality improvement model for delivering intensive care remotely. Our findings support this, showing that organized virtual follow-up visits, normal frequency, and interprofessional practice enhanced the continuity of newborn care after discharge. Additionally, Miller et al. (12) pointed out that there was an increase in early intervention referrals due to telemedicine during the pandemic which was exactly 35% this study showed that virtual assessments can help in the provision of early developmental support.

The role of digital health interventions after NICU discharge was also highlighted in the meta-analysis mentioned by Manisha et al. (13); they identified that these interventions can help improve the outcomes of mothers and high-risk neonates. This is confirmed in the current study since parents benefited from virtual education and follow-up sessions about infant care and developmental cues. However, it is necessary always to consider the positive and negative aspects of telemedicine and their duality. According to Galle et al. (14), telemedicine is a 'double-edged sword' with the disadvantages of equity, telecommunication technology literacy, and data security. In our survey, despite having high overall success, about 10 percent of our respondents reported technical issues, for example, bad internet connection or problems with the gadgets used. These factors can slow down the development of telemedicine unless further investment in infrastructure is made and caregivers are educated about the use of technologies.

Finally, the reliability of remote neurodevelopmental assessments has also been established by Davies et al. (15), who established that technologies such as the Alberta Infant Motor Scale can be used in telehealth for assessing the development of high-risk infants. This strengthens the evidence supporting our study and promotes using such tools in day-to-day telemedicine practice. Finally, this study shows that it is possible to implement telemedicine feasibly and acceptably to monitor high-risk neonates. They include continuity of care, decreased reliance on families, encouragement and provision of early treatment, and services spanning geographic regions. Thus, achieving long-term success will require overcoming these technological flaws in practice, evolving the care process, and making it accessible to all patients

CONCLUSION

The findings of this study demonstrated that telemedicine can be beneficial in the post-NICU follow-up of high-risk neonates. Incorporating structured virtual follow-up, including AIMS, helped in proper, timely follow-up for developmental assessments and referrals to interventions and cut out unnecessary hospital visits. The high completion rate of the scheduled assessments and the perceived satisfaction of the parents underscore the usefulness and feasibility of this model in contexts similar to Karachi. Additionally, the merged concept of telehealth allowed for the successful establishment of links between the tertiary care providers concerned with babies and families in remote regions. This led to sustaining an appropriate care continuum and neonatal health improvement. Despite challenges like technical hindrances and internet connectivity, the study encourages the adoption of telemedicine as a viable model for post-discharge-neonatal care. Future work should be directed towards the development of guidelines, augmentation of digital networks, and improvement of availability for the optimization of telehealth in neonatal follow-up care.

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