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A Wireless Neonatal Intensive Care Unit: Fiction or Closer Reality?

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"In the 1960s, when the first NICUs opened, premature infants had a 95% chance of dying. Today, they have a 95% chance of survival" – Dr. Rahul K. Parikh, a pediatrician from California, published in August 2012 in the *New York Times* [1]. This incredible shift in survival can be considered a great example of the conquest of modern neonatal medicine. Among many technological advancements, the ability to continuously monitor vital signs such as heart rate and respiratory rate, was followed by closed loop body temperature (T) control, blood pressure assessment, and finally by continuous and non-invasive monitoring of oxygen saturation. Monitoring of these vital signs was paramount for the assessment of well-being and detection of pathophysiological states in tiny patients, allowing for adjustments or initiation of treatments or interventions that are lifesaving.

There is no question that neonatal technology has advanced tremendously over the last 60 years and parents have become very approving of this. In the book *From Surviving to Thriving*, Fabiana Bacchini, the mother of a twin baby boy born at 27 weeks, wrote: "I was able to watch in happiness and gratitude, all the technology that exists to keep these tiny beings alive." Later, it also became clear that, despite the important role of technology, it can also cause fear and anxiety for parents. Fabiana mentioned that the first time she entered the NICU "I did not see a baby, I saw wires, monitors and a breathing machine" [2].

Indeed, current technology for vital signs monitoring uses several skin sensors connected to the bedside monitors by wires and cables. In most patients, raw signals, average values and trends of heart rate, respiratory rate, temperature, and oxygen saturation are continuously displayed. However, this system carries some challenges for patients, parents, and healthcare professionals (HCP) as the multiple wires can tangle around the infant body, restrict the patient's movement, and cause discomfort or pressure sore. Hence, regular care involves frequent removal, reapplication, and readjustments of the sensors, which may harm the fragile neonatal skin, cause pain, and/or interrupt resting or sleeping. For parents, not much information is available on what are their perspectives on these vital signs monitoring systems. Some small surveys have reported that the presence of multiple wires and cables can cause intimidation and additional stress, acting as a barrier to skin-to-skin contact for fear

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of disconnecting the sensors or wires, or interfering with regular monitoring [3–5]. This technology may also increase HCP's workload as wires and cables may touch contaminated surfaces or become soiled with urine, blood or stools, increasing the risks of nosocomial infections [3, 6, 7]. Consequently, nurses must constantly inspect, sanitize, reposition, or replace components of the system.

Is a Wireless NICU Possible?

Neonatal intensive care units manage a diversity of health problems with variable degrees of severity and patient maturation. To develop a wireless system that can be used during the first days of life in a 400 g extremely preterm infant born at 22–23 weeks of gestation and a 4-kilo term infant born with perinatal asphyxia is a real challenge. Furthermore, there are some more stable infants that are just feeding and growing, or infants with chronic problems that require prolonged hospitalizations. Noticeably, the needs of these populations are different, creating challenges for the development of new vital signs monitoring systems. As an example, an extremely preterm infant in the first days of life spends most of the time quiet, sleeping inside the incubator, and has very sensitive skin that can easily be damaged by skin adhesives and sensors. In these cases, non-contact technologies may play a very important role, at least for the monitoring of heart rate and respiratory rate. This is not the case with more stable and mature infants that are active, and where parents can constantly hold and promote kangaroo care (KC). Therefore, the adoption of new monitoring technologies needs to consider those different needs, be very familiar with the technology advantages and limitations, and develop protocols and proper training for all healthcare providers involved.

Is a Wireless NICU Desirable?

Although wired vital sign monitors are the standard, they are frequently cited as obstacles to key aspects of family-integrated care and routine clinical practice. Wireless vital sign monitoring technologies are increasingly being explored as a potential solution to these issues. However, there is limited research available which quantitatively or qualitatively examines how key NICU stakeholders such as parents and HCPs, perceive the current monitoring system and these wireless innovations.

The small number of existing studies have highlighted that the wires and sensors used in current systems interfere with skin-to-skin contact and KC, limit parents' ability to hold or touch their infants, and contribute to a highly technical environment that many find overwhelming. Survey and interview studies consistently show that parents perceive the wires as intimidating and as contributing to their anxiety [3, 8–10]. HCPs also express widespread concerns with the current systems, especially regarding the physical clutter created by wires, challenges with positioning and handling of infants, risk of pressure sores from adhesives, and the frequency of false alarms [8, 11–13].

These concerns have led to growing interest in wireless monitoring as a possible solution. While research on parent and HCP in this area is very limited, all existing studies show optimism toward the adoption of wireless technology. Parents have generally responded positively, citing benefits such as reduced anxiety, possible easier interaction with their infant, improved KC, and enhanced infant comfort. However, there are some apprehensions related to signal reliability, sensor size and appearance, battery duration, and potential risks such as radiation exposure [3, 8, 14, 15]. Similarly, HCPs have voiced strong support for wireless monitoring, highlighting its potential to reduce handling difficulties, decrease false alarms, and improve comfort for both infants and families [3, 8, 11, 12]. Importantly, they also emphasize areas of concern, including reliability, safety related to radiation, and costs [8, 12]. In particular, the absence of economic feasibility studies is a significant gap in the current literature.

Overall, the available evidence indicates that wireless monitoring is a promising advancement, with support from key stakeholder groups in the NICU. The shift away from wired systems could improve key aspects of neonatal care, particularly KC and parental engagement, while also addressing some of the frustrations voiced by HCPs. However, to address these challenges, and ensure new technologies will be adopted by NICU staff and parents, concerns around reliability, safety, and cost must be addressed through careful user-centered design, and rigorous research including clinical evaluation. Future research should prioritize that wireless systems not only meet regulatory and clinical standards but are also feasible and acceptable for daily use in the NICU.

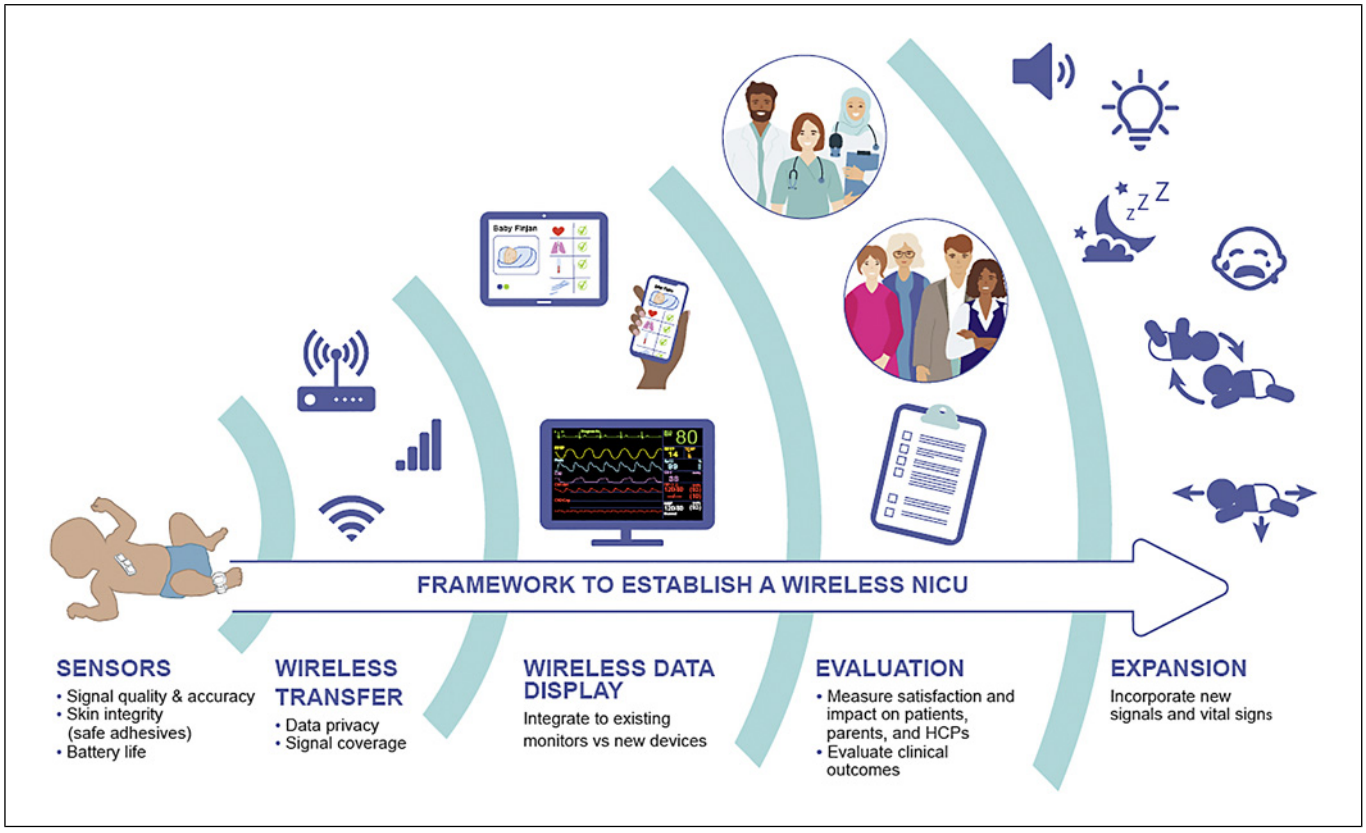

Fig. 1. Framework for the development of a wireless NICU of the future.

What Wireless Technology for Neonatal Vital Signs Monitoring Is Available or Emerging?

Non-Contact

A large number of small studies have investigated the use of non-contact vital sign monitoring in the NICU. Most studies used a single-device system and monitored respiratory or heart rate using offline analysis. The following technologies have been tested: red, green, blue cameras, infrared cameras, monochrome cameras, depth cameras, and radar, primarily for respiratory rate and heart rate monitoring [16–22]. Non-contact sensors are typically placed at the head or foot of the infant's incubator or crib. In some cases, the sensor cannot collect data through the plexiglass and may require either an open incubator or a small opening to maintain a clear line of sight. Depending on the technology and algorithms used, a defined Region of Interest within the sensor's visual field may be designated for vital sign extraction.

These studies generally featured small sample sizes and short recording durations of <1 h [17, 19, 21]. Nearly all exclusively focused on accuracy by comparing novel non-contact methods to a reference measurement using the Bland-Altman method. Analyses of heart rate and respiratory rate using this method revealed low bias and moderately acceptable 95% limits of agreement. Feasibility outcomes were rarely explored and measured using metrics such as the amount of usable data or processing times. No studies explored outcomes related to safety, although this can be expected as these monitoring methods pose no threat to the fragile neonatal skin.

While these technologies show promising preliminary results, several concerns remain. First, feasibility concerns remain as most devices rely on an uninterrupted clear view of the infant. How it would perform in situations where the infant is moving, clothed, or receiving care needs to be better clarified. Additionally, a systematic review of non-contact technologies applied the QUADAS-2 assessment and revealed several areas of concerns regarding risk of bias and applicability due to lack of clear inclusion and exclusion criteria and small sample sizes [23]. Furthermore, many studies lacked key basic descriptors of the population, such as age and weight, making it difficult to ensure a representative range of

NICU patients such as those requiring respiratory support or in incubators were included in the research. Additionally, some studies provided incomplete descriptions of reference measurements, only naming them as "standard" or "routine" monitoring, limiting the ability to determine the risk of bias. Unfortunately, most non-contact studies lack a conflict-of interest statement.

Ultimately, non-contact technologies may represent an appealing monitoring solution for some of the most vulnerable infants in the NICU, such as extremely premature infants with extremely fragile skin. This research area is rapidly growing as non-contact studies often utilize commercially available cameras and present low research risks for patients. However, concerns regarding the ability to perform reliably for prolonged periods in a real NICU environment and across a range of patients require further exploration and validation.

Wireless Wearables

Studies focusing on wearable devices provide slightly more detailed information regarding participant selection criteria and larger sample sizes. Emerging classes of wireless sensors in the form of soft, flexible, skin-like ("epidermal") platforms have the potential to redefine practices for monitoring in the NICU, with additional possibilities for use in the home. Recent work at Northwestern University shows that a pair of devices of this type, each of which gently and non-invasively adheres to the fragile skin of a premature neonate, is capable of capturing complete, clinical grade vital signs information without any wires or cables [24, 25]. These devices include distributed flexible electronic components with stretchable interconnects; all embedded in strategic layouts within medical-grade silicone encapsulating structures. The designs optimize for conformal interfaces to the skin at relevant anatomical locations. In pilot studies on patients in NICU settings, these technologies achieved high accuracy and fidelity similar to those of traditional wired monitors. Extensions enabled by additional sensors allow for precise measurements of body sounds, relevant to cardiac and respiratory monitoring, with additional capabilities in tracking gastrointestinal activity [26]. Specifically, high-bandwidth microphones and accelerometers yield seismocardiograms, lung sounds, bowel motility, and even the spectral and temporal features of crying and other forms of vocalization. In this way, these advanced technologies can not only capture vital signs and physiological signals but also an array of important biophysical metrics of health status, beyond those addressed with conventional NICU hardware.

Commercial translation is also gaining momentum. As an example, Sibel Health (Sibel Health, USA) has secured successive FDA 510(k) clearances since 2021 for its ANNE® One sensor platform, a pair of chest and foot patches to continuously monitor heart rate, respiratory rate, skin and core temperatures, oxygen saturation and biomarkers. It is also noteworthy that ANNE One® is currently under investigation in NICU at Montreal Children's Hospital with the aim of create a wireless NICU. Meanwhile, other emerging technologies, focusing on more specific modalities, include Bambi Belt (Bambi Medical, the Netherlands) and Boppli® (Pyr-Ames, USA) for monitoring ECG/EMG and blood pressure, respectively [27–29].

Collectively, efforts with wireless technologies signal a paradigm shift to transform neonatal care with fewer risks and burdens, and to improve clinical workflow and patient safety. With continued refinement and real-world validation, wireless multimodal sensors are poised to enhance monitoring precision, promote a patient-centric environment, and ultimately give our most vulnerable patients a gentler start to life (Fig. 1). With that, a wireless NICU became a much closer to reality than just fiction.

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Conflict of Interest Statement

John Rogers and Ja Uk are co-founders and unpaid consultants of a company with products for wireless health monitoring. Eva Senechal and Guilherme Sant'Anna have no conflicts of interest to declare.

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Author Contributions

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References

1 Parikh RK. In Preemies, better care also means hard choice. The New York Times; 2012 [cited 2025 Jun 3]; Available from: https://www.nytimes.com/2012/08/14/health/views/better-care-for-premature-babies-alsomeans-harder-choices.html
2 Bacchini F. From Surviving to Thriving: a mother's journey through infertility, loss and miracles. Toronto, Ontario: Burman Books Media Corp; 2017.
3 Bonner O, Beardsall K, Crilly N, Lasenby J. "There were more wires than him": the potential for wireless patient monitoring in neonatal intensive care. BMJ Innov. 2017;3(1):12–8. https://doi.org/10.1136/bmjinnov-2016-000145
4 Johnston CC, Stevens B, Pinelli J, Gibbins S, Filion F, Jack A, et al. Kangaroo care is effective in diminishing pain response in preterm neonates. Arch Pediatr Adolesc Med. 2003;157(11):1084–8. https://doi.org/10.1001/archpedi.157.11.1084
5 Charpak N, Ruiz-Pelaez JG, Figueroa de CZ, Charpak Y. Kangaroo mother versus traditional care for newborn infants ≤2000 grams: a randomized, controlled trial. Pediatrics. 1997;100(4):682–8. https://doi.org/10.1542/peds.100.4.682
6 Patel NZ, Patel DV, Phatak AG, Patel VG, Nimbalkar SM. Reducing false alarms and alarm fatigue from pulse oximeters in a neonatal care unit: a quality improvement study. J Neonatol. 2022;36(2):135–42. https://doi.org/10.1177/09732179221100531
7 Russotto V, Cortegiani A, Raineri SM, Giarratano A. Bacterial contamination of inanimate surfaces and equipment in the intensive care unit. J Intensive Care. 2015;3:54. https://doi.org/10.1186/s40560-015-0120-5
8 Senechal E, Radeschi D, Kearney R, Shalish W, Sant'Anna G. Parents and health care providers' perspectives on vital signs monitoring technologies in the neonatal intensive care unit: an international survey. Am J Perinatol. 1997;100(4):682–8. https://doi.org/10.1542/peds.100.4.682
9 Pepper D, Rempel G, Austin W, Ceci C, Hendson L. More than information: a qualitative study of parents' perspectives on neonatal intensive care at the extremes of prematurity. Adv Neonatal Care. 2012;12(5):303–9. https://doi.org/10.1097/ANC.0b013e318265b3d5
10 Lantz B, Ottosson C. Parental interaction with infants treated with medical technology. Scand J Caring Sci. 2013;27(3):597–607. https://doi.org/10.1111/j.1471-6712.2012.01061.x
11 Poncette AS, Spies C, Mosch L, Schieler M, Weber-Carstens S, Krampe H, et al. Clinical requirements of future patient monitoring in the intensive care unit: qualitative study. JMIR Med Inform. 2019;7(2):e13064. https://doi.org/10.2196/13064
12 Poncette AS, Mosch L, Spies C, Schmieding M, Schiefenhövel F, Krampe H, et al. Improvements in patient monitoring in the intensive care unit: survey study. J Med Internet Res. 2020;22(6):e19091. https://doi.org/10.2196/19091
13 Wikström AC, Cederborg AC, Johanson M. The meaning of technology in an intensive care unit—an interview study. Intensive Crit Care Nurs. 2007;23(4):187–95. https://doi.org/10.1016/j.iccn.2007.03.003
14 Ginsburg AS, Kinshella MLW, Naanyu V, Rigg J, Chomba D, Coleman J, et al. Multiparameter continuous physiological monitoring technologies in neonates among health care providers and caregivers at a private tertiary hospital in nairobi, Kenya: feasibility, usability, and acceptability study. J Med Internet Res. 2021;23(10):e29755. https://doi.org/10.2196/29755
15 Peterson J, Jennings C, Mahaveer A. A clinical evaluation and acceptability study of the innovative SurePulse VS wireless heart rate monitor across the neonatal journey. Front Pediatr. 2024;12:1355777. https://doi.org/10.3389/fped.2024.1355777
16 Lorato I, Stuijk S, Meftah M, Kommers D, Andriessen P, Van Pul C, et al. Towards continuous camera-based respiration monitoring in infants. Sensors. 2021;21(7):2268. https://doi.org/10.3390/s21072268
17 Jain A, Sphurthy S, Bharadwaj P, Krishna L. EVM-iPPG: design and evaluation of a vital monitoring system in NICU. In: 2023 10th international Conference on signal processing and integrated networks (SPIN) [internet]. Noida, India: IEEE; 2023 [cited 2024 Nov 25]. p. 484–9. Available from: https://ieeexplore.ieee.org/document/10117094/
18 Kim JD, Lee WH, Lee Y, Lee HJ, Cha T, Kim SH, et al. Non-contact respiration monitoring using impulse radio ultrawideband radar in neonates. R Soc Open Sci. 2019;6(6):190149. https://doi.org/10.1098/rsos.190149
19 Ottaviani V, Veneroni C, Zannin E, Dellaca' RL, Lavizzari A, Mosca F. Contactless monitoring of breathing pattern and thoracoabdominal asynchronies in preterm infants using depth cameras: a feasibility study. IEEE J Transl Eng Health Med. 2022;10:1–8. https://doi.org/10.1109/jtehm.2022.3159997
20 Paul M, Karthik S, Joseph J, Sivaprakasam M, Kumutha J, Leonhardt S, et al. Noncontact sensing of neonatal pulse rate using camera-based imaging: a clinical feasibility study. Physiol Meas. 2020;41(2):024001. https://doi.org/10.1088/1361-6579/ab755c
21 Sun Y, Wang W, Long X, Meftah M, Tan T, Shan C, et al. Respiration monitoring for premature neonates in NICU. Appl Sci. 2019;9(23):5246. https://doi.org/10.3390/app9235246
22 Villarroel M, Chaichulee S, Jorge J, Davis S, Green G, Arteta C, et al. Non-contact physiological monitoring of preterm infants in the neonatal intensive care unit. NPJ Digit Med. 2019;2:128. https://doi.org/10.1038/s41746-019-0199-5
23 Senechal E, Maximov A, Jeanne E, Daniel R, Gross A, Azevedo V, et al. Non-contact vital sign monitoring technologies for the neonatal intensive care unit: a systematic review. Poster presented at pediatric academic societies conference; Honolulu, HI. 2025.
24 Chung HU, Kim BH, Lee JY, Lee J, Xie Z, Ibler EM, et al. Binodal, wireless epidermal electronic systems with in-sensor analytics for neonatal intensive care. Science. 2019;363(6430):eaau0780. https://doi.org/10.1126/science.aau0780
25 Chung HU, Rwei AY, Hourlier-Fargette A, Xu S, Lee K, Dunne EC, et al. Skin-interfaced biosensors for advanced wireless physiological monitoring in neonatal and pediatric intensive-care units. Nat Med. 2020;26(3):418–29. https://doi.org/10.1038/s41591-020-0792-9
26 Yoo JY, Oh S, Shalish W, Maeng WY, Cerier E, Jeanne E, et al. Wireless broadband acousto-mechanical sensing system for continuous physiological monitoring. Nat Med. 2023;29(12):3137–48. https://doi.org/10.1038/s41591-023-02637-5
27 Scholten AWJ, Zhan Z, Niemarkt HJ, Vervoorn M, van Leuteren RW, de Jongh FH, et al. Cardiorespiratory monitoring with a wireless and nonadhesive belt measuring diaphragm activity in preterm and term infants: a multicenter non-inferiority study. Pediatr Pulmonol. 2023;58(12):3574–81. https://doi.org/10.1002/ppul.26695
28 Hunter RB, Saruwatari MS, Bliss ND, Kim S, Turcu RM, Krbec BA, et al. Accuracy and safety of a continuous noninvasive blood pressure monitor in neonates. Neonatology. 2025;19:1–19. https://doi.org/10.1159/000546187
29 Rao A, Eskandar-Afshari F, Weiner Y, Billman E, McMillin A, Sella N, et al. Clinical study of continuous non-invasive blood pressure monitoring in neonates. Sensors. 2023;23(7):3690. https://doi.org/10.3390/s23073690