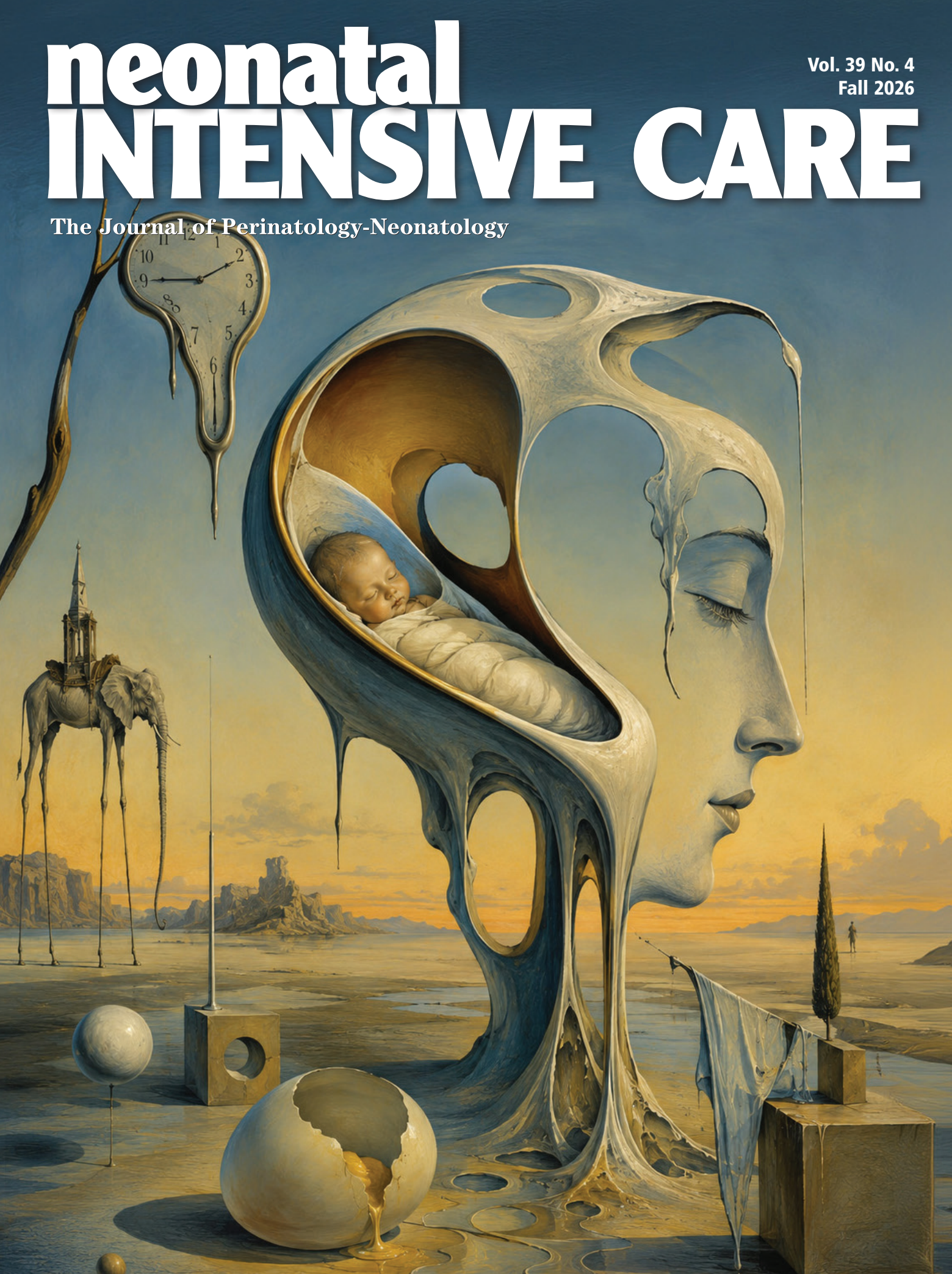
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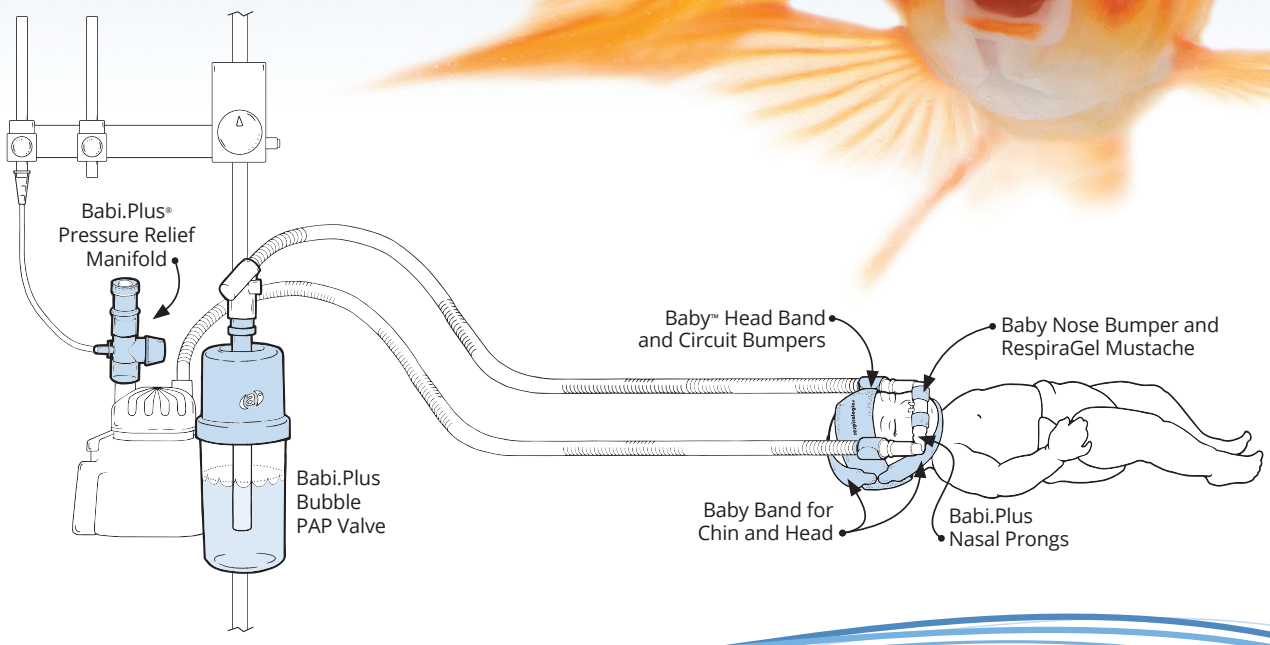
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News

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Axiom Biosciences Reports Positive Phase 1 Results for Investigational Stem Cell Therapy

Axiom Biosciences, a clinical-stage biotechnology company developing next-generation regenerative therapies and targeted biologics, today announced positive Phase 1 results for its investigational Wharton's Jelly-derived mesenchymal stem cell (WJ-MSC) therapy for neonatal brain injury. The therapy, co-developed with South Korea-based Medinno Inc., is being developed to treat intraventricular hemorrhage (IVH) and hypoxic-ischemic encephalopathy (HIE), two severe neurological conditions in newborns associated with high rates of mortality and long-term disability. The investigational therapy consists of conditioned WJ-MSCs administered directly into the central nervous system. The Phase 1 dose-escalation study evaluated the safety, tolerability, and preliminary efficacy of the therapy across a range of doses in 9 newborns diagnosed, 5 with severe IVH and 4 with HIE. Findings include: achieved a 0% mortality rate at 12 months compared to the historical natural mortality rate of approximately 46% within the first year of life for infants with severe IVH; demonstrated a favorable safety profile, with no treatment-related serious adverse events (SAEs) observed across all dose cohorts; and produced promising improvements in long-term functional outcomes at 24 months, including key cognitive and motor development measures. "These Phase 1 results represent an important milestone for a patient population with tragically limited treatment options," said Dr Remo Moomiaie-Qajar, Founder and Chief Executive Officer of Axiom Biosciences. "The fact that all patients survived for a year and showed promising long-term improvement reveals the platform's regenerative potential. These results give us a solid launchpad for our next phase of clinical development." IVH and HIE are among the leading causes of mortality and long-term neurological disability in newborns, frequently resulting in cerebral palsy, developmental impairment, and lifelong medical complications. There are currently no approved regenerative therapies that directly address the underlying neurological injury associated with these conditions. In 2023, the company received Rare Pediatric Disease Designations from the US Food and Drug Administration for both IVH and HIE. The FDA's Rare Pediatric Disease Priority Review Voucher program is currently authorized through September 30, 2029; if a product is approved while the program remains in effect, these designations may make the company eligible to receive Priority Review Vouchers. Building on these results, Axiom is evaluating the expansion of the platform into adult ischemic stroke. Because HIE and ischemic stroke share common mechanisms involving ischemic tissue injury and subsequent inflammatory response, the company believes the platform may have broader applications across neurological disorders. Ischemic stroke affects approximately 700,000 adults annually in the United States and remains a leading cause of death and long-term disability worldwide. "With time being of the essence in stroke care, patients lose 1.9 million neurons every single minute," added Dr Moomiaie-Qajar. "Our platform aims to offer a first-of-its-kind regenerative approach that goes beyond mitigating damage to potentially restoring function." Axiom plans to advance the neonatal program into Phase 2 development and to evaluate expansion into adult ischemic stroke and additional neurological indications.

Preterm Labor: Could a Metabolic Coenzyme Be the Trigger?

Declining placental concentrations of a molecule that plays a key role in metabolism appear to trigger the end of pregnancy and hasten labor and delivery, suggests a study co-led by researchers at UT Southwestern Medical Center. The findings, published in *Science*, could lead to new ways to predict when pregnant women might give birth and who might be at risk for premature delivery. "A normal length of pregnancy is vital to the health of the child. Our findings identify a metabolic mechanism that may influence the length of pregnancy in both health and

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Cover: Abstract. Red and Green Gradation [with some cinnibar in vertical format] (1921). Paul Klee (German, 1879 - 1940).

disease," said Samir Parikh, M.D., Chair and Professor of Internal Medicine and Professor of Pharmacology at UT Southwestern. Dr Parikh co-led the study with first author Erin Ciampa, M.D., Ph.D., Assistant Professor of Anesthesia at Harvard Medical School and Attending Anesthesiologist at Beth Israel Deaconess Medical Center. Healthy mammalian pregnancies tend to be approximately the same length within species. For example, human pregnancies average about 40 weeks and mouse pregnancies about 18.5 days, with little variation. Scientists have long known labor is activated by molecules called prostaglandins—lipids with hormone-like actions that are often used to induce labor. But what signals reproductive tissues to produce prostaglandins, and why this typically occurs after an average length of pregnancy, has been unknown. To answer these questions, Dr Parikh, Dr Ciampa, and their colleagues examined the concentrations of different molecules present in mouse placentas as they progressed from the second trimester to full-term pregnancies. They immediately homed in on nicotinamide adenine dinucleotide (NAD+), a coenzyme that plays a pivotal role in helping cellular organelles called mitochondria generate energy from nutrients and facilitates hundreds of chemical reactions in every cell. As pregnancy neared its end, placental levels of NAD+ and precursor molecules used to generate this coenzyme dropped precipitously. When the researchers examined placentas from women who gave birth via cesarean section at different points during pregnancy before labor started, they found a similar phenomenon: Levels of NAD+ and its precursors also fell close to the time natural labor would have taken place. To determine whether NAD+ plays a role in signaling the end of pregnancy, this molecule was depleted in mouse placentas using either a drug that reduced NAD+ levels or genetic alterations that did the same. In both cases, decreasing NAD+ shortened pregnancy by more than a day on average, a significant length for mouse pregnancies. Conversely, supplementing a mouse model of preterm birth with NAD+ precursors lengthened their pregnancies by nearly a day. These results suggested NAD+ is key for sustaining pregnancy, and its loss kick-starts labor. A closer look revealed the loss of NAD+ affected the activity of another placental enzyme called 15-PGDH, which uses NAD+ as a coenzyme to degrade prostaglandins produced by the placenta throughout pregnancy. The team's results suggest that when NAD+ levels drop at the end of pregnancy, 15-PGDH can no longer degrade prostaglandins, allowing their concentrations to rise and trigger labor. The sudden fall in NAD+ levels seems to be a tipping point in the nutritional balance between the mother and fetus that exists throughout pregnancy, Dr Parikh explained. When the metabolic demands of the fetus outweigh that of the mother, NAD+ drops and labor starts. By monitoring components of the NAD+-prostaglandin pathway, researchers may be able to detect who might be at risk for preterm labor or give full-term mothers a better idea of when they might deliver. In addition, supplementing gestating mothers at risk for preterm births with NAD+-augmenting precursors might prolong pregnancy to a healthier length, while depleting it could represent a new way to induce labor when necessary.

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Maternal RSV Vaccination Reduces Infant Hospitalization Risk by 68%

A study led by researchers at the University of Pittsburgh and UPMC published in *JAMA Network Open*, a peer-reviewed journal of the American Medical Association, found that vaccination against respiratory syncytial virus (RSV) during pregnancy reduced the risk of hospitalization in young infants by nearly 70%. This study provides early real-world evidence from U.S. clinical care, showing that administering one dose of the maternal RSV vaccine (RSVpreF vaccine) reduces hospitalization related to RSV in young infants. The results are consistent with findings from RSVpreF vaccine clinical trials. The RSVpreF vaccine was approved by the U.S. Food and Drug Administration in 2023.

Among infants younger than 3 months, maternal vaccination was associated with approximately 68% effectiveness against hospitalization for respiratory illness caused by RSV, and 69% effectiveness against more severe lung infections also caused by the virus. "We designed this study to focus on what matters most to families: whether their baby might end up in the hospital," said lead author of the study, Anne-Marie Rick, M.D., Ph.D., assistant professor of pediatrics and clinical and translational science at Pitt School of Medicine and a physician at UPMC Children's Hospital of Pittsburgh and UPMC Magee-Womens Hospital. "The findings show a significant impact for families and for the health system, and it highlights how effective this intervention can be during the most vulnerable months of life." RSV is the leading cause of hospitalization among infants in the United States. According to the Centers for Disease Control and Prevention (CDC), about 2 to 3 out of every 100 babies younger than 3 months are hospitalized each year due to RSV, with severe cases sometimes requiring oxygen support or mechanical ventilation. Until the RSVpreF vaccine's approval, there was no reliable way to protect healthy newborns from RSV starting at birth. The study analyzed health records from infants 90 days old or younger who were hospitalized for respiratory illness in Western Pennsylvania during the 2023–2024 and 2024–2025 RSV seasons. Researchers focused on infants who were tested for RSV and compared outcomes between those whose mothers received the vaccine during pregnancy and those whose mothers did not. Infants who received monoclonal antibody protection — a separate RSV prevention option administered after birth — were

excluded. Studying the real-world impact of maternal vaccination presents a logistical challenge because it requires linking medical records from mothers and their infants, which are typically stored as separate patient records. Using integrated health data across UPMC's Western Pennsylvania network, researchers were able to connect these records and evaluate outcomes more comprehensively. "UPMC is really a unique place where we can do this type of work, as our connected system allows us to do it across a large population while maintaining the necessary rigor," added Rick.

Allowing Rotavirus Vaccination in NICU May Boost Coverage

For US kids born after the rotavirus vaccine was introduced, recommendations against administration in the neonatal intensive care unit (NICU) appeared to be a strong barrier to getting immunized, researchers reported. Children most likely to not receive a first rotavirus vaccine dose included those with extremely preterm birth (OR 14.6, 95% CI 11.2-20.0), birth soon after introduction of the vaccine (OR 3.3, 95% CI 2.9-3.8), and lack of health insurance (OR 2.2, 95% CI 1.8-2.7), noted Mary Moran, PhD, MPH, of the CDC, and colleagues, in *Pediatrics*. The CDC's Advisory Committee on Immunization Practices (ACIP) and the American Academy of Pediatrics (AAP) have recommended a maximum age for a first rotavirus vaccine dose of 14 weeks and 6 days and full series completion by 8 months of age, the research team noted. However, ACIP guidelines have recommended NICU patients who are age-eligible not receive the shot until discharge due to a theoretic risk of vaccine virus transmission within the NICU, although AAP guidelines note that hospitals may consider giving the shot to otherwise eligible infants in the NICU, Moran and colleagues continued. "These guidelines may inhibit high-risk infants, such as those born prematurely, from being vaccinated," they wrote. In an examination of NICU details for 230 extremely preterm infants who received diphtheria, tetanus, and pertussis (DTaP) vaccination, more than half were not discharged until at least 15 weeks. Of these infants, 80% did not receive the rotavirus shot.



Clinicians Raise Concerns Over Federal Shift Away From Universal Hepatitis B Vaccination at Birth

The recent federal decision to scale back recommendations for universal hepatitis B vaccination at birth could lead to hundreds of additional infections in US infants each year, particularly if vaccination rates decline among babies born to mothers with unknown infection status, according to a modeling study published in *JAMA Pediatrics*.

The study comes months after the Advisory Committee on Immunization Practices (ACIP) voted in December 2025 to replace its longstanding universal hepatitis B birth-dose recommendation with "shared clinical decision-making" for infants born to mothers who test negative for hepatitis B surface antigen. Under the new guidance, those infants may delay vaccination until at least 2 months of age. Additional stated rationales behind the ACIP change in recommendation is that the prenatal screening test are reliable and almost universal, and that rates of perinatal transmission are very low. Researchers at Boston University School of Public Health, Boston, estimated that the policy shift could result in 69-628 additional neonatal hepatitis B infections annually, depending on how much vaccination coverage falls in infants whose mothers were not screened during pregnancy. The study modeled outcomes for a US birth cohort of about 3.66 million infants using current maternal screening rates and historical vaccination patterns. Researchers found that preventing the increase in infections under the new recommendation would

require screening more than 100,000 additional pregnant women if birth-dose coverage among unscreened mothers remained near current levels. If coverage dropped sharply — as it did after a temporary policy change in 1999 — more than 400,000 additional women would need to be screened to offset the increase in infections. According to the researchers, universal maternal screening and universal newborn vaccination "operate as complementary safeguards" and warned that replacing one layer of protection with more intensive screening "may be difficult to achieve in practice."

Raydiant Oximetry Completes Enrollment of First 15 Patients in IDE Pilot Study

Raydiant Oximetry, Inc., a clinical-stage medical device company pioneering innovations in fetal pulse oximetry through advanced biophotonics and machine learning, announced today the completion of enrollment and data collection for the first 15 patients in its Investigational Device Exemption (IDE) Pilot Study at Louisiana State University Health Shreveport (LSUHS). The study is designed to collect fetal pulse oximetry data using Raydiant's investigational transvaginal sensor, which is positioned on the fetus's cheek during active labor. The company has collected more than 40 hours of data from the first 15 patients, providing valuable insights to support the development and optimization of the machine learning algorithms that will power Raydiant's commercial products. "We have been pleased with our involvement in this clinical study," said Dr P. Scott Barrilleaux, Associate Professor of Obstetrics & Gynecology at LSUHS and Principal Investigator for the study. "We continue to believe in the potential clinical value that fetal pulse oximetry can bring to labor and delivery and look forward to contributing to the advancement of this important technology." Following a review of data from the initial patient cohort, the US Food and Drug Administration (FDA) approved an expansion of the study, allowing enrollment of up to 30 patients. Raydiant and LSUHS will continue enrolling patients to further expand the fetal pulse oximetry dataset and support ongoing product development efforts. "LSUHS has been an outstanding clinical partner and has helped us generate a substantial amount of data during the first phase of this IDE study," said Michael Nagel, Chief Executive Officer of Raydiant Oximetry. "The FDA's authorization to expand enrollment is an important milestone for the program. We look forward to continuing our collaboration with LSUHS as we build the clinical and technical foundation for an entirely new generation of fetal monitoring technologies."



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Video as Clinical Education

For decades, clinical education in neonatal care has been delivered through journals, textbooks, conferences, workshops, and peer-to-peer discussions. While these resources remain essential, the way healthcare professionals consume educational content continues to evolve. Increasingly, clinicians are supplementing traditional educational materials with digital resources, including webinars, recorded presentations, product demonstrations, and online training videos.

In many ways, video has become one of the most effective educational tools available to healthcare professionals. Complex procedures can be demonstrated visually. Clinical techniques can be observed rather than simply described. New technologies can be introduced in a format that allows viewers to see equipment, workflows, and patient care applications in real-world settings.

For neonatal clinicians, this evolution is particularly important. The neonatal intensive care environment demands constant learning. New technologies, monitoring approaches, respiratory support strategies, and nutritional interventions continue to emerge. Healthcare professionals are expected to remain current while balancing the demands of patient care, staffing challenges, and limited time for continuing education. As a result, educational videos have become an increasingly valuable complement to traditional clinical literature.

At *Neonatal Intensive Care*, our mission has always been to identify educational resources that help clinicians improve patient care. With that objective in mind, we are introducing a new feature: the **Video Review Series**.

The purpose of these reviews is not to replace peer-reviewed literature or traditional educational content. Rather, the goal is to help readers discover and evaluate educational videos that may have practical value within the neonatal clinical environment. Each review will examine a selected video presentation, assess its educational content, discuss its clinical relevance, and provide readers with an independent editorial perspective regarding its usefulness.

Much like a review of a textbook, educational program, or conference presentation, these assessments will focus on the quality of the information presented, the relevance of the topic, and the potential value to neonatal healthcare professionals. Particular attention will be given to practical application, educational merit, and the video's ability to address real-world clinical challenges faced by neonatal caregivers.

The inaugural review in this issue examines a video presentation addressing the clinical applications of the RAM Cannula® in neonatal respiratory support. Noninvasive ventilation remains one of the most important topics in contemporary neonatal care, and the reviewed presentation offers an opportunity to explore both the educational content and the practical considerations associated with this widely used respiratory support interface.

We believe this new format represents a natural extension of our educational mission. As the methods by which clinicians learn continue to evolve, so too must the resources available to support that learning. Educational videos have become an increasingly important component of professional development, and our goal is to help readers identify those resources that provide meaningful clinical value.

As this is the inaugural installment of our Video Review Series, we would particularly appreciate hearing from our readers. Do you find educational video reviews valuable? Would you like to see additional reviews covering neonatal respiratory care, monitoring technologies, nutrition, developmental care, patient safety, and other topics relevant to NICU practice?

We are also interested in learning how you currently use video-based education within your institution. Are educational videos incorporated into staff training, competency assessment, orientation programs, or continuing education activities? Have you found certain types of video content especially useful in supporting clinical practice?

Your feedback will help guide the future development of this feature and assist us in identifying the topics and educational resources that are most valuable to neonatal healthcare professionals. We welcome your comments, suggestions, and recommendations for future video reviews.

The future of clinical education will likely combine traditional publishing with emerging digital formats. Through this new Video Review Series, we hope to help bridge those worlds while continuing our commitment to providing neonatal healthcare professionals with practical, relevant, and timely educational information.

Steve Goldstein
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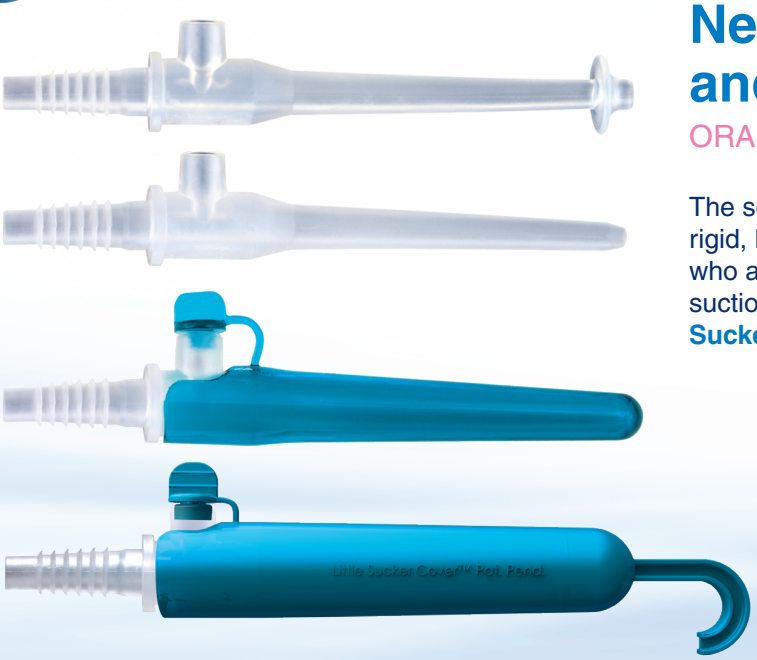
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Why Neonatal Transillumination Technology Continues to Improve Vascular Access in the NICU

The Editors of Neonatal Intensive Care

Obtaining reliable vascular access remains one of the most common—and often most challenging—procedures performed in the neonatal intensive care unit. Extremely premature infants and critically ill newborns frequently require intravenous medications, parenteral nutrition, blood products, and emergency therapies, yet their veins are exceptionally small, fragile, and difficult to visualize. Technologies that improve vein identification can help clinicians perform these procedures more efficiently while reducing unnecessary needle sticks and patient stress.

One technology that has become a valuable adjunct in many neonatal intensive care units is fiberoptic transillumination. By projecting high-intensity, cool white light through neonatal tissue, transillumination enables clinicians to visualize superficial veins more clearly before attempting venous cannulation. Improved visualization can increase first-attempt success, reduce procedure time, and minimize trauma to these highly vulnerable patients.

Sylvan Fiberoptics has been a pioneer in neonatal transillumination technology for more than three decades. The **Neoscan® Neo2-W LED Neonatal Transilluminator** was developed specifically for neonatal and pediatric applications, combining high-intensity LED illumination with a fiberoptic light delivery system that produces excellent visualization while maintaining a cool operating temperature for patient safety. The portable battery-powered design allows clinicians to use the device wherever vascular access is needed, whether at the bedside, in transport, or during emergency situations.

Beyond assisting with peripheral intravenous access, neonatal transillumination has long been used to support bedside assessment of conditions such as hydrocephalus, pneumothorax and other thoracic abnormalities where rapid visualization may provide valuable clinical information while additional diagnostic studies are being arranged. The versatility of these devices has made them a standard piece of equipment in many Level III and Level IV NICUs.

Sylvan Fiberoptics has continued to refine its technology based on direct input from neonatal clinicians. One example is the introduction of its 90-degree fiberoptic lightpipe for the Neoscan Neo2-W, designed in response to recommendations from NICU nurses and neonatologists. The redesigned lightpipe provides improved ergonomics when working around incubators, ventilator tubing, monitoring equipment, and other bedside devices while maintaining the same high level of illumination.

Recent clinical studies continue to support the role of transillumination and vein visualization technologies in neonatal vascular access. Investigators have reported improved visualization of superficial veins, higher first-attempt cannulation success in some patient populations, and fewer repeated punctures when visualization devices are incorporated into routine practice. While clinician experience remains the most important factor in successful vascular access, adjunctive technologies can improve efficiency and help reduce procedural stress for both patients and caregivers.

The readership of *Neonatal Intensive Care* includes many of the professionals responsible for evaluating new technologies for their institutions. Neonatologists, neonatal nurse practitioners, NICU nurses, respiratory therapists, vascular access specialists, and department managers routinely participate in equipment evaluations, product trials, and purchasing decisions. Devices that improve procedural success while enhancing patient safety naturally attract considerable interest from this audience.

As neonatal medicine continues to advance, many of the most meaningful improvements come not from dramatic breakthroughs but from thoughtful refinements to everyday clinical tools. Technologies that make common procedures safer, faster, and less traumatic contribute directly to the quality of neonatal care. Sylvan Fiberoptics continued commitment to neonatal transillumination reflects that philosophy and explains why its products remain relevant to clinicians dedicated to providing the highest level of care for premature and critically ill newborns.

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Summary and Rationale for Grant Application for In-Utero Heart Transplantation

BM Petrikovsky, MD, PhD; E Zharov, MD, DSc; L Neymotin, PhD

Background

Hypoplastic cardiac ventricles are congenital heart diseases with a prevalence of 0.1-0.27 per 1,000 live births.[1] Left heart hypoplasia is more common than right heart hypoplasia. Prenatal diagnosis is usually straightforward, demonstrating a very small ventricle, atretic mitral and aortic valves in the case of left cardiac hypoplasia, and echogenic appearance of the affected ventricle due to fibroelastosis.[1] It can be diagnosed via sonogram at 11-13 weeks of gestation.

Hypoplastic left heart syndrome (HLHS) may be associated with genetic abnormalities, including trisomies 13 and 18, and Noonan and Holt-Oram syndromes, among others.[2] HLHS was considered fatal decades ago, and even today its management remains exceptionally challenging.[3]

Current Staged Surgical Management

Today, survival involves a series of staged palliative surgical interventions. After birth, a newborn with HLHS requires prostaglandin E2 to keep the ductus arteriosus patent, together with oxygen therapy. The first stage of management is the Norwood procedure, which includes recruiting the right ventricle for systemic output via a reconstructed aorta, excision of the atrial septum, and placing a systemic-to-pulmonary artery shunt.

If the baby survives, he or she undergoes the second surgical procedure at 3 to 6 months of age. This procedure involves taking down the systemic-to-pulmonary shunt and connecting the superior vena cava to the pulmonary arteries, the so-called bidirectional Glenn anastomosis.[4,5]

Finally, at 2-4 years of age, a third operation is required, the Fontan procedure. Surgeons redirect the inferior vena cava to the pulmonary arteries, completing a total cavopulmonary connection.

Despite complex surgical management, most children will experience long-term complications, including neurocognitive impairment, atrioventricular valve regurgitation, and Fontan-associated liver disease. Some will suffer life-threatening complications such as plastic bronchitis and protein-losing enteropathy. As unsustainable Fontan physiology starts to decline in the second and third decades of life, circulatory failure and the prospect of heart transplant become a reality for the majority of survivors.[6,7]

The lack of persistent success of staged surgeries and progress in fetal surgery became the reasons to consider in-utero interventions in cases of HLHS.

In-Utero Pathology in Fetuses with HLHS

HLHS is a ductus arteriosus-dependent condition in which pulmonary and systemic circulation are kept by the single right ventricle. The pulmonary circulation is supplied through the left and right pulmonary arteries. The systemic circulation is provided via the truncus pulmonalis, ductus arteriosus, and descending aorta.

The transition of circulation after birth, with the decline in pulmonary vascular resistance and the spontaneous closure of the ductus arteriosus, causes severe hemodynamic consequences in a child with HLHS. The spontaneous closure of the ductus arteriosus compromises the blood flow in the systemic circulation, including the cerebral and coronary pool.

All these changes make HLHS amenable to in-utero treatment.

Fetal Therapy

Fetal Aortic Valvuloplasty

The purpose of fetal aortic valvuloplasty (FAV) is to prevent the development of HLHS. FAV is a percutaneous procedure performed around the 24th gestational week.[8] The procedure is performed while the mother is under anesthesia. The fetal left ventricle is approached from the apex. The guide-wire and balloon are introduced through the stenotic aortic valve. The balloon is inflated repeatedly, gradually dilating the valve.

The early post-procedural complications include fetal bradycardia, hemopericardium, ventricular thrombus, rupture of the balloon or failure to retract it, and fetal demise. Late complications are valvular stenosis and insufficiency, endocardial fibroelastosis, and myocardial fibrosis.

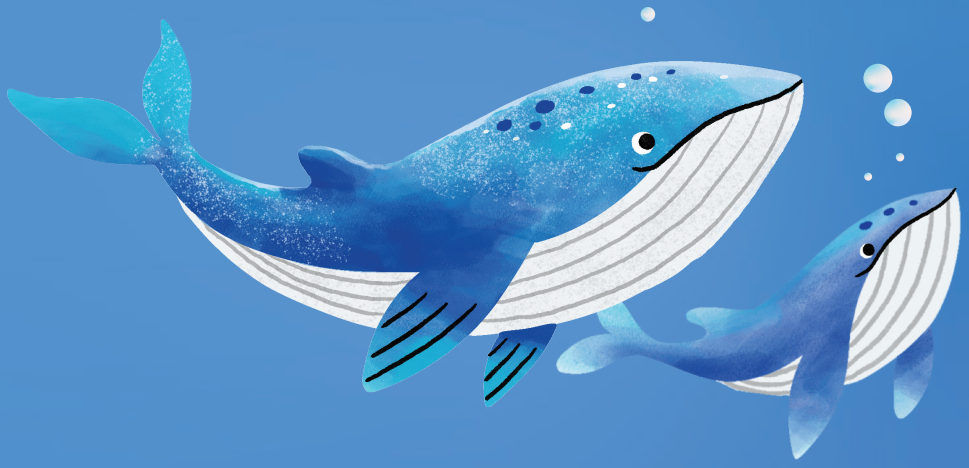
Fetal Atrial Septoplasty

Another type of fetal therapy is atrial septoplasty, performed on fetuses with established HLHS and a restrictive atrial septum. This procedure may prevent or alleviate pulmonary venous hypertension by allowing effective pulmonary blood flow. The atrial septum is approached from the right atrium. If needed, the septum

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is perforated, followed by introduction and inflation of a balloon. A stent may be inserted if the atrial septum is too thick.

Hypoplastic Right Heart Syndrome

Hypoplastic right heart syndrome (HRHS) is a congenital heart defect in which the tricuspid valve, right ventricle, and/or pulmonary valve are underdeveloped or not formed. When these structures are too small, the right side of the heart cannot send enough blood to the lungs. This causes a fetus with untreated HRHS to have abnormally low oxygen levels.

Some forms of HRHS are:

- Tricuspid stenosis
- Tricuspid atresia
- Pulmonary stenosis
- Pulmonary atresia

In-utero intervention consists of placing the cannula tip in the right outflow tract with perforation of the atretic pulmonary valve. Then, a floppy-tipped guidewire is placed in a pulmonary artery or the ductus arteriosus, and a balloon is inflated across the valve. After the final balloon deflation, the wire, balloon, and cannula are removed.[9]

In-utero pulmonary valvuloplasty is a technically challenging procedure. One needs first to enter the right ventricular outflow tract with the right trajectory and then to perforate and dilate the atretic valve. As reported previously, fetal hemodynamic instability during attempted ventricular access attests to the difficulty of the procedure.[9]

One needs to keep in mind that the majority of in-utero interventions provide only temporary relief and require a definitive procedure after the baby is born.

Heart Transplantation as an Alternative

The reasonable alternative to in-utero or staged procedures is heart transplantation. The first human heart transplant was performed by Christiaan Barnard in Cape Town in December 1967.

Recently, Overbey et al. reported partial heart transplantation in children with congenital heart disease. Partial heart transplants are potentially curative and allow for adaptive growth in recipient children.

In the Overbey series, indications for partial heart transplant included truncus arteriosus (6 patients), tetralogy of Fallot (5 patients), critical aortic stenosis (4 patients), severe aortic insufficiency (2 patients), right ventricular outflow tract obstruction (1 patient), and biventricular outflow tract obstruction (1 patient).[13]

A follow-up of 26 weeks showed that partial heart transplant grafts exhibit growth synchronized with a recipient's development.[13]

Conclusions

In-utero partial heart transplantation is a new promising development in fetal cardiology.

We would like to conclude with a remark made by A. Kantrowitz, who performed the first U.S. heart transplant (11):

> *"From the beginning, we believed that transplantation would prove to be the treatment of choice for infants and children with otherwise lethal cardiac lesions. A natural heart, unlike an implanted mechanical device, would grow with the child; it was possible that an infant's less developed immune system might make management of any rejection process easier; and anencephalic infants comprised a potential donor pool."*

Clear evidence of immunological advantages of organ transplantation in utero is derived from in-utero hematopoietic stem cell transplantation, a procedure where stem cells are injected into a fetus's bloodstream before birth to treat genetic diseases, such as alpha thalassemia major, sickle cell disease, and Fanconi anemia. This approach takes advantage of the fetal immune system's immaturity to prevent rejection of the donor cells, aiming for long-term engraftment.[14]

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NICU Nurses' Knowledge, Attitudes, Practices, and Influencing Factors Regarding Breastfeeding of Newborns: A Scoping Review

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Abstract

Background

Improved survival rates of high-risk neonates have been accompanied by persistent challenges in breastfeeding support within Neonatal Intensive Care Unit settings. While the World Health Organization strongly advocates for breastfeeding, global breastfeeding rates in NICUs remains suboptimal. NICU nurses play a key role in breastfeeding support, yet their knowledge, attitudes, and practices (KAP) remain systematically underexplored. This study aims to assess NICU nurses' current levels of breastfeeding-related KAP and explore influencing factors, thereby identifying key intervention areas and providing evidence for targeted interventions and training programs.

Methods

This scoping review followed the Arksey and O'Malley framework and systematically searched Medline (Ovid), Embase (Ovid), Web of Science, Scopus, and CINAHL for studies published up to 6 April 2025. Studies were screened using predefined inclusion and exclusion criteria. Data were extracted and synthesized, focusing on NICU nurses' breastfeeding-related knowledge, attitudes, practices, and influencing factors.

Results

Fourteen studies across nine countries were ultimately included. NICU nurses generally acknowledged the benefits of breastfeeding and maintained positive attitudes, particularly those who had received breastfeeding training. However, their professional knowledge was notably insufficient, particularly regarding lactation physiology and contraindications to breastfeeding. Consequently, positive attitudes did not consistently translate into standardized clinical practice, with notable variability in implementation and heavy reliance on personal experience. These knowledge-attitude-practice gaps were influenced by multiple factors operating at individual, institutional, and family levels. Furthermore, the assessment of KAP revealed significant methodological challenges, as the included studies used highly heterogeneous assessment tools, often self-designed or adapted, highlighting a lack of standardized KAP instruments tailored to NICU settings.

Conclusions

This review reveals a critical knowledge-attitude-practice gap in NICU breastfeeding support. While nurses' attitudes are positive, their knowledge is deficient and practices inconsistent, a discordance driven by individual, institutional, and methodological challenges. Bridging this gap requires a multi-pronged strategy focused on competency-based training, supportive policies, and the development of validated, NICU-specific assessment tools.

Background

Advancements in neonatal care have significantly improved the survival rates of preterm and high-risk infants, many of whom require extended hospitalization in neonatal intensive care units (NICUs). However, the NICU environment, characterized by intensive medical interventions and extended maternal-infant separation, presents substantial challenges to the initiation and maintenance of breastfeeding.[1] These challenges are further compounded by the physiological immaturity of preterm infants, such as poor coordination of sucking and swallowing, low birth weight, and underdeveloped gastrointestinal function.[2] As a result, appropriate feeding becomes a critical component of their survival and recovery.[3]

Breastfeeding is universally recognized as the optimal mode of infant nutrition, offering significant health benefits for both mothers and infants.[4] For mothers, breastfeeding helps reduce the risk of postpartum hemorrhage, breast cancer, and ovarian cancer, while also enhancing maternal-infant bonding.[5,6] For neonates, particularly those admitted to NICUs, breastfeeding is associated with lower rates of necrotizing enterocolitis, bronchopulmonary dysplasia, and late-onset sepsis, in addition to supporting long-term growth and neurodevelopment.[7–9]

The World Health Organization (WHO) and the United Nations International Children's Emergency Fund (UNICEF) advocate for exclusive breastfeeding for the first six months of life.[10,11] However, global breastfeeding rates remain below targets: in 2019, only 43.5% of infants worldwide were exclusively breastfed, with lower rates

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of 37% in low- and middle-income countries.[12–14] The situation is more concerning in NICUs, where exclusive breastfeeding rates at discharge among preterm infants vary widely from 16% to 49% in high-income settings,[15] with rates as low as 9.3% reported in China.[16]

While breastfeeding is well recognized and endorsed at theoretical and policy levels, numerous structural and systemic barriers hinder its implementation in NICUs. These barriers include non-companionable care models, prolonged maternal-infant separation, and inadequate infrastructure.[17–19] Within these constraints, NICU healthcare providers, particularly nurses, remain crucial to supporting breastfeeding during and after hospitalization.[18] Through their direct care and encouragement, nurses significantly influence maternal motivation, confidence, and breastfeeding competence. A large-scale survey involving 2,941 hospitals emphasized the importance of strengthening breastfeeding support systems by increasing the allocation of nursing staff dedicated to lactation guidance and education.[20] However, emerging studies indicate that optimizing this support requires a deeper understanding of NICU staff attitudes, beliefs, and knowledge regarding breastfeeding to inform the design of targeted training interventions.[21]

As the frontline implementers and promoters of breastfeeding in NICU practice, nurses' knowledge, attitudes, and practices (KAP) directly influence breastfeeding outcomes and neonatal health. According to the KAP model, knowledge serves as the cognitive foundation that shapes attitudes and subsequently guides practice behaviors.[22] In the context of breastfeeding support, "knowledge" refers to nurses' understanding of lactation physiology, breastfeeding benefits, and clinical guidelines; "attitude" reflects their perceptions, beliefs, and motivation to promote breastfeeding; and "practice" represents their actual supportive behaviors and clinical interventions delivered to mothers and infants.[23] Understanding the interrelationships among these elements and their influencing factors is crucial to identifying gaps in NICU nurses' breastfeeding-related competence and developing targeted educational interventions.

While research on improving breastfeeding rates has increased in recent years, most studies have focused on mothers and infants, with comparatively limited attention to the nursing workforce. Existing evidence suggests that many NICU nurses lack sufficient knowledge of human milk expression, storage, and feeding initiation for preterm infants.[24] Some also perceive breastfeeding very low birth weight infants as risky, which diminishes their confidence and willingness to provide support.[25] Moreover, most existing studies have been conducted in single centers or specific regions, employing heterogeneous methodologist and yielding disparate results. To date, no comprehensive evidence synthesis has examined NICU nurses' breastfeeding-related KAP across diverse contexts. This knowledge gap hinders the development of evidence-based training and practice interventions. Given the dispersed and heterogeneous nature of the existing literature, a scoping review is particularly suitable for synthesizing such evidence to map the extent and nature of research, identify key themes, and highlight underexplored areas that warrant further investigation. Therefore, this scoping review aims to systematically map and synthesize existing research on NICU nurses' breastfeeding-related knowledge, attitudes, practices, and influencing factors, ultimately seeking to identify key areas for intervention and provide evidence-based recommendations for clinical practice, nursing education, and policy formulation.

Methods

Design

This scoping review was conducted based on the framework proposed by Arksey and O'Malley[26] and followed the PRISMA extension for Scoping Reviews (PRISMA-ScR) reporting checklist.[27] The protocol was registered on the Open Science Framework Registry under the title, "Knowledge, Attitudes, Practices, and Influencing Factors of NICU Nurses on Newborn Breastfeeding: A Scoping Review" (osf-registrations-w32f5-v1).

Research questions

This scoping review sought to address the following research questions:

1. What is the current state of NICU nurses' knowledge, attitudes, and practices regarding newborn breastfeeding?
2. What factors influence NICU nurses' knowledge, attitudes, and practices in supporting breastfeeding in NICUs?
3. What assessment tools have been used to evaluate NICU nurses' knowledge, attitudes, and practices related to breastfeeding?

Search methods

Two researchers systematically searched Medline (Ovid), Embase (Ovid), Web of Science, Scopus, and CINAHL, from their inception to 6 April 2025. The search strategy combined Medical Subject Headings (MeSH) and free-text terms, using Boolean operators to enhance both sensitivity and specificity. The search strategy included key terms related to NICU nurses (e.g., "NICU nurse", "neonatal intensive care unit nurse"), breastfeeding (e.g., "breastfeeding", "breast milk", "lactation"), and knowledge, attitudes, practices, and influencing factors (e.g., "knowledge", "attitude", "practice", "perception", "barrier", "facilitator"). Additionally, the reference lists of all included articles and relevant reviews were manually screened to identify any further eligible studies. Detailed search strategies for each database are provided in Additional file 1 (see Additional file 1).

Study selection

Studies were included if they met all of the following criteria: (1) the study population primarily comprised registered nurses working in NICUs; (2) the study focused on knowledge, attitudes, practices, perceptions, or influencing factors related to breastfeeding or lactation support for newborns; and (3) the study employed original research designs, such as cross-sectional, qualitative, or mixed-methods approaches. Studies were excluded if they: (1) included only non-registered caregivers, nursing students, or medical students as participants; (2) lacked full text availability or contained incomplete relevant data. No language restrictions were applied to the search to ensure comprehensive coverage of relevant literature. Two researchers (HMP, XL) independently screened titles and abstracts against the eligibility criteria. Subsequently, the full texts of potentially eligible studies were retrieved and independently assessed by the same researchers, with reasons for exclusion documented. Disagreements during the screening process were resolved through discussion or consultation with a third reviewer (YL).

Data charting

A standardized data extraction form was developed and pilot-tested prior to implementation. Two reviewers (HMP, XL) independently extracted key information from each included study, including bibliographic details, study characteristics, participant demographics, assessment tools, measured outcomes (knowledge, attitudes, and practices), and influencing factors. The extracted data

were subsequently cross-checked by a third reviewer (YL), with any discrepancies resolved through team consensus.

Data synthesis and reporting

Data were synthesized using descriptive statistics and narrative summaries. Results were categorized into three primary domains: knowledge, attitudes, and practices. Furthermore, influencing factors were inductively summarized and organized into emerging themes for clarity. Reporting process adhered to the PRISMA-ScR guidelines,[27] focusing on identifying gaps in the existing literature and implications for clinical nursing practice. Consistent with established scoping review methodology, no formal quality assessment was undertaken, as the primary aim was to map the extent and nature of available evidence rather than to evaluate study quality. Findings were presented using tables, figures, and narrative descriptions to enhance clarity and comprehension.

Results

Included studies

The systematic search identified 806 records from Medline Ovid ($n = 51$), Embase Ovid ($n = 222$), Web of Science Core Collection ($n = 96$), Scopus ($n = 254$), and CINAHL ($n = 183$) databases. After removing 380 duplicates, 426 unique records remained. Title and abstract screening excluded 382 records, leaving 44 for full-text review. Of these, 31 were excluded for not meeting the inclusion criteria. One additional study was identified through reference screening, yielding 14 studies for final inclusion.[24,25,28–39] Figure 1 presents the selection process following PRISMA-ScR guidelines.[40]

Study characteristics

Characteristics and main findings of the included studies are presented in Table 1. The 14 included studies, published between 2000 and 2024, represented nine countries: the United States ($n = 4$), China ($n = 3$), Korea, Sweden, Colombia, Jordan, Thailand, Turkey, and Italy ($n = 1$ each). Study designs comprised qualitative approaches ($n = 7$); phenomenological, inductive, participatory, ethnographic), cross-sectional surveys ($n = 4$), descriptive ($n = 1$), prospective ($n = 1$), and prepost designs ($n = 1$). Eight studies were multicenter and five single-site; one did not specify setting. Participants were predominantly NICU nurses, with some studies including lactation consultants. Sample sizes ranged from 5 to 252 participants (mean age: 28.9–41.5 years). Educational backgrounds spanned vocational training to postgraduate degrees, with clinical experience ranging from novice to senior-level. Notably, over half of participants in several studies had received breastfeeding training, while more than 40% reported personal breastfeeding experience in others.

Knowledge, attitudes, and practices in breastfeeding

Among the included studies, nine assessed knowledge, nine examined attitudes, and eight reported practices related to breastfeeding. Knowledge assessment revealed paradoxical findings. While most NICU nurses demonstrated awareness of breastfeeding's general benefits for neonatal health,[25,28,30,36,38,39] this basic understanding masked significant clinical knowledge deficits. Nurses showed partial competence in practical areas such as recognizing feeding cues, timing of milk expression, and appropriate pumping frequency.[24,39] However, substantial gaps emerged in critical areas including lactation physiology, breastfeeding management strategies,[28,32] and individualized care for preterm infants.[35] Additional deficiencies included inadequate understanding of breastfeeding duration recommendations, contraindications, and feeding-related decision-making.[29,39] Most concerning was that approximately 49% of nurses incorrectly recommended bottle feeding, reflecting fundamental

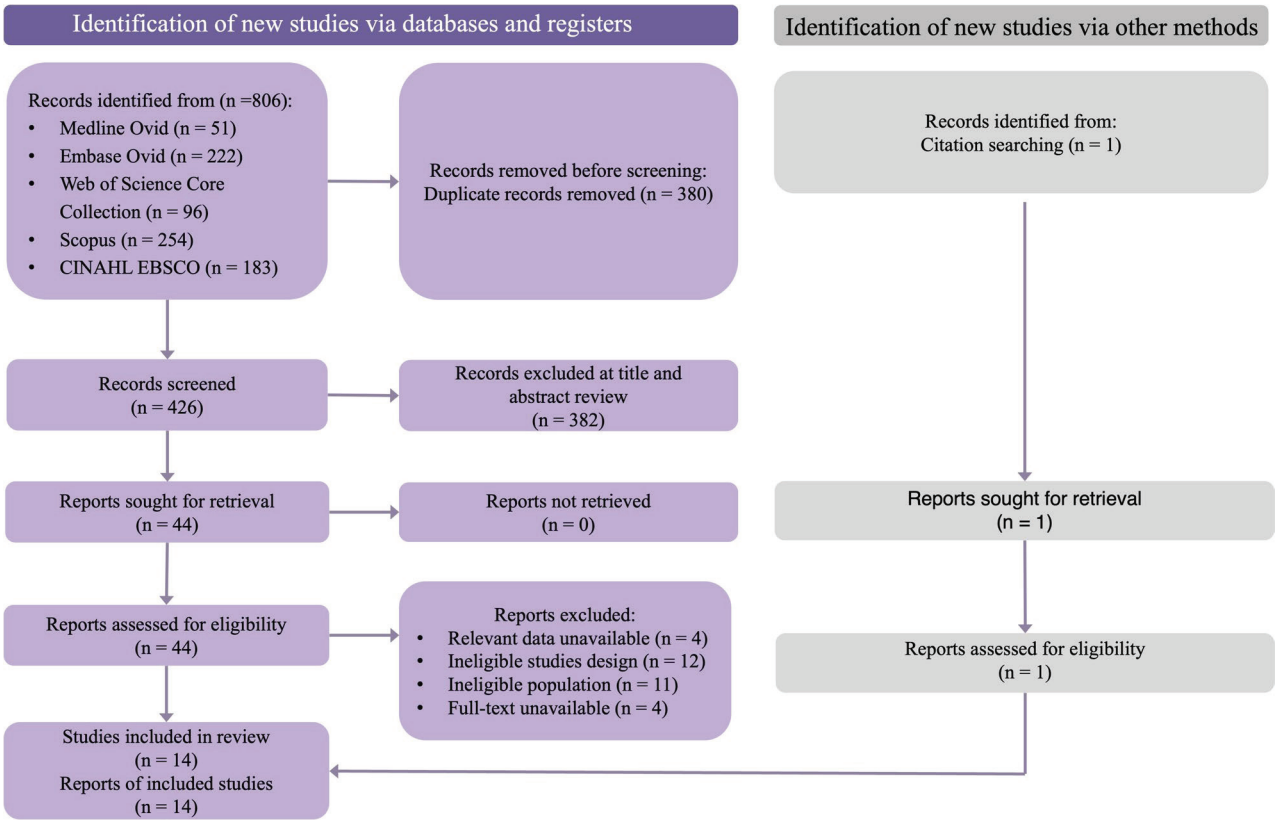


Fig. 1 The PRISMA-compliant study selection process

Table 1 Characteristics of the included studies

Study (Country)	Study Design	Setting	Sample Characteristics	Assessment Methods/Tools	Main Findings
Bernaix 2000 (USA)	Prospective study	Two metropolitan teaching hospitals	• Total sample: 151 • Mean age (M ± SD, years): 38.9 ± 9.6 • Education level: basic nursing education preparation in a diploma program (69%), associate's degree program (17%), bachelor's degree program (15%). Three of the diploma nurses and one of the associate's degree nurses had later earned bachelor's degrees. • Working experience: 10.8 ± 7.8 • Training experience: NR • Breastfeeding experience: NR	Nurses' Support for Breastfeeding Questionnaire (NSBQ, based on theory of reasoned action)	**Knowledge**: • Scores ranged from 7 to 16, with a mean of 12.3 ± 2.9. Seven of the nurses had a perfect score. **Attitudes**: • Attitude scores from the 48 nurses who responded ranged from − 2 to + 24, with a mean of 12.9 ± 6.6, indicating a moderately positive attitude toward providing breastfeeding support. **Practices**: • Scores on the Behavioral Beliefs subscale ranged from 346 to 857, with a mean of 661 ± 121, indicating a moderately positive attitude about the outcomes of providing breastfeeding support. **Influencing factors**: NR
Chen 2024 (China)	Cross-sectional survey	Nine hospitals with independent neonatal departments and NICUs in Qianxinan Prefecture, Guizhou Province	• Total sample: 193 • Mean age (M ± SD, years): NR • Education level: vocational high school (0.5%), Associate degree (19.2%), Bachelor's degree (80.3%) • Working experience: 1-5years (22.2%), 6-10years(32.1%), > 11years (45.6%) • Training experience: 33.2% (64/193) received breastfeeding training • Breastfeeding experience: NR	• A self-designed the knowledge, attitudes, and practices related to breastfeeding in NICUs – Cronbach's alpha coefficient = 0.86	**Knowledge**: • The participants' total mean score: 4.45 ± 1.57 points out of 7 points. **Attitudes**: • The participants' total mean score: 32.15 ± 4.83 points out of 45 points. **Practices**: • The participants' total mean score: 23.49 ± 3.55 points out of 35 points. **Influencing factors**: • The parents of the infants were uncooperative with breastfeeding • Insufficient medical and nursing staff • Lack of establishment or implementation of breastfeeding • management policies • Inadequate awareness among doctors and nurses about the importance of breastfeeding • Excessive workload in the department
Cricco-Lizza 2016(USA)	Qualitative design	NICU	• Total sample: 18 • Mean age (M ± SD, years): 33 • Education level: Nursing diplomas (11.1%), Associate's degree (5.5%), Bachelor's degrees (77.7%), Master's degree (5.5%) • Working experience: NR • Training experience: About 50% of these key informants had taken the hospital breastfeeding course • Breastfeeding experience: NR	Formal, 1-hour, tape-recorded interview	**Themes related to breastfeeding knowledge and attitudes**: Three themes emerged: • Theme 1: The nurses identified health benefits of breastfeeding, but spoke in greater detail and with more emotion about day-to-day challenges of breastfeeding in the NICU. • Theme 2: Formula feeding evoked less emotion, and most nurses viewed it as safe and convenient. • Theme 3: Nurses with training or positive breastfeeding experiences highlighted evidence-based benefits and showed stronger commitment to supporting breastfeeding. **Influencing factors**: NR
Feng 2022(China)	Descriptive phenomenological qualitative approach	Shanghai First Maternity and Infant Hospital	• Total sample: 15 • Mean age (M ± SD, years): NR • Education level: Bachelor's degrees (80%), Master's degree (20%) • Working experience: 6–10 years (46.7%), 11–15 years (13.3%), 16–20 years (13.3%), 21–25 years (6.7%) • Training experience: NR • Breastfeeding experience: NR	In-depth, semi-structured interviews	**Practices**: Four overarching themes: • Theme 1: Extending the education duration(prenatal to postpartum) • Theme 2: Enriching the educational content(mechanism, skills, misconceptions) • Theme 3: Expanding the education subjects (mothers, husbands, family, caregivers) • Theme 4: Perfecting the educational process(standardization, repetition, nurse training) **Influencing factors**: NR

misconceptions about overfeeding risks and alternative feeding methods.[24]

In contrast to knowledge deficits, attitude assessments consistently revealed positive orientations toward breastfeeding. Multiple studies reported favorable attitude scores, with Bernaix et al. documenting a mean score of 12.9 ± 6.6[28] and Jin-Suk et al. finding 3.70 ± 0.41,[32] both indicating supportive attitudes. Although Shattnawi et al. noted a mismatch between attitudes and practice,[25] nurses generally agreed on the importance of

Table 1 (continued)

Study (Country)	Study Design	Setting	Sample Characteristics	Assessment Methods/Tools	Main Findings
Jin-Suk 2013(Korea)	Descriptive study	Seven university hospital NICUs in Seoul, Daejeon, and Daegu	• Total sample: 153 • Mean age (M ± SD, years): 28.86 ± 5.84 • Education level: Junior college (29.4%), 4 years university (57.5%), Master's degree (13.1%) • Working experience: <1 years (20.3%), 1-3years (28.1%), 3–5 years (13.1%), 5–10 years (30.7%), ≥ 10 (7.8%) • Training experience: NR • Breastfeeding experience: Yes (*N* = 27), No (*N* = 6)	• Modified 24-item knowledge questionnaire – Kuder-Richardson 20 (KR-20) coefficient = 0.78 • the Iowa Infant Feeding Attitude Scale (IIFAS) – Cronbach's α = 0.72 • Breastfeeding Knowledge and Nursing Activity Tool – Cronbach's α = 0.96	**Knowledge**: • The participants' total mean score: 14.07 ± 4.21 points out of 24 points. **Attitudes**: • The participants' total mean score: 63.00 ± 6.98 points out of 84 points. **Practices**: • The participants' total mean score: 97.66 ± 22.14 points out of 150 points. **Influencing factors**:NR
Mörelius 2022 (Swedish)	Qualitative inductive approach	Three Swedish FC NICUs	• Total sample: 9 • Mean age (M ± SD, years): 41.5 • Education level: Six of the participants were post-graduate specialists in pediatric and neonatal nursing including a one-year Master of Science degree and three were under-graduate nurses with a Bachelor of Science degree • Working experience: NR • Training experience: NR • Breastfeeding experience: Six had their own experience of breastfeeding	Face-to-face interviews	**Attitudes and Practices**: • Main category: *"A complex and long-lasting collaboration."* Nurses viewed feeding extremely preterm infants as a vulnerable process requiring both practical and emotional support for parents. They emphasized empowering families, promoting milk production, and involving all family members in feeding, consistent with FC NICU principles. **Influencing factors**: NR
Ochoa Marín 2023 (Colombia)	Qualitative action-participatory research	In the NICU of a hospital in the city of Medellín	• Total sample: 5 • Mean age (M ± SD, years): NR • Education level: NR • Working experience: Their experience in breastfeeding counseling ranged from 5 to 16 years, and their professional experience in the healthcare field ranged from 13 to 21 years • Training experience: All five participants were certified in breastfeeding counseling • Breastfeeding experience: NR	Semi-structured interviews	**Knowledge**: • Breastfeeding culture, which includes institutional breastfeeding policy and process standardization. **Practices**: • Quality, which includes activity recording and control; • Indicator monitoring and continuous auditing. **Influencing factors**: NR

initiating breastfeeding in physiologically stable preterm infants.[35] Additionally, studies underscored nurses' endorsement of maternal presence and their widespread recognition of the need for structured breastfeeding education.[24]

Despite positive attitudes, practice assessment revealed the most significant implementation challenges. The included studies demonstrated substantial variability in NICU nurses' supportive behaviors and clinical implementation. While some nurses engaged in supportive actions such as pre- and post-feeding weight checks,[24] skin-to-skin contact facilitation, and emotional support provision,[24,33] these practices were not universal. Multiple studies highlighted critical gaps, including the absence of standardized protocols, inconsistent guideline implementation, and limited structured training.[29,31,34,35] Of particular concern, clinical decisions were often experience-based rather than evidence-based,[36] while current education efforts were deemed insufficient in scope and depth.[31]

Factors influencing knowledge, attitudes, and practices

The factors influencing NICU nurses' KAP operate operated across three interconnected levels (see Fig. 2). At the institutional level, systemic barriers emerged as primary impediments to effective breastfeeding-related practices. These included insufficient staffing, heavy workload, absent or poorly implemented breastfeeding-related policies, and limited organizational support.[25,29,38] These institutional constraints limited nurses' ability to apply their knowledge and positive attitudes in consistent clinical practice. At the individual level, multiple personal and professional factors shaped nurses' KAP outcomes. Key determinants included inadequate systematic training, limited understanding of evidence-based practices, over-reliance on personal experience,

Table 1 (continued)

Study (Country)	Study Design	Setting	Sample Characteristics	Assessment Methods/Tools	Main Findings
Shattnawi 2017(Jordan)	Ethnographic research design	Two NICUs in Jordan	• Total sample: 15 • Mean age (M ± SD, years): 35 • Education level: Diploma (6.7%), Baccalaureate (53.3%), Master (6.7%), Neonatology (33.3%) • Working experience: 0-5years (40%), 6-10years (13.3%), > 11 (46.7%) • Training experience: NR • Breastfeeding experience: Yes (33.3%), No (26.7%), NA (40%)	Participant observation and semistructured interviews	**Attitudes**: Three key themes emerged: • Theme 1: The first described the contradiction that exists between the staff beliefs and behaviors in relation to breastfeeding and supporting mothers. • Theme 2: The second theme was related to staff working conditions, which described the lack of institutional support and barriers to supporting breastfeeding. • Theme 3: The final theme of controlling relationships captured the essence of the practitioner to mother association. **Influencing factors**: • The lack of institutional support and barriers to supporting breastfeeding
Smith 2016 (USA)	Pre-test/post-test study design	A northeastern tertiary children's hospital NICU	• Total sample: 18 • Mean age (M ± SD, years): 41.4 • Education level: NR • Working experience: Total years in a NICU (mean): 11–15 • Training experience: NR • Breastfeeding experience: NR	Participants completed a 10-question pretest evaluating their knowledge regarding the early initiation of breastfeeding. Following the pretest, participants engaged in a 20-min PowerPoint integrated literature review presentation	**Knowledge**: • The NICU staff was divided regarding the existence of a unit protocol for the initiation of breastfeeding in preterm infants. 44.4% ($n = 8$) reported that such a policy exists compared to 33.3% ($n = 6$) who reported that a policy did not exist within the unit. **Attitudes**: • Most participants 77.8% ($n = 7$) reported that the educational program changed or reinforced their ideas about the early initiation of breastfeeding in preterm infants. **Practices**: • However, only 33.3% ($n = 3$) reported making an actual change to their practice as a result of the program. **Influencing factors**: • Barriers included lack of awareness of evidence, maternal absence, insufficient/inconsistent kangaroo mother care (KMC) support, and family dysfunction.
Srichalerm 2024(Thailand)	Descriptive phenomenological approach	Three medical centers in the central region of Thailand	• Total sample: 13 • Mean age (M ± SD, years): NR • Education level: NR • Working experience: NR • Training experience: NR • Breastfeeding experience: NR	Semi-structured questions	**Themes related to breastfeeding knowledge**, **attitudes**, **and Practices**: The five main themes presented in the data were as: • Theme 1: Positive attitude toward breastfeeding and human milk; • Theme 2: Facing breastfeeding challenges at work; • Theme 3: Self-confidence rooted in experience; • Theme 4: Professional skill needs; and • Theme 5: Requiring further support. **Influencing factors**: NR
Suluhan 2023(Turkish)	Cross-sectional descriptive survey design	NR	• Total sample: 252 • Mean age (M ± SD, years): 30.26 ± 6.76 • Education level: High school(27.4%), Graduate(59.9%), Postgraduate(12.7%) • Working experience: ≤1 (62.4%), 2–5 (13%), 6–10 (11.1%), > 10 (13.5%) • Training experience: NR • Breastfeeding experience: NR	• Data collection tools included a data collection form, Survey Questionnaire, and Iowa Infant Feeding Attitude Scale (IIFAS) – Cronbach's α = 0.86	**Attitudes** • The IIFAS median score of the participants was 70.0 (IQR = 9.0). – Participants who were age between 26–30 years ($n = 76$, 30.2%), had post-education degree in nursing ($n = 32$, 12.7%), and attended to international scientific meetings ($n = 47$, 18.6) had higher positive attitudes of breastfeeding. The nurses ($n = 126$, 50%) stated that it was difficult to reach mothers in terms of breastfeeding for newborns, and 61.8% of them ($n = 156$) stated that they had difficulty initiating the mother-baby attachment process in the NICU.

and variations in professional characteristics such as job category, title, and gender.[29,35,39] In particular, nurses with prior breastfeeding training or personal breastfeeding experience were more likely to express positive attitudes toward breastfeeding.[30] The interaction between these individual factors and institutional constraints resulted in practice variations that compromised care standardization. At the family level, limited maternal bedside presence, insufficient family support, and poor communication patterns emerged as significant barriers.[35] These factors often intersected with institutional policies regarding visitation and parental involvement, further complicating family-centered care implementation.

Table 1 (continued)

Study (Country)	Study Design	Setting	Sample Characteristics	Assessment Methods/Tools	Main Findings
Vizzari 2020(Italy)	Multicenter cross-sectional survey	Six NICUs in Lombardy, Northern Italy	• Total sample: 10.3% (19/183) • Mean age (M ± SD, years): 36.9 ± 9.3 • Education level: NR • Working experience: 11.1 ± 9.5 • Training experience: Other specific training on breastfeeding in 11.5% of cases • Breastfeeding experience: NR	Questionnaire based on the Breastfeeding Support Tool	**Themes related to breastfeeding knowledge, attitudes, and Practices**: • Nurses demonstrated awareness of early breast milk expression (start within 12 h; 6–8 times/day) and transition practices from tube feeding to breastfeeding. • Majority supported unrestricted maternal presence (75%), early maternal involvement, importance of breastfeeding training (98%), and feasibility of breast pumping (97.3%). • Reported advising mothers on pumping schedules; 67% cited facility availability as key to feasibility; 53% allowed skin-to-skin contact as soon as parents were present, 47% after stability. **Influencing factors**:NR
Weddig 2010(USA)	Qualitative study	Eight state hospitals	• Total sample:40 • Mean age (M ± SD, years): NR • Education level: More than one half of the nurses had a bachelor of science degree in nursing (BSN), and three had a master of science degree in nursing (MSN) • Working experience: NR • Training experience: NR • Breastfeeding experience: 8.5years	Focus groups on hospital policies, nurses' knowledge and attitudes, and breastfeeding practices in the first 72 h; content validated by RN and IBCLC	**Knowledge**: • Nurses generally reported knowledge of evidence-based breastfeeding initiation, but in non-Baby Friendly settings, knowledge often did not match current best practices. • Hospital policies and actual practices were sometimes inconsistent with evidence-based recommendations. **Influencing factors**: • Hospital lactation policies (formal and informal), nurses' limited education in breastfeeding initiation best practices, high rates of surgical delivery, and lack of continuity of care with the transition of responsibility from one nurse to another from labor and delivery to transition care to postpartum care
Yang 2018(China)	Cross-sectional survey	Nine tertiary level neonatal intensive care units	• Total sample: 180 • Mean age (M ± SD, years): 30.48 ± 6.76 • Education level: Junior college (34.4%), Undergraduate (55%), Postgraduate or PhD (10.6%) • Working experience: ≤ 5years (62.8%), 6–10years (25%), > 10years (12.2%) • Training experience: NR • Breastfeeding experience: Personal breastfeeding experience (44.4%)	• The survey included three sections: (1) demographic information, (2) breastfeeding knowledge in the preterm infant population (knowledge questionnaire), (3) training assessment related to breastfeeding preterm infants – Cronbach's alpha = 0.941	**Knowledge**: • The average breastfeeding knowledge total score was 24.18 ± 4.17 with the range of scores from 34 to 12, highest to lowest respectively. The mean percentage of healthcare providers who correctly answered questions was 53.73%. The majority of the respondents (79.4%) had a score that was 60% (27/45) or below. **Influencing factors**: • Profession, professional title and sex

KMC, Kangaroo Mother Care; NICU, Neonatal Intensive Care Unit; IBCLC, International Board Certified Lactation Consultant; IQR, Interquartile Range; M ± SD, Mean ± Standard Deviation; NR, Not Reported

Assessment methods and instruments for KAP evaluation

Considerable methodological heterogeneity characterized KAP assessment across studies. Qualitative studies employed various approaches including semi-structured interviews, focus groups, and observations, yet lacked standardized protocols for cross-study comparison. Quantitative studies predominantly relied on modified or self-developed instruments with limited validation. Specifically, different tools were utilized for each KAP domain. For overall KAP assessment, Bernaix et al. designed the Nurses' Support for Breastfeeding Questionnaire (NSBQ) based on the Theory of Reasoned Action,[28] while Chen et al. developed a comprehensive questionnaire with good internal consistency (Cronbach's α = 0.86).[29] For knowledge assessment, Jin-Suk et al. adapted a 24-item tool originally created by Brodribb et al. and revised by Ahmed et al. (KR-20 = 0.78).[32] The Iowa Infant Feeding Attitude Scale (IIFAS) emerged as the most frequently used attitude measure (Cronbach's α = 0.72 to 0.86),[32,37] while Jung et al.'s 30-item Breastfeeding Nursing Activity Scale evaluated practices (Cronbach's α = 0.96).[37] However, no comprehensively validated NICU-specific KAP instrument was identified, constituting a critical barrier to research advancement and quality improvement.

Discussion

This scoping review systematically synthesized current evidence on the knowledge, attitudes, and practices of NICU nurses regarding breastfeeding, revealing a substantial disconnect between positive intentions and actual clinical practice. Unlike previous reviews that focused on mothers' breastfeeding experiences or physicians'

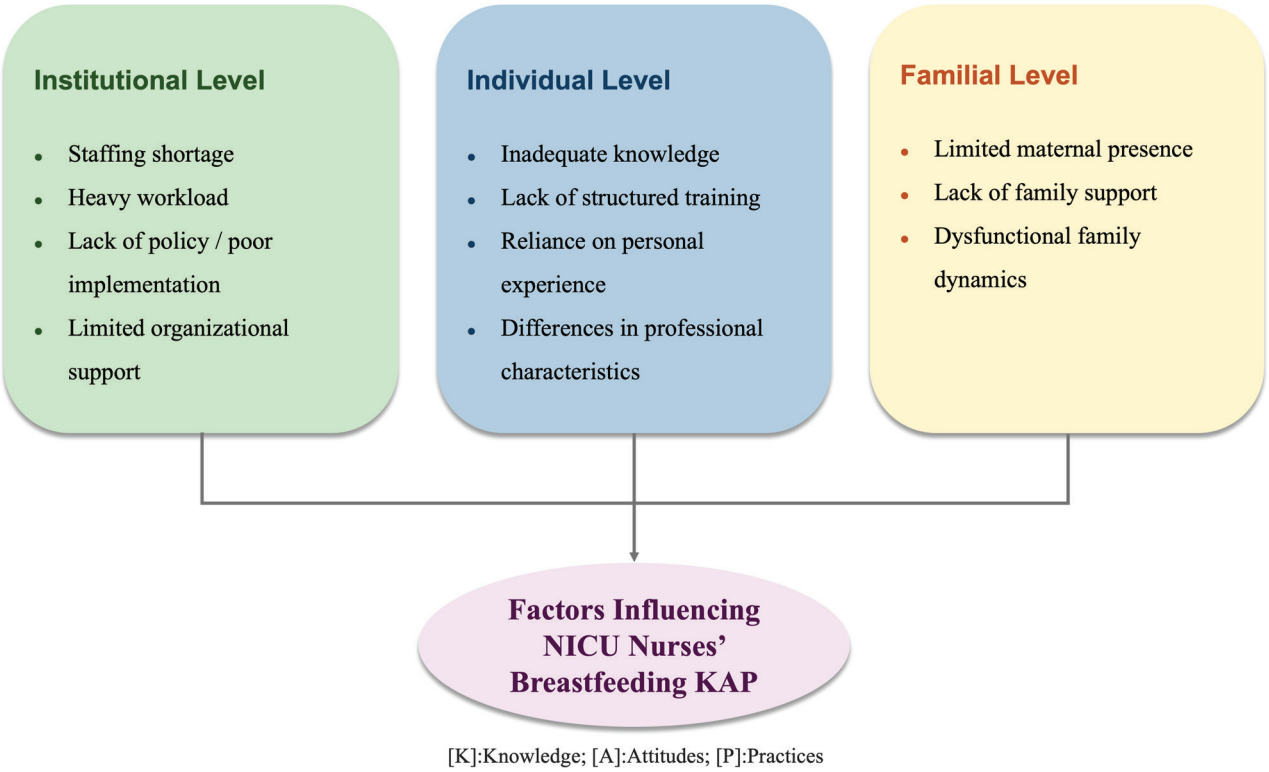


Fig. 2 Factors Influencing NICU Nurses' Breastfeeding KAP

clinical roles, this review emphasizes nurses as the key bedside providers whose competencies directly influence breastfeeding outcomes. We found that although nurses generally hold favorable attitudes, their knowledge base has significant gaps, and their practices are inconsistent. This knowledge-attitude-practice gap is compounded by a range of multi-level influencing factors and a notable lack of standardized assessment tools. These findings underscore the urgent need for comprehensive, multi-faceted strategies to empower NICU nurses, thereby improving care quality and neonatal health outcomes.

First, a central finding of this review is the paradoxical relationship between nurses' attitudes and their knowledge. In general, NICU nurses widely recognize the health benefits of breastfeeding for neonates, especially those at high risk or born prematurely, a finding consistent with prior studies.[41–43] This positive disposition, however, is often built on a fragile foundation of incomplete knowledge. This review revealed significant knowledge deficits among nurses, particularly in breastfeeding physiology and individualized clinical management, including feeding plans, breastfeeding duration, and contraindication identification. Some nurses made incorrect judgments when recommending alternative feeding methods, potentially compromising the continuity and scientific basis of breastfeeding support. These knowledge disparities may be attributed to cross-country differences in basic education, in-service training, and clinical experience.[36,39,44] For instance, an Australian study reported that medical staff often face limited opportunities to acquire structured breastfeeding knowledge during their professional education.[45] Our review reinforces this, showing that some NICU nurses demonstrated an inaccurate understanding of breastfeeding contraindications,[29,39] despite the WHO's stance that absolute contraindications are rare.[46] This reality highlights the critical importance of providing NICU nurses with systematic and continuously updated training in breastfeeding knowledge to build a robust knowledge base that can truly support their positive attitudes.

Furthermore, the pronounced attitude-practice gap challenges conventional assumptions about healthcare behavior change. As this review indicates, positive attitudes have not been reliably translated into consistent, standardized clinical practices. This discordance suggests that the traditional linear KAP model may not fully explain nursing behavior in complex NICU settings. Our findings indicate that positive attitudes, while necessary, are insufficient when confronted with systemic barriers such as workload pressures, inadequate resources, and a lack of standardized protocols.[25] The predominance of experience-based over evidence-based practice[36] further highlights the disconnect between theoretical support and practical implementation. This gap is particularly problematic given that NICU mothers urgently require both emotional and practical breastfeeding support.[47,48] Consequently, nurses' inability to provide consistent, skilled support may significantly undermine maternal confidence and breastfeeding continuation.

The multi-level influences identified in this review necessitate comprehensive, systems-based interventions rather than isolated educational approaches. At the individual level, the positive correlation between personal breastfeeding experience and professional competence[39,49] suggests that experiential learning plays a crucial role, yet this should complement rather than replace formal education. Professional characteristics including gender, title, and years of experience also influenced practice patterns,[39,50] potentially reflecting differential exposure to training opportunities and clinical scenarios. These findings have significant implications for nursing education curricula, which should incorporate both theoretical breastfeeding knowledge and hands-on clinical skills training specific to NICU environments. At the institutional level, the identified barriers — under-staffing, policy gaps, and limited

organizational suppor[39,51,52] — create structural impediments that individual motivation cannot overcome. These findings align with previous research emphasizing institutional preparedness as fundamental to successful breastfeeding support programs.

Evidence from the Neo-Baby Friendly Hospital Initiative (Neo-BFHI) demonstrates that structured, hospital-wide implementation of breastfeeding-supportive policies and training can effectively address these barriers.[53,54] Following Neo-BFHI implementation, healthcare professionals across all NICU staff groups showed significant improvements in breastfeeding-related attitudes, and hospitals achieved notable progress in breastfeeding support practices.[55] Building on these findings, institutional policies must shift from merely encouraging breastfeeding to actively promoting it. First, clear, evidence-based NICU-specific breastfeeding protocols should be established to reduce reliance on experience-based practice. Second, supportive resources should be provided, including the integration of IBCLC specialists and optimized nurse-to-patient ratios to allow dedicated breastfeeding support time. Third, institutional policies should mandate regular competency assessments and continuing education requirements for NICU nurses. Furthermore, consideration should be given to incorporating breastfeeding support into recognized nursing quality indicators to enhance its institutional prioritization. At the family level, limited parental presence and support[56,57] represent missed opportunities for collaborative care, particularly given evidence that paternal involvement enhances breastfeeding continuity. The failure to achieve true family-integrated care contradicts contemporary family-centered care principles[58] and may undermine post-discharge breastfeeding success.

Finally, a critical finding is the methodological heterogeneity in KAP assessment, which has profound implications for evidence synthesis and quality improvement. The absence of validated, NICU-specific assessment tools not only limits research comparability but also impedes the development and evaluation of targeted interventions. While some studies employed validated general instruments like IIFAS,[32,37] these tools may not capture the unique competencies required in NICU settings. This measurement gap creates a vicious cycle: without standardized assessment, it is impossible to accurately identify competency gaps, design appropriate interventions, or evaluate their effectiveness. The development of psychometrically sound, culturally adaptable, NICU-specific KAP instruments should therefore be a clear research priority to break this cycle and advance evidence-based practice.

Limitations

While this review provides a comprehensive overview, several limitations should be acknowledged. First, the number of included studies was limited and predominantly qualitative, restricting causal inference. Second, there was high heterogeneity in study methods, compounded by a general lack of standardized measurement tools with proven reliability and validity. In particular, the absence of NICU-specific, psychometrically tested KAP instruments, which weakens the comparability and robustness of the synthesized results. Third, potential publication bias cannot be ruled out, which may have influenced the synthesized results. Finally, the geographical distribution of studies was uneven, with a predominance of research from China and the United States, which may affect the generalizability of findings. Therefore, future research should employ rigorous designs including multicenter studies with validated instruments and mixed-methods approaches to strengthen the evidence base.

Conclusions

This scoping review reveals a critical paradox in NICU breastfeeding support: while nurses' attitudes are over-whelmingly positive, their clinical knowledge and practices remain inconsistent and suboptimal. The identified knowledge-attitude-practice gap is perpetuated by a triad of challenges: foundational knowledge deficits, systemic institutional barriers, and a critical lack of validated assessment tools. These factors collectively undermine the translation of pro-breastfeeding policies into consistent, high-quality clinical care. Bridging this gap requires a multi-pronged strategy. Priority must be given to implementing competency-based training that moves beyond theory to practical skills, establishing supportive institutional policies that alleviate workload pressures, and fostering true family-integrated care. Crucially, future research must prioritize the development and validation of standardized, NICU-specific KAP instruments. Such tools are essential for diagnosing competency gaps, evaluating interventions, and elevating breastfeeding support standards for vulnerable neonates. Strengthening NICU nurses' breastfeeding competencies is not merely a clinical quality imperative but a critical pathway to achieving WHO/UNICEF's global target of 50% exclusive breastfeeding rates. As frontline providers who translate policy into practice, empowering nurses is pivotal to realizing these international health goals and improving outcomes for the world's most vulnerable neonates.

Abbreviations

IBCLC	International Board Certified Lactation Consultant
KAP	Knowledge, Attitudes, and Practices
Neo-BFHI	Neo–Baby-Friendly Hospital Initiative
NICU	Neonatal Intensive Care Unit
UNICEF	United Nations Children's Fund
WHO	World Health Organization

Supplementary Information

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Author contributions

HMP drafted the manuscript and contributed to its revision. XL, XMG, YXL, and XH were responsible for data acquisition and analysis. LNZ and CML contributed to data interpretation. YL and YLH provided conceptual guidance, supervised the study, and substantially revised the manuscript. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Human ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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An Obstetrician's Response to the 'Free Birth' Movement

BM Petrikovsky, MD, PhD and D Alyeshmerni

Pregnancy is indisputably regarded as a natural state. Like puberty, menarche, and menopause, pregnancy is experienced by most women during their lifetime. The fact that pregnancy is a natural healthy phenomenon is the best justification for home birth: healthy people don't go to the hospital. The outcomes of natural birthing processes in humans and animals are discussed below.

In May of 2026, Science Times' D Mackeen put together an article on the free birth movement.[1] A 35-year-old pregnant woman intended on "free birth" without any medical or otherwise qualified assistance: "On social media, free births are depicted as idyllic: string lights, birthing pools, family present, childbirth returned to the hands of women… The [free birth] society has 132,000 followers on Instagram, its YouTube channel has received more than 27 million views. A podcast, according to the society's website, has had five million downloads." None of the most successful medical practices can claim such a following! "An advertisement for a free birth course says, 'You are powerful- birth like it,' 'From beginning to end, obstetrics is the story of rape, abuse, harm, violation…'"

Now, let's look at the facts, which is an appropriate way to respond to a science section publication: Wild forest macaques lose 70-80% of the offspring during their first year of life, mostly in labor. Big apes in their natural habitat do better, with 84% of their offspring surviving the first year.[2] In zoos or with veterinary care, the risk is much lower. Inbreeding can raise some risks, but vet attendance helps manage complications that would be fatal in the wild.[3] Reviewing scarce publications on the use of forceps, I came across an article on forceps-assisted delivery of a gorilla: a team including zoo veterinarians and obstetricians used forceps to deliver a critically endangered 18-year-old Western lowland gorilla at the Philadelphia Zoo after the mother experienced a prolonged labor. The successful delivery of a healthy newborn highlighted the potential for applying human medical principles to reduce mortality rates in animals.[4] The most common problem for cows is their inability to complete the second stage of labor. Straining of varying intensity is seen, and the fetal feet or nose (in cases of anterior presentation) may be visible at the vulva. In a normal birth the calf is usually delivered within 2 hours. In cases of fetopelvic disproportion this does not occur. If the case is untreated the calf will die, with serious consequences for the cow.[5]

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Now let's go to humans: the best example of unattended or poorly attended birth is Afghanistan. Before 2001, when the country was under Taliban rule and obstetric care was nonexistent, maternal mortality was extremely high — 1,600 deaths per 100,000 live births. After the fall of the Taliban regime, with massive international support and training of midwives, it dropped sharply to around 620-638 by 2020-2021. Since the Taliban took over again in 2021 and severely restricted women's healthcare access, female education, and female health workers, experts expected maternal mortality to rise again. The leading cause of maternal death in these settings is postpartum hemorrhage, followed by infection, high blood pressure complications, and obstructed labor. Most of these problems are treatable in the hospital. Infant mortality in these areas is also very high. In Afghanistan, there are about 43 to 50 deaths per 1,000 live births. The most common cause of fetal demise is postterm pregnancy since lack of prenatal care and early ultrasound does not allow for the determination of a due date.[6,7]

In summary, so-called free birth is a dangerous and potentially life-threatening undertaking with substantial risk of infant and maternal morbidity and mortality. Doctors face similar situations when cancer patients refuse treatment in favor of vitamins or Jehovah's Witnesses refuse blood transfusions despite life-threatening situations. However, pregnancy is a different matter because expectant mothers risk not only their own life and well-being, but those of their unborn baby. While respecting patient autonomy is standard, legally, a physician may intervene if the fetus is viable, at risk of immediate harm, and the procedure's benefits outweigh the risks of the mother. Doctors may perform a cesarean section against a mother's refusal in extreme, life-threatening emergencies, often involving a court order to override consent. While free birth is not illegal, the state has a "compelling interest" in a viable fetus, and some legal analyses suggest that in extreme and rare cases, a parent's duty to provide medical care could lead to legal action if a child is harmed or dies.

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Advancing Neonatal Respiratory Care with AI-Driven Clinical Intelligence: The Emerging Value of Etiometry in the NICU

Evan Butler, Chief Operating Officer and Co-Founder, Etiometry

Introduction

Respiratory instability remains one of the most prevalent and complex challenges in neonatal intensive care, particularly among preterm infants and those requiring mechanical ventilation. Despite continuous monitoring technologies such as pulse oximetry and ventilator-derived parameters, clinicians often lack integrated tools to synthesize these data streams and support review of oxygenation trends within hospital-defined workflows. In parallel, key aspects of respiratory management, particularly carbon dioxide monitoring, still rely on intermittent measurements and indirect indicators to guide clinical decision-making. These limitations can contribute to variability in care and increase the risk of complications, including bronchopulmonary dysplasia (BPD), retinopathy of prematurity (ROP), prolonged mechanical ventilation and repeated invasive procedures.

Recent advances in clinical intelligence platforms have introduced the potential to transform continuously collected physiologic data into actionable insights. Etiometry's Clinical Intelligence Platform integrates high-frequency bedside monitoring data with advanced analytics and AI-based risk algorithms to support real-time clinical decision-making. A growing body of clinical evidence suggests that this approach may enhance the precision, safety and efficiency of neonatal respiratory care.

This article reviews recent studies and clinical data highlighting the emerging value of Etiometry in neonatal care, with a focus on oxygen management, ventilation strategies and non-invasive tracking of hypercapnia.

Optimizing Oxygen Therapy and Clinical Outcomes

Maintaining oxygen saturation within a defined target range is a cornerstone of neonatal care, yet achieving consistent compliance remains difficult. Both hyperoxia and hypoxia are associated with adverse outcomes. Hyperoxia has been linked to the development of ROP, while fluctuations in oxygenation contribute to the pathogenesis of BPD.[1,2]

A retrospective study utilizing Etiometry-derived data evaluated oxygen saturation (SpO_2) compliance in 879 preterm infants receiving oxygen therapy. The study found that mean compliance with target SpO_2 ranges was only 44.7%, highlighting the challenge of maintaining optimal oxygenation in routine practice. Hyperoxic events occurred more frequently than hypoxic events, and the number of clinically intervenable events increased with decreasing gestational age. Importantly, lower compliance with target ranges was associated with a higher incidence of both ROP and BPD, with odds ratios demonstrating significantly increased risk among infants with poor compliance.[3]

These findings underscore the importance of continuous, high-resolution monitoring of oxygenation beyond simple threshold alarms. By capturing SpO_2 and FiO_2 data continuously and identifying periods of deviation from target ranges, the Etiometry platform enables clinicians to recognize actionable patterns and intervene more effectively. This capability represents a shift toward proactive oxygen management, with potential implications for reducing long-term morbidity.

Adjunctive CO_2 Risk Information to Support Clinician Review

Continuous assessment of carbon dioxide levels remains a significant limitation in neonatal care. While pulse oximetry provides reliable oxygenation data, no equivalent non-invasive continuous standard exists for pCO_2. Blood gas sampling, therefore, remains the primary method for assessment but is invasive, intermittent, and resource-intensive.

The IVCO2 Index provides adjunctive information about the increasing risk of inadequate carbon dioxide ventilation using physiologic and laboratory inputs, supporting clinician review alongside primary clinical data. A recent retrospective cohort study in a Level IV NICU evaluated outcomes before and after implementation of this algorithm in 614 infants.

Following implementation, there was a statistically significant reduction in blood gas measurements per day (0.44 vs 0.40 per day, p=0.02), despite the post-implementation cohort demonstrating higher acuity, including increased ventilator days and higher respiratory severity scores. Importantly, the detection of hypercapnia (pCO_2 >60 mmHg) remained unchanged.[4]

Enhancing Ventilation Management and Extubation Decisions

Mechanical ventilation is essential in the management of neonatal respiratory failure but is associated with risks including ventilator-induced lung injury and prolonged hospitalization. Determining the appropriate timing for extubation is a critical and complex decision, requiring careful assessment of respiratory readiness and risk of failure.

Author information found at the end of this article.

Recent studies have explored the role of Etiometry in optimizing ventilation strategies. A study conducted at Children's of Alabama and the University of Alabama at Birmingham demonstrated an association between the use of Etiometry's Clinical Intelligence Platform and a 30% reduction in the duration of mechanical ventilation in pediatric and neonatal patients undergoing automated spontaneous breathing trials.[5]

In addition, a multi-center study from Boston Children's Hospital evaluated Etiometry's risk analytics algorithms in patients undergoing congenital cardiac surgery. The study evaluated relationships between risk analytics outputs and extubation-failure outcomes, providing additional information for clinician review.[6]

Together, these findings highlight how time-aligned physiologic data may support clinician review of respiratory trajectory during extubation-readiness workflows and their evaluations of reducing both premature extubation and unnecessary prolongation of mechanical ventilation. The platform provides adjunctive information to help clinicians evaluate SBT/ERT performance alongside other clinical data.

Advancing CO_2 Risk Review in Neonatal Care

Routinely collected physiologic data can provide useful context for reviewing carbon dioxide ventilation risk in neonatal care. A recent study published in the Journal of Perinatology[7] evaluated the use of Etiometry's platform to support review of hypercapnia risk in neonates, showing how physiologic data may help clinicians assess respiratory status alongside other clinical information.

This capability has been further supported by regulatory advancements, including US Food and Drug Administration clearance of an adjunctive index that indicates an increasing risk of inadequate carbon dioxide ventilation in neonatal patients. The index is intended to bring the patient to the clinician's attention for review and should be interpreted alongside other clinical data when clinically appropriate.

The integration of adjunctive respiratory-risk information into NICU workflows represents an important step toward broader adoption of AI-enabled clinical decision support. These tools may help care teams review patient status, support timely clinical awareness, and evaluate respiratory trends within existing hospital workflows.

Discussion

The growing body of evidence supporting Etiometry's Clinical Intelligence Platform suggests that it offers meaningful benefits across several domains of neonatal care. First, in oxygen management, the platform supports visualization of adherence to hospital-defined SpO_2 targets for clinician review. Associations between oxygenation patterns and ROP/BPD should be attributed to the literature and were observational.

Second, in ventilation management, the platform supports more precise and individualized decision-making by integrating continuous physiologic data with predictive analytics. This has been associated with reductions in mechanical ventilation duration and improved assessment of extubation readiness.

Third, in carbon dioxide monitoring, the ability to predict hypercapnia non-invasively addresses a longstanding clinical challenge. In one retrospective cohort, blood gas measurement frequency was lower, while hypercapnia detection in blood gases was unchanged. The IVCO2 Index is adjunctive and is not a substitute for blood samples.

Importantly, these benefits have been observed even in higher-acuity populations, suggesting that the platform is robust and adaptable across a range of clinical scenarios. Rather than replacing clinical judgment, Etiometry enhances it by providing a continuous, data-driven perspective that complements traditional monitoring approaches.

Conclusion

Etiometry's Clinical Intelligence Platform represents a significant advancement in the application of artificial intelligence and data analytics in neonatal care. By transforming continuous physiologic data into actionable insights, it enables clinicians to deliver more precise, proactive and patient-centered care.

Current observational evidence suggests that platform-supported workflows may support clinician review of oxygenation trends, ventilation-related data and adjunctive respiratory-risk information. As further studies are conducted and adoption expands, such technologies are likely to play an increasingly central role in the evolution of neonatal intensive care.

Author Bio

Evan Butler is an engineer and entrepreneur who co-founded Etiometry in 2010. Previously, he worked at Boston Children's Hospital in the Pediatric Cardiac Bioengineering Laboratory, designing, building and testing novel surgical robots and tools. Evan was also a NASA GSRP Fellow with Dryden Flight Research Center and created intelligent flight control systems. He received his bachelor's degree in Physics and Aerospace Engineering and his master's degree in Dynamics and Control Engineering from Boston University. Evan has published conference papers, journal articles and a book chapter in the fields of medical predictive analytics, concentric tube robots and tools for minimally invasive beating heart surgery, and intelligent flight control systems. Evan has received multiple awards, including the 2010 IEEE Transactions on Robotics Best Paper Award.

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Rethinking Feeding Tube Placement in the NICU: A Path Toward Safer, More Consistent Nutrition

Dr Doron Besser

In the neonatal intensive care unit (NICU), few interventions are as fundamental to survival and development as nutrition. For preterm infants, consistent enteral feeding supports growth, brain development, immune function and overall recovery. Yet many of the infants who need nutrition the most are unable to feed on their own, relying instead on feeding tubes to deliver essential nutrients during some of the most critical weeks of life.

Despite their routine use, feeding tubes carry risks that are too often underestimated in neonatal care. Preterm infants are not simply smaller patients; they have tiny anatomy, fragile tissues and limited physiological reserves. In that context, even brief feeding interruptions can matter, and inconsistent tube placement can quickly lead to delays, repeat procedures and added pressure on already stretched NICU teams.

Research suggests that up to 59% of feeding tubes are misplaced in neonates,[1] with approximately 6% positioned in the upper esophagus rather than the intended location. In a patient population where every gram of weight gain and every day of development matters, those numbers deserve closer attention.

To understand what is at stake, it is worth looking first at the factors that make feeding tube placement so challenging in the NICU and then at how better visibility, training and standardization can help make feeding safer and more consistent for the smallest patients.

Nutrition is a lifeline for NICU patients

Nutrition is often described as a cornerstone of neonatal care, but for preterm infants, it is more accurately a lifeline. In 2024, the US preterm birth rate was 10.41%, meaning roughly one in 10 infants was born before 37 weeks.[2] For these patients, consistent nutrition is essential to growth, neurodevelopment and recovery.

Unlike adults, preterm infants have very little physiological reserve. Research[3] shows that optimal nutrition for preterm infants is critical to growth and neurodevelopment and may help reduce comorbidities of prematurity, including sepsis, bronchopulmonary dysplasia and possibly retinopathy of prematurity. Delays in feeding that might be tolerated in other patient populations can become clinically significant in the NICU, affecting growth trajectories and potentially extending recovery.

Yet maintaining that consistency can be challenging. Feeding tubes may be displaced, removed or replaced during a single NICU stay. Their position can shift as infants move, grow or undergo routine care, and uncertainty around placement can delay feeding altogether.

The result is that a process designed to support growth can become a source of interruption at the exact stage when continuity matters most.

Repeated placements create clinical and operational challenges

The challenges of feeding tube placement in preterm infants extend well beyond the initial insertion.

Neonatal anatomy presents unique obstacles. Nasal passages are exceptionally small, tissues are delicate and the margin for error is minimal. Even in highly experienced hands, placement can be technically demanding.

Repeated insertions are common. Tubes may need to be replaced because of displacement, irritation, infection concerns or uncertainty regarding position. Each replacement introduces additional handling and procedural burden for infants who are already among the most vulnerable patients in the hospital.

For clinicians, these challenges create a workflow burden that is often overlooked. Feeding tube placement may be considered routine, but it requires careful attention, repeated verification and ongoing monitoring. Variability between operators, institutions and protocols can further complicate consistency.

NICU teams work under considerable pressure to deliver safe, timely care. Any process that requires repeated attempts, additional verification or delayed feeding increases demands on staff while potentially affecting patient outcomes.

Verification comes with its own risks

Confirming tube position is essential, but radiographic imaging, the most common verification method, carries its own risk: preterm infants are particularly vulnerable to radiation exposure.[4] Their cells have a high rate of mitotic division, and their small body size means more organs may fall within the radiation field.

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That risk is cumulative. A review of NICU X-ray exposure notes that the potential for radiation-induced harm later in life increases with each image, especially among younger premature infants. In one NICU radiation exposure study, 7% of extremely low birth weight[5] neonates received more than 1 mSv of radiation exposure.

For clinicians, this creates a difficult balance: tube position must be confirmed, but unnecessary imaging should be minimized whenever possible. Repeated X-rays can also delay the start of feeding, creating another barrier to consistent nutrition delivery.

The issue, then, is not simply whether a feeding tube is eventually positioned correctly. It is how quickly, confidently and consistently clinicians can establish that position without adding risk or interruption. As neonatal care continues to advance, feeding tube verification deserves the same scrutiny hospitals have already applied to procedural accuracy in surgery, vascular access and other high-risk areas.

Looking ahead: Improving visibility and consistency

The encouraging news is that the field is beginning to move beyond blind placement. Newer approaches, including electromagnetic navigation and sensor-based guidance systems, are designed to give clinicians real-time visual feedback as the tube advances. Instead of placing the tube first and confirming position after the fact, these technologies can help show the tube's path during insertion, alert clinicians when it may be moving in the wrong direction and support more accurate placement at the bedside.

For the NICU, however, technology is only useful if it fits the realities of neonatal care. Any new methodology must be intuitive, low-risk and easy to teach across teams. It cannot add unnecessary complexity to an already demanding workflow. To be adopted at scale, it must help nurses, dietitians and physicians standardize placement without slowing them down.

That is where the opportunity lies: combining real-time visibility with practical education and repeatable protocols. The goal is not technology for technology's sake. It is fewer repeat insertions, less uncertainty, reduced reliance on unnecessary imaging and more consistent delivery of nutrition. For neonatal caregivers, the measure of success is simple: helping vulnerable infants receive safe, reliable feeding with as few interruptions as possible.

From Placement to Outcomes

Neonatal medicine has made extraordinary progress. More preterm infants are surviving, and NICU teams are managing increasingly complex patients with greater precision than ever before. The next frontier is not only survival, but consistency: making sure every element of care that supports growth and development is as reliable as possible.

Feeding tube placement belongs in that conversation. It may not attract the same attention as ventilation, infection prevention or advanced monitoring, but its impact is difficult to overstate. When feeding is interrupted by misplacement, repeated insertions or uncertainty around verification, the result is not just a procedural delay. It is a disruption to one of the most basic drivers of neonatal recovery.

Solving this will require more than good technique. It will require better visibility during placement, easier-to-teach methods, standardized protocols and technologies designed around the realities of NICU care. The goal should be simple: fewer insertions, less radiation exposure, faster confirmation and more consistent nutrition.

For the smallest patients, consistency is not a marginal improvement. It is part of the care itself.

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Living Healthcare

Airway Patency and Obstruction Risk for Speaking Valve Use in Pediatric Patients

Gabriela Ortiz, BSRT, RCP

Tracheostomy is commonly performed in children with upper airway anomalies, either congenital or, more often, acquired from prolonged intubation, or in those requiring mechanical ventilation due to respiratory failure. Over the past two decades, tracheostomy use in children has increased alongside advances in neonatal and pediatric ICU care. Most pediatric tracheostomy patients today have complex medical needs and depend on long-term technological support. While tracheostomy is common in adult ICUs, it's much less frequent in pediatric ICUs—performed in less than 3% of cases.[1]

Understanding Tracheostomy in Neonates and Infants: A Critical Need for Staff Education

The implications of tracheostomy in neonates and infants are often misunderstood by healthcare staff. This lack of awareness can directly impact the quality of care, as managing a neonatal tracheostomy involves unique challenges that require a coordinated, knowledgeable approach. Comprehensive education and clear communication among all team members are essential to ensure optimal outcomes and provide meaningful support to these vulnerable patients and their families.

Pediatric patients with tracheostomies may have more than one medical concern, including long-term mechanical ventilation. According to Akangire and Manimtim (2023), the survival rate of infants with severe bronchopulmonary dysplasia (BPD) has improved in recent years.[2] Consequently, there has been a rise in the need for long-term mechanical ventilation, making severe BPD the most common indication for tracheostomy in infants. Additional indications for tracheostomy in pediatric patients include congenital airway anomalies, neurological impairments, complex cardiac conditions, and genetic disorders—each with varying implications for short- and long-term survival. Overall, tracheostomies in this population are typically performed to bypass upper airway obstruction, to provide direct access for pulmonary hygiene, and to address respiratory compromise.



More than half of pediatric tracheostomies are placed in infants under 1 year of age. Decannulation rates in this group are low (28%–51%), and when decannulated, the tracheostomy typically remains in place for around 2 years.[1]

Why Small Airways Matter in Children

In infants and young children, the airway is much smaller and softer than in adults. This difference makes it easier for it to become blocked or narrowed. Even a little swelling, extra mucus, or a slight blockage can make it much harder for a child to breathe. When the airway gets smaller, it increases resistance and causes it to become much harder for air to pass through.

There's a scientific rule called Poiseuille's Law, which explains that a small change in airway size causes a big change in how hard it is to breathe. For example, if the airway gets just 1 millimeter smaller, it can almost double the effort needed to breathe. That's why it's so important to keep children's airways as clear and open as possible, especially if they have a tracheostomy or other breathing challenges.

Airway patency is essential for the safe and effective use of the Passy Muir® Valve (PMV). Since the PMV requires the patient to exhale through the upper airway, any obstruction or anatomical limitation can lead to complications.

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Airway Obstructions

Accurately identifying and evaluating the presence and degree of obstruction is a critical step before initiating PMV use.

Common Causes of Obstruction

- **Tracheomalacia**
  - Softening of the airway walls, causing dynamic collapse, especially during exhalation.
- **Stenosis**
  - Narrowing of the airway (e.g., subglottic stenosis is common in children).
- **Granulomas or Edema**
  - Can form near the stoma or inside the trachea.
  - Post-trach changes, infection, or trauma can lead to swelling and obstruction.
- **Congenital or Anatomical Differences**
  - Some patients have airway malformations that alter structure or airflow.

Tracheostomy Tube Considerations

The trach tube itself can significantly impact airway patency and PMV success.

- **Tube Size**
  - Must allow enough airflow around the tube for exhalation through the upper airway.
  - Downsizing may be considered in older pediatric patients.
- **Tube Position**
  - Should remain midline and straight in the trachea.
  - Displacement or angling (from movement or poor support) can block airflow.
- **Ventilator Circuit Support**
  - Heavy tubing should be supported to prevent pulling or misalignment of the trach tube, which can lead to obstruction.
- **Cuff Management**
  - **Cuffed tracheostomies must have the cuffs fully deflated** prior to and during PMV use.
  - A partially inflated cuff can trap air, cause distress, and prevent voicing and other functions.
- **Foam Cuff Tubes – Contraindicated**
  - These cuffs may re-expand on their own, blocking airflow.
  - Unsafe for use with speaking valves (PMV).

Patient Factors & Positioning

- **Growth & Development** (especially in neonates and infants)
  - As children grow, the trachea enlarges, improving airflow and secretion clearance—often increasing PMV tolerance.
- **Patient Positioning**
  - Upright and head at midline, with positions maintained to support an open airway.
- **Anatomical growth changes**
  - Routine re-evaluation is important as airway structure changes over time.

Secretions and Humidification

- Thick, tenacious secretions can obstruct the airway, particularly during exhalation.
- Adequate humidification helps keep secretions thin.
- Suctioning may be necessary before or during PMV use.

Red Flags Requiring Immediate Evaluation

- Inability to exhale or vocalize during PMV trials.
- Respiratory distress or increased WOB.
- Absence of airflow heard at the nose or mouth.
- Sudden change in ventilator pressures or volumes.

Key Takeaways

A patent upper airway is non-negotiable for PMV use. Ongoing assessment—including anatomy, tube factors, secretions, and positioning—ensures safety and supports successful PMV trials.

Assessing Candidacy for PMV Use

The clinical team must first confirm that the patient is a good candidate for Valve placement.

1. Level of Alertness & Interaction
- Tracks movement or attempts to communicate?
- Awake and alert patients are more likely to tolerate the Valve.

2. Medical Stability
- Stable vital signs.
- Consistent oxygen needs.
- No acute medical issues.

3. Cuff Deflation Tolerance
- **Cuff must be fully deflated.**
- Must exhale completely through the upper airway.

4. Secretion Management
- Manageable secretions (thin, secretions that can be suctioned or effectively coughed out) are acceptable.
- Thick/copious secretions may impair patency—treat first, then reassess.
  → Use heated humidity, cool aerosol, or meds if needed.

5. Airway Patency
- Must have a patent upper airway.
- Full exhalation through the upper airway is essential.
  → If not, Speaking Valve use is contraindicated.

Airway Patency Assessment

Before applying patient selection criteria for speaking Valve use, begin with a comprehensive chart review. For patients using a PMV or on mechanical ventilation, upper airway patency is critical. The PMV redirects airflow through the upper airway during exhalation, and any resistance can significantly impact comfort and breathing effectiveness. Using manometry to measure the transtracheal pressure during exhalation can help determine if airflow is being adequately redirected through the upper airway or if resistance is too high. Key information to gather includes:

- Diagnosis and medical status
- Relevant medical history
- Tracheostomy details (tube size, type, and cuff status)

This foundational assessment helps determine whether the patient is an appropriate candidate for PMV placement and guides safe and effective clinical decision-making.

How to Assess Airway Patency

1. Digital Occlusion Trial
- **If the patient can follow commands:**
  Ask them to inhale, then briefly occlude the trach with a gloved finger during exhalation. Ask them to say "AHH" or cough.
- **If the patient cannot follow commands:**
  Observe their breathing and gently occlude the trach for a few seconds after inspiration, watching for the effectiveness of exhalation or signs of distress.

2. Transtracheal Pressure (TTP) – Pediatric Focus
- Transtracheal pressure (TTP) provides an objective method for assessing upper airway patency, helping identify obstructions that may otherwise go undetected. For children, TTP measurement is often used to assess airway patency due to smaller airway size and higher resistance. Conducting the

assessment during quiet breathing or when the child is calm and cooperative is important for accurate reading.
- **How it works**
  A manometer measures pressure at the end of exhalation while the tracheostomy tube is occluded.
- **Interpreting results**
  - **TTP ≤10 cmH_2O** = Likely patent airway (minimal resistance) → May be a good candidate for Valve placement.
  - **TTP > 10 cmH_2O** = Possible obstruction or narrowing → May need further evaluation.

This measurement is considered a reliable predictor of little to zero obstructions in the airway. A lower TTP generally indicates a more patent airway, which is associated with a higher likelihood of success when using the PMV. A study by Brooks et al. (2019) highlighted that a TTP between 0 and 14 cmH_2O was highly predictive of PMV success in pediatric patients with complex medical conditions.[3] Transtracheal pressures and guidelines may vary; clinicians should adhere to the protocols established by their facility. TTP measurements can be conducted either on spontaneous breathers or while still on the ventilator. Proper technique is important for accurate measurements.[4]

In addition to TTP measurements, the study identified other factors that could influence the success of PMV use:
- **Higher Weight (correlated with age)**: the larger and older the patient, the higher the chance of successful PMV use.
- **Tracheostomy Tube Size**: A properly sized tracheostomy tube increases the likelihood of a patent airway.

3. Mechanical Ventilator Parameters
Assessing airway patency in a patient on mechanical ventilation is critical to ensure effective ventilation and oxygenation.
- **Clinical Observations**
  - Symmetrical chest rise may suggest a patent airway.
  - Auscultate both lungs to ensure bilateral breath sounds.
- **Breath sounds**
  - Diminished or absent sounds may indicate obstruction (e.g., mucus plug, kinked tube).
- **Work of Breathing (WOB)**
  - Increased effort could signal partial obstruction or tube problems.

Ventilator Parameters and Alarms

1. High-Pressure Alarms
May indicate increased resistance due to a kinked trach tube, secretions, or bronchospasm.

2. Low-Pressure or Low Tidal Volume Alarms
May suggest disconnection, cuff leak, or decannulation.

3. Peak Inspiratory Pressure (PIP)
- A rising PIP can point to airway narrowing or obstruction.
- Compare PIP to plateau pressure:
  - § ↑ PIP and ↑ plateau = compliance issue

4. Suctioning Response
- If you can't pass a suction catheter, it may be due to a kink or blockage.
- Retrieving thick secretions may suggest a partial obstruction.

Airway Patency Assessment With Cuff Deflation While on the Ventilator
- **Volume-Controlled Ventilation (VCV):**
  - A 40–50% drop in exhaled tidal volume with cuff deflation indicates a sufficient air leak, suggesting a patent upper airway.
  - You may also see a decrease in PIP due to reduced resistance.
- **Pressure-Controlled Ventilation (PCV):**
  - A drop in exhaled volume should be expected with cuff deflation.
  - However, PIP remains relatively stable, so it's less useful in assessing patency.

Key Takeaways
Changes in ventilator readings, suctioning response, and cuff deflation are essential for assessing airway patency, especially when determining readiness for a Passy-Muir Valve. Research by Brooks et al. (2019) highlighted these factors as part of a comprehensive approach to predict PMV success.[3]

During Assessment and Valve Use, Watch for these Red Flags
- Increased WOB.
- Stridor, nasal flaring, or chest retractions.
- SpO_2 (oxygen saturation) drops.
- HR increases/decreases.

If a "red flag" occurs, be sure to reassess the patient and follow appropriate interventions. Interventions would include consideration for Valve removal, adjustments to oxygen levels, nasal cannula, or other options that address the patient's needs.

Recognizing Obstruction: Not Always Obvious
Signs of upper airway obstructions can be subtle in younger children. Stridor, increased WOB, paradoxical chest movement, and changes in vocal quality or crying are important indicators. However, clinicians must also be alert to less overt signs, such as increased inspiratory time or effort, the use of accessory muscles, or poor tolerance of vocalizing or feeding.

In children with tracheostomies, obstruction may occur above or around the tracheostomy site. It may be partial, dynamic, or fixed. Tools such as fiberoptic endoscopy and TTP can help quantify the presence and degree of obstruction, particularly when evaluating candidacy for PMV or decannulation.

Developmental Considerations
As children grow, the shape and tone of their airway changes. Neonates are obligate nasal breathers; therefore, nasal obstruction can be especially problematic. Infants and toddlers may not be able to describe discomfort or distress, so clinicians must rely on vigilant observation and caregiver input. An interdisciplinary approach that includes speech-language pathologists, pulmonologists, otolaryngologists, and respiratory therapists is vital.

Conclusion
Pediatric upper airways are smaller and more reactive, meaning that even minor swelling or the presence of thick secretions can lead to a significant increase in airway resistance. In these cases, airway compromise may not be immediately visible through observation alone.

Speaking Valve placement in pediatric patients, particularly neonates, is a delicate yet highly impactful intervention. It enables verbal communication, supports secretion management, and can significantly improve quality of life. Success depends on a thoughtful, individualized approach that accounts for the unique anatomical and developmental needs of children. Above all, clinicians must prioritize airway safety, patient comfort, and interdisciplinary collaboration throughout the process.

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Newborn Endotracheal Tube Depth Determination: Lip versus the Gum. A Narrative Review

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Abstract

Reliable endotracheal tube (ETT) placement and depth determination remain fundamental challenges in neonatal airway management, with malposition leading to unplanned extubation, airway trauma, and increased morbidity. Neonatal Resuscitation Program guidelines advocate measuring ETT depth from the upper lip using the 7-8-9 rule, yet this approach faces significant limitations. Lip-based measurements introduce variability through lip mobility, edema, and tape displacement; complications that disproportionately affect extremely low birth weight infants.

Recent evidence suggests that the upper gum (alveolar ridge) may offer distinct advantages as an anatomical landmark for ETT depth measurement. Preliminary studies indicate that gum-based formulas, particularly the 5.2 cm + weight (kg) calculation, show promise in extremely low birth weight populations, with early findings suggesting reduced mainstem intubation rates and decreased need for tube repositioning. Point-of-care ultrasound has validated gum-based measurements as reliable alternatives to radiographic confirmation. The gum landmark presents compelling advantages as a fixed, stable anatomical reference point. However, current evidence remains limited in scope and methodological consistency. Definitive validation requires larger, prospective trials directly comparing lip and gum methodologies to establish evidence-based clinical guidelines. Until robust comparative data emerge, clinicians must maintain rigorous radiographic confirmation practices and implement structured airway management protocols to minimize unplanned extubation and optimize neonatal outcomes.

Introduction

Securing endotracheal tubes (ETTs) in neonates is a critical component of neonatal intensive care, as improper fixation can lead to unplanned extubation, airway trauma, and other serious complications. Equally important is the accurate determination of ETT depth, which is essential to ensure effective ventilation and minimize the risk of significant injury. Despite the clinical importance of accurate depth assessment, there remains noteworthy variability in the landmark used as the reference point, specifically, whether ETT depth is measured to the lip or the gum.

Most research in this area has focused on optimizing tube positioning through standardized protocols, gestational age or weight-based guidelines, and the use of specialized securing devices, rather than directly comparing anatomical reference points for depth measurement. There remain two main landmarks for measuring oral ETT insertion depth: the upper gum (alveolar ridge) and the upper lip. Both methods are currently used in neonatal intensive care units to determine ETT insertion depth.

As a result, consensus favoring either lip or gum landmark determination for oral ETTs in newborns is not fully established. This review synthesizes the available literature on the anatomical landmark used for ETT depth determination in neonates, emphasizing clinical outcomes such as tube stability, unplanned extubation rates, and complications, while highlighting the persistent gap in comparative evidence for lip versus gum determination. This review examines unplanned extubation incidence, risk factors, and quality improvement strategies while exploring emerging comparative data between lip and gum reference points.

Unplanned Extubation

Clinical Consequences

Certain populations are at markedly increased risks, with premature neonates born at less than 28 weeks gestational age or with birth weights less than 1500 grams demonstrating the highest vulnerability. Studies have documented UE rates as high as 16.1% of intubated neonates or 22–28% in premature infants,[1] are higher than rates reported in the pediatric population,[2] and is the

Table 1. ETT insertion depth based on weight and gestational age

Birth Weight (kg)	Gestational Age (wks)	ETT length at lips (cm)
0.5—0.6	23—24	5.5
0.7—0.8	25—26	6.0
0.9—1.0	27—29	6.5
1.1—1.4	30—32	7.0
1.5—1.8	33—34	7.5
1.9—2.4	35—37	8.0
2.5—3.1	38—40	8.5
3.2—4.2	41—43	9.0

Adapted from reference 20

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4th most common adverse event in North American NICUs.[3(p472)] Specific challenges of securing neonatal endotracheal tubes are associated with the population's smaller face, immature skin, prolonged intubation times, type of artificial airway (uncuffed endotracheal tubes), and minimal sedation and/or paralytics.[3] The clinical impact of UE extends far beyond the acute event, with UEs being associated with increased morbidity including prolonged mechanical ventilation, airway trauma, ventilator-associated pneumonia, pneumothorax, intraventricular hemorrhage, and extended hospital stays.[2-4] The need for reintubation following UE is substantial, required in more than half of cases (52–71%), with lower gestational age and birth weight significantly increasing the risk of needing reintubation.[2,4]

Immediate adverse events following UE present serious clinical challenges, with desaturation occurring in 33% of cases, bradycardia in 22.8%, and cardiac arrest in 12% of cases.[2] Beyond these acute complications, UEs are linked to poorer cognitive outcomes, although they do not necessarily correspond to deficits in motor or language development.[5]Additional significant adverse outcomes associated with UEs include airway trauma in 10% of cases, increased need for reintubation in 64-76% of cases, and cardiorespiratory instability, clinical sepsis, and prolonged mechanical ventilation.[6-8] Particularly concerning is the increased risk of bronchopulmonary dysplasia (BPD) in infants born at less than 29 weeks who require reintubation after UE.[9] In addition to pulmonary complications, long-term airway morbidities may also occur; for example, one study reported subglottic stenosis in 9% of affected patients.[6]

Unplanned extubation of preterm infants is also associated with additional financial costs. Hatch et al.[10] conducted a retrospective match cohort study in a level IV NICU for patients with similar gestational age and mechanical ventilation length at the time at the time of an UE event. Patients with at least one UE event experienced roughly one additional week of mechanical ventilation, 10-day increase in hospital length of stay, and approximately $50,000 more in total hospital cost compared to matched patients who did not experience an UE event.

Risk Factors

Multiple factors contribute to the occurrence of UE in newborns and infants, spanning patient-specific, procedural, and institutional domains. Patient-specific factors include low birth weight (less than 1500 grams), younger gestational age, agitation, and active infants who self-extubate.[1,11] Procedural factors encompass poor fixation of the endotracheal tube (ETT), excessive secretions, handling during care interventions such as suctioning, weighing, and kangaroo care, as well as unsupported ventilator tubing.[11] Institutional factors include nursing workload, lack of sedation, and inconsistent ETT securement methods.[11,12] Most UEs occur during routine care activities such as tube retaping or suctioning, and occur more frequent in infants with lower gestational age and birth weight.[2,4]

Prevention and Quality Improvement

Recent research findings reveal that incidence rates range from 0.14–5.3 per 100 ventilator days.[4,8,13] Despite these concerning baseline rates, recent multicenter studies demonstrate that focused quality improvement (QI) efforts can achieve substantial reductions, bringing UE rates below 1 per 100 ventilator days, with some centers reporting sustained reductions over several years.[8,13] Several notable quality improvement projects in level IV NICUs exemplifies this potential for improvement. One project initially reported a UE rate of 7.47 per 100 intubated days, which was dramatically reduced to 0.66 per 100 intubated days following targeted interventions.[8] Another project used an interdisciplinary approach to conduct a cause analysis in response to a sudden increase in UE incidence and found standardization of ETT fixation to be an important aspect of reducing UE.[14] The project developed a tape template based on patient size and developed policies for ETT retaping (i.e. patient return to the NICU following surgical procedures in the operating room). These projects did not address the anatomical reference point (lip vs. gum) used for depth measurement. The key to sustaining these improvements lies in consistent adherence to care bundles and regular analysis of each UE event.[13] Successful prevention strategies center on standardizing ETT taping and securement procedures, implementing UE care bundles that include process audits and post-event debriefs, and enhancing staff training and communication through a multidisciplinary approach to event review and prevention.[8,13,15] Additionally, increasing respiratory therapist staffing levels has been associated with lower UE rates.[4]

Table 2. Comparison of Lip to Gum Measurement Location

Feature	Lip (weight + 6 cm)	Gum (weight + 5.2 cm)
Landmark	Upper lip	Upper alveolar ridge (gum)
Mobility	Highly mobile; affected by suctioning, edema, crying	Fixed bony structure
Displacement Risk	0.5–1.0 cm from movement or edema	Minimal due to anatomic stability
Accuracy in ELBW Infants	Overestimates by 0.5–0.6 cm	More accurate; reduces risk of mainstem intubation
Ease of Use	Familiar; guideline-supported	Less familiar; emerging practice
Validation	Widely studied; supported by NRP	Supported by regression analysis and POC-US studies (Zaytseva et al., Gupta)
Recommended for	Term or >750 g infants	Potentially all weights (emerging evidence); especially <750 g

Summary of Recent Data on Unplanned Extubation in the NICU

The latest research underscores that unplanned extubation in the NICU are preventable adverse events with significant clinical consequences. Sustained reductions in UE rates are possible through multidisciplinary quality improvement initiatives, standardization of care, and vigilant monitoring. Continued focus on risk factor mitigation and evidence-based interventions is essential to further enhance neonatal safety and outcomes.[4,8,13]

A growing body of evidence emphasizes the importance of consistent and anatomically reliable reference points for endotracheal tube (ETT) placement in neonates. Morris et al.[16] conducted a quality improvement initiative aimed at reducing UEs in a level IV NICU by focusing on precise ETT tip positioning and standardizing securement practices. Their intervention bundle included regular assessment of ETT tip location via imaging, documentation of insertion depth, and clear designation of the lip as the reference point. The frequency of ETT positioning too high (at or above T1) varied across the study phases. Specifically, during phase 1, 50% of subjects (23 out of 46) had a high ETT. In phase 2,

this was reduced to 23% (11 out of 37). The authors did not discuss the depth reference point, lip or gum. However, when an oral ETT is initially positioned near the upper margin of the trachea, the site of securement can influence its vulnerability to displacement from factors such as crying, suctioning, or changes in soft tissue integrity.[16]

Given that inadequate ETT fixation and securement emerge as primary risk factors for UE, the specific methodology and anatomical reference point used for depth measurement warrant careful examination. A critical component of standardizing ETT securement procedures involves determining the optimal anatomical landmark from which ETT depth is measured and documented. This fundamental decision between using the lip versus the gum as the reference point has significant implications for tube stability, accurate depth measurement, and ultimately, the prevention of unplanned extubation in the neonatal population.

Lip Landmark

The Neonatal Resuscitation Program (NRP) 7th edition recommends using the lip as the landmark for measuring ETT insertion depth in newborns.[17] This is referred to as the "Tip-to-Lip" method, where the depth of the ETT is measured from the tip of the tube to the upper lip. The lip measurement technique, commonly referred to as the "7-8-9 rule or the Tochen rule," provides a guideline for estimating endotracheal tube insertion depth in neonates. This rule estimates ETT depth at the lip as the infant's weight in kilograms plus 6 cm. According to this rule, a 1 kg infant should be intubated to 7 cm, a 2 kg infant to 8 cm, and a 3 kg infant to 9 cm.[18,19] This traditional technique measures insertion depth from the middle of the upper lip, and several formulas have been developed to enhance its accuracy. In addition, gestational age- and weight-based tables offer more individualized recommendations, particularly for preterm and very low birth weight neonates.[17,20]

The accuracy of the 7-8-9 rule depends on several critical factors, with infant weight being paramount. For infants weighing less than 750 g, the rule overestimates ETT depth in extremely low birth weight infants, increasing the risk of right mainstem intubation.[19,21,22] For example, for a 0.5 kg infant, the rule suggests 6.5 cm insertion depth, but this distance could be 0.23 to 0.6 cm too deep.[19,21,22] In contrast, accuracy improves for infants over 750 g, with minimal deviation from midtracheal position.[19,22]

To improve the accuracy of endotracheal tube (ETT) placement in neonates, Kempley et al.[20] conducted a prospective audit evaluating the relationship between ETT length, gestational age, and weight. Their findings demonstrated that while the relationship between ETT length and gestation was linear, the relationship with weight was non-linear, making traditional weight-based formulas like the 7-8-9 rule less reliable, particularly for infants at the extremes of weight. To address this, the researchers developed regression equations using a large, diverse cohort of over 200 neonates undergoing inter-hospital transfer.[20] These equations were used to approximate recommended ETT lengths to the nearest half-centimeter, which were then organized into a gestation-based and weight-based guideline (see table 1). This practical reference tool was designed to support more accurate initial tube placement and reduce the frequency of malpositioned ETTs and associated complications such as uneven lung expansion.

The nasal-tragus length (NTL) method is a bedside technique used to estimate endotracheal tube (ETT) insertion depth in neonates, particularly during orotracheal intubation.[17] The clinician measures the distance from the base of the nasal septum to the tragus of the ear; an external anatomical landmark that approximates the airway length. For orotracheal intubations, 1 cm is added to the measured length to account for the distance from the oral cavity to the trachea, yielding the recommended depth for tube insertion at the lip or gum. This method is especially useful in delivery room or emergency settings, where weight and gestational age may not be immediately available. It offers a patient-specific approach to ETT depth estimation and is included in the NRP guidelines as one of several recommended techniques.

Despite its ease of use and anatomical rationale, the NTL method has notable limitations. It's been demonstrated that even with individualized measurement, the accuracy of ETT placement remains inconsistent. In a prospective observational study, Priyadarshi et al.[23] compared the NTL method with both weight-based and gestational age-based approaches in a cohort of deceased neonates and fresh stillbirths. The results demonstrated that all three methods led to a high rate of malpositioned tubes, with the NTL method achieving optimal placement in only 30% of cases. These findings underscore that while the NTL method is practical, it is not reliably superior to other techniques and should always be followed by post-intubation confirmation using imaging or ultrasound when possible.[23]

The primary concern is not necessarily the depth estimation method itself, but the reliability of the anatomical reference point. While many depth estimation methods provide reasonable starting points, their accuracy diminishes over time when the lip is used as the reference location. Measurements may initially be appropriate, but as lip tissue swells or shifts, they become increasingly prone to inaccuracy. The mobility of the lips significantly impacts the reliability of most current lip-based recommendations for neonatal endotracheal tube placement. The lip represents a dynamic structure, especially during crying, suctioning, or handling, causing the ETT to shift from its initial taped position. Preterm infants often develop lip edema from repeated suctioning or tape irritation, altering the reference point for depth measurement. Soft, pliable lip tissue in very low birth weight infants increases displacement risk compared to term infants. Adhesive tape continues to be a popular securing device, even if used temporarily in the delivery room. Using adhesive tape on mobile lips can lead to tube movement up and down and further complicate airway management.[24] Although lip-based measurements are user-friendly and widely adopted, they are susceptible to variability due to superficial anatomical differences and lip mobility, which is especially problematic in smaller infants, where tissue looseness or edema can lead to malposition, increasing the risk of extubation or risk of right mainstem intubation.[19] While using the lip as the reference landmark has support, there is evidence supporting the gum as a potentially more accurate alternative, particularly in certain neonatal populations.

Gum (Upper Alveolar Ridge) Landmark

Emerging evidence suggests that gum-based measurement for endotracheal tube (ETT) placement may offer greater accuracy than traditional lip-based methods, particularly in preterm and low birth weight infants.[25,26] The upper alveolar ridge, or gum line, is anatomically closer to the airway and more structurally stable than the lips, which can shift due to edema, facial anomalies, or positioning. Unlike the lip, the gum is fixed relative to the trachea and carina, providing a more consistent reference point for estimating ETT depth. This is especially important in neonates,

where the margin for error is narrow and small deviations in ETT placement can have significant clinical consequences, including right mainstem intubation, inadequate ventilation, or airway trauma. As a result, clinicians and researchers have increasingly explored whether gum-based measurements might reduce placement errors and improve outcomes.

This growing interest has led to several studies examining the feasibility and accuracy of using the gum as a landmark, including a notable investigation that developed a regression-based formula to optimize initial ETT depth in neonates. Zaytseva et al.[25] 2020 study included 75 neonates with a median weight of 1300 grams. This study aimed to determine the optimal initial endotracheal tube (ETT) depth from the upper alveolar ridge (gum) in neonates relative to weight and to compare the accuracy of point-of-care ultrasound (POC-US) with chest X-ray (CXR) for confirming ETT tip placement. The regression equation for optimal depth from the gum was determined to be 5.21 + 1.03 × weight (kg) in centimeters, with weight explaining 83% of the variability ($R^2 = 0.83$). Two simplified formulas, e.g., "5 + weight" and "5.5 + weight", were evaluated for practical use, with "5 + weight" improving accuracy particularly in infants under 1500 grams. The authors determines that the optimal depth from the gum can be estimated as 5.2 cm plus weight in kilograms.[25] For additional confirmation, POC-US, performed in 40 infants, demonstrated substantial agreement with CXR (intraclass correlation coefficient 0.95, 95% CI: 0.92–0.98) and may provide a rapid, non-invasive alternative to radiography. The findings suggest that using the gum as a reference point for ETT depth could improve tube stability, and reduce respiratory complications associated with malposition or frequent tube manipulation.

Recent research presented at the Pediatric Academic Societies (PAS) 2024 Meeting further supports the "Tip-to-Gum" method as a more stable and reliable anatomical landmark, especially in very low birth weight infants. Gupta et al.[26] conducted a retrospective study to evaluate whether measuring endotracheal tube (ETT) depth from the gum (Tip-to-Gum) offers more reliable placement in very low birth weight (VLBW) infants compared to the traditional Tip-to-Lip method supported by the NRP. The authors included 266 infants under 1500 grams and <32 weeks' gestation. Only 29% had appropriately positioned ETT tips on the first chest X-ray, and nearly half required repositioning within 24 hours. Using electronic calipers and enhanced imaging techniques, the team found that Tip-to-Gum depth measurements consistently increased with gestational age and birth weight and closely paralleled the NRP Tip-to-Lip measurements at the lower border of T2. Based on their findings, Gupta et al.[26] suggest that converting from a Tip-to-Lip to a Tip-to-Gum method could improve placement accuracy, proposing a 4 mm (1.4 cm) reduction in NRP guidelines when switching to gum-based measurements.

Comparison of Lip vs. Gum Measurements

The clinical implications of these differences are particularly pronounced in extremely low birth weight infants. For infants weighing less than 750 g, the 7-8-9 rule suggests 6.5 cm for a 0.5 kg infant, but the gum formula recommends 5.7 cm, reducing malposition risks. For infants over 750 g, both methods are acceptable, but gum measurement may reduce repositioning needs and accuracy improves significantly with minimal deviation from midtracheal position.[19,22,25]

Beyond its mobility, the lip lacks a consistent surface from which to read ETT depth markings; the thickness of the upper lip can result in different depth readings depending on whether the measurement is taken from the top or bottom edge. This variability introduces uncertainty when verifying tube position or monitoring for migration. Given these limitations, the lip may not be an ideal reference point for measuring ETT depth. In contrast, the upper gum provides a fixed bony landmark that is less influenced by external forces or anatomical variability. Adopting gum-based reference points may offer a more stable and consistent method for reducing ETT migration and its associated complications, particularly in extremely low birth weight infants who are most vulnerable to the consequences of UE. Table 2 summarizes key differences between lip and gum-based depth measurement methods.

Although multiple methods have been proposed to estimate endotracheal tube (ETT) depth in neonates, including weight-based formulas (e.g., Tochen), gestational age-based approaches (e.g., Kempley), and anatomical measurements like nasal-tragus length, their accuracy remains variable. Pinheiro et al.[27] highlight the critical importance of declaring a predicted ETT depth prior to intubation as a safety practice and support the use of standardized methods combined with pre-intubation checklists and multidisciplinary communication. However, a prospective observational study by Priyadarshi et al.[23] directly compared the Tochen, Kempley, and NTL methods and found that none reliably ensured optimal lip-to-tip ETT positioning. In their study, over half of all ETTs were malpositioned across all three techniques, with the majority inserted too deeply. These findings reinforce that while proactive depth estimation and clear team communication are essential components of safe neonatal airway management. However, the currently available methods for estimating ETT depth remain suboptimal and warrant further refinement. Continued research and innovation are urgently needed to develop more accurate bedside techniques for ETT placement in neonates.

In summary, referencing the gum improves ETT placement by providing a stable, consistent anatomical landmark that enhances measurement accuracy and consistency, ultimately contributing to safer and more effective intubation procedures in neonates.

Conclusions

The available evidence suggests potential advantages of gum-based measurement over traditional lip-based techniques for neonatal endotracheal tube placement, particularly in extremely low birth weight infants where anatomical variability and procedural precision are most critical. The gum landmark offers theoretical benefits as a fixed reference point, eliminating variability from lip mobility and tissue compliance that may compromise accuracy in vulnerable populations.

However, the current evidence base remains limited, highlighting a significant gap in neonatal airway management research. The observed discrepancies between measurement techniques and the heightened risks associated with malposition in preterm infants underscore the urgent need for larger, well-designed studies to definitively establish optimal placement methods. Several factors further compromise the reliability of current ETT depth measurements. Anatomical variability presents challenges, as tracheal length in extremely low birth weight infants measures only 4-6 cm, leaving little margin for error.[28,29] Head position significantly affects measurements, with neck flexion or extension shifting ETT position by up to 0.5-1.0 cm, even when secured.[21,29] Clinical practice limitations include weight estimation errors during emergencies and practitioner skill variations, particularly

with extremely low birth weight infants.[21] ETT markings with whole-centimeter graduations make fine adjustments difficult for tiny infants.[22]

Verification methods are still critically important, regardless of the measurement technique and anchoring location. Chest X-ray remains the gold standard but is often delayed, allowing temporary malposition risks.[21,29] Auscultation has limited reliability in distinguishing bronchial versus tracheal placement, especially in noisy NICU environments.[21,22]

Future research should prioritize head-to-head comparisons of measurement techniques across diverse neonatal populations, with particular focus on extremely low birth weight infants where current evidence suggests the greatest potential benefit. Such studies would provide the robust evidence base necessary to inform evidence-based practice guidelines and potentially improve outcomes in this vulnerable population. Until definitive evidence emerges, clinicians should remain cognizant of the limitations of existing measurement techniques and continue to rely on radiographic confirmation for optimal tube positioning. The pursuit of improved placement accuracy represents a critical patient safety imperative that warrants dedicated research investment.

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From Survey Scores to Earlier Intervention: The Operational Case for Real-Time Family Voice in the NICU

Detecting communication gaps, parental distress, and social needs while there's still time to make a difference

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Why Post-Discharge Surveys Arrive Too Late

Real-time family surveys delivered through established digital family engagement platforms represent a scalable, evidence-informed approach to capturing family experience and holistic wellness needs during Neonatal Intensive Care Unit (NICU) hospitalization.

NICU leaders face growing expectations to improve family experience, communication, equity, and psychosocial support while operating under persistent staffing constraints and increasing clinical complexity. Traditional post-discharge surveys provide delayed, retrospective insight that limits opportunities for timely care alignment and real-time quality improvement. In contrast, real-time family surveys, digitally enabled family connection tools, and automated psychosocial screenings offer a scalable, evidence-informed mechanism to capture family wellness baselines during hospitalization. This infrastructure enables earlier identification of parental mental health struggles, Social Determinants of Health (SDOH) vulnerabilities, and communication preferences, supporting more responsive and proactive care delivery.

Because NICU-specific evidence on real-time digital family feedback continues to evolve, this white paper draws on neonatal, pediatric, intensive care, and broader patient/family experience literature to identify practical considerations that may be applicable to NICU settings. The literature demonstrates that when real-time feedback and validated screenings are paired with clear, automated response pathways, these approaches are associated with:

- improved family satisfaction
- stronger communication
- enhanced family engagement
- reduced family stress
- proactive psychosocial support

Importantly, the evidence consistently shows that technology alone is insufficient; impact is realized when digital tools are embedded into workflows as a team support system, backed by staff alignment, and connected directly to specialized resource pathways.

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For NICU leaders and executives, real-time family survey and screening infrastructure embedded within an existing family engagement platform should be viewed as more than an experience initiative; it can serve as an important component of modern, family-integrated NICU operations. When embedded into platforms families already trust and use, participation increases and sharing needs become a routine part of care rather than an administrative burden (Remer et al., 2024). Digital systems provide leaders with actionable data, earlier clinical and social risk signals, and equitable access to family voice capabilities that are increasingly essential for quality, clinical equity, and organizational performance.

The Gap Between Measuring Experience and Acting on It

Family-integrated care is a foundational principle of high-quality neonatal intensive care, emphasizing respect, information sharing, participation, and collaboration with families throughout prolonged and highly stressful NICU hospitalizations (Goldfarb et al., 2023; Sakonidou et al., 2023). However, measurement of family experiences and evaluation of family needs in the NICU have historically relied on retrospective surveys administered weeks after discharge or on families' physical presence at the bedside. While valuable for high-level benchmarking, these tools do not allow clinical teams to identify wellness gaps in real time or intervene while families are still actively engaged in care at the bedside.

The shift toward real-time family surveys reflects broader trends in quality improvement, patient engagement, and digital health. Advances in mobile technology, text messaging, and web-based platforms have enabled families to share feedback, ask questions, and complete vital screenings even when physical presence at the bedside is limited. For NICUs, where prolonged hospitalizations, emotional stress, and complex communication needs are common, the ability to capture family voice and health equity baselines during hospitalization is particularly critical.

The literature consistently positions real-time family feedback as a mechanism to close the gap between experience measurement and clinical action. Rather than serving solely as a performance scorecard, real-time surveys and digital screening entry points function as operational tools that surface communication breakdowns, psychosocial distress, and unmet social resource needs early enough to support a meaningful response from the interdisciplinary care team.

What the Evidence Actually Says

The evidence base for real-time family surveys and digital screenings draws on several complementary frameworks. The Family Activation Theory emphasizes the role of family knowledge, confidence, and agency in shaping care experiences. Validated measures demonstrate that higher family activation is independently associated with greater satisfaction, underscoring the importance of tools that give families structured, low-friction opportunities to express needs and participate in care (Hallot et al., 2024).

Implementation science further informs how real-time feedback and screening systems become embedded into routine practice (Jesus et al., 2024a, 2024b). Studies applying Normalization Process Theory show that feedback tools are more likely to be successfully adopted and sustained when their purpose is framed as a team support mechanism, roles are well defined, workflows are minimally disrupted, and data are routed dynamically to reduce the cognitive load on frontline staff (Jesus et al., 2024a).

From a psychosocial and equity perspective, a NICU admission constitutes a profound crisis that dynamically shifts a family's mental health status and resource needs (Oak & Kim, 2025). Rather than viewing families purely through the lens of satisfaction, modern healthcare models position them as partners who require holistic support. Real-time digital platforms expand the unit's ability to detect parental trauma, depression, and social vulnerabilities early, supplementing traditional, episodic clinical rounds with continuous, accessible screening infrastructure (Khan et al., 2024).

How Real-Time Feedback Reaches Families

Meeting Families Where They Are: Digital and Text-Based Surveys

Web-based survey tools embedded within existing digital family engagement platforms are a commonly studied and effective modality for real-time family feedback. When surveys are integrated into platforms families already use for communication and information access, response burden is reduced, and participation is more likely to occur during active care episodes (Remer et al., 2024; Sakonidou et al., 2023). Platform-based digital surveys delivered within an existing family engagement ecosystem demonstrate high usability and completion rates when families are already routinely logging in for updates, education, and connection (Remer et al., 2024).

Embedding surveys within a trusted platform reduces friction, eliminates the need to respond to external prompts, and increases the likelihood of completion during hospitalization (Remer et al., 2024; Rothschild et al., 2024). Response rates for real-time surveys vary by design and implementation strategies. Still, they are comparable to or exceed those of traditional post-discharge surveys when workflows are optimized, and staff encourage participation (Remer et al., 2024). Importantly, higher response rates alone do not guarantee impact; studies consistently emphasize the importance of timely review and automated response pathways (Jesus et al., 2024b).

One Platform, Not One More Login

Comprehensive mobile health platforms integrate experience surveys with education, communication, and psychosocial screening tools (Oak & Kim, 2025). These platforms have demonstrated high acceptability among families and clinicians, particularly in pediatric and neonatal populations (Rothschild et al., 2024). For families, integrated platforms support sensemaking, reduce uncertainty, and create structured pathways to communicate satisfaction levels and psychological needs (Oak & Kim, 2025). For clinical teams, they consolidate multiple engagement functions into a single digital environment that handles data translation behind the scenes.



Rigor Without the Survey Fatigue

Several validated instruments have been adapted or refined for real-time use in intensive care and neonatal settings (Sakonidou et al., 2023). These tools preserve psychometric rigor while reducing length and focusing on domains most actionable during hospitalization, such as communication clarity, parental involvement, and emotional support. Refinement studies highlight the importance of minimizing missing data, avoiding redundant items, and ensuring questions are understandable to families experiencing high stress (Sakonidou et al., 2023). This includes the digital deployment of validated mental health screens, such as the Edinburgh Postnatal Depression Scale (EPDS), to track parental well-being dynamically alongside standard Social Determinants of Health (SDOH) intake fields.

What Changes for Families — and the Team

Fewer Phone Calls, More Trust

Across neonatal and pediatric intensive care settings, real-time family surveys and digitally enabled family connection tools are associated with improved satisfaction scores, particularly related to communication quality, timeliness, and perceived responsiveness of the care team (Manna, 2021; Pozzoli et al., 2023; Yu et al., 2022). Studies demonstrate meaningful improvements when families can ask questions proactively, receive regular updates, and report satisfaction barriers as they arise rather than after discharge (Yu et al., 2022).

Digitally enabled family platforms that combine communication, information access, and feedback collection reduce reliance on inbound phone calls while improving continuity of information for families who cannot be physically present (Bruce et al., 2023a). Studies consistently show that when families can access updates and share experience data through a single digital entry point, perceived responsiveness and satisfaction increase (Bruce et al., 2023a; Pozzoli et al., 2023). Families consistently report that regular, structured communication conveys attentiveness and compassion, reinforcing trust in the care team.

Identifying Parental Distress Before It's a Crisis

Beyond satisfaction, studies in intensive and neonatal care settings demonstrate reductions in family stress and improvements in self-

efficacy associated with digitally supported family engagement during hospitalization, which is especially critical in the NICU, where prolonged uncertainty and separation are common (Oak & Kim, 2025; Rothschild et al., 2024). By providing timely information and opportunities for feedback, real-time systems help mitigate uncertainty, a major driver of anxiety in the NICU. Families report feeling more informed, more confident, and better prepared to participate in care and decision-making (Oak & Kim, 2025).

Furthermore, the integration of real-time screening tools enables proactive identification of parental mental health challenges and Social Determinants of Health (SDOH). Because a NICU admission is an acute crisis, the traditional model of paper forms or intermittent bedside social work visits cannot always keep pace with a family's evolving needs. Research reveals that leveraging digital platforms to deliver discreet, real-time screening tools significantly increases parent engagement with support services (Oak & Kim, 2025). Bedside and distance caregivers can privately flag severe postpartum anxiety, depression, or critical SDOH vulnerabilities, such as transportation barriers, food insecurity, or housing instability, directly from their mobile devices.

Reaching the Families Surveys Usually Miss

Evidence suggests that real-time surveys contribute to increased family activation by legitimizing family voice and reinforcing the expectation of partnership. Activation measures show independent associations with satisfaction, supporting the premise that giving families structured opportunities to express their needs has intrinsic value beyond the specific fields reported (Hallot et al., 2024).

Importantly, traditional survey methods often suffer from stark demographic disparities, heavily favoring families with higher resources and English proficiency. When real-time digital experience and screening tools are designed with health literacy in mind and delivered in multiple languages, they may help reduce barriers to participation (Khan et al., 2024; Remer et al., 2024). Emerging evidence suggests that health-literacy-informed digital screenings can capture psychosocial and social risk factors that may be missed during standard clinical workflows, giving distance caregivers and historically underserved families a more accessible pathway to seek support resources (Khan et al., 2024).

Making It Work: Technology That Supports the Team

The literature is clear that technology alone does not drive improvement; real-time feedback and screening programs show strong results only when paired with actionable data relay, defined response pathways, and intentional workflow integration (Jesus et al., 2024b; Remer et al., 2024). To achieve a true return on investment, these digital tools must be implemented as supportive systems that uplift, protect, and empower the frontline healthcare team. Successful programs hardwire three core pillars into their operations:

A Safety Net, Not a Scorecard

Real-time feedback functions as a proactive layer of support for bedside staff, catching minor communication gaps or unaddressed family questions before they escalate into formal patient relations complaints (Jesus et al., 2024a). By providing an early, gentle alert that a family needs extra clarity, education, or reassurance, the system allows the care team to collaborate smoothly and align with the family's expectations in real time. It shifts the unit's posture into a supportive, proactive rhythm that protects and enhances the patient-nurse relationship.

The Right Alert to the Right Person — Automatically

A well-designed digital platform simplifies operations by establishing clear, automated routing for specific family inputs, ensuring that specific family needs are routed directly to the appropriate team member (Jesus et al., 2024b; Remer et al., 2024). Rather than adding to a bedside nurse's cognitive and documentation load, the system manages the logistics behind the scenes. For example, if a postpartum parent completes a digital EPDS screening and flags acute mental health needs, the platform routes the alert directly to the appropriate social work or psychology team without requiring the bedside nurse to manually triage the concern. This structured relay ensures that vulnerable families get targeted, rapid intervention from the right resource seamlessly, allowing bedside clinicians to keep their focus primarily on clinical care.

Catching the Good, Too

While leadership systems often focus on service recovery, real-time surveys may also capture positive feedback from families. Parents may use these tools to express gratitude for bedside nurses and clinicians who provided compassion, clarity, or reassurance. When shared thoughtfully, these comments can reinforce meaningful care behaviors, support team recognition, and help leaders identify practices that families experience as especially supportive (Remer et al., 2024).

What This Means for NICU Leaders

For NICU executives and nurse leaders, real-time family survey data provide actionable operational insight, identifying communication gaps, mental health distress, and social risks earlier in prolonged hospitalizations, informing targeted resource allocation, and supporting strategic goals related to experience, equity, and holistic neonatal support (Khan et al., 2024; Remer et al., 2024).

Real-time digital infrastructure enables:

- Earlier detection of satisfaction barriers and psychosocial needs (Khan et al., 2024).
- Scalable family engagement and automated screening routing despite staffing constraints (Remer et al., 2024).
- More equitable access to participation and support services for families at a distance (Khan et al., 2024).
- Data-informed leadership decision-making that drives staff recognition and morale.

NICUs without mechanisms to understand family experience, psychosocial needs, and equity-related barriers in real time may face widening gaps between family-centered care intentions and operational execution.

The Real Investment

The available evidence suggests that real-time family surveys, digitally enabled connection tools, and automated screening workflows can strengthen communication, enhance visibility into family experience, support earlier identification of psychosocial needs, and inform resource allocation when implemented thoughtfully. For NICU leaders and executives, these systems represent a practical, evidence-informed approach to operationalizing family-integrated care while protecting and supporting the frontline clinical team.

Investing in real-time family feedback is not simply an investment in experience scores; it is an investment in a more responsive, supportive, and equitable neonatal care environment (Bardach et al., 2022; Khan et al., 2024; Remer et al., 2024).

Join the Conversation

To continue this conversation, feel free to email Lisa Davenport, DNP, RN, RNC-NIC, Vice President of Clinical Commercialization at AngelEye Health. Email ldavenport@angeleyehealth.com.

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Restoring What the Processing Removes: Bioactivity, Donor Human Milk, and Fortification Choices in the NICU

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Introduction

Human milk is not simply nutrition. It is a complex, bioactive fluid matrix containing immune proteins, antimicrobial substances, growth factors, microbiota and glycans that influence gut maturation, immune development, and microbial colonization. These functions are especially relevant for very low birth weight (VLBW) infants whose immature gut and immune systems leave them particularly vulnerable.[1,2] Mother's own milk (MOM) is nature's gestation-specific and individualized immuno-nutrition designed for the enteral priming of the most vulnerable VLBW infants. When MOM is unavailable or insufficient, pasteurized donor human milk (DHM) is recommended, along with fortification.[3,4]

In our 2023 publication, my colleagues and I reported that processing DHM, including the conventional pasteurization, can diminish its bioactivity, compared with freshly expressed MOM.[5] Bioactivity can be complemented and, in some cases, enhanced, via the use of human milk-based fortifier (HMBF) that has been vat pasteurized to preserve key bioactive compounds that are beneficial for immunity, growth, and neurodevelopment.[5]

Exclusive Human Milk Diet and the Benefits

Over the past several years, dozens of clinical studies have demonstrated improved short-term and long-term clinical outcomes when VLBW premature infants are fed Human Milk (HM), instead of cow milk-based nutrition.[6-10] While HM is the normative enteral nutritional choice for the extremely low birth weight (ELBW, <1,000 gm) and VLBW infants, additional multi-nutrient fortification is recommended for tissue accretion approximating an intrauterine growth curve. Historically a cow milk-based fortifier (CMBF) was used, however the addition of currently available HMBF to the HM base (either MOM or DHM) offers an exclusive human milk diet (EHMD), that is species-specific, free of bovine proteins, and is associated with reductions in a list of complications that commonly affect VLBW premature infants[11-17] as well as contributing to better long-term neurodevelopmental outcomes.[18-20]

In addition to the primary role of macronutrient provision, HM also delivers unique bioactivity linked to protein, carbohydrate, and fat, and needless to highlight that for the immature and immunologically vulnerable ELBW and VLBW infants, human milk as the source of such components would be preferable to bovine, murine or plant-based additives, supplements, and fortifiers.

A recent meta-analysis, which included 20 studies and a total of 6,794 VLBW infants, found an EHMD is associated with 35% reduced risk of medical necrotizing enterocolitis (NEC) and 49% reduced risk of surgical NEC, compared to diets containing cow milk-based products.[21] An additional meta-analysis found a 50% reduction in mortality among preterm infants fed human milk-based nutritional fortifiers.[22] An EHMD has also been linked with shorter hospital stays and ultimately cost savings.[11,13,16,23,24]

Taken together, these data suggest that HM is not only a source of calories and macronutrients, it delivers biologic signals and protective factors that may matter most for the smallest infants.

Human Milk Bioactive Components

The demonstrated clinical benefits of an EHMD may largely be explained by bioactive factors that are only present in HM. Premature infants have immature intestinal and immune systems, which place them at increased risk for nutritional deficiencies and infection. HM contains lactoferrin[25] and α-lactalbumin,[26] both of which enhance mineral absorption. Lactoferrin also promotes gut maturation,[27,28] along with another component of human milk, transforming growth factor β.[27] It additionally protects against both bacterial and viral pathogens,[29,30] as do the lysozyme and pathogen-specific immunoglobulins (Ig) present in human milk.[31,32]

While both human and cow's milk contain fatty acids, those found in human milk are uniquely suited to support infant growth and development. These include arachidonic acid (ARA) and docosahexaenoic acid (DHA) as well as their precursors, linoleic acid (LA) and α-linolenic acid (α-LA). ARA supports growth, brain development, immunity, and the immune response.[33] DHA also supports brain development.[34,35] Both LA and α-LA support maturation of multiple organ systems, promote growth, and aid in the regulation of inflammation.[36]

The milk fat globule (MFG) found in HM is a source of both DHA and ARA and also provides ready energy.[37] The MFG membrane (MFGM) supports maturation of the gut and promotes development of a healthy microbiome. It also has antimicrobial, anti-inflammatory, and prebiotic functions, and supports cognitive development.[31,37]

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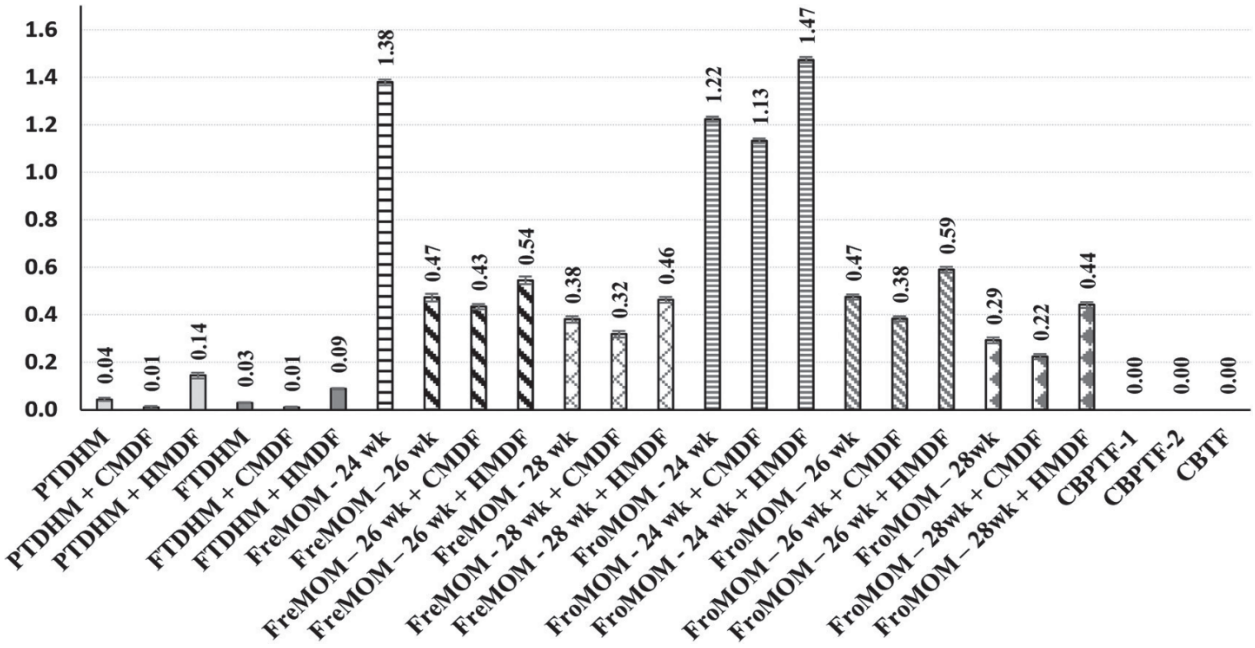


Figure 1. Lactoferrin content (mg/mL) of DHM and MOM (fresh and frozen) supplemented with HMDF and CMDF and commercial preprepared bovine-based formulas. Values are means of triplicate measurements with their standard deviations represented by vertical bars. Column headed by Human LF content. CMDF, cow's milk-derived fortifier; DHM, donor human milk; HMDF, human milk-derived fortifier; LF, Lactoferrin; MOM, mothers' own milk; PTDHM, preterm donor human milk; CBPTF, cow milk-based preterm formula; CBTF, cow milk-based term formula; FreMOM, Fresh mother's own milk; FroMOM, Frozen mother's own milk. [Philip et al. 2023 *Breastfeeding Medicine*. Figure included with permission, CC-BY-4.0.]

Only HM contains a diverse variety of digestible sugars/glycans called human milk oligosaccharides (HMOs).[38] Some HMOs have a prebiotic effect, supporting the growth of beneficial bacteria, and have anti-adhesive properties that protect against infection. HMOs also promote maturation of gut epithelial cells, which may explain why an EHMD is associated with a lower risk of NEC.[38-40] Finally, HMOs are a source of sialic acid, an important nutrient for brain development.[38-40]

With the rich prebiotic, probiotic, symbiotic and antibiotic properties of HM, nearly a decade ago we coined the term 'lovebiotic' to summarize the immuno-nutritional complexities of the unique biofluid which also fosters the emotional bond to the mother-infant dyad.[41]

Fundamental Differences in Human Milk Processing

DHM must be processed to meet safety standards for fragile preterm infants, but different processing methods can significantly impact the bioactive components in HM.

Milk homogenization and heating milk to ultra-high temperatures (UHT) disrupt MFG structure and bioactivity.[42] UHT processing denatures heat-sensitive proteins like lactoferrin. Published research shows UHT processing reduces lactoferrin by 76% and immunoglobulin A (IgA) by 82%, compared to raw HM. When UHT is followed by homogenization, those reductions increase to 87% and 91% respectively.[43]

Preserving and Replenishing Bioactivity

In the 2023 publication, our lab compared the biochemical and immunohistochemical properties of fresh and frozen MOM with pasteurized DHM to determine the degree to which bioactive compounds are preserved in DHM. MOM was collected from mothers being cared for at University Maternity Hospital Limerick in Ireland. Samples were collected in the morning (7–9 am), afternoon (1–3 pm), and night (7–9 pm) and were analyzed in triplicate to adjust for the diurnal variation. On chromatography, DHM was found to have significantly lower concentrations of lactoferrin and α-lactalbumin ($p < 0.05$ for both), compared with fresh and frozen MOM.[5] (Fig 1, used with permission)

The study also evaluated fortification choices that could accentuate or reduce the concentration of bioactive components. Findings showed milk samples fortified with HMBF contained higher protein, fat, and total solids ($p < 0.05$) compared to unfortified samples and those fortified with cow milk-based fortifier (CMBF).[5]

The HMBF reinstated lactoferrin and α-lactalbumin and exhibited higher protein, fat, and total solids ($p < 0.05$) in comparison to unfortified specimens and those supplemented with CMBF.[5] Samples with added HMBF also had the highest ($p < 0.05$) antioxidant activity (AA), suggesting the potential capability of HMBF to enhance oxidative scavenging.[5]

Processing Method Matters

For HMBF to replenish the bioactivity of HM, the bioactive factors must survive the processing required to ensure that HMBF is both safe from pathogens and contamination and has a reliable, reproducible composition. The HMBF used in our study is produced with vat pasteurization, a form of processing that has been shown to relatively better preserve the bioactive components of HM compared to other processing methods, such as UHT and retort sterilization. Meredith-Dennis et al. demonstrated that vat pasteurized human milk samples had higher concentrations of immune-protective proteins and specific HMOs than samples that underwent retort sterilization.[44] Similarly, Liang et al. demonstrated greater preservation of HMOs, protein, and fat concentrations, including IgA, IgG, IgM, lactoferrin, lysozyme, α-lactalbumin, casein, osteopontin, and α-1-antitrypsin proteins with vat pasteurization, compared with retort sterilization.[45] Finally, Ozturk

et al. demonstrated that UHT and retort sterilization reduced the bioactivity of MFGs completely or nearly completely, while vat pasteurization resulted in 28% retention.[42]

HM is "liquid gold" for VLBW preterm infants and represents the nutritional standard of care.[3,4] To make DHM safe for these infants, however, it requires processing, and such processing may diminish some of the very bioactivity that makes it such a beneficial nutritional intervention. Choosing vat pasteurization over UHT, homogenization, or retort sterilization helps to reduce the processing and pasteurization-associated reduction of bioactivity of HM, and restoration of certain HM-associated bioactivity can be accomplished with the addition of HMBF that has been processed using vat pasteurization. This might help explain why an EHMD, consisting of HM, especially DHM, fortified with vat pasteurized HMBF, has been shown in multiple clinical studies to result in better short- and long-term outcomes among VLBW preterm infants.

For the neonatal 'nutritional critical care' and individualized immune imprinting of ELBW and VLBW infants, the 3E approach of *"Early, Enterally and Exclusively"* would offer the protective bioactivity during the most vulnerable postnatal period.[5] Available clinical evidence supports the need for further research in bioactivity-focused enteral nutrition as the foundational first line for the very premature infants during the critical early extrauterine period, especially to solidify evidence for the non-nutritional and extra-gastrointestinal benefits associated with bioactivity and immunogenicity of HM.[46]

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Maternal Stress in the Neonatal Intensive Care Unit: A Concept Analysis

Mitsuki Nojima and Hisayo Okayama

Abstract

Aims

This study aimed to provide a clear definition of the concept of maternal stress in the neonatal intensive care unit (NICU), which has been inconsistently described in previous studies. It also aimed to identify the essential attributes, antecedents, and consequences of maternal stress through concept analysis.

Methods

Rodgers' concept analysis method was used. A search was conducted using the web version of the Central Journal of Medicine, PubMed, PsycINFO, and CINAHL, yielding 223 hits. Of these, 32 were selected for the analysis.

Results

Three attributes of maternal stress in the NICU were identified: "Earnest feelings for my infant," "Stuck feeling," and "Vague anxiety about the future." Six antecedents and four consequences were identified.

Conclusions

The results of this study indicated that mothers felt a sincere desire for their infants, as well as a vague sense of helplessness due to circumstances beyond their control, and anxiety about the future. These findings suggest that while the NICU environment can be a source of stress for mothers, it may also serve as a supportive space and an opportunity for them to reflect on their role as mothers.

Introduction

According to the findings of the United Nations International Children's Emergency Fund (UNICEF) and the World Health Organization (WHO), approximately 15% of newborns worldwide have low birth weight (United Nations Children's Fund (UNICEF) & World Health Organization, 2019). As these infants require immediate treatment and care in the neonatal intensive care unit (NICU), they are separated from their mothers immediately after birth. This separation can lead to increased anxiety, depression, and stress among mothers (Shetty et al., 2024). Fathers may also experience similar emotions; however, research has demonstrated that mothers frequently exhibit elevated levels of anxiety, depression, and stress in comparison to fathers (Caporali et al., 2020; Shetty et al., 2024). Moreover, approximately one-third of mothers of infants admitted to the NICU have been observed to manifest post-traumatic stress disorder (PTSD) because of their NICU experience (McKeown et al., 2023). In this regard, research indicates an elevated incidence of PTSD in mothers compared to fathers (Aftyka et al., 2017). Anxiety and stress symptoms have been demonstrated to negatively impact mother-infant bonding; depressive symptoms during NICU admission are predictors of depressive symptoms at two to three months postpartum (Bonacquisti et al., 2020). This suggests a potential concern: insufficient maternal care during the NICU episode may have negative consequences not only for the mother but also for the infants. Consequently, healthcare professionals in the NICU play a pivotal role not only in preserving the life of the infants but also in providing comprehensive care for the attending family, particularly the mother. Nevertheless, NICU settings face many systemic and environmental challenges. The NICU environment is characterized by the constant presence of medical devices and alarms, which can be distressing for mothers visiting their infants. Some studies have reported that the lack of private space can be emotionally taxing for mothers, as it may lead to unintended exposure to the distress or conversations of other families within the shared environment (Bry & Wigert, 2019). Another study found that one of the challenges in NICUs is the inadequate respect for the privacy of mothers and infants (Maleki et al., 2024). Previous studies have indicated that both the physical and organizational characteristics of NICUs and family stress and anxiety can hinder the implementation of family-centered care (FCC; Abukari & Schmollgruber, 2024; Aljawad et al., 2025). In particular, high levels of stress and anxiety among family members can reduce their participation in caregiving and communication with healthcare staff, thereby limiting the practice of FCC. Because FCC benefits both mothers and infants (De Bernardo et al., 2017), healthcare providers need to address both environmental and family-related factors to promote FCC.

Maternal psychological burden is commonly expressed with words such as anxiety, fear, and stress. Of these, stress is defined as "the physiological or psychological response to internal or external stressors" (American Psychological Association, n.d.). External triggers, known as stressors, elicit stress responses in individuals, which are mediated by cognitive appraisal and

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expressed through coping mechanisms (Lazarus & Folkman, 1984). Based on this theory, most previous studies of mothers of infants admitted to the NICU focused on specific stress reactions such as anxiety and fear (Grieb et al., 2023; Suzuki et al., 2016). However, these studies only viewed stress as an emotional "outcome" and did not fully consider the process as a whole, including the stressor and evaluation process.

Furthermore, even when faced with the same stressor, mothers may differ in their perceptions and responses. Therefore, focusing solely on individual stress responses, such as anxiety or fear, is insufficient to fully capture the complexity of maternal stress experiences. Accordingly, a more comprehensive understanding of maternal stress would require consideration of the entire process, from stressors to stress responses.

Therefore, this study aimed to provide a clear definition of the concept of maternal stress in the NICU, which has been inconsistently described in previous studies (Grieb et al., 2023; Suzuki et al., 2016). In addition, the study sought to clarify the essential attributes, antecedents, and consequences of this concept through concept analysis. While systematic or scoping reviews synthesize prior findings, they do not provide a theoretical definition of a concept. Concept analysis, in contrast, is specifically intended to define concepts based on their essential attributes (Rodgers & Knafl, 2000). Because maternal stress in the NICU had not been theoretically defined, concept analysis was considered the most appropriate method for this study. By clarifying the factors that mothers respond to and how they react psychologically, it is possible to identify directions for more individualized support. Furthermore, a deeper understanding of maternal stress is expected to contribute to the promotion of FCC. Therefore, this study aimed to clarify the concept of maternal stress in the NICU through concept analysis to provide a theoretical definition and identify its essential attributes, antecedents, and consequences.

Methods

Study design

This study used Rodgers' method of conceptual analysis (Rodgers & Knafl, 2000). Walker and Avant's (2005) method is also well known for conceptual analysis. The latter method aims to distinguish similarities and differences between concepts by examining their underlying elements and revealing their internal structure, which is also useful for creating measurement tools and interview guides (Walker & Avant, 2005). In contrast, Rodgers' method views concepts as constantly changing objects, and is described as "a heuristic method for clarifying and further exploring the current use of concepts with attention to contextual and temporal aspects" (Rodgers & Knafl, 2000). The purpose of this study was to explore the components and characteristics of maternal stress, rather than to develop a measurement instrument or interview guide. Moreover, the stress experienced by mothers of infants admitted to the NICU occurs in the contextual and temporally variable environment of the NICU. Therefore, Rodgers' conceptual analysis was chosen as the analytical method that would best serve the purpose of this study.

Literature collection methods

The term "stress" is employed not only in the domain of nursing science but also in various other fields, including psychology, behavioral science, and social science. Four databases were used to collect literature in these fields: the Central Journal of Medicine web, PubMed, PsycINFO, and CINAHL. The search formula was designed to encompass relevant keywords, such as "NICU," "mother," and "stress," and was formulated as follows: ("neonatal intensive care unit" or "NICU") and "mother" and "stress." The inclusion criteria were (1) articles written in English or Japanese and (2) articles published in or after the year 2000. The exclusion criteria were (1) articles that did not address maternal stress in the NICU and (2) articles focusing on the effects of interventions such as programs or educational media. Although gray literature is generally included in systematic reviews, it was excluded from this study because of its low search reproducibility, leading to a lack of objectivity in literature selection, and the difficulty of ensuring research quality when non-peer-reviewed literature is included. The concept analysis was limited to peer-reviewed academic papers because the purpose of this study was to clarify the definition of the concepts of maternal stress in the NICU. We also searched for publication types without any restrictions. The first author searched the database in September 2024.

The selection process is shown in Figure 1. The first author selected the studies based on the inclusion and exclusion criteria. First, duplicates were excluded from all literature hits in the four databases. Second, the titles and abstracts of the studies were read, and those that did not mention maternal stress in the NICU were eliminated. Ten articles were found on the Central Journal of Medicine Web, and 213 were found in PubMed, PsycINFO, and CINAHL, for a total of 223. According to Rodgers and Knafl (2000), "a minimum of 30 items from each discipline or hierarchy or 20% of the population, whichever is greater, should be selected." Using this as a guideline, a random selection of 45 papers, or 20% of the 223 hits, was obtained using a computer program. Finally, the papers were selected through a comprehensive review of the entire text of the 45 cases. Although the title and abstract mentioned maternal stress, 13 papers met the exclusion criteria based on the full-text reading. After excluding these 13 papers, a total of 32 articles were included in the analysis. In accordance with Rodgers and Knafl (2000), no additional literature search was conducted because the minimum number of references required for concept analysis was 30. All references were imported and managed using Refworks. In cases for which the selection decision was uncertain, consultation was sought with the second author to ensure the reliability of the literature.

Analysis

Based on Rodgers and Knafl (2000) method of conceptual analysis, we sought to clarify maternal stress in the NICU in terms of its antecedents, attributes, and consequences. Specifically, the following five steps were performed.

1. Articles describing maternal stress in the NICU were identified. We then extracted the descriptions of maternal stress from the articles. During the extraction, several studies included in the analysis addressed both mothers and fathers. Therefore, only those statements that explicitly referred to mothers' experiences were extracted. For cases in which it was unclear whether a statement referred specifically to mothers, the matter was discussed with the second author until consensus was reached
2. The extracted data were organized into a matrix table. Factors reported in the literature as causing stress were identified as antecedents, stress reactions directly arising from these factors were recognized as attributes, and subsequent reactions were interpreted as consequences.

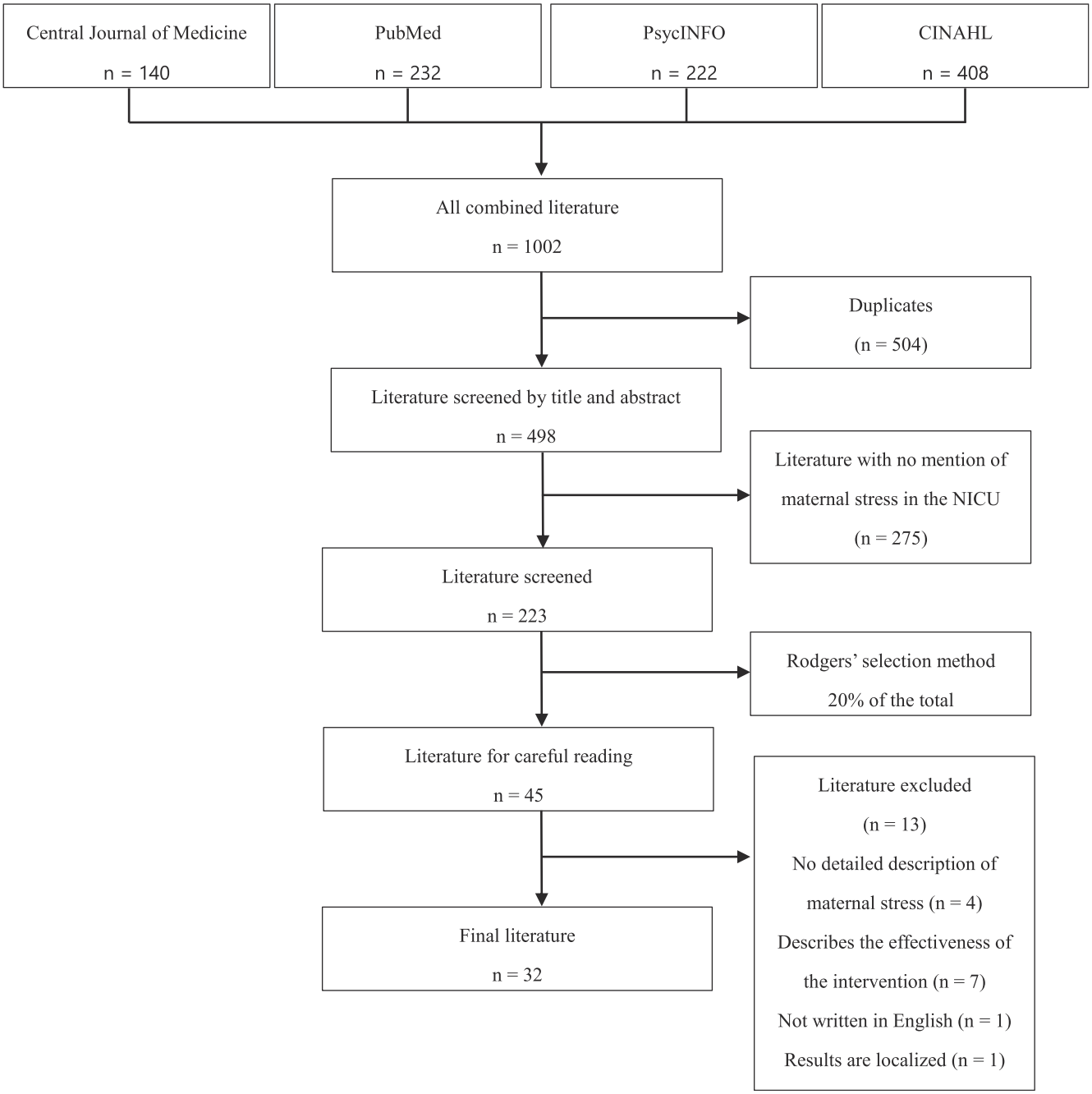


Figure 1. Literature selection process.

3. Each dataset was inductively grouped into extracts with similar semantic content and labeled.
4. Related concepts and surrogate terms for this concept were identified
5. Maternal stress in the NICU was defined based on prior antecedents, attributes, and consequences.

To ensure the integrity of the analysis, the sections of the paper and the analysis results were repeatedly reviewed. Throughout the analysis process, the results were discussed with the second author, who is versed in conceptual analysis, to ensure the validity of the findings.

Results

Overview

The characteristics of the 32 references obtained from our search are shown in Table 1. Of these, 13 were published after 2019, indicating a recent increase in research focusing on maternal stress in the NICU. Upon review of the 32 references, 40 subcategories and 76 codes were extracted. Consequently, the analysis yielded six antecedents, three attributes, and four consequences, as illustrated in Figure 2.

Antecedents

The six antecedent categories identified are displayed in Table 2. The "Admission of my infant to the NICU" was found to be separated by their own infant's NICU admission (Holditch-Davis & Miles, 2000; Ong et al., 2019; Schecter et al., 2020),

TABLE 1 Literature list.

No.	Author	Country	Research design	Population	NICU level	Findings
1	Aftyka et al. (2017)	Poland	Observational study	125 parents (72 mothers and 53 fathers)	NA (third-referral neonatal intensive care unit)	Compared to the fathers, the mothers felt greater stress and presented a higher severity of post-traumatic stress disorder.
2	Aftyka et al. (2014)	Poland	Cross-sectional observational study	39 mothers and 27 fathers	NA (children's university hospital)	Mothers reported significantly higher severity of PTSD symptoms, particularly intrusion and arousal symptoms.
3	Al-Akour et al. (2015)	Jordan	Cross-sectional study	150 mothers (75 NICU group, 75 non-NICU group)	NA (three large hospital)	The results showed that mechanical ventilation, lower birth weight, and lower gestation age were predictors of higher anxiety level and depression among mothers of infants admitted to the NICU.
4	Bonacquisti et al. (2020)	United States	Prospective longitudinal observational study	127 mothers	NA (three hospitals)	Maternal–infant attachment was negatively associated with anxiety and stress symptoms.
5	Caporali et al. (2020)	NA (Meta-analysis including data from 31 countries)	Meta-analytic study	14,875 parents (146 studies)	NA (varies by included study)	Mothers report higher NICU-related stress than fathers.
6	D'Souza et al. (2009)	India	Descriptive cross-sectional survey	62 mothers, 38 fathers	Tertiary level NICU	Nursing support was mildly negatively correlated with parental stress.
7	Fernández Medina et al. (2019)	Spain	Qualitative, interpretative design	15 mothers	Level-III	The subcategory "My job was to make milk" was extracted, which indicated that mothers felt an obligation or stress from providing breast milk.
8	Fróes et al. (2020)	Brazil	Cross-sectional study	74 mothers	Level-III	"Alteration in parental roles" was identified as the main source of stress experienced by mothers.
9	Greene et al. (2015)	United States	Prospective study	69 mothers	Level-III	The associations between distress and maternal visitation are substantial, with apparent lasting associations between visitation and long-term maternal distress.
10	Grieb et al. (2023)	United States	Qualitative Study	26 mothers	NA (two urban hospital NICUs)	Most of the mothers described their experience in the NICU as overwhelming and traumatizing, filled with stress, uncertainty, sadness, guilt, and isolation.

(Continues)

TABLE 1 (Continued)

No.	Author	Country	Research design	Population	NICU level	Findings
11	Guillaume et al. (2013)	France	Qualitative study	30 mothers, 30 fathers	NA (three tertiary care centers)	The nurses' caring attitude toward the baby and parents, and their communication with parents, reduced stress and made interactions with the baby possible.
12	Hatters Friedman et al. (2013)	United States	Descriptive observational study	150 mothers	NA (babies and children's hospital)	Mothers were more likely to receive psychiatric treatment in the NICU if they had longer infant hospitalizations, were younger in age, had fewer living children, and had lower levels of education.
13	Holditch-Davis and Miles (2000)	United States	Qualitative study	31 mothers	Tertiary university-based NICU	The study indicates that health care providers, and especially nurses, can have a major role in reducing parental distress by maintaining ongoing communication with parents and providing competent care for their infants.
14	Holditch-Davis et al. (2003)	United States	Qualitative study	30 mothers	Tertiary university-based NICU	All mothers interviewed had at least one posttraumatic symptom, 12 had two, and 16 had three symptoms.
15	Holditch-Davis et al. (2015)	United States	Longitudinal study	232 mothers of preterm infants	NA (four hospitals)	The mother experiences persistent stress due to the baby's admission to the NICU.
16	Kaur et al. (2022)	India	Descriptive study	17 parents	NA (tertiary care teaching hospital)	Mothers and fathers were very stressed during the period of hospitalization of their preterm neonates.
17	Kim et al. (2020)	South Korea	Cross-sectional study	294 mothers	Tertiary hospitals	Maternal self-representation was the strongest predictor of maternal postpartum attachment.
18	Lee et al. (2005)	United States	A cross-sectional, descriptive, correlational study	30 Chinese-American families (30 mothers, 25 fathers)	NA (three ICU sites)	Lack of support from healthcare providers significantly contributed to parental stress.
19	Levinson et al. (2022)	United States	Prospective study	135 mothers	NA (regional perinatal center)	Maternal stress, measured by PSS: NICU, was significantly associated with PPD screening outcomes.
20	Lotterman et al. (2019)	Columbia	Longitudinal study	91 mothers	Level-IV	This study noted elevated rates of psychological symptoms in mothers of moderate- to late-preterm infants over time.

TABLE 1 (Continued)

No.	Author	Country	Research design	Population	NICU level	Findings
21	Suzuki et al. (2016)	Japan	Longitudinal study	100 mothers	NA (university hospital)	There is a negative correlation between social support and the mother's mental and physical stress responses.
22	Ong et al. (2019)	Malaysia	Cross-sectional descriptive study	180 mothers	NA (public hospital)	The infant's NICU admission will trigger stress in mothers.
23	Orovou et al. (2023)	Greece	Prospective observational study	469 postpartum women	NA (university hospital)	NICU admission significantly increases the risk of postpartum PTSD.
24	Reimer et al. (2023)	Sweden	Mixed-methods study	437 mothers and 301 fathers	Level-III	Higher NICU-related stress was significantly associated with increased relationship strain.
25	Rossman et al. (2013)	United States	Qualitative descriptive design	23 mothers	Level-III	Mothers had faith in the healing properties of their milk and equated providing milk with "giving life" to their infants.
26	Schappin et al. (2013)	United States	Meta-analytic study	3025 parents (38 studies)	NA (varies by included study)	The results indicate that parents of preterm-born children experience only slightly more stress than parents of term-born children.
27	Schecter et al. (2020)	United States	Cross-sectional survey study	80 parents	NA	15% of parents reported moderate to high severity PTSD symptoms, more than 1 year after the NICU experience.
28	Shaw et al. (2009)	United States	Prospective longitudinal study	18 parents (11 mothers and 7 fathers)	NA (children's hospital)	At the 4-month follow-up, 18% of parents had high levels of PTSS.
29	Siva et al. (2024)	India	Meta-analytic study	descriptive quantitative studies ($n = 1889$) and qualitative study ($n = 173$)	NA (varies by included study)	The systematic review and meta-analysis findings show that the neonatal condition, parental role alteration, NICU environment, and communication gaps were stressors for mothers of neonates admitted to the NICU in India.
30	Stotts et al. (2019)	United States	RCT (longitudinal mediation analysis)	360 postpartum mothers	NA (urban children's hospital)	Psychological inflexibility measured 2 weeks after infant discharge from the hospital fully mediated the relationship between early and later depressive symptoms at 3 months postpartum.

(Continues)

TABLE 1 (Continued)

No.	Author	Country	Research design	Population	NICU level	Findings
31	Nakazawa et al. (2006)	Japan	Descriptive observational study	20 mothers	NA (seven hospitals)	Mothers' stress increases when the NICU is the place where they meet their baby for the first time.
32	Woodward et al. (2014)	New Zealand	Longitudinal cohort study	133 mothers	Level-III	Parental role alteration is the most stressful NICU-related factor for mothers. Higher NICU-related maternal stress was linked to poorer child outcomes at age 4 years.

Abbreviations: ICU, intensive care unit; NA, not available; NICU, neonatal intensive care unit; PPD, postpartum depression; PTSD, post-traumatic stress disorder; PTSS, post-traumatic stress symptoms; RCT, randomized controlled trial.

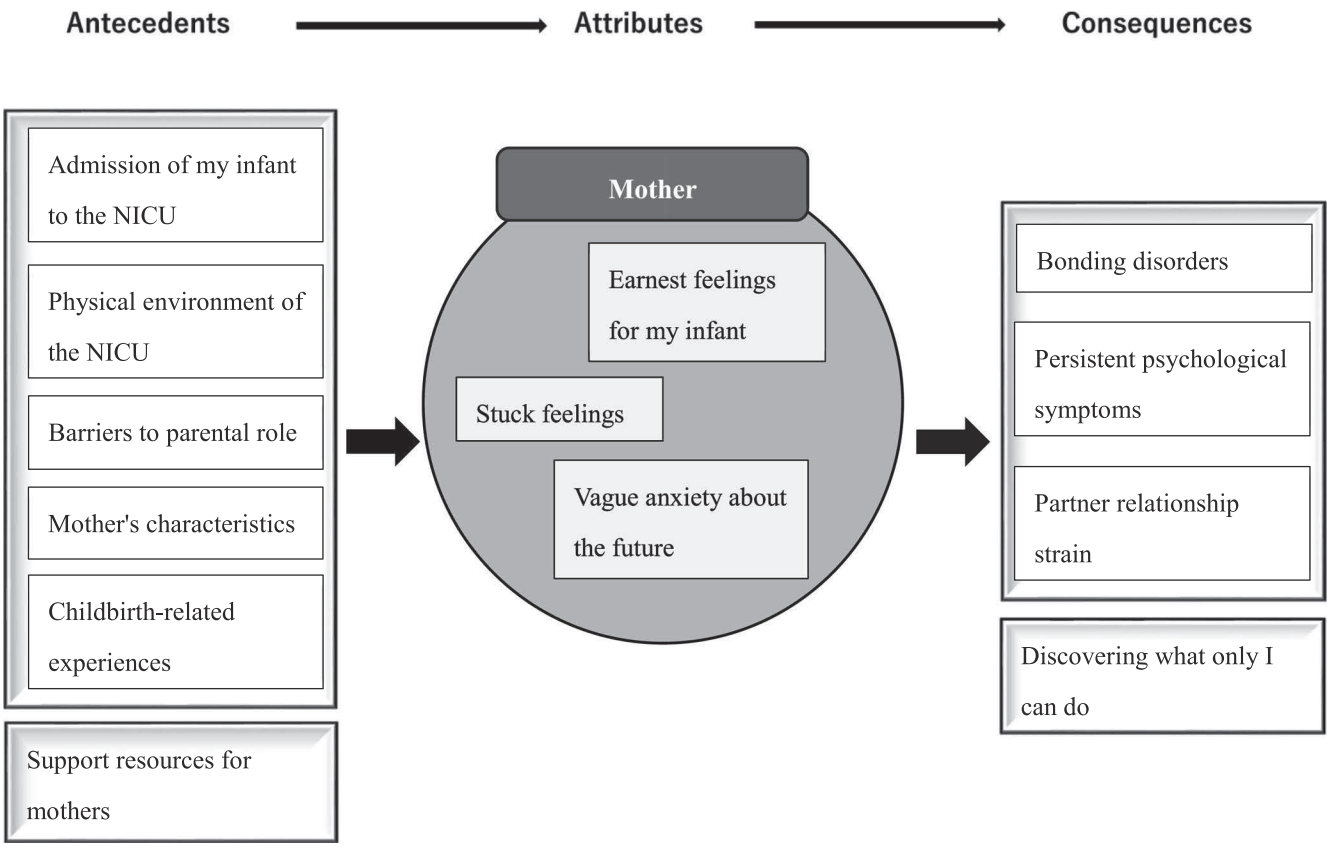


Figure 2. Conceptual model of maternal stress in the neonatal intensive care unit (NICU) (antecedents, attributes, and consequences).

and by prolonged hospitalization (Caporali et al., 2020; Hatters Friedman et al., 2013; Siva et al., 2024), which can trigger maternal stress reactions. Furthermore, it was observed that the infant's presence in the NICU itself was a stressor for the mother (Al-Akour et al., 2015; Caporali et al., 2020; Kaur et al., 2022). The "Physical environment of the NICU" encompassed the NICU environment itself, which was characterized by the presence of medical equipment and alarms (Fern'andez Medina et al., 2019; Kim et al., 2020). For example, Grieb et al. (2023) reported that the NICU environment, filled with machines and alarm sounds, heightened maternal stress. One mother described her experience by saying, "*I feel like I'm this cat ready to pounce because I'm just staring at the monitors*," illustrating the constant vigilance and tension induced by the surrounding medical equipment. The "Barriers to parental roles" were expressed as stressors, that is, situations that limited mothers' actions. Specifically, these barriers manifested as the inability to nurture their infants according to their initial expectations (Grieb et al., 2023; Holditch-Davis & Miles, 2000; Siva et al., 2024), the incapacity to relieve their infants' pain (Fro'es et al., 2020; Siva et al., 2024), and the inability to interact with their infants (Guillaume et al., 2013). The literature indicates that learning new healthcare systems and symptoms, as well as abrupt changes in lifestyle and plans, are also stressors

for mothers (Grieb et al., 2023). "Mother's characteristics," including being younger (Hatters Friedman et al., 2013; Schappin et al., 2013), less educated (Hatters Friedman et al., 2013; Holditch-Davis & Miles, 2000; Woodward et al., 2014), having psychological distress (Holditch-Davis et al., 2003; Woodward et al., 2014), and having economic constraints (Siva et al., 2024), were found to intensify mothers' stress responses. In the "Childbirth-related experiences" category, having a previous miscarriage (Holditch-Davis & Miles, 2000) or a preterm baby (Schappin et al., 2013; Siva et al., 2024), and meeting one's infant for the first time in the NICU after delivery (Nakazawa et al., 2006), were factors found to increase the mother's stress response. The final category, "Support Resources for mothers," referred to human and institutional resources supporting the mothers. This included emotional (Suzuki et al., 2016) and financial support (Siva et al., 2024) from the family and others, as well as the NICU healthcare staff (D'Souza et al., 2009; Guillaume et al., 2013; Holditch-Davis & Miles, 2000). It also encompassed community support, such as access to environments in which mothers can consult childcare professionals (Suzuki et al., 2016). A study conducted in India revealed that nursing support reduced maternal stress (D'Souza et al., 2009). Conversely, communication challenges with healthcare staff have been reported to increase maternal stress (Holditch-Davis & Miles, 2000; Lee et al., 2005). In summary, support resources act as stressors that can have both positive and negative effects on mothers' mental health.

Attributes

Three categories of attributes were identified: "Earnest feelings for my infant," "Stuck feeling," and "Vague anxiety about the future" (Table 3). The "Earnest feelings for my infant" category was defined as mothers' feelings of guilt for the preterm birth (Grieb et al., 2023; Holditch-Davis & Miles, 2000; Lee et al., 2005), being overwhelmed by having their infant in the NICU (Grieb et al., 2023; Holditch-Davis & Miles, 2000; Lee et al., 2005), and heartache (Holditch-Davis & Miles, 2000). For example, Holditch-Davis and Miles (2000) reported that some mothers expressed feelings of guilt for having given birth earlier than expected. In interviews with 13 mothers, Grieb et al. (2023) revealed that most felt guilty and overwhelmed. Furthermore, when their infants' condition deteriorated, mothers felt distant from their infants (Guillaume et al., 2013) and were traumatized by this experience (Holditch-Davis & Miles, 2000). The present findings indicate a deeply connected relationship between the infant's condition and the mother's emotions. The "Stuck feeling" category encompassed feelings of frustration due to reliance on information from the father (Guillaume et al., 2013), feelings of not knowing what to do (Grieb et al., 2023; Hatters Friedman et al., 2013; Holditch-Davis & Miles, 2000), and feelings of fear and anxiety (Hatters Friedman et al., 2013; Suzuki et al., 2016). Guillaume et al. (2013) found that a source of isolation and stress was frustration at not being able to see the baby for the first few days after birth and having to rely on the father for new information about the infant. Furthermore, mothers experienced difficulties in coping with unexpected situations (Hatters Friedman et al., 2013) and the appearance of a small and sick premature infant (Holditch-Davis & Miles, 2000). The "Vague anxiety about the future" consisted of a sense of loss of control (Grieb et al., 2023) and uncertainty (Lee et al., 2005). This implies that the mothers felt out of control with respect to their vision of the future (Grieb et al., 2023), and had concerns about the infant's illness and its impact on the future (Lee et al., 2005).

Consequences

Four categories of consequences were identified: "Bonding disorders," "Persistent psychological symptoms," "Partner relationship strain," and "Discovering what only I can do" (Table 4). These four categories represent long-term stress responses that occurred in mothers because of prolonged stress reactions. In the "Bonding disorders" category, some mothers reported difficulty developing emotional attachments with their infants after childbirth (Bonacquisti et al., 2020; Kim et al., 2020). Bonacquisti et al. (2020) reported a significant negative association between attachment and stress between mother and infant, suggesting that maternal stress negatively affects bonding with the infant. The "Persistent psychiatric symptoms" category revealed that mothers exhibited symptoms of PTSD (Aftyka et al., 2014; Aftyka et al., 2017; Hatters Friedman et al., 2013; Holditch-Davis et al., 2003; Orovou et al., 2023; Schecter et al., 2020), postpartum depression (PPD; Levinson et al., 2022; Stotts et al., 2019), and post-traumatic stress symptoms (PTSS; Shaw et al., 2009). One study reported the appearance of PTSD symptoms such as reexperiencing trauma, avoidance, negative thoughts and feelings, and arousal and reactivity in mothers of infants in the NICU (Orovou et al., 2023). Levinson et al. (2022) also found that higher stress scores in the NICU were associated with a higher rate of positive screening for PPD. Reportedly, psychological stress in the early stages of NICU admission is also a risk factor for the subsequent development of PTSS (Shaw et al., 2009).

Not only did other psychiatric symptoms such as anxiety and depression persist up to 6 months postpartum at follow-up (Lotterman et al., 2019), but mothers with high depressive and anxiety symptoms in the NICU remained in psychological distress 1 year after NICU discharge (Holditch-Davis et al., 2015). In the "Partner relationship strain" category, as stress in the NICU increased, mothers became more likely to perceive tension in their relationship with the father (Reimer et al., 2023). In the "Discovering what I can do" category, it was revealed that even in situations in which the mother's role was limited, some mothers identified and acted on what only they could do—such as delivering breast milk (Rossman et al., 2013).

Surrogate term

"Psychological distress" and "psychological burden" were used to measure maternal stress. Unlike stress, these terms focus on purely psychological aspects.

Related concept

In the 32 references analyzed, "depression" (Levinson et al., 2022) was extracted as a concept related to maternal stress. Although this concept shares some similarities with maternal stress, it is independent and can be measured using specific scales. That is, this does not share the same set of attributes to which Rodgers refers, but it is a concept related to stress.

Definition of maternal stress in the NICU

Maternal stress in the NICU is caused by various stressors surrounding the mother and can be defined as a feeling of desperation for her infant, as well as feelings of inadequacy and vague anxiety about the future due to circumstances beyond her control. Moreover, maternal stress is cumulative, characterized not only by a direct response to the stressor but also by the effects on herself and her relationship with her infant and partner caused by the persistence of the stress response.

Discussion

Characteristics of the concept

While systematic or scoping reviews integrate prior findings, they do not provide theoretical clarity. Concept analysis, in contrast, defines the essential attributes of a phenomenon. By applying concept analysis, this study not only synthesized the literature on maternal stress in the NICU but also clarified its definition, attributes, antecedents, and consequences. In the following, we discuss the characteristics of the concept revealed by this study from three perspectives.

Antecedents: Stressors

The current results indicate that the NICU environment itself is a stressor for mothers. Unlike general hospital wards, NICUs are often open spaces where healthcare staff can respond to sudden changes in the affected infant from a distance. Prior studies have indicated that the absence of private space can be emotionally exhausting due to exposure to the problems of other families, even if they are not aware of them (Bry & Wigert, 2019). Furthermore, this study identified alarms as a significant source of stress for mothers (Guillaume et al., 2013). These findings underscore the need to create an environment where mothers can relax and engage with their infants.

In the "Barriers to parental roles" category, mothers experienced stress due to limitations on what they could do for their infants. Specifically, they could not engage in the caregiving they had envisioned, such as holding, breastfeeding, and bathing their infants (Holditch-Davis & Miles, 2000), or have physical contact with their infants (Guillaume et al., 2013). Consistent with the findings of Miles et al. (1993), parents of infants admitted to the NICU commonly reported three major stressors: the infant's condition, changes in the parental role, and the environment. Among these, a meta-analysis of parental stress in the NICU reported that "changes in the parental role" were the most significant stressor for parents (Caporali et al., 2020). This study also supported these findings by showing that the inability to fulfill the parental role serves as a major stressor for mothers.

According to Lazarus and Folkman (1984), stressors can sometimes have positive effects, such as fostering personal growth and motivating coping efforts. The present study demonstrated that "Support resources for mothers" can have both positive and negative impacts. While communication gaps with healthcare professionals (Siva et al., 2024) and the behaviors of these professionals (Holditch-Davis & Miles, 2000) may cause anxiety in mothers, both physician and nurse visits to the bedside (Lee et al., 2005) and support from nurses (D'Souza et al., 2009) have been found to reduce stress levels. Previous research has reported that nursing support increases maternal empowerment (Maleki et al., 2022). Another study found a positive correlation between social support provided by nurses and mothers' satisfaction with their care (Eskandari et al., 2021), underscoring the need for health professionals to effectively address and regulate these stressors. Furthermore, factors identified beyond the "support resources for mothers" category may also buffer maternal stress. However, the 32 papers examined in this study did not describe any other factors, suggesting the need for further research to examine additional stress-reducing factors in this field.

Attributes and consequences: Stress responses

Postpartum, the maternal body experiences substantial hormonal changes. Levels of prolactin, which is responsible for milk production, and oxytocin, which is required for uterine contractions, increase. Meanwhile, levels of progesterone and estrogen, which are responsible for maintaining pregnancy, decrease (Walter et al., 2021). Evidence suggests that hormonal fluctuations during the postpartum period are associated with temporary mood changes, including maternity blues and PPD (Brummelte & Galea, 2016). Research has also indicated that postpartum women who have infants admitted to the NICU experience elevated levels of anxiety, depression, and stress compared to mothers of full-term infants (Garg et al., 2023). Moreover, these forms of psychological distress are interconnected (Staver et al., 2021), indicating that maternal stress responses are not adequately explained by a single concept. The present study found that, in addition to anxiety and depression, a wide range of emotions was experienced by mothers, including guilt, uncertainty, and frustration. A salient feature of stress responses among NICU mothers also includes the presence of psychological distress rooted in their infant's condition, such as the emotional pain of being physically separated from their infant or the trauma associated with the fear of the infant's condition further deteriorating. For mothers, their babies are irreplaceable; even when a medical course is favorable, underlying stress related to the baby's condition is always present. Previous studies have reported that maternal stress symptoms can persist from admission to two to four months postpartum (Bonacquisti et al., 2020), indicating that NICU mothers are constantly experiencing some level of stress throughout the hospitalization period. Consequently, it is important for healthcare professionals who interact with mothers daily to go beyond superficial observations and recognize the unspoken, internal emotions that mothers may be experiencing. In this regard, the present study contributes to deepening healthcare professionals' understanding of the complex emotions experienced by mothers.

Relationship with existing theoretical frameworks

The findings of the present study suggest that one stress theory, namely, that of Lazarus and Folkman (1984), can explain the stress experienced by mothers of infants in the NICU. First, the findings of the present study align with Lazarus and Folkman's (1984) theory that stressors and stress responses are dynamic processes. Here, stressors were categorized as antecedents, and stress reactions were categorized as attributes and consequences. Among these, the diverse stress responses arising from stressors differ in their mechanisms of occurrence, including stress responses directly generated by the stressor and those arising incidentally alongside it. In other words, maternal stress involves complex causality and is a dynamic process that can change over time.

Second, the current findings align with Lazarus and Folkman's (1984) theory that stressors and stress responses differ from person to person, even for the same stressor. According to Lazarus and Folkman (1984), stressors and stress responses are part of a process mediated by cognitive appraisal and coping. Therefore, even when exposed to the same stressor, the stress responses may differ, reflecting individual differences. In this study, the stress response of "discovering what only I can do" emerged as one of the identified outcomes. Some mothers who were unable to fulfill their role as parents experienced intense emotions and feelings of helplessness toward their infants, which resulted in a positive stress response to discovering what only they could do. This finding supports Lazarus and Folkman's (1984) stress theory and suggests that the same

stressor may elicit a positive stress response in some individuals. These two findings indicate that maternal stress in the unique NICU environment can be explained within the framework of Lazarus and Folkman's (1984) stress theory.

The results of this study can be explained not only by stress theory but also by applying the Aguilera and Messick crisis model (Aguilera & Messick, 1982). According to this model, balance maintenance factors are important for maintaining psychological equilibrium in the face of stressful events, and their presence or absence can lead to crisis avoidance (Aguilera & Messick, as cited in Hazle, 1982). This study's findings can be explained by applying the crisis model; the results suggest that a psychological imbalance occurs when a mother experiences the stressful event of her infant's hospitalization, which leads to a crisis. Furthermore, based on this model, social support is a balance-maintaining factor (Aguilera & Messick, 1982). That is, the support resources identified in this study correspond to social support in Aguilera and Messick's crisis model, which suggests that such support may lead to both positive and negative maternal stress reactions.

Limitations and implications for nursing

There are several limitations to this study. First, the procedure for selecting the literature needs to be considered. The literature was selected based on Rodgers' method of concept analysis. However, the initial screening was inadequate, resulting in the need to rescreen after a close reading of 45 articles (20%). The selection procedure would have been clearer and more reproducible if 223 papers had been included in the initial screening process. Second, the validity of the analysis must be considered. Although the analysis was conducted in collaboration with the second author to enhance credibility, the possibility that the interpretation was influenced by the researcher's subjectivity cannot be entirely ruled out. Third, the comprehensiveness of the literature search should be considered. The search terms, strategies, and time frame used in this study may not have fully captured all relevant research in this field. In particular, the number of articles in this area has increased since 2019, and because the literature search was conducted in September 2024, more recent studies may not have been included. Therefore, caution is required when applying these results to clinical nursing practices. As Rodgers conceptualizes phenomena as continually evolving (Rodgers & Knafl, 2000), the findings of this study should not be regarded as fixed. Future research incorporating broader and more up-to-date literature will allow for further refinement of the concept of maternal stress in the NICU.

However, the present study yielded a novel finding: among the various stressors, some have the capacity to help reduce maternal stress responses. These stress-relieving factors include "relationships with healthcare professionals" and "support resources." Nurses have a significant influence on the mothers of infants admitted to the NICU. Prior studies have demonstrated that various strategies employed by nurses, including individualized support programs and training initiatives, can effectively reduce the stress levels of mothers with infants in the NICU (Maleki et al., 2022). To enhance the effectiveness of interventions for mothers, nurses must improve their skills in assessing individual mothers' needs and providing personalized care. Although educational programs traditionally focused on maternal stress as an outcome, there is a growing need to develop educational programs that measure NICU nurses' assessment of individual mothers and their care skills as program outcomes.

Furthermore, family stress is one of the inhibitors of FCC (Abukari & Schmollgruber, 2024). Therefore, the development of an assessment tool for stressors experienced by mothers based on the findings of this study will allow for more accurate assessment and intervention to promote FCC in the NICU. The Parental Stressor Scale: Neonatal Intensive Care Unit (PSS: NICU), developed by Miles et al. (1993), is a well-known tool for assessing maternal stressors. However, further research is needed to investigate the relationship between such scales and FCC. In today's society, understanding mothers' stress is essential to ensuring timely access to appropriate support when needed.

The findings of this study reinforce the relevance of existing programs, particularly Family Integrated Care (FICare), an evidence-based and practical model grounded in the principles of FCC (Waddington et al., 2021). FICare is designed to support parents as primary caregivers by encouraging their active participation in the NICU, with healthcare providers acting as mentors and facilitators (Waddington et al., 2021). One of the maternal stress responses identified in this study—"Discovering what only I can do"—reflects a mother's attempt to find meaningful ways to fulfill her role despite the stress of the NICU environment. This response aligns directly with the core philosophy of FICare, which emphasizes empowering parents to participate in their infants' care. Moreover, FICare addresses a key stressor identified in this study—"Barriers to the parental role"—by facilitating opportunities for parents to engage in caregiving tasks and decision making. In summary, the primary contribution of this study is to provide evidence to support the promotion of FICare in NICUs.

Conclusions

Based on a concept analysis of maternal stress in the NICU, six antecedents, three attributes, and four consequences were identified. It was revealed that mothers in the NICU experience deep emotional attachment to their infants while also feeling helpless in situations beyond their control, and harbor vague anxieties about the future. Moreover, "Support resources for mothers" may positively influence mothers' psychological well-being. Additionally, the consequence of "Discovering what only I can do" indicated that some mothers, despite experiencing stress, demonstrated a forward-looking attitude. These findings imply that the NICU environment is not only a source of stress for mothers but can also function as a supportive space and an opportunity for them to reflect on their role as mothers.

Author Contributions

Mitsuki Nojima designed the study and collected data. Mitsuki Nojima analyzed data and wrote the paper. Hisayo Okayama critically reviewed the manuscript and supervised the entire process. All authors read and approved the final manuscript.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest.

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