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Using Sensor Technology to Support Lactation for Parents and Breastfeeding Babies

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Lurie Children's Hospital, Division of Neonatology

BEST CHILDREN'S HOSPITALS U.S.News RANKED IN 11 SPECIALTIES 2024-2025

MAGNET RECOGNIZED AMERICAN NURSES CREDENTIALING CENTER

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Disclosures

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Scientific Advisory Board/Consultant/Board of Directors	Baxter (ended)
Speakers Bureau	Baxter (ended)
Stock Shareholder	None
Employee	None
Other	None

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Team: cross-discipline collaboration

Jennifer Wicks, MD
Instructor of Pediatrics

Craig Garfield, MD
Professor of Pediatrics

Dr. Jihye Kim
Ajou University

John Rogers, PhD
Louis Simpson and Kimberley Querrey Professor
Department of Materials Science and Engineering
McCormick School of Engineering

Northwestern University Feinberg School of Medicine
Lurie Children's Hospital, Division of Hospital-Based Medicine

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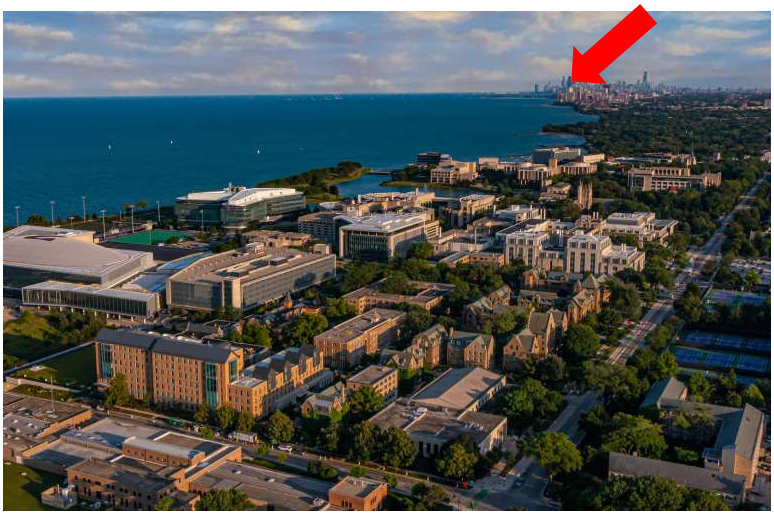
Campus context: Northwestern University



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Clinical context

- Prentice Women's Hospital
  - ~12,000 annual deliveries
  - Level III NICU, 80 beds
- Lurie Children's Hospital
  - Level IV NICU, 64 beds
- Breastfeeding/pumping initiation rates >90%

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Clinical experiences directly informed this idea

- Repeated experience
  - Numerous infants/families impacted
- During clinical rounds
- Lack of objective information
  - Family centered rounds
- Preterm infant (extremely, moderately, late preterm) in the NICU
  - Prescribed feeding amount q3
  - Some feedings by mouth, some by nasogastric tube
  - Mother/parent starting to feed at breast
  - NICU nurse asks how to manage volumes for these feedings
- Decisions impact feeding progression

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Objectives

1. Explain situations where measurement of milk transfer could be of value
2. Describe benefits and risks of using an external sensor to determine milk transfer during breastfeeding
3. Review process of sensor development and next steps

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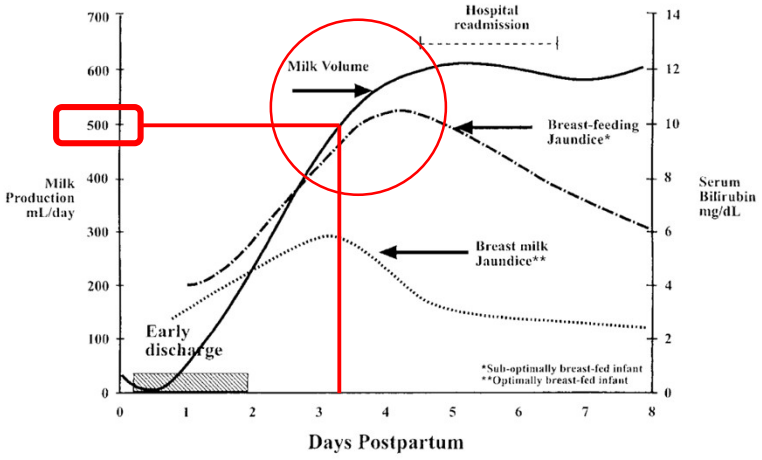
Intersection of breastfeeding progress and infant risk: jaundice as an example



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Radamacher et al. J Perinatol 2002

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Revisiting statements with changes to clinical practice

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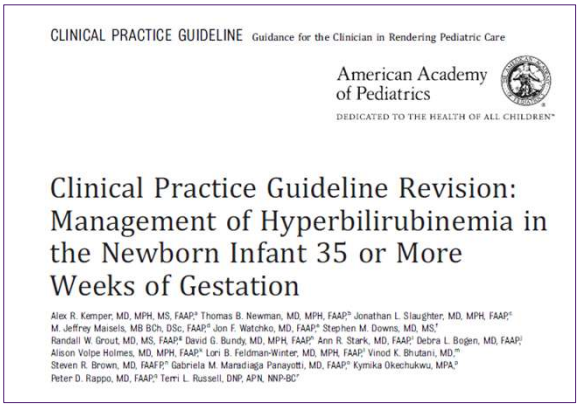

CLINICAL PRACTICE GUIDELINE Guidance for the Clinician in Rendering Pediatric Care

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™

Clinical Practice Guideline Revision: Management of Hyperbilirubinemia in the Newborn Infant 35 or More Weeks of Gestation

Alex R. Kemper, MD, MPH, MS, FAAP,[a] Thomas B. Newman, MD, MPH, FAAP,[b] Jonathan L. Slaughter, MD, MPH, FAAP,[c] M. Jeffrey Maisels, MB BCh, DSc, FAAP,[d] Jon F. Watchko, MD, FAAP,[e] Stephen M. Downs, MD, MS,[f] Randall W. Grout, MD, MS, FAAP,[g] David G. Bundy, MD, MPH, FAAP,[h] Ann R. Stark, MD, FAAP,[i] Debra L. Bogen, MD, FAAP,[j] Alison Volpe Holmes, MD, MPH, FAAP,[k] Lori B. Feldman-Winter, MD, MPH, FAAP,[l] Vinod K. Bhutani, MD,[m] Steven R. Brown, MD, FAAFP,[n] Gabriela M. Maradiaga Panayotti, MD, FAAP,[o] Kymika Okechukwu, MPA,[p] Peter D. Rappo, MD, FAAP,[q] Terri L. Russell, DNP, APN, NNP-BC[r]

PEDIATRICS Volume 150, number 3, September 2022

"This article updates and replaces the 2004 American Academy of Pediatrics clinical practice guideline…"

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Circumstances specific to preterm infant feedings: additional uncertainty

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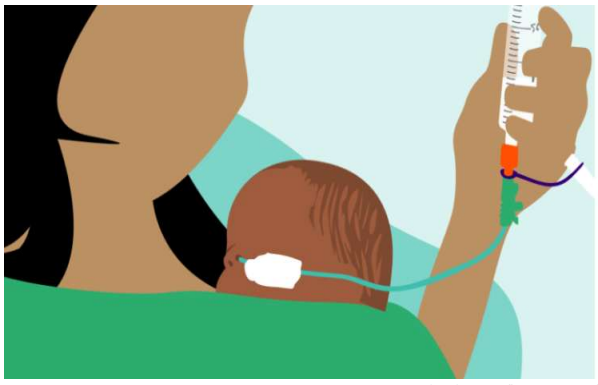
- Initial dependence on tube feedings for preterm infants
- As infants develop and mature, transition to breastfeeding occurs
  - Current methods to assess intake during this transition phase are cumbersome
  - Uncertainty regarding the milk volume an infant takes
  - Stress for parents and hospital staff
    - Fathers, coparents



www.futurelearn.com (last access 3.2023)

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Amaizu N et al. Acta Paediatr 2008; Sihota et al. Am J Mens Health 2019

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Breast milk exposure by gestational age category

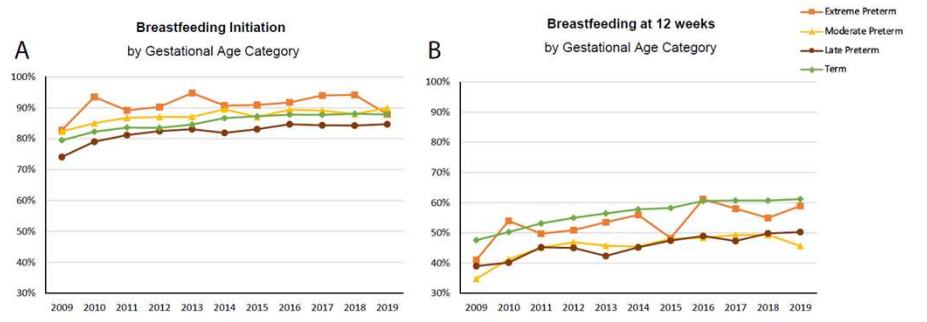

Figure. Rates of US breastfeeding **A,** initiation and **B,** continuation at 12 weeks from 2009 to 2019 by gestational age category. Breastfeeding initiation among mothers with MPT, LPT, and term infants increased significantly over time ($P < .001$), as did breastfeeding at 12 weeks among all gestational age categories ($P < .001$).

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Kalluri NS et al. J Pediatr 2025

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Addressing uncertainty: perception of insufficient milk

- Perception of insufficient milk is a common cause of breastfeeding cessation
- Reasons for stopping breastfeeding within the first month:
  - United States: "I didn't have enough milk": 51.7%
- Systematic review of risk factors for self-reported insufficient milk
  - 79 studies from high income countries; 30 from upper-middle-income; 10 from low-middle-income
  - Key message: "Intervention studies specifically designed to reduce the risk of [self reported insufficient milk supply] are urgently needed in low- and middle-income countries."
    - Discharge of preterm, low birth weight infants may occur before feeding certainty established

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Li Pediatrics 2008; Segura-Perez Maternal & Child Nutrition 2022

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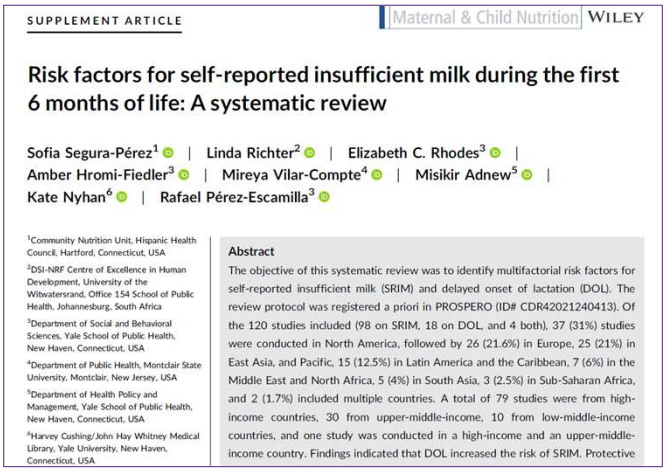
Addressing self-reported insufficient milk volume



SUPPLEMENT ARTICLE

Maternal & Child Nutrition WILEY

Risk factors for self-reported insufficient milk during the first 6 months of life: A systematic review

Sofia Segura-Pérez[1] | Linda Richter[2] | Elizabeth C. Rhodes[3] | Amber Hromi-Fiedler[3] | Mireya Vilar-Compte[4] | Misikir Adnew[5] | Kate Nyhan[6] | Rafael Pérez-Escamilla[3]

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[3]Department of Social and Behavioral Sciences, Yale School of Public Health, New Haven, Connecticut, USA
[4]Department of Public Health, Montclair State University, Montclair, New Jersey, USA
[5]Department of Health Policy and Management, Yale School of Public Health, New Haven, Connecticut, USA
[6]Harvey Cushing/John Hay Whitney Medical Library, Yale University, New Haven, Connecticut, USA

Abstract

The objective of this systematic review was to identify multifactorial risk factors for self-reported insufficient milk (SRIM) and delayed onset of lactation (DOL). The review protocol was registered a priori in PROSPERO (ID# CDR42021240413). Of the 120 studies included (98 on SRIM, 18 on DOL, and 4 both), 37 (31%) studies were conducted in North America, followed by 26 (21.6%) in Europe, 25 (21%) in East Asia, and Pacific, 15 (12.5%) in Latin America and the Caribbean, 7 (6%) in the Middle East and North Africa, 5 (4%) in South Asia, 3 (2.5%) in Sub-Saharan Africa, and 2 (1.7%) included multiple countries. A total of 79 studies were from high-income countries, 30 from upper-middle-income, 10 from low-middle-income countries, and one study was conducted in a high-income and an upper-middle-income country. Findings indicated that DOL increased the risk of SRIM. Protective

2022

- Focused on LMIC
  - Most data from high income countries
- To address this concern: "…use objective measures of breast milk volume and quality."

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Opportunities for sensor technology to improve lactation/breastfeeding outcomes

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- Reduce uncertainty in milk volumes that infants get during breastfeeding
- Ease of wireless sensor facilitates utilization
- Facilitate:
  - Management of specialized medical circumstances including prematurity
    - Feeding pathology independent of etiology
  - Achieving global public health goals for breastfeeding

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The beginning

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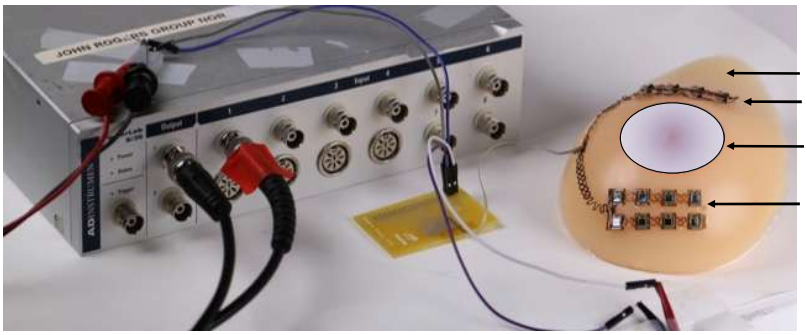
Starting with a wired version



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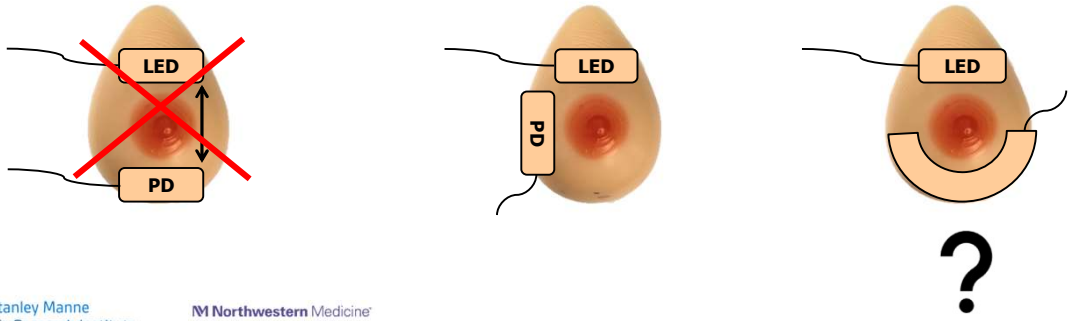
Photodetector: determining optimal position and shape

- Testing with non-pregnant individual
- Signal quality low when placed opposed
- Improved with device position at 90°



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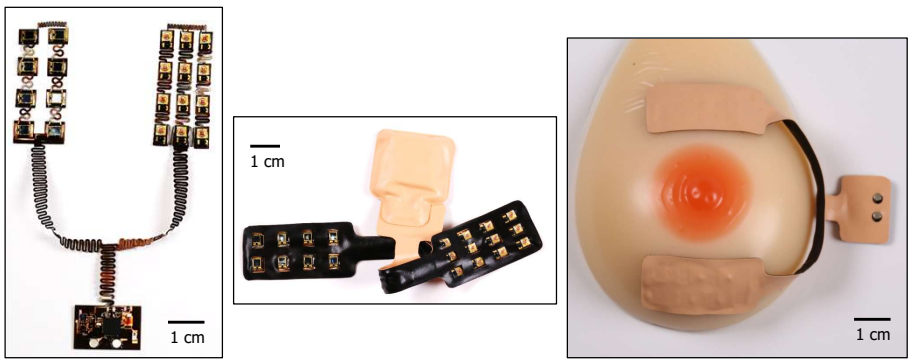
Moving towards wireless



- Soft, comfortable, stretchable
- Powered by an external battery
  - 500 mAh battery: estimated >12 h battery life
  - Electrically and magnetically coupled via magnets
  - Working device

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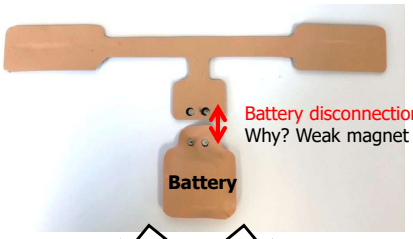
Each part requires consideration



Battery disconnection issue
Why? Weak magnet connection & Heavy battery

- **Solution 1 : Board to Board Connectors**
  → Easy to change PCB board
  → Detachable design

- **Solution 2 : Integration by soldering**
  → Bulky device
  → Hard to change PCB board
  (Add NFC and On/Off switch)
  → NFC charging efficiency issue
  (26 hours charging time
  to fully charge the 500mAh battery)

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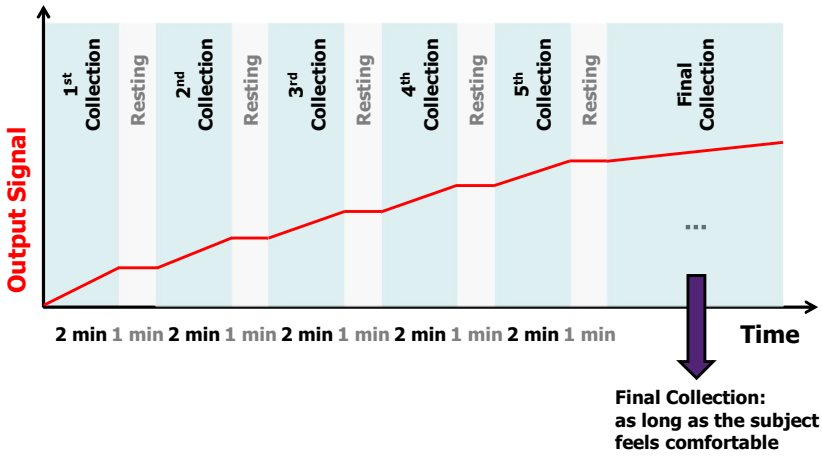
Planning clinical testing: mapping out first 15 min



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Moving forward with bioimpedance

nature biomedical engineering

Article

https://doi.org/10.1038/s41551-025-01393-w

A compact, wireless system for continuous monitoring of breast milk expressed during breastfeeding

Received: 20 May 2024

Accepted: 7 April 2025

Published online: 14 May 2025

Check for updates

Jihye Kim[1,2,16], Seyong Oh[3,4,16], Raudel Avila[5,16], Hee-Sup Shin[3,6], Matthew Banet[7], Jennifer Wicks[8,9], Anthony R. Banks[3], Yonggang Huang[3,10,11,12], Jae-Young Yoo[13], Daniel T. Robinson[8,9], Craig F. Garfield[8,9] & John A. Rogers[3,12,13,14,15]

Human milk is the ideal source of nutrition for infants. Most health organizations recommend direct breastfeeding from the first hour of life, extending throughout the first and second year. However, uncertainties regarding the volumes of milk ingested by the infant contribute to suboptimal rates of breastfeeding. Here we introduce a compact and unobtrusive device that gently interfaces to the breast via four electrodes and accurately

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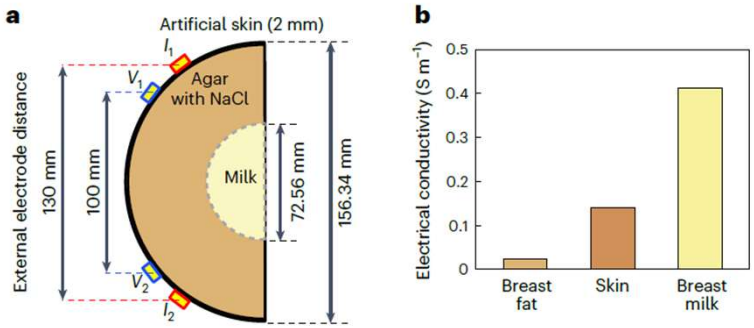
Pre-clinical testing at the bench: Mock system to generate compartments



Kim et al. nature biomedical engineering. 2025

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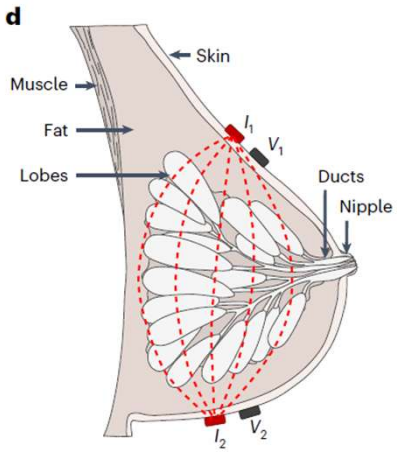
Planning ahead: schematic of future testing



Kim et al. nature biomedical engineering. 2025

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Characteristics of participants

	n=12 Median	25th, 75th %ile	Range
Age, years	34	32, 38	28-42
Parity	2.5	1, 3	1-3
Gestational age at delivery, completed weeks	32.5	31, 34	27-39
Pre-pregnancy BMI, kg/m^2	22.75	22.1, 24.8	20.9-31
Infant birth weight, grams	1785*	1430, 2080	680-3033
	n (%)		
Primiparous	5 (41.7)		
Multiple gestation	3 (25)		
***n=15**			

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Characteristics of participants

	Median	25th, 75th %ile	Range
Infant age at testing, d*	20.5	15, 24	11-57
Postpartum hour of first milk expression, h	3	1, 8	0-18
	N (%)		
Current use of medication for production	3 (25)		
Method of first expression			
Infant feeding	3 (25)		
Pump	7 (58.3)		
Hand	2 (16.7)		
Current primary method of milk expression			
Exclusive pumping	7 (58.3)		
Pumping and breastfeeding	4 (33.3)		
Breastfeeding	1 (8.3)		
***n=2 not recorded**			

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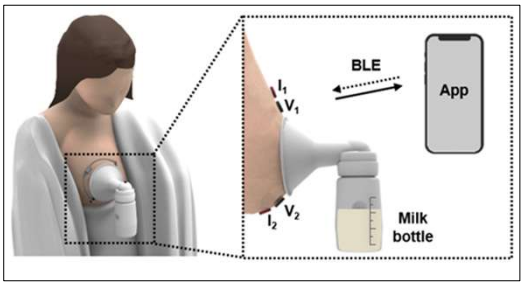
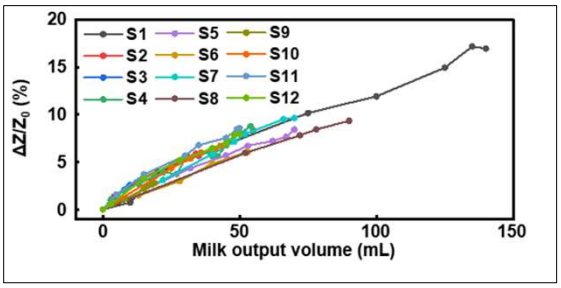
Testing during pumping allows volume measurement





- Key results: Mean milk output volume recorded versus inferred from the bioimpedance system differed by 0.1±4.9mL
- No adverse skin reactions, monitored through 24 hours post-testing

Kim et al. nature biomedical engineering. 2025

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Future directions

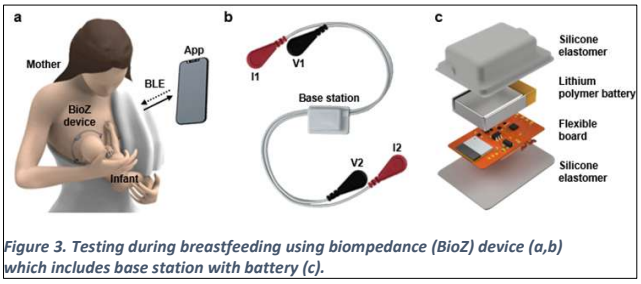

Figure 3. Testing during breastfeeding using biompedance (BioZ) device (a,b) which includes base station with battery (c).

- How do parents feel about this technology?
- How do clinicians feel about this technology?
- How do we as investigators and creators remain confident in this technology?

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Next steps in progress: Preliminary bench testing for a sensor upgrade

- Four-electrodes somewhat limited
  - Specific positioning required
- Ideally allow flexibility for user
- Increasing number of sensors may allow flexibility
- Phantom breast can mock scenarios

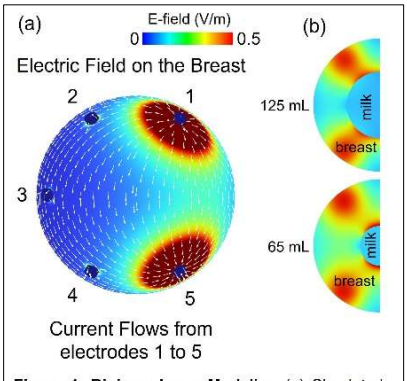

Figure 1. Bioimpedance Modeling (a) Simulated electric field distribution in the breast for proposed 5-electrode design. (b) Cross-sectional surface plots show electric field distribution as milk decreases from 125mL→65mL.

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Additional considerations to enhance sensor

- Testing during pumping provided high quality data…during pumping
- Testing during pumping not sufficient
- Considerations for feeding at the breast:
  - Infant movement
  - Maternal movement
  - Holding position

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Acknowledging concerns: "Will this add stress?"

- Objective measures can reduce uncertainty
- Data utilization and interpretation should not fall entirely on the parents

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Future direction: low burden, easily accessible, objective information

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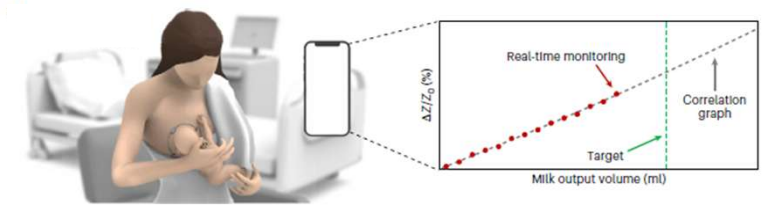

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Thank you!

Please reach out: dtrobinson@luriechildrens.org

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