Patient Safety Learning Laboratory to Enhance the Value and Safety of Neonatal Interfacility Transfers in a Regional Care Network

Rachel A. Umoren, MBBCh, MS
Megan Gray, MD
Taylor Sawyer, DO, MEd, MBA
Zeenia Billimoria, MD
Robert Digeronimo, MD
Prashanth Rajivan, PhD
Thomas Furness, III, PhD
Jocelyn Ludlow, RN, MSN, PhD
Matthew Cook, MS
John Feltner, MS

University of Washington, Seattle, Washington

September 6, 2019-August 31, 2023

Denise Burgess

This project was supported by the Agency for Healthcare Research and Quality.
R18 HS027259

A. Structured Abstract

Purpose: The purpose of this project was to optimize clinical workflow and transport communications systems to enhance the value and safety of neonatal transport in a multi-state regional network.

Scope: Every year, thousands of newborns are transferred by specialized pediatric transport teams from one healthcare facility to another to receive specialty care. This project focused on improving neonatal patient safety through addressing three critical elements of neonatal transport that are inter-related in clinical settings, with the first aim addressing clinical workflow processes; the second aim, the transport environment; and the third aim, real-time safety issue tracking.

Methods: A five-stage innovation cycle—problem analysis, design, development, implementation, and evaluation—was used to identify and address the salient issues and risks of regional neonatal transportation. Methods included observations, surveys, interviews, design workshops, discrete event simulation modeling, usability testing, and clinical simulations.

Results: The results of the project described neonatal transport trends and outcomes, including the parent experience; evaluated neonatal transport workflow; developed a neonatal transport discrete event simulation model; and evaluated novel tools for improving transport monitoring, communication, and safety documentation using simulation methods.

Key Words: neonatal, transport, simulation, safety, monitoring, communication, documentation, risk, workflow

B. Purpose

The objective of this proposal was to co-design, with neonatal transport stakeholders, optimal clinical workflow and transport communications systems to enhance the value and safety of neonatal transport in a multi-state regional network. We hypothesized that optimizing clinical workflow, facilitating transport team communication, and tracking patient safety data on transport will lead to fewer safety lapses in simulated transports. To accomplish this, we proposed the following three specific aims:

Specific Aim 1: Co-design clinical workflow processes to optimize regional neonatal consultation, triage, and transport.

Specific Aim 2: Engineer a novel transport monitoring and communications system to improve information flow within the transport environment.

Specific Aim 3: Develop a system for timely and accurate online tracking of patient safety data during neonatal transport.

C. Scope

1. Background

As many as 350,000 children and 68,000 critically ill newborns are transported each year by specialized transport teams to facilities with the capacity to deliver higher levels of intensive care (1,2). The outcomes of children improve when they are transported by specialty pediatric transport teams rather than basic emergency medical services (3). Preterm birth is the largest contributor to infant mortality in the U.S., with over 380,000 premature babies born each year (4). The problem of prematurity accounts for an estimated $26 billion annually in avoidable medical and societal costs (5). Term infants may also be diagnosed at birth with congenital malformations, requiring urgent referral to specialists. To transfer these infants to health facilities with higher levels of care, referring providers call on specially trained neonatal transport teams, capable of performing a wide variety of interventions and procedures, including mechanical ventilator support, high-frequency oscillation, administration of nitric oxide, passive cooling, and even extracorporeal membrane oxygenation (ECMO) on transport.

Though essential and often lifesaving, medical transports carry significant risk for safety-related adverse events that may range from delays in therapy, loss of intravenous access to increased cardiopulmonary support, or even cardiopulmonary arrest (6). The complexity of patient care and the number of professionals involved on neonatal transports increase the risk of medical error, as do human factors such as fatigue, distractions, time pressures, and workload (7,8).

Team communication is particularly important to patient safety during procedural interventions like neonatal intubation, which has a high reported rate of adverse events (9-11). In settings where team members are not co-located, good teamwork and communication skills are even more essential to avoid gaps in care (12-15).

Most neonatal transport communication is through phone calls between the referring provider, the transport team, and the medical control physician at the receiving facility. However, there is emerging evidence that video calls improve neonatal care and outcomes (16-18). Unfortunately, the devices that are commercially available for telemedicine are derived from use cases in outpatient clinical settings and are not purpose-built for critical care services or transport (19). In simulation studies, telemedicine influenced the perceived stability of neonates during transport, with significant differences in ratings of stability and confidence in medical control physician diagnosis and recommendations compared to telephone calls (20). Telemedicine improves the quality of post-resuscitation monitoring (17,21) for pediatric critical care in underserved communities and supports decision making for triage (22,23). However, the use of conventional telemedicine carts and devices in pediatric transport is limited due to their size and reliance on internet connectivity (24). Furthermore, current systems do not provide information on team proximity to the referring and receiving facilities and on current patient status, both of which the medical control physicians need to safely triage and oversee care (25).

2. Context: The University of Washington and Seattle Children's hospitals receive pediatric referrals from a geographic region of a size that is one fourth the landmass of the U.S. and includes the states of Washington, Alaska, Montana, and Idaho (WAMI). The NEST Patient Safety Learning Laboratory to Improve the Safety and Value of Interfacility Neonatal Transports (Neonatal Transport PSLL) was established in 2019 to advance patient safety and high-value care for critically ill newborns (0-28 days of life) during medical ground or air transport from one hospital to another within a regional network in the Pacific Northwest.

3. Setting: This region features large urban centers and wide expanses of rural and remote areas.

4. Participants: The Neonatal Transport PSLL has provided research and study opportunities for 15 faculty in engineering, economics, neonatology, and epidemiology; three postdoctoral fellows (n=1 engineering, 1 medicine, 1 epidemiology); five graduate students in engineering (n=1), public health (n=1), and medicine (n=3); 17 engineering undergraduate students; two undergraduate pre-med and public health students; and one undergraduate economics major student. Transport stakeholders included transport team members, referring and receiving hospital physicians and advanced practice providers, charge nurses, administrators, and parents/caregivers.

D. Methods

1. Study Design

The project used a five-stage innovation cycle—problem analysis, design, development, implementation, and evaluation—to identify and address the salient issues and risks of regional neonatal transportation. Methodologies that were used included practical, benchmarked, risk-adjusted estimates of the quality of neonatal transport, clinical workflow process evaluation through the Lean quality improvement approach, and agile methodologies for development.

The problem analysis for Aims 1-3 involved assessment of current workflow and processes, transport records, facilities, resources, and clinical settings at referral and receiving facilities to develop a complete understanding of transport system issues.

The research team gathered and analyzed data obtained from focus groups and interviews with the transport team and other stakeholders regarding pain points. The transport team, referring providers, and medical control physicians participated in design workshops to sketch a hypothetical ideal system for transport decision making, communication, and documentation based on the identified goals.

Flow diagramming and storyboarding techniques were used to create a diagram of how, when, and where patients move across the five-state WWAMI region following consultation or referral to Seattle Children's Hospital.

We used this process to develop a simulation model of regional transport events including patient, provider, and environmental variables using Simio™ discrete event modeling software and to identify the key elements of an ideal transport monitoring and communications system, including communication, monitoring, and safety documentation.

Simulation lab-based and in situ simulations were used to evaluate the impact of transport monitoring and communication tools.

2. Data Sources/Collection

We reviewed data on:

- Transport team factors: team and mode of transport, transport time (arrival on scene, departure, arrival at receiving facility), and procedures performed.
- Transport call logs were used to elicit call patterns and durations of referral calls, and neonatal transport data were used to identify transportation routes and task time distributions.
- Patient factors: age, weight, gestation, vital signs (temperature, heart rate, respiratory rate), primary diagnosis (known at transport), severity of illness, hypotension (blood pressure, use of vasopressors, volume administration, establishment of arterial access), acidosis (pH, base deficit, volume resuscitation, bicarbonate or acetate administration), and respiratory failure (oxygen saturation, partial pressures of oxygen and carbon dioxide, mode of respiratory support, type of artificial airway).
- Patient outcomes: length of stay (total hospital days, intensive care unit days, ventilator days), mortality (transport, 12-hour, 7-day, overall).
- Transport team procedures and guidelines, including current decision support tools and current pre/post-procedural communication with medical control physicians.

3. Interventions

Simulations included a wide range of providers, including neonatologists, neonatal fellows, pediatric hospitalists at referring facilities, and neonatal nurse practitioners. In situ simulations were conducted in the transport area to test under realistic conditions.

4. Measures

During in situ clinical simulations, we measured situational awareness of simulated patient vital signs and trends and knowledge of patient and team location for both the medical control physician and transport team members. NASA-TLX was used for workload assessment

5. Limitations

Access to health facilities for observations was limited by the COVID-19 pandemic restrictions.

Comprehensive Hospital Abstract Reporting System (CHARS) data were not available due to Washington State Department of Health resources being directed to the COVID-19 pandemic.

E. Results

1. Principal Findings

a. Neonatal transport trends and outcomes: In our review of local transport data from 1,989 neonatal patients, we found a significant trend toward increased use of noninvasive respiratory support on transport from 7% in 2014 to 22% in 2019 (RR 1.26 per year, 95% CI 1.17-1.35, p<0.001) and a decrease in invasive respiratory support from 38% to 31%, with no significant changes in birth weight over time (p>0.6) (26). On review of the outcomes of neonatal transports, the median length of stay was 7 days (range 0-398), with 20% (n=380) of patients discharged home within 2 days. Trends toward increased discharge to home (RR 1.45 per year, 95% CI 1.37-1.54, p<0.001) and decreased discharge within the first 2 days of admission (RR 0.86 per year, 95% CI 0.82-0.91, p<0.001) were noted, but deaths occurring at <2 days remained unchanged (27). Length of stay was greater in referrals from level III-IV NICUs than from level I-II NICUs (median: 8 vs. 5 days, p<0.001) (27). A wide range of medications was found to be utilized during neonatal transport (28). A systemic review on neonatal transport risks and adverse safety event reporting was conducted (29).

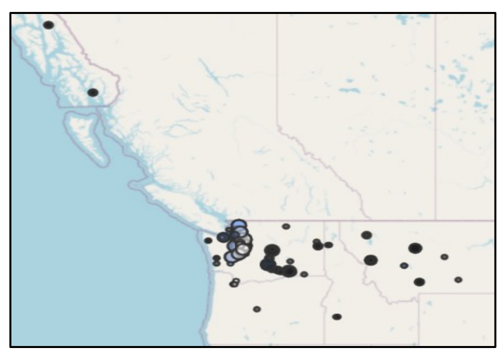
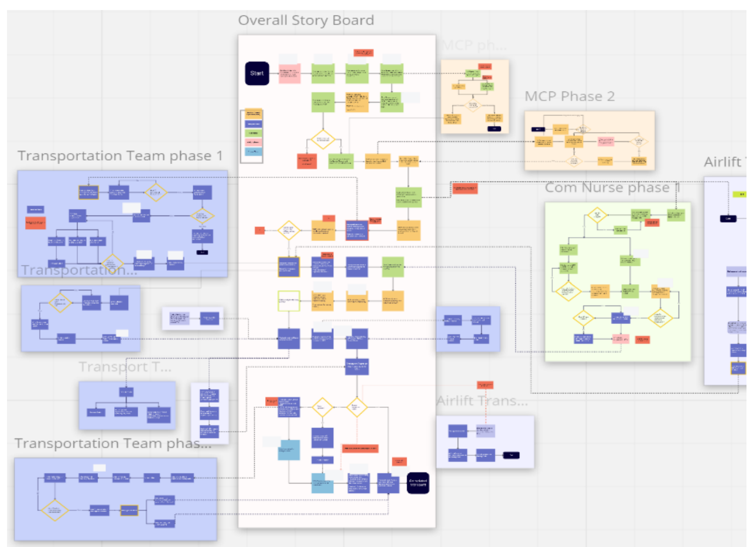


Figure 1. *Air and ground transports to Seattle Children's Hospital from facilities in the Pacific Northwest Region. (The size of the point is proportional to the number of transports. Lighter colors indicate fewer air transports and darker indicates more air transports.)*

b. Parent surveys and interviews. From December 2020 to August 2022, parents of recently transported neonates who were admitted to the University of Washington received surveys on their experience and preferences for communication around transport. Of the 57 parents who responded (response rate 62%), 34 (77%) identified as mothers and 10 (23%) identified as fathers. Parents reported a wide range of race, ethnicity, education, and income levels. More than half of neonatal transports (57%) occurred under 1 day of age, leading to early separation from their parent (27).The majority (n=36, 78%) felt that their child was moderately to extremely sick at the time of transport. In many cases (n=22, 47%) parents were notified before their child was born that, based on their child's prenatal diagnosis, they would be transported to another facility. About a quarter (n=11, 23%) of respondents were notified less than 1 hour before their newborn was transported. Parents sometimes, but not always, received information such as driving directions (n=35, 78%), parking information (n=25, 56%), contact information (n=32, 71%), sleep accommodations (n=30, 68%), parent support services (n=32, 71%), and visitor restrictions (n=34, 76%) from the transport team. Distance from home to the receiving facility varied, with 60% of families living at least 30-60 minutes from the receiving hospital and 23% living more than 2 hours away (driving distance with average traffic). The majority (n=27, 90%) of parents wanted an update on their child's status during transport (94% by text, 79% by phone, 30% by video call). Most (n=31, 86%) would like to participate in telemedicine related to their child's care, and only four (11%) were concerned about technology or privacy issues (as reported by McKissic D, et al., in 2022). Finally, this project is significant because it will support vulnerable patients and families. In our cohort, 35% were referred from zip codes with high health transportation shortage index (HTSI) scores, indicating limited or no public transit available. Nearly all patients came from communities with higher than national average rates of homes without internet (<95%), and 14% from communities with school districts that have poverty rates over the national median (31).

c. Neonatal transport workflow: In total, 85 interviews with healthcare team members in various roles (neonatologist medical control physician (MCP), referring pediatric hospitalist or neonatal advanced practice provider, receiving neonatologist, communications center staff, transport team, charge nurses, and social workers) on the neonatal transport workflow process were conducted. These interviews explored current workflow processes and identified communication and patient monitoring challenges during neonatal transport (25). The results of these interviews and observations led to the creation of a storyboard of the transport process and a communication network diagram (Figure 2). Using these data and insights, the research team used the Simio™ modeling software to develop a discrete event simulation (DES) model of the neonatal transport.

***Figure 2**: The Neonatal Transport Process Is Complex*



d. Neonatal transport discrete event simulation model: The neonatal transport model is based on discrete-event simulation (DES) that comprises a communication sub-model and transportation sub-model, as shown in Figure 3. The model also includes several referring and receiving facilities in the Pacific Northwest region, represented as capacity (beds and clinicians)-constrained resources with cost. Workflows associated with transportation were modeled based on insights from the interviews conducted with healthcare professionals involved in neonate transportation and through iterative evaluations using subject matter experts in the team. The communication sub-model to represent the information exchange that happens between several roles (e.g., MCP, charge nurses, referring pediatric hospitalists) prior to transportation was modeled by analyzing the telephone logs preserved at Seattle Children's. The communication was modeled as a probabilistic task sequence, in which each sequence represents a probable telephone exchange between two roles. For each referral, the model triggers both the communication sequence and transportation workflows. Inputs to the model are discrete-time stochastic processes derived through standard input modeling procedures using communication logs and neonatal transport data (32).

Multiple simulation experiments were conducted to investigate the effects of patient attributes, bed capacity, communication process, and ambulance resource allocation on bedside wait times and total transportation time. For example, the Independent Variables were the arrival rate (transport referral, direct) of the receiving hospital, NICU capacity (Number of beds available), and ambulance resource distribution; the Response Variables were wait time (time from first call to pick up at bedside), transport time (time from first call to drop-off at Seattle Children's Hospital), and communication time (total communication time before transportation).

Experiments used a run time of 12 months with a warm-up period of 90 days. The warm-up period to account for initialization bias was determined using Welch's sliding window procedure (33). Each scenario was replicated 30 times. The model was expanded to include two ambulance hubs in the North (Everett) and South (Renton) models. The baseline model was validated against historical transport data from September 2020 to June 2021. The results demonstrated that the arrival rate was close to theoretical approximations, with the higher call volume resulting in longer patient wait time and longer transport time.

Figure 3: Neonatal Transport Discrete Event Simulation Model

e. Improving Transport Monitoring, Communication and Safety Documentation: The Engineering and Medical teams undertook a literature review and product research on existing communication and remote monitoring tools, the feasibility of transmission of vital signs (ground and air transport), and the availability of network access. Vital sign trajectories for term and premature infants and rates of abnormal vital signs and lab values for infants with hypoxic ischemic encephalopathy were examined (34,35). A 90-minute technology review session featuring cutting-edge technologies was conducted with transport stakeholders, followed by surveys on their perspectives of adapting new technologies and systems into neonatal transport. The findings showed that, although communication technologies remained high scoring amongst providers with all experience levels and roles, the perceived usefulness rating for other technologies increased with decreasing years of experience (25). Three in situ healthcare simulations were developed, featuring neonatal patients being transported from UW Medical Center to Seattle Children's Hospital. Results of these simulations demonstrated better situational awareness of patients' vital signs and trends as well as the location of the baby during transport with the use of a transport monitoring and communication tool.

2. Outcomes

In addition to the enhanced understanding of the neonatal transport process and workflows, during our PSLL, there has been adoption of clinical telemedicine at referring sites, with four level II community facilities initiating telerounding and/or teleresuscitation services from 2019 to 2022 and growing interest in teletransport options.

The Neonatal Transport DES model was used to strategically evaluate the impact of ambulance location and neonatal bed availability in Seattle Children's Hospital, and results were communicated to clinical leadership.

3. Discussion

Local transport data from 2014 to 2019 was utilized by our Neonatal Transport Patient Safety Learning Laboratory (PSLL) to explore trends and outcomes of neonatal transports for newborns (0-28 days) from lower to higher levels of care in the Pacific Northwest region. Of the 1,989 acute neonatal transports identified, 495 (26%) were air transports. Air transport was more common from rural level I facilities (72% air vs. 28% ground) and out-of-state level III-IV facilities. Though some newborns were transported as young as 23 weeks gestational age, the median gestational age of transported newborns was 38 weeks gestation. More than half of newborns had respiratory failure (58%) along with congenital heart disease or surgical, neurologic, or infectious disease problems. Up to one third of newborns required conventional or high-frequency ventilation for respiratory support (26). In our cohort, 35% were referred from zip codes with high health transportation shortage index (HTSI) scores, indicating limited or no public transit available. Nearly all patients came from communities with higher than national average rates of homes without internet (<95%), and 14% were from communities with school districts that have poverty rates over the national median.

Transport decisions are highly complex. The patient diagnosis, condition (measured by illness severity scores such as Transport Risk Index of Physiologic Stability, version II (TRIPS II) for neonates (36), and Transport Risk Assessment in Pediatrics (TRAP) for older children (37) must be considered. In addition, traffic, weather, geography, transport team location and staffing, receiving facility capabilities, bed availability, and staffing must be factored in. Our review of neonatal transports from 2014 to 2019 revealed that they originated from over 150 healthcare facilities, making it nearly impossible for an individual MCP to be familiar with all facility characteristics. Topography influenced transport mode due to water bodies or mountain ranges making air transport more likely west or east of the Seattle area (27).

Many adverse events are rooted in inefficiencies associated with communication, prioritization, assessment of urgency, appropriateness of transfer, and selection of equipment. Krennerich et al. described greater efficiency through a centralized hospital communication center (38). However, the use of conventional telemedicine carts and devices in pediatric transport is limited due to their size and reliance on internet connectivity (24). Furthermore, current systems do not provide information on team proximity to the referring and receiving facilities and current patient status that medical control physicians need to safely triage and oversee care (25). We evaluated approaches to address these gaps by presenting timely information to MCPs and transport teams in order to support communication and safety monitoring of critically ill newborns.

Although it is feasible to provide transport communication, monitoring, and documentation to track safety issues in real time, the complexity of the transport process clinical workflows may benefit from decision support via a digital twin model of the pediatric transport process. Though previous discrete event simulation (DES) models were developed using historical data and allowed for evaluation of potential changes in workflow conditions, such as location of the transport team based on the transport times, the proposed model is innovative because it will utilize real-time data on critical factors influencing decision making and workflow on transports, including staffing, bed availability at receiving and referring hospitals in a regional network, regional weather, and prevailing traffic patterns, to support MCPs and transport teams.

4. Conclusions

Upon successful completion of this project, we have identified and modeled the current and ideal states for neonatal interfacility transfers in a regional network and developed new protocols and systems, including a novel approach to monitoring and communication on neonatal transport to support the clinical workflow of the transport team.

5. Significance

This contribution is significant because adverse events occur in up to 70% of pediatric critical care ambulance transports, even if performed by a highly trained team (39-41). Ground and air transport environments need to contain many of the same things as an intensive care unit room but in a considerably smaller space. Transport personnel must be able to reach necessary equipment, see monitors, and access their patients in the incubator, all while keeping themselves safely restrained. Human factors are the root cause of 67% of avoidable adverse events on transport, with most adverse events occurring due to communication errors and equipment problems (42). Medical control physicians (MCPs) are remotely located and respond by phone to referral calls, updates, and questions from the transport team. The MCP is responsible for triage, identifying a receiving facility, and providing care recommendations to transport teams. Inaccurate or incomplete information shared between the sending facility, transport team, medical control physician, and receiving facility is associated with one third of all identified adverse events (43). Finally, this project is significant because it will support vulnerable patients and families. More than half of neonatal transports (57%) occurred under 1 day of age, leading to early separation from their parent (27). When patients live in remote, rural and/or underserved communities, it is important to support the patient and their family before, during, and after transport.

6. Implications

This project has the potential to significantly influence the field of pediatric transport by addressing the problems of incomplete or inaccurate information shared between care providers at sending and receiving facilities, the transport team, and the medical control physician that affects triage and transport decision making. The new approaches proposed will promote the delivery of the right care, at the right price, in the right setting, from the right provider and support the development of customizable transport system models that other programs can apply to their own transport situations, including pediatric and adult Emergency Medical Services (EMS) transports.

F. List of Publications and Products

1. Patel S CM, Feltner J, Rajivan P, Nguyen L, Slater G, Le D, Umoren RA. Health Professional Perspectives on Communication and Monitoring During Interfacility Neonatal Transport Paper presented at: Agency for Healthcare Research and Quality PSLL Abstract Session 2022; Virtual.
2. Umoren RA GM, Billimoria ZC, Hippe DS, Feltner J, Baker C, Stiffler AK, Patel S, Afenir D, Cook MW, Ludlow J, Furness TA, Strandjord TP, DiGeronimo R, Sawyer TL. Trends in respiratory support for neonatal interfacility transports in the Pacific Northwest. Paper presented at: Pediatric Academic Societies2021; Virtual.
3. Umoren RA GM, Billimoria ZC, Hippe DS, Feltner J, Baker C, Stiffler AK, Patel S, Afenir D, Cook MW, Ludlow J, Furness TA, Strandjord TP, DiGeronimo R, Sawyer TL. Trends and outcomes of neonatal transports to a Level IV Neonatal Intensive Care Unit in the Pacific Northwest. Paper presented at: Pediatric Academic Societies 2021; Virtual.
4. McKissic D, Billimoria, Z, Mastroianni, R, Riley, ST, Umoren, R, Gray, MM. Intra-Transport Medication Use by a Regional Neonatal Transport Service. Paper presented at: American Academy of Pediatrics National Conference and Exhibition2022; Anaheim, CA.
5. McKissic D, Castera, M, Weiss, E, Shearlock, A, Feltner, J, Patel, S, Umoren, R. Perspectives on the Neonatal Interfacility Transport Experience and the Use of Technology During Transport. American Academy of Pediatrics National Conference and Exhibition; 2022; Anaheim, CA.
6. Yam T, Li, Lun, Kim, YeEun, Feltner, John, Cook, Matt, Umoren, Rachel, Rajivan, Prashanth. Improving Neonatal Transportation Process through Simulation. Paper presented at: INFORMS2021.
7. McKissic D RS, Mietzsch U, German K, Jha M, White C, Umoren R, Gray MM. Rates of Peri-Transport Abnormal Vital Signs and Laboratory Values for Infants with Hypoxic Ischemic Encephalopathy. Paper presented at: American Academy of Pediatrics National Conference and Exhibition 2022; Anaheim, CA.
8. Greene ND, Riley T, Mastroianni R, et al. Neonatal Vital Sign Trajectories and Risk Factors During Transport Within a Regional Care Network. Air Medical Journal. 2022;41(6):542-548.
9. Gray MM, Riley T, Greene ND, Mastroianni R, McLean C, Umoren RA, Tiwari A, Mahankali A, Billimoria ZC. Neonatal Transport Safety Metrics and Adverse Event Reporting: A Systematic Review. Air Medical Journal. 2023 May 25. PMID: 37356892
10. Cook MW, Patel S, Umoren R, Feltner J, Nguyen L, Slater G, Le D, Rajivan P. Health Professional Perspectives on Communication and Monitoring During Interfacility Neonatal Transport. Proceedings of the Human Factors and Ergonomics Society Annual Meeting 2023.0(0). https://doi.org/10.1177/21695067231192605
11. Riley T, Umoren R, Kotler A, Feltner J, Billimoria Z, James J, Mahankali A, White C, Brajkovic I, Gray MM. Disparities in access to healthcare services in a regional neonatal transport network. International Journal of Industrial Ergonomics. 2024 Jan 1;99:103526.

G. References

1. Karlsen KA, Trautman M, Price-Douglas W, Smith S. National survey of neonatal transport teams in the United States. Pediatrics. 2011;128(4):685.
2. França UL, McManus ML. Trends in regionalization of hospital care for common pediatric conditions. Pediatrics. 2018;141(1).
3. Shinozaki RM, Schwingshackl A, Srivastava N, Grogan T, Kelly RB. Pediatric interfacility transport effects on mortality and length of stay. World Journal of Pediatrics. 2021;17(4):400-8.
4. Martin JA, Hamilton BE, Osterman MJK. Births in the United States, 2016. NCHS data brief. 2017(287):1.
5. Russell RB, Green NS, Steiner CA, Meikle S, Howse JL, Poschman K, et al. Cost of hospitalization for preterm and low birth weight infants in the United States. Pediatrics. 2007;120(1):e1.
6. Faine BA, Noack JM, Wong T, Messerly JT, Ahmed A, Fuller BM, et al. Interhospital Transfer Delays Appropriate Treatment for Patients With Severe Sepsis and Septic Shock: A Retrospective Cohort Study. Critical care medicine. 2015;43(12):2589.

7. Leonard M, Graham S, Bonacum D. The human factor: the critical importance of effective teamwork and communication in providing safe care. Quality and Safety in Health Care. 2004;13(suppl 1):i85.
8. Hatch LD, Grubb PH, Lea AS, Walsh WF, Markham MH, Whitney GM, et al. Endotracheal Intubation in Neonates: A Prospective Study of Adverse Safety Events in 162 Infants. The Journal of Pediatrics. 2016;168:62-6.e6.
9. Foglia EE, Ades A, Napolitano N, Leffelman J, Nadkarni V, Nishisaki A. Factors Associated with Adverse Events during Tracheal Intubation in the NICU. Neonatology. 2015;108(1):23-9.
10. Sawyer T, Foglia E, Hatch LD, Moussa A, Ades A, Johnston L, et al. Improving neonatal intubation safety: A journey of a thousand miles. Journal of Neonatal-Perinatal Medicine. 2017;10(2):125-31.
11. Klotz JJ, Dooley-Hash SL, House JB, Andreatta PB. Pediatric and neonatal intubation training gap analysis: instruction, assessment, and technology. Simulation in healthcare : journal of the Society for Simulation in Healthcare. 2014;9(6):377.
12. Sweigart LI, Umoren RA, Scott PJ, Carlton KH, Jones JA, Truman B, et al. Virtual TeamSTEPPS(®) Simulations Produce Teamwork Attitude Changes Among Health Professions Students. The Journal of nursing education. 2016;55(1):31.
13. Umoren RA, Poore JA, Sweigart L, Rybas N, Gossett E, Johnson M, et al. TeamSTEPPS Virtual Teams: Interactive Virtual Team Training and Practice for Health Professional Learners. Creative nursing. 2017;23(3):184.
14. Umoren RA, Scott PJ, Sweigart L, Gossett E, Hodson-Carlton K, Johnson M, et al. A comparison of teamwork attitude changes with virtual TeamSTEPPS® simulations in health professional students. Journal of Interprofessional Education & Practice. 2018;10:51-5.
15. Umoren R, Stadler DJ, Gasior SL, Al-Sheikhly D, Truman B, Lowe C. Global collaboration and team-building through 3D virtual environments. Innovations in Global Medical and Health Education. 2014;2014(1):1.
16. Fang JL, Collura CA, Johnson RV, Asay GF, Carey WA, Derleth DP, et al. Emergency Video Telemedicine Consultation for Newborn Resuscitations: The Mayo Clinic Experience: The Mayo Clinic Experience. Mayo Clin Proc. 2016;91(12):1735-43.
17. Scheans P, McElwain L. Telemedicine for neonatal resuscitation. Journal of Obstetric, Gynecologic, & Neonatal Nursing. 2015;44(s1):S23-S.
18. Curfman A, Markham C, Groenendyk J, Turmelle M, Quayle K, Tieken B, et al. Implementation of Telemedicine in Pediatric Patient Transport. Journal of Pediatrics2018. p. 724.
19. Beck JA, Jensen JA, Putzier RF, Stubert LA, Stuart KD, Mohammed H, et al. Developing a Newborn Resuscitation Telemedicine Program: A Comparison of Two Technologies. Telemed J E Health. 2017.
20. Umoren RA, Gray MM, Schooley N, Billimoria Z, Smith KM, Sawyer TL. Effect of video-based telemedicine on transport management of simulated newborns. Air medical journal. 2018;37(5):317-20.
21. Fang JL, Collura CA, Johnson RV, Asay GF, Carey WA, Derleth DP, et al., editors. Emergency video telemedicine consultation for newborn resuscitations: the Mayo Clinic experience. Mayo Clinic Proceedings; 2016: Elsevier.
22. Marcin JP, Ellis J, Mawis R, Nagrampa E, Nesbitt TS, Dimand RJ. Using telemedicine to provide pediatric subspecialty care to children with special health care needs in an underserved rural community. Pediatrics. 2004;113(1):1-6.
23. Marcin JP, Nesbitt TS, Kallas HJ, Struve SN, Traugott CA, Dimand RJ. Use of telemedicine to provide pediatric critical care inpatient consultations to underserved rural Northern California. J Pediatr. 2004;144(3):375-80.
24. Beck JA, Jensen JA, Putzier RF, Stubert LA, Stuart KD, Mohammed H, et al. Developing a newborn resuscitation telemedicine program: a comparison of two technologies. Telemedicine and e-Health. 2018;24(7):481-8.
25. Patel S CM, Feltner J, Rajivan P, Nguyen L, Slater G, Le D, Umoren RA, editor Health Professional Perspectives on Communication and Monitoring During Interfacility Neonatal Transport Agency for Healthcare Research and Quality PSLL Abstract Session; 2022; Virtual.

26. Umoren RA GM, Billimoria ZC, Hippe DS, Feltner J, Baker C, Stiffler AK, Patel S, Afenir D, Cook MW, Ludlow J, Furness TA, Strandjord TP, DiGeronimo R, Sawyer TL., editor Trends in respiratory support for neonatal interfacility transports in the Pacific Northwest. Pediatric Academic Societies; 2021; Virtual.
27. Umoren RA GM, Billimoria ZC, Hippe DS, Feltner J, Baker C, Stiffler AK, Patel S, Afenir D, Cook MW, Ludlow J, Furness TA, Strandjord TP, DiGeronimo R, Sawyer TL., editor Trends and outcomes of neonatal transports to a Level IV Neonatal Intensive Care Unit in the Pacific Northwest. Pediatric Academic Societies; 2021; Virtual.
28. McKissic D, Billimoria, Z, Mastroianni, R, Riley, ST, Umoren, R, Gray, MM, editor Intra-Transport Medication Use by a Regional Neonatal Transport Service. American Academy of Pediatrics National Conference and Exhibition; 2022; Anaheim, CA.
29. Gray MM, Riley T, Greene ND, Mastroianni R, McLean C, Umoren RA, et al. Neonatal Transport Safety Metrics and Adverse Event Reporting: A Systematic Review. Air Med J. 2023.
30. McKissic D, Castera, M, Weiss, E, Shearlock, A, Feltner, J, Patel, S, Umoren, R. Perspectives on the Neonatal Interfacility Transport Experience and the Use of Technology During Transport. American Academy of Pediatrics National Conference and Exhibition; Anaheim, CA2022.
31. Riley T, Umoren R, Kotler A, Feltner J, Billimoria Z, James J, et al. Disparities in access to healthcare services in a regional neonatal transport network. International Journal of Industrial Ergonomics. 2024;99:103526.
32. Yam T, Li, Lun, Kim, YeEun, Feltner, John, Cook, Matt, Umoren, Rachel, Rajivan, Prashanth, editor Improving Neonatal Transportation Process through Simulation. INFORMS; 2021.
33. Law AK, W.D, Kelton, W.D. Simulation Modelling and Analysis. New York: McGraw-Hill; 2007.
34. McKissic D RS, Mietzsch U, German K, Jha M, White C, Umoren R, Gray MM., editor Rates of Peri-Transport Abnormal Vital Signs and Laboratory Values for Infants with Hypoxic Ischemic Encephalopathy. American Academy of Pediatrics National Conference and Exhibition; 2022; Anaheim, CA.
35. Greene ND, Riley T, Mastroianni R, Billimoria ZC, Enquobahrie DA, Baker C, et al. Neonatal Vital Sign Trajectories and Risk Factors During Transport Within a Regional Care Network. Air Medical Journal. 2022;41(6):542-8.
36. Lee SK, Aziz K, Dunn M, Clarke M, Kovacs L, Ojah C, et al. Transport Risk Index of Physiologic Stability, version II (TRIPS-II): a simple and practical neonatal illness severity score. American journal of perinatology. 2013;30(05):395-400.
37. Schmidt CD, Thompson AN, Welsh SS, Simas D, Carreiro P, Rozenfeld RA. Pediatric Transport–Specific Illness Severity Scores Predict Clinical Deterioration of Transported Patients. Pediatric Emergency Care. 2022;38(8):e1449-e53.
38. Krennerich EC, Graf JM, Shekerdemian LS, D’Ambrosio D, McPherson ML. Enhanced Efficiency in Pediatric Interfacility Transport Through a Centralized Hospital System Communication Center. Pediatric Critical Care Medicine. 2022;23(9):e408-e15.
39. Meckler G, Hansen M, Lambert W, O'Brien K, Dickinson C, Dickinson K, et al. Out-of-hospital pediatric patient safety events: results of the CSI chart review. Prehospital Emergency Care. 2018;22(3):290-9.
40. Edge WE, Kanter RK, Weigle C, Walsh RF. Reduction of morbidity in interhospital transport by specialized pediatric staff. Critical care medicine. 1994;22(7):1186-91.
41. Lim MTC, Ratnavel N. A prospective review of adverse events during interhospital transfers of neonates by a dedicated neonatal transfer service. Pediatric Critical Care Medicine. 2008;9(3):289-93.
42. Lim MTC, Ratnavel N. A prospective review of adverse events during interhospital transfers of neonates by a dedicated neonatal transfer service. Pediatric critical care medicine : a journal of the Society of Critical Care Medicine and the World Federation of Pediatric Intensive and Critical Care Societies. 2008;9(3):289.
43. MacDonald RD, Banks BA, Morrison M. Epidemiology of adverse events in air medical transport. Academic emergency medicine. 2008;15(10):923-31.