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Featured Article

Evaluation of an In-Situ Neonatal Resuscitation Simulation Program Using the New World Kirkpatrick Model

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adrenaline

Abstract

Background: The impact of an ongoing in-situ interprofessional neonatal resuscitation simulation program (NeoSim) on participants' perception of its usefulness and resuscitation outcomes in clinical practice was assessed.

Method: A mixed methods approach was undertaken. Content analysis using the New World Kirkpatrick Model was undertaken on survey-based feedback responses post-NeoSim workshop attendance between 2012 and 2018. Clinical outcomes were compared between two epochs: 2007-2011 (pre-NeoSim) and 2012-2018 (post-NeoSim).

Results: Professional development, communication, and teamwork were the key learning outcomes identified. NeoSim was associated with a decrease in deaths, need for suction, intermittent positive pressure ventilation, intubation, chest compressions, and adrenaline use during resuscitation at birth.

Conclusions: NeoSim was associated with perceived improvements in practitioner behavioral skills and a decrease in need for resuscitation at birth, supporting its ongoing role in clinical practice.

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Authors' Contributions: M.B. collated and analyzed the data and wrote the first draft of the article. A.W., A.S., and A.M. are the core NeoSim workshop facilitators, who helped run the workshops and helped with data collection. A.M. and A.K. designed the evaluation study and helped in data analysis, and A.M. is the guarantor of the data in the study. All authors approved the final draft of the article.

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Background

Approximately 300,000 babies are born in Australia every year (Australian Bureau of Statistics, 2018). Although most babies initiate spontaneous breathing effortlessly within the first 15-30 seconds of birth, up to 15% require some form of resuscitation (Australian and New Zealand Committee on Resuscitation, 2018). Being prepared for emergencies is the first step in delivering effective care. Trained clinicians are expected to be available and perform neonatal resuscitation if needed at birth, even if there are no anticipated problems.

Key Points

- Interprofessional in-situ neonatal resuscitation simulation training was associated with improved clinical resuscitation outcomes for neonates.
- Medical and nursing staff reported that the NeoSim program contributed to ongoing improvements in their teamwork, communication, and professional development.
- In-situ neonatal resuscitation simulation was thought to be a realistic experience and found useful in clinical practice by health care staff.

Neonatal resuscitation simulation (NRS) training is now a standardized form of neonatal resuscitation education in Australia and many other countries (NeoResus, 2017). Simulation-based training is an important tool for health professionals to improve resuscitation scores and decrease time to achieve resuscitation steps, thereby protecting patients from unforeseen risks (Rakshasbhuvankar & Patole, 2014). The setting of NRS training is important. In-situ simulation occurs in the actual clinical environment (Patterson, Blike, & Nadkarni, 2008), whereas off-site simulation involves workshops outside the patient care unit (Walker et al., 2013). We have previously shown that in-situ simulation provided a more realistic environment compared with off-site simulation training through a focused group interview, but we had not investigated quantitative clinical neonatal outcomes post—NRS training (Kosanam, Stewart, Wallace, & Malhotra, 2018).

NRS training has been shown to improve practitioner confidence (Bruno et al., 2016; Mileder, Urlesberger, Szyld, Roehr, & Schmolzer, 2014; Rakshasbhuvankar & Patole, 2014) and knowledge (Bruno et al., 2016; Jabir, Doglioni, Fadhil, Zanardo, & Trevisanuto, 2009), with trainees feeling a high level of satisfaction (Halamek et al., 2000) and improving their technical skills and resuscitation performance ability (Bruno et al., 2016; Rubio-Gurung et al., 2014; Sawyer et al., 2011).

Literature suggests that NRS training may also improve clinical outcomes (Bruno et al., 2016; Cepeda Brito et al., 2017), particularly early neonatal death (Pammi, Dempsey, Ryan, & Barrington, 2016). However, information on neonatal clinical outcomes post—NRS training is limited and requires further investigation (Mileder et al., 2014; Rubio-Gurung et al., 2014).

Theoretical Framework

The primary aim of this study was to qualitatively evaluate the effectiveness of an in-situ model of NRS training, its impact on participant learning, and their perception of NRS in an interprofessional setting. This was done through the use of the New World Kirkpatrick Model (NWKM) and the performance of a content analysis of postintervention survey responses. The secondary aim was to evaluate the impact of in-situ NRS training on clinical neonatal outcomes through statistical analysis of neonatal death and the use of resuscitation measures.

Methods

Setting

Monash Newborn in Monash Children's Hospital (MCH), Clayton, is a busy tertiary level neonatal unit in Melbourne, Australia, which caters to approximately 9,000 births across three hospital sites, with around 1,500 admissions. NeoSim is Monash Newborn's in-situ NRS program, which has been running since late 2011. Medical and nursing staff are invited to attend these simulation workshops, which are conducted around 10-12 times a year, occurring during double-staff shift times.

The NeoSim Program

NeoSim is an interprofessional NRS program, consisting of workshops focused on neonatal resuscitation. Participants (usually three to four medical, three to four nursing per session) practice technical and teamwork skills needed to respond to a neonatal resuscitation emergency. The workshop includes online prereading of the neonatal guidelines from the Australian Resuscitation Council (Liley, Mildenhall, & Morley, 2017), an ice-breaker activity, introduction to crisis resource management, familiarization of the Sim NewB manikin (Laerdal, Stavanger, Norway), and other equipment. There are two neonatal resuscitation emergency scenarios with debrief after each scenario. The scenarios are based on common neonatal resuscitation emergencies where further help would usually be needed, and doctors and nurses would be required to work together. The sessions are run by two to three facilitators (neonatologist, neonatal nurse, sim center staff), one of whom acts as a midwife confederate. Participants who are not involved in

Table 1 Breakdown of Questions in the Paper-Based Evaluation Form

Five-Point Likert Scale				
1 Strongly disagree	2 Disagree	3 Neither agree nor disagree	4 Agree	5 Strongly agree
Likert style questions				
Question 1	The opportunity to practice clinical skills and participate in the resuscitation of a newborn infant, as part of an interdisciplinary group, was a valuable learning experience?			
Question 2	The opportunity to debrief with my colleagues was beneficial?			
Question 3	The debrief discussion exposed me to issues I had not considered before?			
Question 4	The facilitators were engaging?			
Question 5	It was useful to participate in a simulation session within my own clinical environment?			
Free text questions				
Question 6	What did you like most about participating in the session?			
Question 7	What aspect(s) of the session do you consider have influenced your management of newborn resuscitation?			
Question 8	What did you like least about participating in the session?			
Question 9	Any further comments?			

the scenario observe either in the same room or through live streaming facilities in MCH Simulation Centre.

Questionnaires

Between 2012 and 2018, inclusive feedback was collected after every session using a paper-based evaluation form. This consisted of five questions to be answered using a five-point Likert scale, three questions with free text responses, and one section for further comments (Table 1).

Feedback responses from participants were collated by year. Likert scale data were compiled and analyzed using numerical statistics. Free text responses were subjected to qualitative content analysis, undertaken independently and inductively by the lead author (M.B.) and an experienced simulation educator and clinician (A.K.) to identify key categories. M.B. was a final year medical student, and A.K. was an expert qualitative researcher, neither had any role in running NeoSim. After establishing consensus, all data were recoded. Some categories overlapped, but statements were counted only once. Discrepancies were negotiated, enabling final attribution of text within only one category leading to final themes.

The NWKM

The final qualitative and quantitative data were analyzed and reported using the NWKM (Figure 1) (Kirkpatrick & Kirkpatrick, 2019). The original Kirkpatrick Model comprised four levels: reaction, learning, behavior, and results. It gained popularity, as it involved asking simple questions, could be applied in many contexts, and resulted in easily measurable outcomes (Kirkpatrick & Kirkpatrick, 2007, 2009). The NWKM, on the other hand, enhances these four levels.

Level 1 in the NWKM looks at engagement and relevance of training alongside participant satisfaction. Level 2 includes an assessment of participant confidence and commitment in addition to knowledge, skills, and attitudes. It adds required drivers to Level 3, and finally,

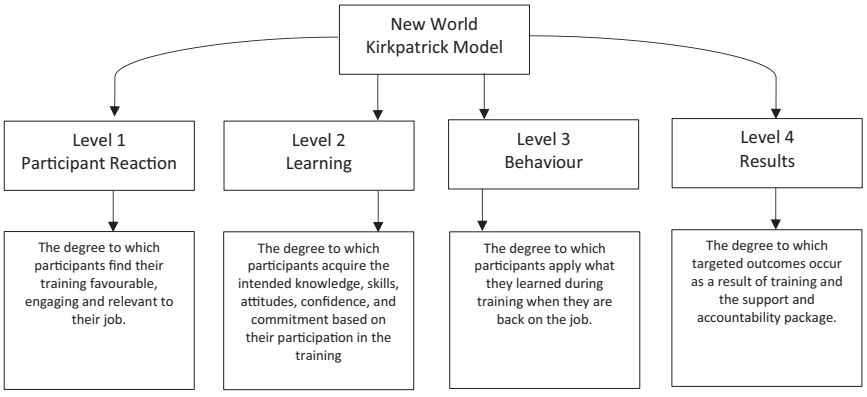

Figure 1 The New World Kirkpatrick Model.

leading indicators are included for Level 4 outcomes. Leading indicators are short-term observations and measurements that suggest that critical behaviors are on track to create a positive impact on a desired result. We have observed and measured participant attitudes and skills and their impact on neonatal deaths and need for resuscitation.

Multiple different types of data were used as data sources in each level of the model for our analysis. In Levels 1-3, free text responses subjected to content analysis were used alongside Likert scale data to evaluate participant reaction. In Level 4, clinical outcome data were integrated into the analysis.

Rationale for Using the NWKM

Criticism of the original four-level Kirkpatrick's framework has been that it focuses only on the outcome and not the process (Yardley & Dornan, 2012). If the focus is not on "how" outcomes are achieved, research could miss the strategic influences a program has on a learner's approach. On the other hand, the NWKM is targeted more toward individuals, team behaviors, and processes and is more applicable to the real-world setting (Kirkpatrick & Kirkpatrick, 2019). It follows a top-down approach, where the focus is on achieving results and implementing the program to align with achievable goals.

This framework resonates with our methodology where we are evaluating patient outcomes to establish what works (or does not) in the NeoSim program to achieve clinical targets. Our study also assessed the impact on confidence, attitude, and commitment that was perceived after attending the workshop, which is highlighted in Level 2 of the NWKM.

Clinical Outcome Measures

Data on clinical outcomes were extracted from the hospital's maternity Birthing Outcome Summary database. Data from 2007 to 2018 were obtained for all inborn babies who needed resuscitation at birth. Neonatal resuscitation features evaluated included Apgar scores at one and five minutes, neonatal death (at the time of resuscitation), need for suction, intermittent positive pressure ventilation chest compressions, continuous positive airway pressure (CPAP), intubation, and adrenaline. The collected data were then divided into two epochs: pre-NeoSim (2007-2011) and post-NeoSim (2012-2018) for analysis.

Statistical Analysis

Categorical or continuous numerical data are presented as n (percentage) or mean (standard deviation), respectively. Outcomes were compiled on a yearly and all years combined level. Analysis of variance was conducted to compare outcomes between the years. Pre- and post-NeoSim data were analyzed using *t*-tests for continuous data and chi-squared testing for categorical data. Statistical significance was determined at $p < .05$.

Results

The NeoSim workshops were evaluated over a 7-year period (2012-2018). Over this time, 445 participants attended, including medical (n = 216) and nursing (n = 229) staff. Three hundred and sixteen (71.0%) participants completed the post-test evaluation. There were 129 missing or incomplete evaluations, which were excluded. Participation of both medical and nursing staff was high in 2012, consistent between 2013 and 2016, dropping off in 2017-2018. The drop in 2017-2018 was likely because of a decline in the number of workshops held after the neonatal unit moved to the new MCH.

Content analysis of textual data was based on 316 participants who made 1,017 comments. The most frequently cited comments related to professional development (n = 402). This was followed by the realistic nature of NeoSim training (n = 229), communication (n = 225), and teamwork (n = 161).

Participant Reaction (Level 1 NWKM)

Participants found the NeoSim training program to be a realistic representation of their clinical practice (n = 229). Realism was cited in relation to the simulation environment (n = 163) or the clinical scenarios (n = 66) presented (Figure 2). The safe and controlled nature of the simulation environment was appreciated (n = 44).

On average, participants enjoyed the opportunity to practice clinical skills and participate in the resuscitation of a newborn infant in an interdisciplinary environment, finding it to be a valuable experience (mean 4.87/5). The opportunity to debrief with colleagues was highly valued (4.80/5) and resulted in exposure to issues that had not been considered before (4.52/5). Facilitators were thought to be engaging (4.79/5), and participants found it useful to participate in a simulation session within their own clinical environment (4.80/5). Thus, there was strong positive participant reaction (average Likert scale scores of more than 4.5/5 for all questions), with no major variation in the quality of responses through the 7-year period (Table 2).

Learning Acquired From NeoSim Training (Level 2 NWKM)

The major learnings acquired from the NeoSim training program are outlined in Table 3, and the themes from the content analysis are described below. The most common theme was professional development (n = 402), followed

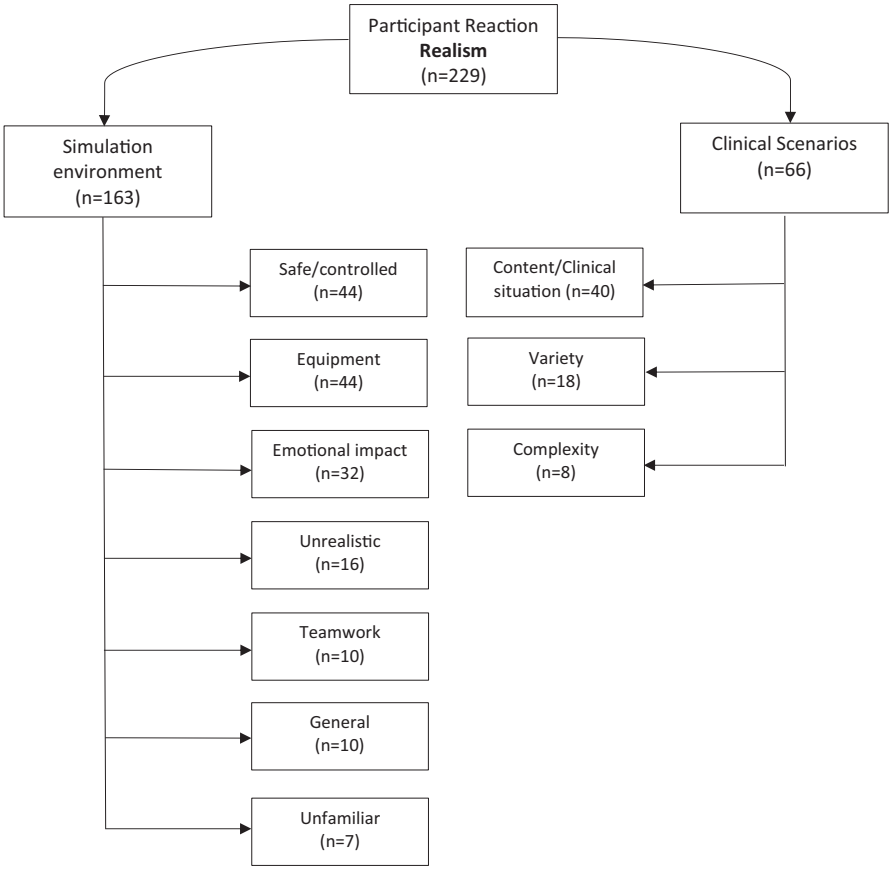

Figure 2 Participant reaction to the NeoSim program.

by communication (n = 225), and finally, teamwork (n = 161).

Professional Development (Level 2 NWKM)

Skill development was highly valued by staff (n = 112) and was the most frequently occurring theme. The opportunity to practice skills (n = 48) and develop new and specific skills (n = 46), with a hands-on approach (n = 13) in a skill-based learning environment, was appreciated. This resulted in requests for further or repeated simulation training (n = 63), including but not limited to requests for more sessions (n = 26), longer sessions, or more scenarios (n = 19). Although some practitioners were discouraged by performance anxiety (n = 49), others established confidence (n = 18), consolidating their prior knowledge (n = 14) while recognizing their weaknesses. The overall experience (n = 54) was noted by the majority to be helpful (n = 16), enjoyable (n = 14), and opportunistic (n = 12).

Communication (Level 2 NWKM)

Communication was the second most common theme; within that the most frequently occurring category was debrief (n = 103). Discussion (n = 25), reflection (n = 24), and feedback (n = 22) in a group setting (n = 6) were seen as positive aspects of the debrief process. Participants noted communication efficacy (n = 24) and the opportunity to practice communication skills (n = 28) in an interdisciplinary environment. With effective closed-loop communication (n = 12), participants recognized the importance of communication quality and learnt to vocalize thought processes. They developed clarity, learnt to listen, and built a nonjudgmental attitude. The effectiveness of communication was noted to be the most influential in participants' future resuscitation management (n = 22) with a perceived belief that continued re-enforcement of communication skills would result in translation to practice (n = 21).

Teamwork (Level 2 NWKM)

Teamwork was frequently referred to as the best part of simulation training as well as being the biggest influence on future practice. Of all the aspects of teamwork, interdisciplinary teamwork (n = 41) was most enjoyed (n = 30). Participants thought that exposure to leadership (n = 34) in a team environment would most significantly define their future neonatal resuscitation management (n = 30), as it created the opportunity for medical and nursing staff to work together in an interdisciplinary fashion. In their leadership roles within the NeoSim training, participants learnt

Table 2 Year-Wise Likert Scale Responses to Feedback Questions

Likert Scale Outcomes	2012	2013	2014	2015	2016	2017	2018	Overall
Question 1	4.94 (0.24)	4.82 (0.39)	4.92 (0.27)	4.83 (0.38)	4.83 (0.61)	4.77 (0.44)	4.94 (0.25)	4.87 (0.39)
Question 2	4.77 (0.42)	4.78 (0.42)	4.84 (0.37)	4.78 (0.42)	4.80 (0.63)	4.77 (0.44)	4.88 (0.34)	4.80 (0.45)
Question 3	4.40 (0.74)	4.52 (0.58)	4.62 (0.51)	4.52 (0.57)	4.46 (0.72)	4.38 (0.51)	4.69 (0.48)	4.52 (0.61)
Question 4	4.69 (0.47)	4.80 (0.40)	4.87 (0.33)	4.80 (0.41)	4.76 (0.64)	4.69 (0.48)	4.88 (0.34)	4.79 (0.45)
Question 5	4.69 (0.62)	4.82 (0.39)	4.86 (0.35)	4.83 (0.38)	4.70 (0.74)	4.77 (0.44)	4.94 (0.25)	4.80 (0.50)

Data presented as mean (SD).

to have clarity, stand back, be assertive, and deal with complex cases. Role understanding (n = 11) and role allocation (n = 18) were cited as the next most influencing factors for future resuscitation management, highlighting the importance of teamwork in neonatal resuscitation.

Applying Learnt Skills (Level 3 NWKM)

Doctors and nurses most frequently commented on recognizing the importance of escalation and planning ahead (n = 39). Many practitioners learnt to develop a framework (n = 17), from observation or through others (n = 11), and developed a global perspective, which they believed would translate into their practice. This improved their decision-making, as they learnt from their mistakes in a high-pressure environment. However, the Level 3 data were limited to the feedback surveys and could not be formally assessed in our study.

Clinical Outcomes (Level 4 NWKM)

Clinical resuscitation outcomes in the pre (2007-2011) and post (2012-2018) NeoSim epoch are shown in Table 4. There was a significantly decreased requirement for all resuscitation measures except CPAP use between 2012 and 2018. This improvement has remained consistent since the commencement of the NeoSim program, with no trends in any of these clinical outcomes over the individual years the workshop was conducted (detailed data not shown).

Neonatal Deaths

In the pre-NeoSim epoch, neonatal deaths during resuscitation accounted for 0.8% of all live births, decreasing to 0.6% of all live births in the 2012-2018 epoch. Thus, there was a significant decrease in neonatal deaths by 0.2% ($p = .04$) postintroduction of the NeoSim program.

Maximum Intervention During Resuscitation Required

There was a significant difference between the number of neonates requiring resuscitative measures in the pre-NeoSim and post-NeoSim epochs. There was a 3.4% decrease in need for suction ($p < .00001$), 3.3% decrease in intermittent positive pressure ventilation requirement ($p < .00001$), 1.4% decrease in intubation ($p < .00001$), 0.08% decrease in compressions ($p = .006$), and 0.16% fewer babies needed adrenaline ($p = .0001$). In the same period, the proportion of babies requiring CPAP increased from 4.1% to 16.2% ($p < .00001$).

Discussion

The NWKM was used for the first time to formally evaluate a neonatal resuscitation training program, NeoSim. We found that there were improvements at all levels with the participants attributing the realistic simulation environment to improvements in teamwork, communication, and professional development, with associated improvement in clinical resuscitation outcomes.

The first stage of our assessment analyzed the participant reaction to NeoSim training (Level 1 NWKM). Participants found NeoSim training to be realistic, highlighting its safe and controlled nature and the diversity and complexity of presented clinical scenarios. These prompted participants to request further sessions, supporting how NWKM reflects interest and engagement in learning and how the relevance to practice can be identified. This step termed as ''participant reaction'' may appear on the surface to only represent ''participant satisfaction'' or ''happiness''; however, it makes an epistemological connection with ''how much learning'' is acquired by the program (Hughes et al., 2016).

The next stage of our assessment focused on learning outcomes achieved by our participants (Level 2 NWKM). Communication (Cordero et al., 2013; Edwards et al., 2015; Sawyer, Laubach, Hudak, Yamamura, & Pocrnich, 2013; Yamada, Fuerch, & Halamek, 2016), teamwork (Rubio-Gurung et al., 2014; Sawyer et al., 2013), and professional development (Bruno et al., 2016; Rubio-Gurung et al., 2014; Sawyer et al., 2011) were considered the most important learnings, with participants reporting increased confidence (Bruno et al., 2016; Mileder et al., 2014; Rakshasbhuvankar & Patole, 2014), knowledge (Bruno et al., 2016; Jabir et al., 2009), and higher satisfaction (Halamek et al., 2000) that would influence their future practice. Confidence and commitment are the new features added in the Level 2 NWKM, both of which are essential for a change in attitude to be translated to a change in

Table 3 Major Learning Outcomes From NeoSim Training

Theme	Subthemes	Responses	Comments
Professional development (n = 402)	Skills	112	"Hands on activity"*
			"Good experience of practice"*
			"New education"*
			"Active participation gives me insight"†
			"Specific management of APH/hypovolemia"†
			"Consider reasons why baby deteriorate, ETT, equipment, other baby's condition"†
	Learning	85	"Learning how to improve on skills"*
			"Using the algorithm and debriefing"†
			"Structured approach (ABCDE)"†
			"Systematic thinking about equipment and patient factors"†
	Requesting longer or further sessions	55	"Session is quite brief—would be helpful to have an opportunity to consolidate skills learnt"‡
			"More clinical scenarios would be good"‡
			"Useful session, would be great to have every 3 months"§
	Overall experience	54	"Exposure to these things is always helpful"*
			"It was a useful session"§
			"Great learning experience"§
			"Really beneficial"§
			"Overall, a very valuable experience"§
			"Very enjoyable session"§
			"Very well organised"§
	Performance anxiety	49	"The anxiety"‡
			"People watching was uncomfortable"‡
			"Feeling stressed"‡
			"On show—felt pressure"‡
			"Worry that I will do something wrong"‡
	Building confidence	18	"Enhanced confidence in neonatal resuscitation"*
			"To learn by putting myself above my usual level of practice"*
			"Prepare…for the not so perfect deliveries"*
			"Keep calm and carry on"†
	Prior knowledge	14	"Being able to practise skills I've read about"*
			"To be prepared prior to crisis"†
			"Feeling really inexperienced and forgetting things in my scenario"‡
			"Being caught with little information and my role identification"‡
	Repeated exposure	8	"Being able to revise things I had learnt in the Neo resuscitation program earlier in the year such as importance of leadership and teamwork"*
	Recognizing weaknesses	7	"The opportunity to see my strength and weaknesses in a simulated environment"*
			"Becoming aware of my role, where I need to improve"*
			"Learning my areas of weakness, improving"†
Communication (n = 225)	Debrief	103	"Debriefing to analyse what could be done better next time"*
			"Being able to reflect/debrief and gain new skills"†
			"Re-evaluation of my own approach to a simulation in regard to teamwork/leadership"†
			"Opportunity to reflect on practices"†
			"Good learning experience by talking through the issues"†
			"Lots of debrief"‡
			"Opportunity for debrief … was valuable"§
	Efficacy	24	"Reminds me to communicate more effectively"†
			"that effective communication ensures resuscitation runs smoothly"†
			"Importance of effective communication"†
	Opportunity for practice	28	"Practice communicating … was particularly helpful"*
			"Ability to clarify and practice"*
			"Clarification of resuscitation skills, ability to focus on communication"*

(*continued on next page*)

Table 3 (*continued*)

Theme	Subthemes	Responses	Comments
	Interdisciplinary	11	" … It helped me to feel more comfortable communicating with doctors and learn about roles"*
			"Opportunity to hear nurses' perspective"†
			"Talking through with the rest of the team"†
	Closed loop	12	"The importance of ensuring everyone is on the same page"†
			"I always find it good to let others know what you are up to, whether this the registrars letting the fellow know what kind of risky delivery he/she is going to attend and equally the fellow should communicate with the consultant."§
	Quality	11	"Non-judgemental"†
			"Speak up"†
			"Listening better"†
	Vocalizing thoughts	6	"Talking through your thought process aloud"†
			"Reminder to verbalise roles and diagnosis"†
	Continuous	5	"Opportunity to discuss and troubleshoot"*
			"Encouraging communication"†
	General comments	25	"Communication segment"†
			"Communication"†
Teamwork (n = 161)	Interdisciplinary	41	"Interdisciplinary SIMS are extra helpful"*
			"Great that we got to train and practice with doctors as a team"*
			"Good opportunity to practice common scenarios with nursing staff"*
			"That everyone had the opportunity to be included"*
			"Really good for the new doctors to learn how to work with the nurses in these situations"§
	Leadership	34	"The opportunity to take a leadership role"*
			"It has made me think about how to be a more assertive leader"†
			"Ensuring to allocate a team leader"†
			"Facilitating leadership as a clear member"†
			"The importance to stand back as a leader"†
	Role understanding	25	"Learning the experience of my colleagues and understanding their knowledge so if in future situations we will know each other's capabilities"*
			"Observing different roles each person should take"†
			"Being able to observe and participate on what needs to be done"†
	Role allocation	21	"Doing a different role to what I would normally take on"*
			"Clarity of roles and their individual importance"*
			"The importance of clear allocation of roles"†
	General comments	17	"Experience of the team"†
			"Participate in teamwork"†
	Relationships/ understanding people	9	"Knowing that my concerns new accepted and solutions were given without judgement"*
			"Getting to work with other staff members in a stressful situation and understand each other's ability and limitations"*
			"Consideration of human factors"†
	Resource allocation	5	"Utilising all available resources"†
			"Utilisation of staff"†
	Practice	4	"Being able to practice in a group scenario"*
			"The focus on teamwork"*
	Efficacy	3	"How effective teamwork impacts outcome"†
	Intradisciplinary	2	"Doing scenarios with people I worked before"*
			"Practising these scenarios with my nursing colleagues from the unit"*

* In response to Question 6.
† In response to Question 7.
‡ In response to Question 8.
§ In response to Question 9 of the evaluation form.

Table 4 Clinical Outcomes Across the Two Epochs

	Pre-NeoSim Epoch 2007-2011	NeoSim Epoch 2012-2018	*p* value
Total live births	15,903	25,040	
Gestation (wk)	38.4 (3.0)	38.4 (2.8)	1
Birthweight (g)	3,131.0 (748.5)	3,158.2 (734.9)	.0003
1 minute Apgar	8.1 (0.8)	8.1 (1.6)	1
5 minutes Apgar	8.8 (2.1)	8.8 (0.9)	1
Neonatal death	139 (0.8)	174 (0.6)	.04
Maximum resuscitation needed			
Suction	2,008 (12.2)	2,211 (8.8)	<.00001
IPPV	981 (6.1)	707 (2.8)	<.00001
CPAP	689 (4.1)	4052 (16.2)	<.00001
Intubation	314 (2.2)	222 (0.8)	<.00001
Chest compressions	22 (0.13)	14 (0.05)	.006
Adrenaline	40 (0.25)	24 (0.09)	.0001

Data presented as mean (standard deviation) or number (percentage).

behavior (Level 3 NWKM) (Kirkpatrick & Kirkpatrick, 2019). In the high-pressure environment, participants noted opportunities to apply techniques such as escalation, forward planning, and framework development to clinical practice. Although Level 3 outcomes were not studied or reported in this paper, the Level 2 outcomes demonstrate the likely influence on participant behavior in clinical practice.

Our final analysis reviewed clinical neonatal resuscitation outcome data (Level 4 NWKM), and improvements in clinical resuscitation outcomes were seen in the post-NeoSim epoch. Clinical outcomes described in studies to date include decreased early mortality (Dempsey, Pammi, Ryan, & Barrington, 2015; Mduma et al., 2015; Pammi et al., 2016), resuscitation duration (Pammi et al., 2016; Rakshasbhuvankar & Patole, 2014), use of positive pressure ventilation (Sawyer et al., 2011), and requirement for bag and mask ventilation (Mduma et al., 2015). Although Dempsey et al. noted a significantly decreased early neonatal mortality, the included studies were limited to the developing world and only a few included mannequin based learning (Dempsey et al., 2015). Our study has shown decreased early neonatal mortality and decreased need for invasive resuscitation measures in an in-situ setting in the developed world.

The proportion of babies requiring CPAP increased four times from 4.1% in the pre-NeoSim epoch to 16.2% in the post-NeoSim epoch. This is consistent with Australian and New Zealand trends in the last 15 years (Chow, Marsney, Hossain, Haslam, & Lui, 2015), with decreased use of invasive ventilation measures. Finally, previous evidence regarding the benefits of NRS training have been limited. (Rakshasbhuvankar & Patole, 2014). Our study establishes that in-situ NRS training may have led to improved clinical outcomes, suggesting the need for ongoing workshops.

Strengths and Limitations

We have previously reported our evaluation of multiple levels of the original Kirkpatrick's framework in obstetric emergency team–based simulation to demonstrate the impact on participant satisfaction, learning, attitudes, and patient outcomes (Kumar et al., 2018). As far as we are aware, this is the first time the NWKM has been used to describe a neonatal simulation program. The authors have used the NWKM in their previous publication on an online education program for weight management in pregnant women (Walker et al., 2019). Our study has provided robust data on multiple levels within the NWKM, whereas previous work in NRS training has been largely limited to qualitative assessment of participant learning and reactions (Level 1 and 2 NWKM outcomes).

We have shown previously the superiority of in-situ simulation training in our work on obstetric simulation (Kumar et al., 2018). It has been suggested that although in-situ simulation improves resuscitation knowledge and skill performance immediately after training, the long-term retention of these benefits is controversial, and they may not translate into real-life situations (Huang et al., 2019). Our work has associated in-situ NRS training with improved knowledge, skill performance, and better clinical resuscitation outcomes over a 7-year period, suggesting longevity in retention and translation into practice, particularly with close to 10% of the participants completing the workshop more than once. This association would be strengthened by formally assessing Level 3 outcomes.

The major strength of this evaluation is that it allowed us to explore the relationship between perceived learning in a simulated setting and its relationship to real-world clinical outcomes using a structured evaluation system. Given that patient care and clinical outcomes are rarely reported as evidence of the effectiveness of educational programs using

a mixed methods approach (Rakshasbhuvankar & Patole, 2014), this is particularly valuable. The limitation of evaluating a large clinical data set over a number of years is that it is difficult to associate a causal link or effect of NRS with clinical outcomes. Furthermore, there a number of ways the comparative analysis of the clinical outcomes data can be conducted, and the one we chose was a pre- and post-intervention analysis, but the intervention continued through the second epoch. A number of other factors, such as mandatory training of all neonatal nursing staff in neonatal resuscitation in our institution in the last few years, increased use of CPAP, changes in obstetric practice and delivery room surveillance, or variation in baseline neonatal characteristics between the two epochs, may have contributed to the improvements seen in clinical outcomes in the second epoch.

Applicability

The NWKM has been acknowledged to be applicable in a business setting to achieve desired outcomes, but its role in health care teaching programs remains to be established. We have demonstrated its role in a previous publication on continuing professional development for weight management in pregnancy, where we reported multiple levels of the NWKM (Walker et al., 2019). This paper demonstrates a novel application of the NWKM in neonatal resuscitation training, with no other health care simulation programs having applied this framework to date.

The NeoSim Program appears to have contributed to changing organizational practice. However, our study design entailed analysis of reported feedback rather than direct observation, rendering us unable to formally assess any change in observed clinical behavior that may have helped to directly connect workshop learning with clinical practice (Level 3 NWKM). Formal evaluation could occur in future NeoSim workshops through direct observation, clinical checklists, video recordings, creation of scenarios that require Level 2 learnings to be applied, focus groups with standardized indicators, and interhospital analyses, all allowing for formal assessment of applied knowledge (Public Health Foundation, 2015).

Conclusions

This study highlights the importance of continuous professional development in neonatal resuscitation training and its influence on communication and teamwork, both integral components of the NeoSim program. The paper also demonstrates a novel application of the NWKM in the health care setting, linking perceived participant learnings to facilitated change in clinical outcomes. An in-situ environment proved to be realistic, and the impact on clinical outcomes while evident remains to be strengthened, with a future direction of applying the NWKM to analyze the translation of learnt skills outside the simulated environment. High participant enthusiasm, confidence, and repeated exposure will likely continue to strengthen these behavioral skills, bringing to light the integral role of in-situ-simulated NRS training in clinical practice.

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Simulation for Neonatal Endotracheal Intubation Training

How Different Is It From Clinical Practice?

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Introduction: Neonatal endotracheal intubation is a critical skill that is difficult for learners to acquire even with simulation-based training (SBT). Trainees prefer clinical experiences over SBT. The objective of the study was to explore the differences between SBT and clinical practice in acquiring neonatal intubation skills to inform mannequin design and to improve fidelity.

Methods: A basic qualitative study using semistructured interviews was conducted to determine the experience of newly competent trainees (second- and third-year neonatal-perinatal medicine fellows) and their instructors in developing intubation skills. Participants were asked to compare learning through SBT with clinical practice in terms of context, equipment, and environment. Their responses were analyzed using an inductive approach.

Results: Thirty-two participants (20 fellows and 12 faculty) indicated that SBT does not equal the real experience. Specifically, the look, feel, and function of the simulators differ enough from the real patient and the clinical environmental that they do not elicit the desired learning responses. The clinical environment prompted heightened emotions and had a chaotic atmosphere that was not fully captured by SBT. Participants suggested that programs use SBT in the initial phases of training only to gain basic skills and they provided several solutions for mannequin and SBT session design.

Conclusions: Simulation-based training does not fully prepare neonatal-perinatal medicine fellows for neonatal intubation. Mannequins with unique active features, such as multiple airway configurations, slipperiness, secretions, and softer textures should be developed. Realistic environments that replicate the interprofessional nature and stressors of the clinical environment might better prepare learners for the complexity of clinical practice.

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Key Words: Simulation, intubation, neonate, qualitative.

Simulation-based training (SBT) using task trainers and mannequins is an integral part of neonatal endotracheal intubation education.[1–3] The Neonatal Resuscitation Program provides a foundation for learning this skill, including SBT sessions.[4] Despite initial Neonatal Resuscitation Program training, refresher courses every 2 years, and clinical experience in the delivery room and neonatal intensive care unit (NICU), pediatric trainees consistently show poor clinical performance and are often unable to attain competency in neonatal intubation after 3 years of residency training.[5–9]

Simulation-based training provides a safe educational environment and spares trainees from practicing on patients.[10] However, a qualitative study indicated that neonatal-perinatal medicine (NPM) fellows believe that repeated attempts on actual patients are most beneficial for attaining competency in neonatal intubation.[11] The preparation, equipment, and technical steps seemed to be similar in both, yet clinical intubations may still be viewed as the criterion standard because the clinician ultimately needs to successfully intubate real patients in real environments. This suggests that intubation SBT has yet to achieve its potential. Although studies recommend SBT,[2,11] it remains unclear how it differs from the clinical experience and how intubation SBT needs to progress to achieve the desired goal. To address these gaps, a hypothesis-generating inquiry using a basic interpretive qualitative study design[12] was conducted to gain the perspective of newly competent NPM fellows and NPM faculty who teach this procedure.

METHODS

E-mail solicitations were sent to second- and third-year NPM fellows and NPM faculty in US programs from May through September 2016 inviting them to participate in the study. The list was derived from an existing list of NPM faculty involved in SBT, and they forwarded to their fellows. Purposeful sampling and recruitment by referral "snowballing" allowed us to reach participants who were interested and motivated to

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share their experience.[13] Fifty-three participants were invited (29 NPM fellows and 24 faculty) of which 42 (79%) agreed to participate. Participation was voluntary with no incentives offered, and signed consent was obtained before each interview. Participant demographic information was collected and deidentified. The study was approved by the Children's National Institutional Review Board.

Individual semistructured interviews of 45-minute to 2-hour duration were conducted in person or by phone using an interview guide (Appendix 1). One researcher (L.M.S.), an experienced neonatologist trained in qualitative research methodology and simulation, conducted all interviews, representing a "true insider." Participants, identified by number, were asked how the intubation experience differed between SBT and the clinical setting. Probing questions specifically asked about differences in the equipment, intubation environment, technique, and/or context of the intubation. Interviews were audiotaped and transcribed verbatim.

Data were entered into Atlas.ti software (v7.0, Berlin, Germany), and inductive analysis was conducted by 3 researchers (L.M.S., K.R.F., H.A.W.) who independently generated a list of codes.[12] Codes were refined by discussion until consensus was reached. Data were continually compared in search of emergent themes, and discrepancies were resolved through discussion.[12] The process continued until no new codes emerged, and findings were unanimously confirmed. Coders debriefed with the senior investigator (E.F.G.) to further clarify the meanings of overarching themes. Bracketing, peer-checking, and reflective journaling after each interview were performed. Credibility and trustworthiness were assured by purposive sampling, member checks, triangulation during data analysis, and use of rich thick descriptions. Interviews were conducted until thematic saturation was reached. Recommendations for improving endotracheal intubation training were derived directly from participants' responses, comparison with the literature, analysis of observations, and discussion. The terms "simulator" and "mannequin" were used synonymously.

RESULTS

Of the 53 participants invited, 32 from 10 different programs in 10 different states completed the interview. Of the 29 NPM fellows invited, 4 did not respond, 3 could not be scheduled, and 2 accepted after thematic saturation had been achieved. Of the 24 invited faculty, 7 did not respond and 5 accepted after thematic saturation had been achieved. No discernible differences were noted between fellow and faculty responses. Of the 12 neonatology faculty, 4 identified as NPM fellowship directors, 4 as medical educators, and 4 as clinical faculty. Faculty had an average of 5 (±4.36) years of experience after graduation (range = 0–13 years). Faculty and third-year fellows had significantly more self-reported intubation experience than second-year fellows (Table 1). All participants had previously used SBT for teaching or learning neonatal intubation.

Although participants acknowledged that simulation provides basic training, all noted that it was inferior to intubating a live patient as it simply was "not real." They reported that SBT approximates but does not completely replicate the complexity of a clinical intubation. Simulation-based training was described as "low stakes," as consequences are not dire and are limited to the learner and mannequin. Three main themes emerged (Fig. 1):

1. The look, feel, and function of the simulators.
2. Lack of a complex clinical environment in simulation.
3. Heightened emotions during clinical encounters.

TABLE 1. Participant Demographics, Intubation Experience, Primary Practice, and Training Site Characteristics

	Second-Year Fellows (n = 10)	Third-Year Fellows (n = 10)	Neonatology Faculty (n = 12)
Demographics			
Male, n	2	0	5
Female, n	8	10	7
Age, mean ± SD, yr	30.6 ± 1.43	32 ± 1.56	39.2 ± 4.98
Estimated intubations performed, median (IQR)	25 (20–37.5)	42 (33–50)	200 (125–275)
Primary practice NICU site (level III/IV)			
Community or military hospital	1	0	1
Free-standing children's hospital	6	4	5
NICU bed capacity, median (IQR)	58 (48–60)	69 (51–97)	54 (45–66)
Primary training program characteristics			
Neonatal-perinatal fellowship program	100%	100%	67%
NPM fellows per program, median (IQR)	9 (8–11)	9 (8–18)	6.5 (0–8)
Training sites per program, median (IQR)	2 (2–2.75)	2 (2)	1.5 (0–2)
Pediatric residents per program, median (IQR)	86.5 (53–100)	120 (87–141)	50 (22–116)

IQR, interquartile range.

Theme 1: The Look, Feel, and Function of the Simulators

The inaccuracies inherent in the mannequins undermine physical and psychological fidelity and led to execution flaws (Table 2). Participants noted that these flawed techniques could lead to serious patient complications, as trainees might carry bad habits back to the bedside.

In terms of look, respondents reported that the mannequin airway is predictable, and the vocal cords are easily visible. One participant said that in real life, "you never know what the airway truly looks like until you actually meet the baby" (P4). The natural color of the human tissue, reflections created by secretions, and subtle anatomical differences even in neonates of similar size create imperfect situations compared with the "perfect situation" in the mannequin (P13). Learners who had only trained on mannequins had difficulty recognizing the airway in real life.

In terms of feel, participants indicated that the mannequins require excessive force to open the airway, as they are much stiffer than neonatal tissue. During SBT, learners could not build the procedural "muscle memory" (P25) needed to execute the task on patients. For example, in simulation the endotracheal tubes (ETTs) would need to be placed directly inside the laryngoscope bore (because of the mannequin

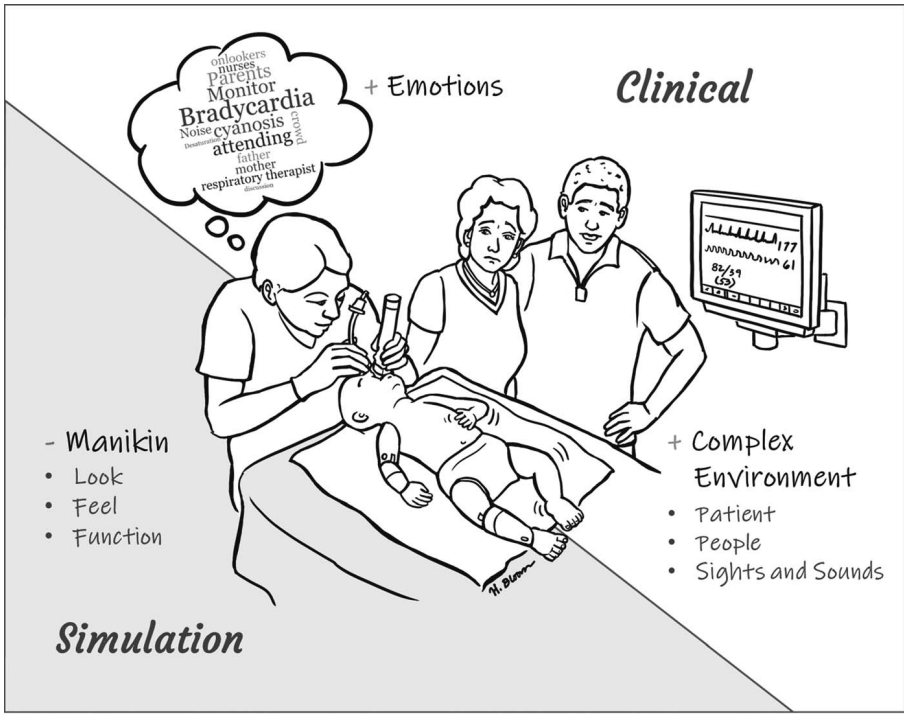

FIGURE 1. Differences between simulated and clinical environments. Poor simulator design detracts from fidelity while emotions and environment create a complex clinical environment.

stiffness and small mouth area), thus obstructing the line of sight, with more pressure or "rocking" of the laryngoscope on the upper gum and mandatory use of a stylet to allow passage of the ETT through the stiff cords. Participants believed that the absence of secretions and tongue/neck motion does not allow the learners to acquire troubleshooting

TABLE 2. The Look, Feel, and Function of the Simulation Equipment Compared With Real Patients

Subtheme	Illustrative Quotations
Look	• The landmarks are not as clear [in the mannequin]. In a real baby, there's lots of saliva back there.... Everything looks very shiny. You do not have the nice white outlined vocal cords as you do on a mannequin. (P10)
	• The color of the anatomy, the subtle differences from patient to patient in anatomy, the pressure that's required when using the laryngoscope—those are all things that are different on a real patient than on the model. (P12)
	• On a lot of the dummies, the vocal cords are bright white, which is not how they look in an actual patient, so I really had to learn what I was looking for.... After probably about three unsuccessful attempts, I was able to get the intubations and know what I was looking for. (P11)
	• The airway is right there [in the mannequin].... The moment that you go in with the laryngoscope and you turn it, the airway comes into view and the tube slides easily in. Whereas, in real life, the airway might not be so easily visible—you know, the epiglottis may cover it, the cords may not be open, there may be a lot of secretions obscuring your view—so to me it's a very different experience. (P20)
Feel	• The problem with the mannequins in learning the skill is the airway does not look the same, it does not have that dynamic feel and also the ability to lift, and the slide of the tube does not feel the same, because the mannequins tend to be so stiff that it's hard to actually lift them.... You cannot use the same pressure that you'd use on a mannequin on our neonates; you'd break their jaw,... lift them off the bed. (P3)
	• The feel of [the mannequin] is different, and even though the mouth is open, it's rigid enough that it's hard to pass the endotracheal tube from the side. You almost have to put it down the middle. The visual will completely occlude your line of sight. (P4)
	• The other thing that I still struggle with is in the delivery room—how slippery the [babies] are. And, I've found recently... if I touch the baby with my right hand, which is the hand I'm going to use the tube in,... then the tube slips a little bit and so... you do not have that in simulation. (P19)
	• Even if you can visualize everything within the mannequin, sometimes it's hard to slide the ET [endotracheal] tube in, because it might not be lubricated and... because it's plastic and not actual tissue. (P24)
	• One thing is that simulated patients do not actually really move and fight you so sometimes it can be a little... less stressful of an environment.... Also, the baby is not trying to hit you or clamp down their mouth while you are trying to intubate them. (P9)
	• Depending on how much sedation or... if you use paralysis for rapid sequence intubation, I do not think you really appreciate how difficult it can be when a kid's moving around or fighting you.... Trying to... get the tongue out of the way I found to be a lot more challenging than I realized. (P19)
	• The mannequin is just usually 1 or 2 sizes, whereas even in the NICU you get a good variety.... You walk into a room and if the patient needs to be intubated, to know what size tube either they had or... what's an appropriate size to pick for their weight or their age. (P15)
	• You might try an intubation repeatedly on a mannequin and feel very comfortable, because it's sort of the exact same baby, with the exact same airway and everything, and so sometimes, it might not translate when you are going to intubate a real-life baby. (P22)
	• The mannequin's head is at baseline midline whereas in a real infant it's very easy for the head to not be midline and for you not to recognize it, which I think can potentially sabotage your ability to intubate. (P16)
Function	• Usually in a lot of these simulated sessions, you do not have the carbon dioxide detector... to check whether you have color change,... confirm tube placement. You will not have secretions and the ability to simulate that or the actual suction. (P3)
	• Some of the simulated babies... that are supposed to be 'term' cannot be intubated with a 3.5 tube... because it's too big, so you have to do it with... a 2.5 tube, so those things make the scenario less realistic. (P14)
	• For figuring out the best way to position infants so that you are really able to see the cords, I think the mannequins are absolutely wonderful. (P22)
	• Once you get the intubation in, it does not end there. Once you get the tube in, you have got to think about adequately securing and making sure vital signs continue to be good and like really tape—put the actual tape on.... Sometimes in the practice you just say okay it's in, but you have got to tape it. (P31)

techniques that address a slippery infant in the delivery room, a slippery ETT, ETT dislodgement caused by patient motion, or an active infant. They also reported that each mannequin has a single size airway and a fixed midline configuration to which learners acclimate very quickly. Learners can become confident in their skills after SBT but may fail to recognize that patients have airways of diverse sizes and differing configurations. Learners were therefore unable to transfer intubation skills to the patient's bedside.

In terms of function, limited or absent mannequin feedback during SBT at critical junctures of the procedure was reported as having the potential to perpetuate bad habits. Participants cited the absence of carbon dioxide generation from the mannequin's lungs and accompanying change of the carbon dioxide detector as gaps in SBT because the clinician does not receive feedback on successful ETT placement in the trachea. Learners are not able to suction heavy secretions that obscure the view of the vocal cords because mannequins do not generate secretions. Consequently, learners are not able to build the memory required to suction during clinical encounters. Rough handling could cause a tear of the lips or airway, but learners would not be aware of this complication as no signs would be apparent on the mannequin as it is more durable than live tissue. Discrepancy between the mannequin size and the internal diameter of the artificial airway results in inability of the learner to correctly select the ETT, which was identified as undermining fidelity. In addition, preintubation medication selection, preparation and administration, and postintubation ETT securement were cited as shortcomings of SBT, as faculty do not routinely incorporate those steps. Participants agreed that intubation equipment used during SBT is the same as that used in the clinical environment, which allows learners to practice the natural sequence of steps and that mannequins helped learners understand the importance of head positioning.

Theme 2: Lack of a Complex Clinical Environment in Simulation

Learners identified clear differences between the simulation environment and clinical setting—what 1 trainee called a "cultural atmospheric difference" (P5). On one hand, learners recognized that SBT allows them to organize supplies, take time to think more clearly, and develop their style, and faculty noted that SBT allows them to create situations that put trainees in the driver's seat and gives them time for reflection. On the other hand, faculty indicated that a calm, dimly lit room with a mannequin lying on a warmer bed starkly contrasted with the NICU environment where an infant in distress would be attached to beeping monitors, with staff bustling around, and adrenaline pumping. Patient instability, the unpredictability of the airway, and variability in the patient size were identified as additional challenges in clinical settings. In addition, trainees reported that the interprofessional dynamics and expectations in a clinical intubation differ from those experienced during SBT. Simulation-based training sessions typically have fewer people present and are generally confined to residents and fellows from a single discipline. Simulation-based training lacks the presence of nurses and respiratory therapists who may be talking and/or sharing opinions. As 1 participant commented, in the NICU, "there's always an audience.... It can be daunting" (P7). Furthermore, parents are often present during intubations. "There have been times where we have let the parents stay and so you put a little bit of pressure on yourself like, 'Oh, I hope I can get this on the first try'" (P28).

Often missing from single-discipline simulation events was discussion about "medication dosages and entering orders" (P23). One trainee noted the challenge in gauging adequacy of sedation: "We're bagging the patient the entire time, making it hard for me to know when to pull the trigger to say: Okay, I think we are sedated enough; we can intubate" (P27).

Faculty commented on ways to increase the fidelity of the environment: learners "have the same kind of noise around them to better simulate the environment, so we gradually advance [the scenario] to try to make it as real as possible even though we know the mannequin is not real" (P23). Mimicking the clinical environment by using the same clinical space, equipment, with the same complement of responders, was deemed important. Interprofessional SBT that includes a standardized participant as a parent may provide context, allowing learners to put the "motor/technical skills together with the more cognitive communication teamwork skills" (P23).

Theme 3: Heightened Emotions During Clinical Encounters

The emotions evoked in real-life clinical encounters are complex. Participants described feeling stress, anxiety, pressure, and a fear of causing harm. Lack of emotional activation in SBT has the potential to impact the learner's ability to become proficient. As 1 NPM fellow said, "[When there is] a critical situation and you are struggling, you know that cannot really be mimicked in simulation so it's—the stress and the nerves" (P5). These emotions elicited physiological reactions. One participant described, "My body would physically shake when we were waiting for the baby to come out and I would be so nervous that people were going to see that when I went to go grab the blade.... When you are doing the mannequin, there's zero of that" (P5). Another reported that when an intubation is prolonged and the infant's color changes, they became "tachycardic, sweaty,... a little bit more pressed for time, a little bit more stressed" (P10). In real life, there is the possibility that the procedure could cause further instability. "Even if the baby is stable to start, there's always that possibility that the baby is going to become acutely unstable while you are trying to get the tube in, so I definitely feel like my own emotions and anxiety are significantly heightened in a real-life intubation compared to a simulation" (P19) and "the stress associated with intubating a mannequin is different from intubating a baby who's someone else's child, who the parents are trusting you to take good care of and who every second of anoxia can be a second of brain injury" (P13).

Participants described the simulation environment as not providing a true representation of the clinical environment. As noted by 1 participant, "Despite anyone's attempts to make it feel real, you have the human nature that you cannot just fully suspend disbelief, so I think that aspect of [the simulation] is just not recreatable" (P7). One faculty also commented, "It's never going to be the same. So [in] the sim[ulation] you are walking into it knowing that it's a sim and you are walking out of it knowing that it was a sim, whatever the outcome" (P28).

DISCUSSION

Simulation is recognized as less effective than clinical encounters for neonatal intubation training.[1] Our qualitative study aimed to analyze the differences between SBT and the clinical environment as a means of assessing learner and instructor needs. Three factors differentiate SBT from clinical learning of neonatal intubation: simulator differences, environmental complexity, and emotional intensity. Here, we offer recommendations for each, building upon prior recommendations.[14–21]

Simulator Factor Recommendations

Mannequin differences dominated all interviews. Participants expressed concerns about mannequin fidelity noting that poor mannequin design not only hampered learning but also propagated incorrect technique ("negative transfer") causing patient harm.[22] In an analysis of physical and functional fidelity of 8 neonatal airway simulators, Sawyer et al[3] outlined that mannequins should have minimum standards for fidelity to promote effective learning and thus effective skill transfer. The airway anatomy of mannequins differs enough from live patients that researchers have cautioned about the use of anatomically imprecise models to study the efficacy of airway devices as precursors to clinical trials.[23–25] In addition, airway equipment tested on mannequins has been shown to be more difficult to use clinically compared with use during simulations.[26]

Our qualitative study reinforces these findings and provides more expansive recommendations for mannequin design than previous reports (Table 3).[14,15] Specifically, 3-dimensional printing could be used to create differing sizes of normal and atypical airways. In addition, a shift to virtual models could create more variety and complexity. Materials and features that feel and look more realistic would enhance the fidelity of the mannequin and encourage proper technique, such as less rocking with instrumentation of a softer jaw.

Environment Factor Recommendations

The participants described the interplay between aspects of the clinical environment (patient, people, sights, and sounds) and their performance and subjective workload. Specific descriptions of chaotic clinical environments contrasted sharply with the calm atmosphere of SBT. To enhance realism, patient factors such as vital sign deterioration and a hectic atmosphere could be mimicked in SBT through scenario design. It is possible that the participants' experiences reflect poorly designed or executed SBT sessions. For example, participants noted uniformity of disciplines, classroom set-up not conducive to performing intubation scenarios, and no accountability for outcomes in simulation. We speculate that improving the psychological fidelity of intubation training by comparing high- and low-stress environmental designs could improve training outcomes instead of focusing only on simulator type, such as high- versus low-technology simulators.[27,28]

The presence of multiple observers during SBT has been associated with higher trainee stress level as evidenced by elevated heart rate compared with a single observer.[29] Trainees' technical performance, however, was not affected by the presence of observers. Other studies suggest that even with a supportive audience (compared with unsupportive or no audience), fear of peer evaluation offset any benefit provided by the supportive audience.[30] Our data support these observations. This phenomenon of "choking under pressure" as a result of evaluative observation could be attributed to a shift in the participants' executive function away from the task by distraction, overemphasis on individual aspects of the task, or overmotivation and/or overarousal.[31] The presence of family members also created a fear of judgment in our participants, similar to other studies.[32] A NICU study demonstrated that family presence was associated with high team stress but not adverse events.[33] Further investigation using validated stress scales that capture individual reactions,[34] physiological stress measures,[34,35] level of intubation difficulty, and performance outcomes will be needed to fully understand the effects of family presence and observers on learners.

The effect of auditory distractors (eg, monitor sounds, background noise, and speech) on intubation performance is unknown. Variation in noise level alone has not been shown to affect intubation performance.[36] Faculty reported that they gradually advanced the level of scenario difficulty by adding these extraneous factors to increase learner cognitive load[37,38]; however, the effect of these conditions on performance needs to be tested.

We recommend SBT with added environmental factors, such as those mentioned previously, to allow learners to acquire the skills necessary to handle stress when conditions are nonmodifiable (embodiment training simulations[16]). Integrating interprofessional team members and standardized participants portraying "parents" require learners to focus on nontechnical (ie, behavioral) and technical skills (intubation) simultaneously. Additional external factors require learners to prioritize multiple tasks, such as handling equipment, performing intubation, working with the team, ordering medications, and explaining the procedure to the "parent." During scenario design, instructors should carefully consider extraneous elements that align with the learner level. For example, novice learners may be distracted by an angry "parent" and thus unable to perform under conditions that present an extraneous cognitive load. Research should be conducted to identify the best conditions to train for optimal performance under stress.

Emotion

Intubation is a complex emotional procedure that induces stress,[35] particularly if the procedure is difficult relative to the learner level or results in unanticipated complications. Intubation is considered a rite of passage and a core competency for graduation from an NPM fellowship.[39] Our participants described experiencing stress, anxiety, pressure, and fear of causing injury. In addition, they described physiological reactions such as sweating and shaking in response to stressful intubations. Similar reactions were not elicited during SBT. This could be related to the lack of time pressure, absence of distractions, well-rested state before SBT, light workload that day, scenario design, or lack of realism, as noted in other studies.[40]

Although training in high-stakes environments allows trainees to acclimate to stress, we recommend stress management training to assist learners to handle stress (Table 3). This is important because training learners to recognize stress triggers and to apply techniques such as relaxation, positive self-talk, visualization, or mental imagery has been shown to improve performance.[18]

TABLE 3. Recommendations for Simulator and Session Design to Maximize Neonatal Intubation Skill Acquisition

Category	Recommendations
Simulator	• Provide a variety of infant airway sizes (eg, extremely low birth weight, preterm, full-term, 1 mo, and 3 mo old).* • Provide a variety of configurations of normal and abnormal airways. • Improve accuracy of anatomic airway dimensions (eg, each weight category should accept the correct size ETT, allow for the accurate depth of ETT placement, and have proportional occipital dimensions[15]).* • Create vocal cord markings that are less obvious. • Use softer materials with variable tissue textures[14] (eg, the tongue should be more muscular than the skin, different anatomic structures should have the appropriate degree of floppiness[15]).* • Provide a visual or audible response to trauma (eg, bleeding, buzzing) or to touch with the laryngoscope[14] (eg, laryngeal spasm). • Waterproof high-technology mannequins to withstand fluid internally (inside the airway) and externally (on the skin) without affecting the internal electronic components of the mannequin. • Allow the mannequin to extrude saliva, or fluid[14] (with a variety of consistencies, eg, frothy, thick sticky, meconium-like) into the oropharynx to prompt suctioning. • Create head and tongue movement (to increase the degree of difficulty) that can be stopped once adequate sedation has been given.* • Increase the degrees of freedom of neck motion with a decrease in air entry if overflexed or overextended.[15] • Allow mannequins to provide a feedback response to demonstrate a correctly placed ETT (in the trachea) by exhibiting a response to a carbon dioxide detector (color change) or displaying end-tidal carbon dioxide readings on the cardiorespiratory monitor.* • Allow mannequins to exhibit misting in the ETT when correctly placed in the trachea. • Use durable material that allows the tape to stick to the manikin during tube securement. • Allow for bilateral chest rise in response to bag-mask ventilation, correct endotracheal tube placement, and correct laryngeal mask airway placement.*
Environment	• Conduct in situ airway simulations with a multidisciplinary group of learners.* • Use standardized participants to portray parents (eg, angry, upset, or concerned that their infant needs to be intubated) to increase cognitive load. • Create realistic sights and sounds that mimic the clinical environment such as, cardiorespiratory monitors, prerecordings of alarm sounds, or team discussions. • In situ training of learners in a high-stress environment[16] where trainees can become acclimated to stressors to ensure that they can develop and maintain their performance in real life (eg, scenario of patient deterioration with delays in intubation, timed attempts during skills training,[17] addition of auditory distractors).
Emotional stressors	• Graduate stress levels as learners become facile with the basic skill of intubation (begin with a simple intubation scenario and escalate to an infant who requires intubation and full resuscitation).* • Train learners with multiple observers present in the room (both supportive and unsupportive). • Offer stress management training[18,19] to improve learners' capability of controlling emotions without affecting performance. • Train at different times of the day and night to capture both rested and tired states.
General instructional design	• Create a library of images to familiarize learners with a variety of airways.* • Create videos to assist with identification of vocal cords and airway movement.* • Augment learning with technology such as, smartphone apps,[20] telehealth glasses,[21] and virtual reality. • Use videolaryngoscopy during clinical encounters to improve recognition of anatomical structures.* • Create more clinical learning opportunities for trainees by prioritizing their opportunities using written guidelines.*

*Participants gave these direct suggestions to improve the mannequin and session design.

General Recommendations

Faculty noted that scaffolding may be a useful strategy to enhance skill attainment; learners begin with straightforward intubation on a task trainer and the instructor then introduces mannequins with more difficult airways or a complex scenario once learners become proficient. Educators have found emerging technology, such as smartphone applications[20] and telehealth glasses[21] useful in teaching intubation before or during SBT. Other participant suggestions included watching videos to enhance visualization of the vocal cords and using the video laryngoscope to improve identification of anatomic structures as an adjuvant to SBT.

Strengths and Limitations

This study is the first to explore NPM fellow and faculty perceptions of SBT compared with clinical intubations. The diverse backgrounds of the participants allow transferability to other academic institutions and NICUs where fellow training occurs, which adds to the strength of this study. Limitations of this study include the potential for recall bias; however, all participants were actively engaged in training programs either as trainees or faculty during this period. The use of triangulation and the achievement of thematic saturation also minimized bias. Participants may have had additional positive or negative experiences that were not captured during interviews. The duration of participants' previous experience with simulators and the types of neonatal mannequins used were not quantified. There were more female fellows (90%) compared with male fellows (10%) in the study. This could be reflective of the current trends of increasing female NPM fellows (75%) overall in training programs.[41] There were no differences in responses between male and female participants and between participants with different levels of experience. Participants did not mention any differences between high- and low-technology mannequins because both lack airway, head, and neck motility. A bigger difference was observed between mannequins and live infants.

CONCLUSIONS

Although SBT is a key component of NPM fellow training, it has yet to achieve its goal of shifting training from the bedside to the simulator. Despite mannequin limitations, SBT is still recommended for the early phases of intubation training.[2,11] Our recommendations (summarized in Table 3) outline potential mannequin and environmental redesign modifications and ways to increase the stakes and elicit heightened emotional responses. With these changes, SBT has the potential to better train learners in neonatal intubation in general and specifically under stressful clinical conditions. Carefully designed studies

are needed to help instructors determine the ideal training environment for neonatal intubation simulation.

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Appendix 1: Interview Guide for Program Directors and Educators (short version):

Participant ID number:

Date:

Introductory Remarks: I want to thank you for agreeing to participate in this interview and fitting this into your schedule. I have asked for your help because you are an educator who teaches and performs neonatal endotracheal intubation. I would like to learn from your experience regarding how you learned to intubate, how you teach this procedure to others, and essentially what can we do to teach this skill better. I really appreciate your help; you are the expert, and I need to learn this information from you. I anticipate this interview will last from 45-60minutes. I will be recording the interview, so that I can get an accurate report of what is said. I will not be identifying you personally in the recording. Your participation is voluntary. You are welcome to not answer questions that you feel uncomfortable with and you may stop the interview at any time. There are no wrong answers, say what you believe. Please talk clearly so that I can get what you say on the recording. To be cognizant of your time, I may move the conversation along at certain points. Everything discussed here today is strictly confidential and will not leave this room.

Rapport and Reconnaissance: at least 7 minutes of tape time.

Please tell me about your background in treating neonatal patients…

Tell me a little about the NICU where you currently work (census, size, delivery vs. non-delivery). In your institution, where are most of the intubations done? Who performs them?

In-Depth Investigation:

1. How important do you think it is for fellows to learn neonatal intubation? Why?
2. What are some of the specific type of things/tasks that you performed that helped you develop your skill in neonatal intubation? Is this part of your formal training?
3. What are the challenges to learning this skill?
4. What are the things that the fellows are currently doing to attain skills?
5. How does the experience of intubation during practice sessions differ from live patients? Regarding equipment, environment, technique, context?
6. In the ideal world, how would you propose setting up a training program for trainees that would lead them to competency quickly?

Closure: As we close our interview today, what are the things that you would like me to capture when I prepare the findings? Would any other faculty member/ trainee be interested in participating in the study?

A copy of the interview will be emailed to you once it has been transcribed. I would like you to review the document and email me back any corrections or additions that you would like to make.

Thank you very much this has been very helpful.