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Short paper

Integration of a respiratory function monitor into newborn positive pressure ventilation training; development of a standardised training intervention

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Abstract

Objective: One in twenty newborns require resuscitation with positive pressure ventilation (PPV) at birth. Newborn face mask ventilation is often poorly performed. To address this, the potential role of respiratory function monitors (RFM) in newborn resuscitation training has been highlighted. The objective of this study was to develop a standardised training intervention on newborn PPV using an RFM with a simple visual display to identify and correct suboptimal ventilations.

Methods: We adapted the framework from a simulation development guideline to create a hands-on intervention on newborn PPV using an RFM with simple visual feedback (Monivent NeoTraining). We enrolled a group of healthcare professionals to a manikin-based pilot study as part of this process, conducting a series of teaching sessions to refine the intervention. Suggested changes were gathered from participants and instructors. Our main objective was to develop a standardised, reproducible training intervention.

Results: A standardised training intervention on newborn PPV was systematically developed. Twenty-six healthcare professionals working in tertiary neonatal care participated in a pilot study, consisting of eight training sessions. Each iteration of the intervention was informed by the previous session. Instructions for the delivery of teaching were standardised and a training algorithm was developed.

Conclusion: RFM's have been shown to be effective tools in research settings, addressing poor technique and face mask leak. They are not routinely used in newborn resuscitation training. To address this, we developed a standardised training intervention on newborn PPV using an RFM with simple visual feedback.

Keywords: Infant, Newborn, Resuscitation, Positive pressure ventilation, Face mask

Introduction

Delivery of effective positive pressure ventilation (PPV) is the cornerstone of neonatal resuscitation.[1] Learning how to perform this technique using a manual ventilation device and face mask is an essential part of neonatal resuscitation training.[2] It is a challenging skill to master as highlighted by high and variable mask leak,[3–6] the delivery of excess tidal volumes,[4,7] airway obstruction [8] and the application of excessive compressive forces with the face mask during PPV.[9] Furthermore, resuscitation skills deteriorate over time.[10] In manikin-based training sessions, the visual estimation of adequate chest rise is frequently used as a surrogate marker of skill acquisition. This is both subjective and difficult to evaluate.[11] Respiratory function monitors (RFM) are devices that provide objective feedback to the operator on the quality of inflations. A number of manikin and clinical studies have shown that RFM's improve the effectiveness of face mask ventilation, [12–14] however challenges with interpretation have been reported.[15,16] This study aimed to systematically develop a standardised training intervention on newborn PPV using an RFM (Monivent, NeoTraining) with simple visual feedback.

Abbreviations: RFM, Respiratory function monitor, PPV, Positive pressure ventilation

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Methods

The study protocol was approved by the Research Ethics Committee of The National Maternity Hospital, Dublin, Ireland before enrolling the first participant (EC24.2021).

We sought prospective written informed consent from all participants. The development of the intervention is described in the following nine steps adapted from a simulation development guideline.[17]

Step 1: Planning the intervention in consultation with content experts

Two neonatology consultants (AC, EOC), a neonatal fellow (CNC) and neonatal resuscitation officer (LS) planned the training intervention on PPV in line with established resuscitation guidelines.[2] The design process was led by EOC and AC, neonatal consultants in tertiary care with experience in simulation, education and neonatal ventilation course development.

Step 2: Performing a needs assessment based on delivery room and manikin based studies and a survey of healthcare professionals

A variety of challenges are encountered during newborn mask ventilation including air leak, the delivery of excessive and suboptimal tidal volumes and airway obstruction (mechanical and physiological). Previous studies have primarily focused on reducing mask leak and improving technique without developing standardised algorithms to correct suboptimal inflations.[13] Furthermore, older studies have used RFMs designed for use on ventilated infants in neonatal intensive care.[5,12–14] These monitors can require considerable experience to interpret which may lead to incorrect management.[15,16] We collected baseline characteristics on participants in the pilot study including their confidence levels and frequency performing mask ventilation, familiarity with RFMs and their preferred resuscitation device to decide which to use in training.

Step 3: Identify measurable objectives

The main objective was to optimise participants' technique in a standardised, reproducible way. Measurable, quantitative objectives were to reduce mask leak and improve delivered tidal volume during PPV. Specific learning outcomes for participants were to identify and correct high leak, suboptimal inflation, excessive tidal volume and airway obstruction using feedback from the RFM.

Step 4: Building the training intervention to align with the objectives / performing a pilot study

We chose the Monivent NeoTraining RFM (Göteborg, Sweden) which has a user-friendly, simple visual display presented on a portable tablet device (iPad, Apple Inc., US). Peak inspiratory pressure (PIP), positive end expiratory pressure (PEEP), percentage leak and ventilation rate are displayed numerically while expiratory tidal volume (Vt_e) is displayed numerically and graphically, as a cylinder that changes colour to reflect the measured Vt_e; low (red), within target range (green) or high (orange). An LED light on the sensor module which sits above the face mask, has the same traffic light system.

Using an iterative design process, we standardised the intervention and training algorithm. We conducted a pilot study consisting of eight sessions, with 2–5 participants per session. After training, we gathered participants' opinions on the acceptability and usefulness of the intervention. Instructors and participants then held a debrief, sharing suggestions on how to improve the intervention. Each iteration was informed by the previous session.

The training intervention was built upon the framework of deliberate practice (DP),[18] a highly structured activity whereby a performance goal is chosen and the learner repeatedly performs the same exercise with continuous feedback. The intervention began with an instructor led demonstration on how to optimise PPV technique, focusing on: airway position, mask placement, hold, pressure and jaw lift.[19] Attention was drawn to the whistling sound from the PEEP valve achieved with adequate mask seal. This was followed by a standardised description on RFM interpretation. Picture cards illustrating the visual feedback during suboptimal inflation, high leak, excess tidal volumes and airway obstruction were used to accompany a step wise demonstration of corrective strategies. The structured learning activity consisted of a period of DP where participants were tasked with using the RFM to achieve or maintain leak < 30% and tidal volume of 4–8 ml/kg in line with published studies.[7,14] An outline of the training intervention is illustrated in Fig. 1 and equipment set-up Fig. 2.

Step 5: Providing a clear overview of the session and context to the task

A scripted pre-brief was developed and described the sequence of the session, context to the intervention and the specific learning objectives.

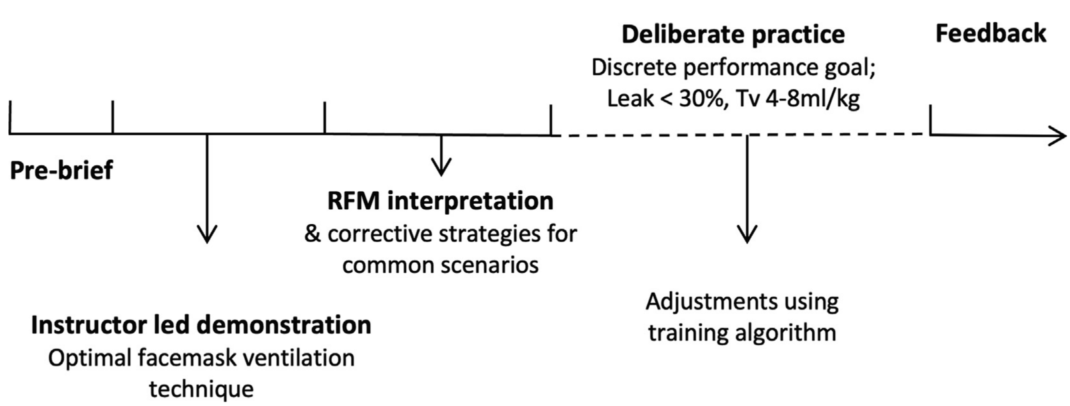

Fig. 1 – Outline of the training intervention. RFM, respiratory function monitor.

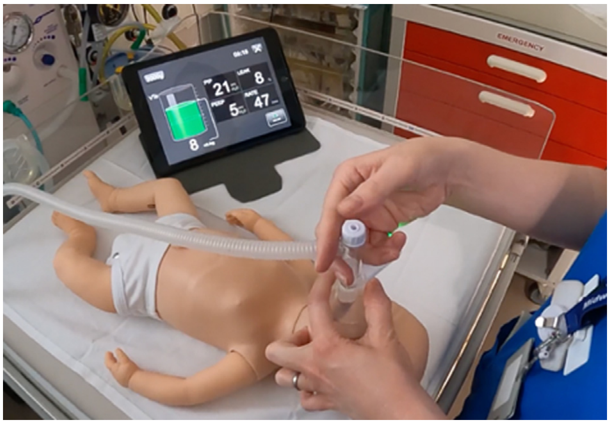

Fig. 2 – Monivent NeoTraining in use during the training intervention. The visual display during optimal ventilation is depicted here. All data from the sensor module is transmitted wirelessly to the external monitor which displays continuous feedback of ventilation parameters.

Step 6: Developing the intervention using the appropriate type of fidelity

The intervention was conducted in the clinical area relevant to the participants (e.g. delivery room for midwives), using a T-piece and the face mask available on site. We chose a term manikin (Laerdal Resusci Baby) whose airway can be manipulated with ease to minimise air leak and inserted a 50 ml test lung (Dräger, Lubeck, Germany) into the chest cavity to create a leak-free system, as previously described.[20].

Step 7: Planning a learner-centred facilitative approach

Participants of the same healthcare professional group were trained together in groups of 2–3. If inflations remained suboptimal (leak > 30%) after a period of DP with self-correction, the instructor followed a stepwise, standardised algorithm to identify elements of the participants technique that needed adjustment. Adjustments were limited to one change each time. These steps were repeated until leak was minimised. If the participants leak remained > 30% the training session was repeated.

Step 8: Feedback

As this was a skills-based intervention, we chose to conclude the session with individualised feedback. Any adjustments which lead to improved inflations informed the basis of this feedback.

Step 9: Developing a plan for evaluation of the participant and the intervention

We plan to conduct a before and after intervention study to assess the effectiveness of this intervention. We will evaluate mean face mask leak (%) before and after training, blinding participants to the RFM's visual display during assessment periods.

Results

A standardised training intervention on newborn PPV was systematically developed using a structured framework.[17] As part of this process, twenty-six healthcare professionals (20 [77%] neonatal nurses, 5 [19%] doctors and 1 [4%] advanced nurse practitioner) were enrolled in a pilot study which comprised of eight training sessions. Suggested improvements were made by participants and instructors during post-training debriefs and included: limiting group size, training colleagues of similar experience together, in-situ location, adding visual aids, scripting instructions and standardising corrections for suboptimal mask technique. Changes were made to the intervention after each session (Table 1). Standardised, simplified instructions for each section of training and illustrative picture cards (e.g., face mask holds) to accompany instructor led demonstrations were developed. The whistling sound emitted from the PEEP valve when adequate seal is achieved was identified as a useful feedback cue and was incorporated into training. Instructors were guided not to interrupt the participant during DP. Thereafter, adjustments to technique were limited to one change at a time, if needed. The process of trialling and refining the intervention continued until a standardised training algorithm was developed. All participants (26 [100%]) preferred the T-piece resuscitation device and felt the intervention would help their clinical practice (Table 2).

Discussion

We describe the systematic development of a training intervention on newborn PPV using an RFM with a simple visual display. Adhering to a set of design criteria ensured the approach was structured and reproducible [17] while piloting the intervention within our target population helped refine the curriculum. We chose a user-friendly RFM to address challenges with feedback interpretation expressed by resuscitators.[15,16] The addition of an RFM into the skills station environment may compete with other devices and key clinical observations, adding to cognitive overload. We considered embedding the task of performing PPV into a resuscitation scenario with additional monitoring devices however, we felt the aim of the development process was to create a short, reproducible intervention that focused on the improvement of a single skillset in isolation. Future studies could assess the impact of using this device in resuscitation training by including a method of eye tracking in the simulation. This study was not designed to measure the effectiveness of the training intervention or clinical transfer of skills. Further studies are warranted.

Conclusions

We have developed a standardised training intervention on newborn PPV addressing the need for teaching on how to use and interpret RFM's in newborn resuscitation training.

Contribution statement

All authors have actively contributed. CNC contributed to the study design, wrote the first draft of the protocol, delivered the training intervention, collected the data and wrote the first draft of the manuscript. LS collected the data, delivered the training intervention and reviewed and revised the manuscript. AC and EOC conceptualised and designed the study, supervised the project and reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Table 1 – Changes made to the training intervention during the pilot study.

Training session	Main features	Changes made after session
1.	**Incorporating feedback**	After each session, feedback was gathered from participants and the instructors (CNC, LS, AC and EOC) held a debrief. Elements of the training intervention that went well were discussed as well as challenges encountered by participants. Proposed changes to the structure of the intervention were documented and incorporated into the intervention before the next session was conducted.
2.	**Standardising the training intervention to ensure consistency across sessions and simplifying the instructions given to participants**	Standardised, scripted instructions for each section of training were developed (CNC), edited (EOC, AC) and trialled with seven individuals who had participated in the first and second pilot sessions. The finalised version was agreed upon by consensus. Scripted descriptions outlined: 1. The purpose of the training intervention and outline of the session 2. How to optimise PPV technique focusing on six critical points 3. The function and utility of the RFM 4. How to interpret feedback from the RFM's visual display 5. Corrective strategies for common scenarios including high leak, excessive tidal volume and airway obstruction
3.	**Introducing illustrative picture cards**	At the appropriate timepoint, the instructor introduced illustrative picture cards of mask holds (A-C) and the monitor's visual display during common scenarios (D-G). Illustrative picture cards depicted: A. OK rim hold B. Two-point top hold C. Stem hold D. Optimal ventilation E. High leak F. Excessive tidal volumes G. Airway obstruction
	Ensuring instruction is individualised to each site	Emphasis was placed on the most appropriate hold(s) for the face mask in use on site
4.	**Refining the delivery of instruction**	The concept of mask pressure and jaw lift performed as a single manoeuvre to achieve adequate mask seal was introduced into the demonstration on PPV optimisation: Mask down, chin up.
	Utilising feedback cues	Attention was drawn to the whistling sound emitted from the PEEP valve when adequate mask seal is achieved.
5.	**Building self-confidence**	Participants were not interrupted by the instructor during DP to allow for self-correction. If instructor direction was required after DP, elements of the participants technique that were done well were reinforced first.
	Identifying specific adjustment(s) leading to improved technique	Any adjustments made to technique were limited to one change at a time and followed a step-wise order; Airway position was addressed first followed by mask placement, mask hold, mask pressure and finally jaw lift. A period of DP was introduced after each adjustment. If the participants leak remained >30% after an adjustment was made, the instructor proceeded to the next step.
6.	**Creating a learner-centred facilitative approach**	Participants of the same healthcare professional group were trained together to improve comfort levels during participation.
	Maintaining confidence levels	A time cap was introduced for participants who's technique remained suboptimal after five minutes of deliberate practice. After this time, the instructor-led demonstration and training intervention was repeated.
7.	**Maximising engagement**	The number of participants were limited to 2-3 individuals per session.
	Reducing fatigue and ensuring a streamlined delivery of training	It was decided that two facilitators were required for each session; one in the role of instructor and another in technical support ensuring all equipment was functioning adequately.
8.	**Deciding on the appropriate level of fidelity**	To create an appropriate level of fidelity, the training intervention was held in the clinical area relevant to the group of participants (e.g. delivery room for midwives) using the facemask and ventilation equipment in use on site.

PPV, positive pressure ventilation; RFM, respiratory function monitor; PEEP, positive end expiratory pressure; DP, deliberate practice.

Table 2 – Survey results from healthcare professionals who participated in the pilot study.

Question	Response	N = 26 Number (%)
Baseline survey		
Professional role	Neonatal nurse	20 (77)
	Advanced nurse practitioner	1 (4)
	Doctor	5 (19)
Preferred equipment	T-piece	26 (100)
Confidence performing PPV	Extremely confident	2 (8)
	Very confident	13 (50)
	Somewhat confident	11 (42)
Frequency performing mask ventilation	Daily	1 (4)
	Weekly	12 (46)
	Monthly	11 (42)
	Never outside of structured training programme	2 (8)
Previously used an RFM	Yes	9 (35)
Post training		
Confidence performing PPV	Extremely confident	12 (46)
	Very confident	14 (54)
Interpretation of the RFM's visual display	Very easy	13 (50)
	Easy	13 (50)
Training intervention useful to clinical practice	Yes	26 (100)

PPV, positive pressure ventilation; RFM, respiratory function monitor.

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CRediT authorship contribution statement

CM Ni Chathasaigh: Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **L Smiles:** Writing – review & editing, Investigation, Data curation. **E O'Currain:** Writing – review & editing, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **AE Curley:** Writing – review & editing, Supervision, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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