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Simulation to assess safety with a high-frequency transport ventilator

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Introduction

The advancement in the specialized care of critically ill neonates often requires the adoption of new technology into clinical practice. The use of high-frequency ventilation during transport allows for infants with the most severe cardio-pulmonary pathology to be transferred for surgical, haemodynamic and pre-extracorporeal membrane oxygenation assessment [1,2]. There is a paucity of publications regarding the human factors and latent safety threats (LSTs) of utilizing a neonatal high-frequency transport ventilator (HFTv) [1–3]. We present our work using simulation to identify and address the human factors and LSTs associated with the introduction of an HFTv to our critical care, neonatal transport team.

Innovation

The HFTv was a new respiratory modality for nearly all team members. To address the lack of collective experience with the HFTv, neonatologists experienced with the HFTv and simulation created three simulation scenarios involving the TXP-2D high-frequency transport ventilator with Phasitron circuit (International Biomedical, Austin, TX) each lasting approximately 5 minutes. These scenarios involved (a) initial set-up and transfer of a clinically ill neonate from a high-frequency oscillating ventilator to the HFTv (b) adjusting the HFTv to optimize the neonate's oxygenation and (c) adjusting the HFTv to optimize the neonate's ventilation.

Simulation sessions were led by a neonatologist with 2–4 transport members. Transport members participated in at least two sessions. Each debrief specifically asked teams to identify and discuss potential actions to address any challenges or LSTs identified while using the HFTv. All previous challenges, LSTs and solutions were carried forward to subsequent sessions and discussed in addition to any new concerns or uncovered LSTs by team members.

Evaluation

A total of 13 sessions were held prior to the deployment of the HFTv into clinical service. Sessions included transport nurses (n = 6), transport respiratory therapists (n = 9), neonatal fellows (n = 5) and neonatology faculty (n = 2) during the 2020–2021 academic year. Several LSTs were consistently identified by the team and addressed through serial debriefing and discussions following the simulations (Table 1).

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Table 1. Latent safety threats identified and team actions addressing them.

Latent safety threat (LST)	Threat description	Team actions addressing the latent safety threats (LSTs addressed)
1	Separate controls at the patient interface (Figure 1A) and on the transport isolette (Figure 1B)	The variable environments can prevent the separate, dedicated controls to be within reach of a single user. Recognition and practice operating the HFTv using a two-person team allows for a team member to always remain focused on the patient while operating the HFTv (**LST 1-6**). Adopted frequent, closed-loop communication relaying the HFTv adjustments being performed and parameter response (**LST 1-5**).
2	Display is not backlit with a narrow viewing angle (Figure 1A)	Having a dedicated member at the display to report HFTv values during the initiation and titration of HFTv due to challenges viewing the display from distance, in low lighting, or from an angle.
3	Controls have variable control response depending on the patient and ventilator settings	Recognition that there is a risk of large, unintentional, swings in parameters with even small adjustments due to the variable control response. Adopted the practice of making small ventilator adjustments during initiation and titration of the HFTv (**LST 3-5**).
4	Adjusting one HFTv parameter can lead to unintentional changes to other ventilator parameters without direct user input	Intentional training and a team-wide, shared, mental model ensuring awareness and knowledge of the inter-dependency of the three HFTv parameters: 1) HFTv breath frequency has an inverse relationship to the amplitude and mean airway pressure. 2) HFTv amplitude has a direct relationship with the mean airway pressure. Adopted the practice of only making single HFTv parameter adjustments at a time and prioritizing the order of parameter adjustments: (1) frequency (2) amplitude (3) mean airway pressure (**LST 3-5**). Creation of a specific HFTv titration reference card in an HFTv FAQ attached to the HFTv.
5	Lag time between HFTv parameter adjustment and display registering the change	Recognizing the lag time between a parameter adjustment and display value change led to awareness not to rapidly make consecutively adjustments to the reduce potential large swings in multiple parameters (**LST 3-5**).
6	Large airway circuit interface with increased tension on the endotracheal tube (ETT)	An additional 'snorkel' extender piece (Figure 1C) was added as part of the standard equipment with the HFTv to unload tension at the ETT to reduce the risk of unintentional extubation or malposition. Additional simulation focusing on awareness, communication, and teamwork of patient loading and unloading to the transport isolette were added to simulations.
7	Multiple, integral pieces to assemble breathing circuit that can be lost or improperly connected leading to malfunction	Intentional team awareness and recognition that unintentional leaks, particularly at connections between the breathing circuit and gas sources, can lead to malfunction. Demonstrate proficiency in the setup of the HFTv by all team members with a specific reference card for set-up included in the HFTv FAQ.
8	A unique operational process to utilize iNO with the HFTv	Incorporation of iNO titration and troubleshooting in follow-up simulations. Creation of a specific iNO reference card for titration and troubleshooting of iNO within the FAQ.

Outcomes

To address these LSTs, the team recognized the need for closed-loop communication, deliberate practice and the adoption of a shared mental model to proactively prepare for the human-factors-related challenges and LSTs associated with the introduction of the HFTv. Specific actions for uncovered LSTs were incorporated into subsequent simulations and annual team competencies included:

1) All members demonstrate the set-up of the HFTv to prevent unintentional leaks or malfunctions from poorly connected pieces.
2) Prioritized, single-parameter adjustments using small control changes.
3) Application of an ETT extender to reduce the tension and risk of unintentional extubation placed on it by the HFTv breathing circuit.
4) Transferring of the patient into and from the transport isolette with attention paid to the breathing circuit and ETT.
5) Adjusting and troubleshooting iNO levels.

The team also adopted specific behavioural changes particularly recognizing the need for increased frequency of closed-loop communication between team members during

Figure 1: Transport team utilizing the HFTv. (A) TXP-2D with digital display of the ventilator parameters and controls for amplitude and frequency. (B) Phasitron breathing circuit with positive and expiratory pressure control. (C) Endotracheal tube extender.

the initiation and titration of the HFTv and patient transfers to and from the transport isolette. Following the 13 simulations, a FAQ covering the set-up and operation of the HFTv was created and attached to the HFTv for immediate reference. Following the completion of the simulations in 2021, the HFTv was deployed and has safely transported critically ill neonates.

What's next?

The use of simulation proved to be an essential component in the safe incorporation of the HFTv for the transport team. Important LSTs were identified and addressed using simulation prior to the go-live introduction of the HFTv in transport. This knowledge was subsequently incorporated into the training to advance the shared mental model amongst the entire team. With the experience and knowledge gained using simulation, we aim to further use simulation to refine our practices and share our experiences to advance the care and technology used in neonatal transport. This work is impactful in that it demonstrates simulation can be used, not just for deliberate practice and reinforcement of clinical algorithms, but when combined with debriefing and discussion, to uncover and address human factors and LSTs associated with new technology.

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Authors' contributions

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Competing interests

None declared.

References

1. Honey G, Bleak T, Karp T, MacRitchie A, Null D, Jr. Use of the Duotron transporter high frequency ventilator during neonatal transport. Neonatal Network. 2007;26(3):167–174.
2. Mainali ES, Greene C, Rozycki HJ, Gutcher GR. Safety and efficacy of high-frequency jet ventilation in neonatal transport. Journal of Perinatology. 2007;27(10):609–613.
3. Rosen O, Nayak B, Olivera J, Bondal E, Payne M, Connors J. Neonatal transport ventilation: simulation to improve knowledge and skills. MedEdPORTAL. 2022;18:11272.