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Effectiveness of positive pressure ventilation during newborn care unit evacuation

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ABSTRACT

Objective: Assess the utility of high fidelity simulation in understanding effectiveness of bag-valve ventilation in a simulated newborn intensive care unit vertical evacuation.
Participants: A total of 70 participants, (13 teams of 4–6 staff) including physicians, nurses, respiratory therapists and other support personnel participated in a 90-min evacuation sessions.
Methods: Two wireless high-fidelity newborn mannequins (Gaumand Scientific[R]) provided real-time data of ventilation support during a NICU evacuation exercise. Trained evaluators also recorded data related to performance. Following the exercises, the simulator data were downloaded and analyzed for rate and consistency of respirations.
Results: Using the data from the simulators and evaluator comments, it was found the infants received proper airway management during the evacuation only 58% of the time. This study highlights the need for ongoing training for NICU staff around safe, effective, coordinated, and timely care of these fragile newborns in the event of an evacuation.

Introduction

Neonatal intensive care unit evacuation is a low probability, high patient and staff risk scenario. However, the recent experience during Hurricane Sandy of a vertical evacuation of 21 neonates from a level III neonatal intensive care unit down nine flights of stairs revealed the importance of effective emergency evacuation planning, particularly in this high risk, critically ill group (Espiritu et al., 2014). Development of effective training methods for these high-risk low-volume events is essential for hospital staff. Vertical evacuation limits the use of ventilators in these fragile infants, so effective ventilation using a variable resuscitation flow-inflating bag is essential for safe transport. Recognizing actual patients could not be involved during a simulation of events of this magnitude, high-fidelity human patient simulators provide a useful alternative. High-fidelity simulators have offered innovative educational opportunities for medical education, in particular around teamwork and essential skill training (Rubio-Gurung et al., 2014). The specific aim of the project was to assess the utility of high-fidelity simulation in understanding effectiveness of bag-valve ventilation in a simulated newborn intensive care unit vertical evacuation.

The immature lungs of neonates, especially those who are premature, are already susceptible to fatigue, increased surface tension, and decreased compliance. These fragile lungs can be easily damaged by excessive pressure of ventilation, barotrauma, and oxygen toxicity (Farquar and Fitgerald, 2010; Kattwinkel et al., 2009). Premature neonates often have not produced the surfactant necessary to coat the lungs and relieve surface tension and increase lung compliance. Without surfactant, the lungs collapse and with each breath become harder to reopen, which leads to increased respiratory distress (Shaffer et al., 2012). Respiratory support is often necessary for these neonates. In preterm neonates, there is

Abbreviations: Newborn Intensive Care Unit, NICU; Respiratory Rate, RR; Human Patient Simulator, HPS.

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impairment in the proliferation of the pulmonary vascular bed, especially in those requiring more intensive respiratory support (Farquar and Fitgerald, 2010). Without proper proliferation of the pulmonary vessels, pulmonary pressures do not drop, and there is increased pulmonary vascular resistance, increased interstitial edema, and an increased sensitivity to stimuli (Farquar and Fitgerald, 2010). Neonates that receive ventilator pressure support that is too high are at risk for barotrauma (alveolar over-distention) that can lead to the rupture of alveoli and as a result, decreased area for gas exchange. Oxygen toxicity can further cause damage to pulmonary structure and function, as it can prevent normal alveolar development. The combination of oxygen toxicity and barotrauma can change the neonate's pulmonary structure and function, contributing to pulmonary hypertension and chronic lung disease (Farquar and Fitgerald, 2010).

Methods

Setting

A large Midwest children's hospital's Newborn Intensive Care Unit (NICU) with 59 beds providing level IV care was the study setting. This hospital is the primary teaching hospital for a major university and medical school as well as the Level I Pediatric Trauma Center. The unit is on the fourth floor of the hospital and is supervised by two neonatal intensivists, two neonatal fellows, five advanced practice nurses, two residents, 32 registered nurses (RNs), five respiratory therapists and several ancillary staff per shift.

Evacuation simulation

The evacuation exercise was part of a larger research study of NICU evacuation. Within the simulated exercise, 13 teams of four-six staff made up of physicians, RN's respiratory therapists and other support personnel participated in a 90-min evacuation session. A total of 70 consented staff participated in this portion of the study. Staff were able to self-schedule over the two-day period in which the evacuation sessions occurred. Each team was tasked with a vertical evacuation of two-three simulated neonates down four flights of stairs. One of the neonates (Infant 3) was not critically ill and could be bundled and carried down the steps; however, the other two required ventilatory support. The research study was conducted in accordance with ethical standards for human subject research and was reviewed by the hospital's Institutional Review Board and found to be of exempt status.

High fidelity human patient simulation is a standard form of education of the NICU staff, completing annual competencies and monthly in situ mock codes. Simulator mannequins were used to track manual ventilations during evacuation. The type of simulators used during the study were the same that NICU staff regularly work with during their unit training sessions. In addition, the advantage of these particular mannequins is that they are wireless, making them easily transportable. Two wireless high-fidelity newborn mannequins (Gaumand Scientific^{R}) were used to represent Infant 1 and Infant 2 in the NICU evacuation exercise. Prior to the evacuation, Infant 1 was connected to a ventilator set at a respiratory rate (RR) of 20 breaths per minute and Infant 2 was connected to an oscillator set at approximate RR of 600 breaths per minute. Once the patients were removed from the devices, they required manual ventilation throughout the remainder of the evacuation. The goal for Infant 1 was manual ventilatory support at 20–60 breaths/min, while the goal for Infant 2 was delivery of 30–60 breaths/min via bag-valve connected to the stabilized endotracheal tube (ETT). The two high-fidelity infant simulators provided real-time data of the effectiveness of ventilatory support during transport.

Trained evaluators followed each staff group and patient throughout the evacuation. Prior to the exercise, the evaluators participated in two training sessions to review the evaluation documents and expectations for each group. Additionally, independent evaluators utilized the same evaluation documents to evaluate performance to test for inter-rater reliability. Following the exercise, each group then participated in a post exercise debriefing session to discuss exercise highlights, lessons learned, performance improvement opportunities, and initial data from infant simulators. Following the exercises, the information from the simulators was downloaded and analyzed for rate and consistency of respirations. Data were assessed using both simulator information and evaluator comments.

Results

The data from the simulator records are presented in Table 1 (see Appendix A). Infant 1 had eleven recordable data events out of thirteen evacuation drills. Mannequin data were lost on the very first group (software error) and Infant 1 was not run in the fifth evacuation drill. Of the eleven events with data, nine groups ventilated in the ideal range, with the lowest ventilation rate being 20.8 RR and the highest ventilation rate being 46.1 RR with a mean average of 28 RR. Of the two groups that did not meet the ideal range, one group did not bag appropriately for the entire exercise, therefore no ventilations were recorded, and the other group had extended lapse times, averaging only 4.4 RR. In conclusion, nine of the eleven recordable groups, or 82%, provided adequate ventilations during the evacuation for Infant 1.

Meanwhile, Infant 2 had data for all thirteen evacuation drills. Of the thirteen events, eleven had recordable data reflecting effective ventilation of the patient. Their average range was between 19.9 RR and 79.2 RR, with a mean average of 34.85 RR. Nine of the thirteen groups ventilated at rates higher than 30 RR. Interestingly, five of the groups ineffectively ventilated the patient when initially removed from the oscillator, some with no bagging at all for up to 3 min. Another RN stopped bagging the patient in the stairwell for two full minutes so she could hold the handrail on the stairway. Of the eleven groups, five ventilated the patient very consistently, without lapses. There were two groups who had no recorded ventilations for their entire evacuation event due to improper bagging or not bagging the patient at all since it was a simulation. In conclusion, eleven of the thirteen groups, or 84.6%, provided some ventilation, but less than 50% were effective for the patient. These lapses in ventilation were from periods of minutes to the entire evacuation. See Table 1 (Appendix A) comment section for details describing these events.

Discussion

The use of human patient simulators (HPS) is now commonly used in many different venues in medical education (Jeffries, 2014). There are numerous studies in the literature that show the use of HPS can improve not only teamwork, but detect hazardous events, as well as improve an individual's skill development and retention of that skill (Bingham et al., 2015; Cheng et al., 2015). In particular, high-fidelity HPS has been shown effective in improving technical skills and teamwork in neonatal resuscitation in the NICU (Rubio-Gurung et al., 2014). Nevertheless, there is little data in the literature surrounding use of high fidelity simulation during disaster/evacuation exercises.

In 2005, Gildea and Etengoff, described a simulation of a vertical evacuation of an intensive care unit. The outcomes of that paper focused on the speed at which staff were able to evacuate patients as well as a thorough assessment of the providers with vital sign