Examination of the Effect of Low versus High-Fidelity Simulation on Neonatal Resuscitation Program (NRP) Learning Outcomes

Final Report of Study Findings

A Study Conducted By:

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- Funding provided by the Janeway Research Advisory Committee, Janeway Children's Hospital Foundation, St. John's, NL.

- Ethics approval received from the Interdisciplinary Committee on Ethics in Human Research (ICEHR), Memorial University.

- NRP training in conjunction with the study was only possible due to the collaborative efforts of the following:

    - Newfoundland and Labrador Provincial Perinatal Program:
        - Coordinated and provided NRP training to medical students (coordinated by Susan White, Neonatal Educator).
        - NRP instructors who were to teach using the high-fidelity simulators attended training sessions in advance of teaching.
        - Instructors provided up-to-date NRP instruction in either high or low simulation formats and facilitated completion of study instruments.

    - Ms. Darlene Toope, Neonatal Educator, Neonatal Intensive Care Unit, Janeway – Drafted and programmed case studies for the high-fidelity manikins (same case studies were adapted for use with the low-fidelity groups).

    - Undergraduate Medical Education (UGME), Faculty of Medicine, Memorial University:
        - Paula Mullins-Richards (MD Program Coordinator during study period) and Wandalee Cole (Clerkship Administrator during study period).
        - Provided support to NRP program in coordinating the teaching of NRP with medical students (i.e. purchase of text books and NRP online exam, scheduling of NRP training and preliminary online exam preparation, providing students with information, providing investigators with time to meet with students to explain study and obtain consent, etc.).

  - Medical Simulation Unit, Faculty of Medicine/Eastern Health:
    - Joanne Hapgood (Education Consultant, ATLS Course and Simulation Unit Curriculum Coordinator, Learning and Development, Eastern Health) and, Sherry Pritchett-Kelly (Coordinator, High Fidelity Simulation Program, Clinical Learning and Simulation Centre, Faculty of Medicine).
    - Provided use of three high-fidelity manikins for use in NRP training, simulator training to instructors, supported creation and programming of training scenarios, and provided technical support.

- Laerdal Canada (Scott Spearn, Vice-President and General Manager) – provided an infant manikin for use in the study (Medical Simulation Unit have 3 high-fidelity manikins; a 4th was required to implement the study given numbers of students and instructors).

- College of the North Atlantic – provided compressor and attachments for use with loaner manikin from Laerdal

- 'Behavioural Markers of Neonatal Resuscitation' form
  - Adapted for use in the study with permission of the lead author (Eric Thomas). Cited from Pediatrics 2010;125(3):539-46.
  - Utilized by Ms. Darlene Toope and Ms. Diana Parsons in their review of all NRP teamwork simulation videos.

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Executive Summary

The purpose of this study was to examine the effect of using low versus high-fidelity manikin simulators in Neonatal Resuscitation Program (NRP) instruction. Low and high-fidelity manikin simulators provide trainees with an opportunity to learn, practice and demonstrate neonatal resuscitation skills in a learning environment which simulates the experiences involved with real resuscitation emergencies. High-fidelity manikin simulator systems have been developed which approximate a full-term newborn in size and weight, possess a realistic airway that can be intubated, lungs that can be inflated with positive pressure ventilation, and an umbilical cord containing a single vein and 2 arteries that allow insertion of umbilical venous and arterial catheters. Integrated computer programs allow primary cues important for accurate assessment of the neonate (heart rate, respiratory rate, and skin color) to be controlled remotely.

In 2003, the International Liaison Committee on Resuscitation (ILCOR) recommended that high-fidelity simulation-directed training should increasingly supplement instructor-directed training in advanced life support/advanced cardiac support (Chamberlain & Hazinski, 2003). Several studies have examined the use of simulation in resuscitation training and specifically compared the utility and effectiveness of low and high-fidelity simulation. However, few studies have compared low and high-fidelity simulation for NRP learning outcomes, and more specifically on team performance and confidence.

This study was funded by a grant from the Janeway Children's Hospital Foundation, Research Advisory Committee. It was led and managed by Professional Development & Conferencing Services (PDCS), Faculty of Medicine, Memorial University, as well as a team of study investigators (see Section 1.1). Ethics approval was received from the Interdisciplinary Committee on Ethics in Human Research (ICEHR), Memorial University.

Methodology

In June 2012, NRP was one of the components of the MD Clerkship Preparation Course – a two-week course which all medical students must successfully complete in advance of their third and fourth years of medical school (clerkship). In advance of the NRP training (and to facilitate this study), all beginning third year medical students were randomly assigned to one of two instructional groups by UGME in collaboration with the Neonatal Educator/NRP coordinator:[1]

1. An Experimental Group who participated in NRP training and megacode assessment using a high-fidelity manikin simulator (N=31 students divided across 8 groups).
2. A Control Group who participated in NRP training and megacode assessment using a low-fidelity manikin simulator (N=35 students divided across 9 groups).

Medical students were required to participate in and complete the NRP training and assessment components (online exam, performance skills stations, integrated skills stations which incorporated the megacode assessment, and recorded teamwork simulation). As part of participating in the study, students were asked to consent to release of the following to investigators:

- Their completed NRP Megacode Assessment Form.
- Their recorded teamwork simulation which was reviewed by two independent raters.

Students were also asked to complete:

- A Participant Evaluation Survey.
- A Neonatal Resuscitation Confidence Scale.

Summary of Findings

Prior to commencement of the study, four hypotheses were developed regarding the impact of the comparison of high versus low-fidelity simulation on the experimental and control groups. The investigators hypothesized that:

- There will be no significant differences in knowledge or megacode performance between the experimental group participants and the control group participants.

[1] There were some exceptions to the randomization and grouping process. Medical students at this level typically have no previous exposure to NRP. However, 1 student is a former neonatal nurse experienced in NRP and in using low-fidelity. He/she was therefore placed in a high-fidelity group to counteract possible bias towards either fidelity. In addition, 5 students attended the training and megacode in various groups, but then participated in the teamwork simulation together as a separate group due to an inability to attend the teamwork simulation with their originally assigned groups (due to previously approved leave.).

- Confidence ratings of the experimental group participants will be significantly higher than those of the control group participants.

- There will be no significant differences in team performance scores between the experimental group participants and the control group participants.

- Satisfaction scores of the experimental group participants will be significantly higher than those of the control group participants.

Overall, the study findings were consistent with the hypotheses. Students who participated in the high-fidelity NRP training demonstrated significant increases in overall satisfaction ($p=.001$) and confidence ($p=.001$). There were no significant differences in team performance scores, as observed by two independent raters. While there was a significant overall difference in knowledge and skills ($p=.003$), this difference was largely attributable to performance differences on one item that was not influenced or related to a fidelity feature of the manikins - "dries, removes, wet towels and repositions head". Students from both low and high-fidelity study groups demonstrated no difference on mandatory performance items for the megacode assessment.

The study findings suggest that the most significant impact of high-fidelity training for NRP is on students':

- Satisfaction with the training experience.
- Confidence to perform NRP:
    - Specifically in areas where the manikin 'automatically' responds to correct performance of a skill (i.e. correct ventilation automatically makes the chest rise vs. the instructor telling students that the chest is rising).
    - As part of a team.

Students who participated in the high-fidelity groups reported it to be a 'great learning experience' and an 'excellent learning tool', citing that the 'hands-on experience is much more valuable than reading from a book'. Students who participated in the low-fidelity groups also reported an 'excellent experience', that the 'manikin was adequate to learn what we needed to', and it was 'much better than classroom/lecture learning'. However, students in the low-fidelity groups also reported that having 'real' oxygen saturation levels and/or being able to hear the heart rate would have been helpful.

Recommendations

- Continued use of low-fidelity simulation for basic NRP/basic resuscitation skills training.

  The ability of educational and healthcare institutions to utilize high-fidelity simulation may be limited given the required resources (e.g., costs and personnel time) to operate such manikins. The study findings demonstrate that low-fidelity simulation manikins are effective for training in basic NRP or other basic resuscitation skills. While there were significant differences in self-report satisfaction and confidence data, there were no significant and observable differences in most skill performance areas, including teamwork, which is an important aspect of resuscitation training and performance.

- Use of high-fidelity simulation for advanced resuscitation skills training and complex tasks.

  The literature supports the use of low-fidelity simulation for basic resuscitation tasks such as airway management, but suggests that using high-fidelity simulation may have a greater impact on participants' knowledge, performance and confidence as tasks become more complex (Rodgers, Securro, & Pauley, 2009).

- Provide students, residents, and practitioners with some resuscitation training using a high-fidelity manikin if available.

  The study findings demonstrate that the fidelity level had a significant impact on medical students' overall satisfaction with this training experience. It is therefore recommended that if available, high-fidelity simulation should be accessible for resuscitation training/re-certification. If the learning experience is enjoyable, learners may be more motivated to attend the session, make time for re-certification and updates, etc.

Study Limitations

- Instructor variability – the instructors participating in this NRP training had diverse professional backgrounds and experiences (i.e. nursing, respiratory therapy, etc.), as well as diverse levels of training on high and/or low-fidelity manikins. These differences could have impacted their confidence with their assigned form of simulation and in turn, the level of instruction provided to the students.

- Generalizability of findings to health care practitioners – this NRP training was conducted with medical students with limited clinical experience and in using NRP. The results and study findings must be considered in that context.

- Limitation of the video behavioural rating form due to the length of simulation recorded – a longer simulation may have allowed for greater observance and frequency of the skills being reviewed.

Future Research

- Students in the high-fidelity groups reported greater satisfaction and confidence with the training experience. What effect might high-fidelity simulation usage have on retention of knowledge and/or skill over time?

- Repeat the study with more advanced students or residents and using advanced NRP, longer megacodes, etc. to further determine impact of fidelity used.

- Translation of findings into clinical practice and on patient care. Are there differences between low- and high-fidelity usage in NRP training on provider performance in the clinical care setting?

1.0 Purpose of Study

The purpose of this study was to examine the effect of using low versus high-fidelity manikin simulators in Neonatal Resuscitation Program (NRP) instruction. Low and high-fidelity manikin simulators provide trainees with an opportunity to learn, practice and demonstrate neonatal resuscitation skills in a learning environment which simulates the experiences involved with real resuscitation emergencies. High-fidelity manikin simulator systems have been developed which approximate a full-term newborn in size and weight, possess a realistic airway that can be intubated, lungs that can be inflated with positive pressure ventilation, and an umbilical cord containing a single vein and 2 arteries that allow insertion of umbilical venous and arterial catheters. Integrated computer programs allow primary cues important for accurate assessment of the neonate (heart rate, respiratory rate, and skin color) to be controlled remotely.

Four hypotheses were developed regarding the impact of this comparison on the experimental group participants (who receive NRP instruction utilizing a high-fidelity simulator) and the control group participants (who receive NRP instruction utilizing a low-fidelity simulator):

1. There will be no significant differences in knowledge or megacode performance between the experimental group participants and the control group participants.

2. Self-efficacy scores of the experimental group participants will be significantly higher than those of the control group participants.

3. There will be no significant differences in team performance scores between the experimental group participants and the control group participants.

4. Satisfaction scores of the experimental group participants will be significantly higher than those of the control group participants.

1.1 Study Funding & Investigators

This study was funded by a grant from the Janeway Children's Hospital Foundation, Research Advisory Committee. It was led and managed by Professional Development & Conferencing Services (PDCS), Faculty of Medicine, Memorial University. The study investigators were as follows:

- Dr. Vernon Curran, PhD (Principal Investigator) – Director of Academic Research and Development, Professor of Medical Education, Faculty of Medicine, Memorial University
- Ms. Lisa Fleet, MA, Dip.Ad.Ed., BEd – Manager, Research Programs, Professional Development & Conferencing Services, Faculty of Medicine, Memorial University
- Ms. Susan White, RN, BN – Neonatal Educator, NL Provincial Perinatal Program, Janeway Children's and Rehabilitation Centre
- Ms. Clare Bessell, RN, B. Voc.Ed – Obstetrical Educator, NL Provincial Perinatal Program, Janeway Children's and Rehabilitation Centre
- Dr. Akhil Deshpandey, MBBS, MRCPI - Neonatologist, Janeway Children's and Rehabilitation Centre, Assistant Professor of Pediatrics, Faculty of Medicine, Memorial University
- Dr. Anne Drover, MD, FRCPC - Pediatrician, Janeway Children's and Rehabilitation Centre, Associate Professor of Pediatrics, Faculty of Medicine, Memorial University

1.2 Study Rationale

In 2003, the International Liaison Committee on Resuscitation (ILCOR) recommended that high-fidelity simulation-directed training should increasingly supplement instructor-directed training in advanced life support/advanced cardiac support (Chamberlain & Hazinski, 2003). Several studies have examined the use of simulation in resuscitation training and specifically compared the utility and effectiveness of low and high-fidelity simulation. However, few studies have compared low and high-fidelity simulation for NRP learning outcomes, and more specifically on team performance and confidence. Researchers have recommended teaching team behaviors during simulated neonatal resuscitations, but few studies have conducted such activities and analyses.

1.2.1 Neonatal Resuscitation

Approximately 6% of all newborns and up to 80% of infants weighing less than 1,500 grams require some resuscitation intervention at birth and the quality of care provided at that time can have a significant impact on the outcome of that life. In 1984, the Canadian Coalition for the Prevention of Developmental Disability and the Canadian Paediatric Society (CPS) identified newborn resuscitation as an important target for improving perinatal care. However, results of a Canadian Institute of Child Health (CICH) survey published in 1987 reported wide variations in neonatal resuscitation preparedness and standards among 577 Canadian institutions (Chance & Hanvey, 1987). Only 55% of hospitals reported having written guidelines for neonatal resuscitation in the delivery room and 56% of hospitals reported having no resuscitation team (Chance & Hanvey, 1987). These findings resulted in a Canadian Medical Association (CMA) recommendation that hospitals with obstetrical units establish protocols and training programs for personnel responsible for neonatal resuscitation (Hanvey, 1988). Similar conclusions were also made in the United States which resulted in the development of the Textbook of Neonatal Resuscitation. This landmark text established a standard for neonatal resuscitation training, the Neonatal Resuscitation Program (NRP), a program that would eventually be endorsed by the American Heart Association, the American Academy of Pediatrics, the CPS, the Heart and Stroke Foundation of Canada, and the CICH. In April 2000, Health Canada declared completion of NRP to be “essential for all personnel likely to care for babies immediately after birth”, and that “personnel skilled in neonatal resuscitation and able to function as a team should be available for every birth” (Health Canada, 2000).

NRP combines a self-directed learning approach utilizing a textbook with practical face-to-face teaching sessions. Each chapter in the text contains information, algorithms and diagrams that depict the stages of neonatal resuscitation. Teaching methods include case scenarios, key points and checklists. Every chapter also has a multiple choice post-test that evaluates the student’s knowledge. The practical sessions reinforce the skills required for each chapter and are taught by NRP-registered instructors. Completion of the NRP course is demonstrated by passing a written examination, a performance checklist, and a megacode. A national NRP Steering Committee recommends that NRP trainees be updated every 2 years utilizing a multiple choice questionnaire (MCQ) and megacodes.

Neonatal resuscitation requires a combination of theoretical knowledge and practical hands-on skill. The pediatrician (or other health care provider) is often charged with prompt recognition, resuscitation, and stabilization of the neonate in distress. Carrying out this responsibility requires thorough knowledge of fetal and neonatal physiology, proficiency in technical skills such as endotracheal intubation, positive pressure ventilation, and umbilical vessel catheterization, and the ability to manage all of the technologic, pharmacologic, and human resources available in the delivery room (Halamek et al., 2000). Researchers have evaluated the impact of NRP courses on providers' knowledge, skills, and comfort levels to conduct resuscitation after training, the results indicating significant improvements/increases in all areas (Skidmore & Urquhart, 2001; Ergenekon, Koç, Atalay, & Soysal, 2000).

1.2.2 Simulation-Based Training

Research indicates that optimal acquisition and retention of knowledge and skills by adult learners is achieved by active rather than passive participation. Computer-based training and computerized simulator systems have been used to provide interactive resuscitation training in NRP, advanced pediatric life support (APLS), advanced cardiac life support (ACLS), advanced life support (ALS), and other resuscitation and clinical skill areas. According to Halamek and colleagues (2000), simulation-based training involves immersion of the trainee in a realistic situation (scenario) created within a physical space (simulator) that replicates the real environment. In the context of medical education, simulation can be defined as an education technique that allows interactive and immersive activity by recreating all or part of a clinical experience without exposing patients to associated risks (Perkins, 2007).

In general, there are two forms of integrated clinical simulators. High-fidelity simulators are computer-driven and utilize physiological and pharmacological modeling algorithms to mimic real-life situations (Perkins, 2007). The manikins display physiological signs and the administration of drugs is sensed by the simulator and triggers a response. High-fidelity simulation-based training offers a controlled environment in which multiple intense clinical experiences can be provided in a relatively brief period, and unlike the real world, simulator training offers the convenience of scheduling and the option of repetition. By contrast, low-fidelity simulators are manikins which are instructor-driven, with limited physiological feedback (Perkins, 2007). It relies on the instructor providing feedback or cues, not the manikin.

Yaeger and Arafeh (2008) suggest that the most effective way to teach neonatal resuscitation is through simulation-based training. Halamek and colleagues (2000) and Halamek (2008) highlight the success of the NeoSim program developed in the Center for Advanced Pediatric and Perinatal Education at Stanford University in 1997. This program was the first simulation-based training program in neonatal medicine and has successfully trained health care providers in the skills required for resuscitation of newborns. NeoSim includes a neonatal manikin (Medical Plastic Laboratory, Inc, Gatesville, TX) which approximates a full-term newborn in size and weight (Halamek et al., 2000). It possesses a realistic airway that can be intubated, lungs that can be inflated with positive pressure ventilation and an umbilical cord containing a single vein and 2 arteries that allow insertion of umbilical venous and arterial catheters. An integrated computer program allows the primary cues for accurate assessment of the neonate (heart rate, respiratory rate, and skin color) to be controlled remotely and displayed on a pulse oximeter (hemoglobin oxygen saturation is used as a surrogate for color). The initial physiologic state and the subsequent responses of the neonatal manikin to the actions of the subjects are controlled by a single observing faculty member during each NeoSim program.

1.2.3 Impact of High vs. Low-Fidelity Simulation for Training

Several of the advantages of simulation-based training are highlighted in the literature (Murphy & Halamek, 2005; Issenberg, McGaghie, Petrusa, Gordon, & Scalese, 2005). It provides trainees with increased clinical experiences without training on real patients. High fidelity-simulations also allow the provision of feedback, repetitive practice, including scenarios with a range of difficulties, and the ability to capture clinical variations, features which can impact the learning environment and outcomes (Issenberg et al., 2005).

While several studies have compared the use of high versus low-fidelity simulators, few have conducted such work in the field of neonatal resuscitation (Campbell, Barozzino, Farrugia, & Sgro, 2009). Campbell and colleagues (2009) conducted a comparison of the use of high and low-fidelity simulation in neonatal resuscitation with fifteen (N=15) PGY1 Family Medicine residents at St. Michael's Hospital in Toronto, ON (Campbell et al., 2009). Residents were randomly assigned to work with a high-fidelity manikin (N=8) or a low-fidelity, standard plastic manikin (N=7). Written examination, megacode performance and satisfaction scores were compared. The study findings demonstrated that residents in the high-fidelity group did not have improved written scores or improved intubation times. However, residents in the high-fidelity group rated the experience significantly higher than those in the low-fidelity group ($p=.026$).

The literature appears to indicate a divide in comparing the benefits of high versus low-fidelity simulators outside of the neonatal resuscitation domain. Several studies illustrate the benefits of high-fidelity simulation over low-fidelity in healthcare provider knowledge, skills, attitudes, and satisfaction. Scholz et al. (2012) randomly assigned N=46 undergraduate medical students in an obstetric rotation to be taught using either high or low-fidelity simulators. The study found that high-fidelity simulation improved students' feeling that they understood and felt better prepared for obstetric procedures. As well, students in the high-fidelity simulation group also performed better in obstetric skills evaluations. Another study supporting the benefits of high-fidelity simulation was published by Crofts et al. (2006) who investigated the effectiveness of simulation training for shoulder dystocia management. There were N=141 participants (n=45 doctors, n=95 midwives) randomized to training with high or low-fidelity manikins. A pre/post-test study design was utilized. Although both groups were associated with improved performance, participants training with the high-fidelity manikin demonstrated a higher successful delivery rate than training with traditional devices (94% vs. 72%, p=0.002).

By contrast, other non-NRP studies indicate little to no benefit in knowledge, skills, attitudes, and/or satisfaction when comparing use of high and low-fidelity simulation. Hoadley (2009) compared the effects of high versus low-fidelity simulation on ACLS knowledge and performance of healthcare providers, including physicians, nurses, respiratory therapists, advanced practice health care providers, and paramedics. The experimental group (N=29) was exposed to high-fidelity simulation; the control group (N=24) used low-fidelity simulation. A pre/post-test study design was utilized. The study findings demonstrated that there were no significant differences in the post-knowledge and megacode performance scores between the groups. There was also no significant difference reported in the satisfaction or confidence of either group. Lee, Grantham, and Boyd (2008) compared the use of high and low-fidelity simulation with advanced pediatric life support. The majority of study subjects (intensive care paramedics recruited from the South Australian Ambulance Service) reported a preference for using the high-fidelity manikin.

Tan et al. (2012) examined use of high or low-fidelity laparoscopic simulators on learning outcomes. There were N=228 participants recruited (n=100 high-fidelity, n=128 low-fidelity). Mean crossover scores increased from baseline for both simulators, but there was no significant difference between fidelity groups (11.0 % vs. 11.9 %). After the crossover, low-fidelity participants demonstrated a greater ability to translate their skills to successfully complete high-fidelity simulation tasks. The study concluded that the benefit of low-fidelity simulation, compared with high-fidelity simulation, improved participants' abilities to transfer their skills to new settings (Tan et al, 2012). Davoudi et al. (2010) examined the perceptions and preferences of both learners and instructors regarding the effectiveness of low and high-fidelity simulation for training in transbronchial needle aspiration (TBNS). A prospective, randomized, crossover design was utilized. Likert scale questionnaires were completed to determine preferences and opinions regarding educational effectiveness of the models. The study found that low-fidelity simulation was preferred as an ideal model. Learners reported no difference in satisfaction between the simulation model, but preferred low-fidelity simulation with regards to realism, ease of learning, and learning overall. Similarly, Instructors reported that low-fidelity was more effective in teaching and learning TBNA (Davoudi et al., 2010).

1.2.4 Teamwork Training

Effective teamwork and communication skills are cornerstones of safe, reliable, and high-quality health care (Greiner & Knebel, 2003; Reeves & Freeth, 2002; Wee et al., 2001; Frankel, Gardner, Maynard, & Kelly, 2007). A comprehensive review of the literature sponsored by the Agency for Healthcare Research and Quality (AHRQ) provides evidence supporting a positive relationship between effective teamwork and patient safety (Paige, 2009). The Institute of Medicine (IOM), Association of American Medical Colleges (AAMC) and the Association of Faculties of Medicine of Canada (AFMC) suggest that training programs should place greater emphasis on team and leadership training to best shape these skills in providers entering the workforce (Daniel & Simpson, 2009; Carlson, Min, & Bridges, 2009; Association of Faculties of Medicine of Canada, 2010). The Canadian Patient Safety Institute (CPSI) has developed a Canadian interprofessional competency-based framework for patient safety (Canadian Patient Safety Institute, 2008). The Working as a Team domain specifically describes the ability of health professionals to effectively collaborate with others to maximize patient safety and the quality of care.

There is a growing body of literature demonstrating that when healthcare professionals understand each other's' roles and are able to communicate and work effectively together, patients are more likely to receive safe, quality care. A team can be identified as a co-located group of two or more individuals working to plan, problem solve, and carry out safe, quality care across a population of patients, over time, within the context of high-stress, high-stakes, time compressed environments where information is unavailable or uncertain; or within the confines of a structured simulated setting (Shapiro et al., 2008). Team behaviors have been classified in the literature as nontechnical skills - cognitive or social skills that play an important role in promoting safety and successful problem management (Gaba et al., 1998; Fletcher et al. 2004; Flin & Maran, 2004; Fletcher et al. 2003).

Training in teamwork and communication, known as Crew Resource Management (CRM) training, has been implemented in the aviation industry to reduce the potential for human error (Klinect, Murray, Merritt, & Helmreich, 2003). Lauber first defined CRM to mean "using all available sources - information, equipment, and people - to achieve safe and efficient flight operations" (Lauber, 1987). CRM has expanded to include the identification of potential threats of error, to avoid or mitigate these threats, and to improve morale and enhance efficiency of operations (Frankel et al., 2007; Helmreich & Wilhelm, 1991; Helmreich, Merritt, & Wilhelm, 1999; Wiener, Kanki, & Helmreich, 1993). Behavior-based aviation safety audits, such as line-oriented flight training and line operation safety audits (LOSA) are used to document team skill proficiencies of leadership, communication, workload management, and monitor ⁄cross-check performance. A ‘‘nontechnical skills’’ assessment tool has also been developed specifically to evaluate CRM behaviors of individual pilots during flight deck maneuvers (Van Avermaete, 2005). The Institute of Medicine and others have encouraged healthcare providers to look to the aviation industry because of its long history of measuring and improving teamwork to prevent and mitigate errors. Several studies suggest the use of CRM in resuscitation training (Andersen et al., 2010 & Falcone et al., 2008). In 2003, ILCOR recommended that CRM and communication should be a component of ALS/ACLS training, either as an add-on module or a separate course (Chamberlain & Hazinski, 2003).

1.2.5 Impact of Simulation-Based Training on Team Behaviours

Patient safety research is now targeting ways to observe and measure the teamwork skills of health care providers in a variety of high-intensity medical environments (Frankel et al. 2007). The use of high-fidelity, simulation-based training has been recommended as an authentic, low risk learning environment for teaching teamwork competencies and promoting reflective, deliberate practice (Paige et al., 2009; Beaubien & Baker, 2004). The popularity of simulation-based training is largely due to its ability to offer a lifelike learning environment where clinicians can practice their skills. In the absence of live patients, health care providers can operate in a setting in which it is safe to try new skills without risk of patient harm (Shapiro et al., 2008). Because of its ability to safely recreate the complex scenarios and environments in which medical teams operate, high-fidelity simulation has been identified as a methodology for training and assessing team behavior in undergraduate and graduate medical education as well as in experienced providers (Carlson, Min, & Bridges, 2009). Anesthesia, surgery, and emergency medicine have increasingly reported team training and assessment methods incorporating formats from other high-risk industries and high-fidelity simulation (Fletcher et al., 2004; Flin & Maran, 2004; Malec et al., 2007; Reznek et al., 2003; Moorthy et al. 2005; Flin & Yule, 2005; Lighthall et al., 2003). Although there is more than one method, teams commonly are trained in teamwork and error preventing strategies, implement these strategies during simulated training events, and receive feedback on their performance to facilitate the learning process and improve future practice (Carlson et al., 2009).

The NRP approach is one of developing a multidisciplinary team who will be available for case room emergencies. Researchers have recommended teaching team behaviors during simulated neonatal resuscitations, but there are few validated tools in the literature and few studies which have conducted such analyses. Thomas et al. (2010) used simulation to evaluate the effectiveness of team training and NRP performance. A randomized controlled trial was conducted at the University of Texas Medical School in which half of the participants utilized high-fidelity simulators while the remaining practiced with low-fidelity. Participants were incoming interns for pediatrics, combined pediatrics and internal medicine, family medicine, emergency medicine, and obstetrics and gynecology. Blind, trained observers viewed video recordings of high-fidelity simulated resuscitations for teamwork and resuscitation quality. Two of the groups received team training. The results showed that teams who received teamwork training managed the resuscitation workload significantly better ($p=<.001$) than the control subjects, however, there was no evidence of association between teamwork training intervention and NRP performance. Thomas, Sexton, and Helmreich (2004) developed the University of Texas Behavioral Marker Audit Form (UTBMNR) after reviewing decades of research on teamwork in aviation, recent survey and focus group data from healthcare providers, and video recordings of neonatal resuscitations. The form contains three sections: event demographics, behavioural markers, and threats to patient care. Two scales are used to rate each behaviour. The observability scale allows one to indicate how well a behaviour could be observed and the frequency scale is used to indicate how often a behaviour occurred (Thomas et al., 2004).

2.0 Study Methodology

All beginning clerks (3rd year medical students) are required to participate in and successfully complete NRP as part of their medical school curriculum in advance of specific rotations. A randomized posttest-only control group study design was implemented in conjunction with this training to meet the study objectives. All medical students were randomly assigned to one of two instructional groups by the office of undergraduate medical education (UGME) in collaboration with the Neonatal Educator/NRP coordinator:[2]

1. An Experimental Group who participated in NRP training and megacode assessment using a high-fidelity manikin simulator.
2. A Control Group who participated in NRP training and megacode assessment using a low-fidelity manikin simulator.

2.1 NRP Instruction & Assessment

In January 2012, the NRP program was re-formatted and now requires participants to review the NRP textbook (chapters 1-4 and 9) and complete an online multiple choice knowledge exam prior to attending their session with the instructor. Participants must provide a Certificate of Completion for the online exam to the instructor before they can participate in the training. The training is delivered over approximately 4 ½ hours, with 3 hours for performance skills stations (a skills development process in which participants learned and practiced resuscitation skills on a manikin) and a megacode skills assessment, and 1 ½ hours for a teamwork simulation scenario (for which recording is recommended so that it can be viewed as part of a debrief with students following the simulation). Participation in and completion of all of the above was required for students to receive a Course Completion Card in NRP and had no relationship to this study.

2.2 Manikins

Low and high-fidelity manikin simulators provide trainees with an opportunity to learn, practice and demonstrate neonatal resuscitation skills in a learning environment which simulates the

[2] There were some exceptions to the randomization and grouping process. Medical students at this level typically have no previous exposure to NRP. However, 1 student is a former neonatal nurse experienced in NRP and in using low-fidelity. He/she was therefore placed in a high-fidelity group to counteract possible bias towards either fidelity. In addition, 5 students attended the training and megacode in various groups, but then participated in the teamwork simulation together as a separate group due to an inability to attend the teamwork simulation with their originally assigned groups (due to previously approved leave.).

experiences involved with real resuscitation emergencies. High-fidelity manikin simulator systems have been developed which approximate a full-term newborn in size and weight, possess a realistic airway that can be intubated, lungs that can be inflated with positive pressure ventilation, and an umbilical cord containing a single vein and 2 arteries that allow insertion of umbilical venous and arterial catheters. Integrated computer programs allow primary cues important for accurate assessment of the neonate (heart rate and skin color) to be controlled remotely.

There were four (4) high-fidelity simulators used with the Experimental Group for the NRP training:

- Laerdal 'SimNewB' high-fidelity simulator (2):
    - Represents a full-term, 40 week newborn; various patient scenarios can be simulated, ranging from a limp, cyanotic newborn with no vital signs, to a moving, crying, vigorous newborn. Its airway is designed to allow for training in all aspects of newborn airway management, including the use of positive-pressure airway devices. The umbilicus has a life-like pulse that can be assessed, cut and catheterized for IV access.
- Gaumard Newborn Hal:
    - Represents a full-term, 40 week newborn with breathing, pulses, color and vital signs that are responsive to hypoxic events and interventions. Also includes trending, crying, convulsions, oral and nasal intubation, and airway sounds.
- Gaumard Premie Hal:
    - Represents a 30 week premature neonate with breathing, pulses, color and vital signs that are responsive to hypoxic events and interventions. Weighs less than 1400 grams and also includes trending, crying, convulsions, oral and nasal intubation, and airway sounds.

Study co-investigators and NRP instructors (Susan White and Clare Bessell) examined the manikins and determined all to be appropriate for NRP training. Participants in the Control Group received NRP instruction using a traditional low-fidelity manikin (in this case the Nasco Life Form Infant Crisis Manikin). This manikin is anatomically correct in both size and detail and includes landmarks such as gum line, tongue, oral and nasal pharynx, larynx, epiglottis, arytenoids, false and true vocal cords, cricoid ring, tracheal rings, trachea, and esophagus.

2.3 Study Instruments/Data Collected

Ethics approval for this study was received from the Interdisciplinary Committee on Ethics in Human Research (ICEHR), Memorial University. As part of this, ICEHR reviewed and approved all study instruments and consent documents. Medical students were required to participate in and complete the NRP training and assessment components (online exam, didactic lecture, performance skills stations, megacode assessment, and recorded teamwork simulation). To facilitate this study, students were also asked to consent to the release of some of their data to investigators and to complete additional study instruments.

A UGME representative (Wandalee Cole) and study co-investigator (Lisa Fleet) met with the medical students prior to their NRP training. Students were provided with the NRP textbooks and access to the online exam. They were also provided with information regarding the structure of the NRP training and its relationship to the research study. Ms. Fleet then provided all students with a confidentiality/consent form for their review and signature. As part of participating in the study, students were asked to consent to release of the following to investigators:

1. Their completed NRP Megacode Assessment Form (**Appendix A**), which is completed by the NRP instructors. The megacode assessment form includes the list of skills which those receiving NRP training must demonstrate. These results were de-identified, grouped and analyzed by simulator used for training (high vs. low fidelity).

2. Their recorded teamwork simulation (recording is recommended as part of the NRP debriefing process) which two independent raters reviewed using the Behavioural Markers of Neonatal Resuscitation Form[3] (**Appendix B**) to examine teamwork perceptions and performance.

As part of participating in the study, students were also asked to complete:

- A Participant Evaluation Survey (**Appendix C**) to assess satisfaction with use of low vs. high fidelity.

- A Neonatal Resuscitation Confidence Scale (**Appendix D**) to assess participants' confidence.

Details regarding the study instruments are shown in Table 1.

[3] Adapted and used with permission of Thomas et al. (2004).

Post-NRP instruction knowledge/skills, satisfaction, self-efficacy, and teamwork performance scores were compared between groups to measure the effect of the simulation fidelity. Quantitative data was entered in SPSS (v.19) and statistical analysis included frequencies analyses, t-tests, mann whitney, and cohen's kappa analyses. Qualitative data was reviewed and summarized based on common themes.

Table 1 - Study Instruments/Activities

Instrument/Activities	Details
Megacode Assessment Form	• 16 items (score out of 32) • Scale 0=not done, 1=done incorrectly, incompletely or out of order, 2=done correctly in order • 5 items must be performed correctly (score 2) • Minimum score of 26 points to pass
Behavioural Markers of Neonatal Resuscitation[1]	• 9 items rated on: observability (scale 0-4) & frequency (scale 1-4)
Participant Evaluation Survey	• 14 items (5-point likert scale, strongly disagree to strongly agree) • 4 open-ended questions
Neonatal Resuscitation Confidence Scale	• 20 items related to NRP abilities, skills, tasks • Scale 0-100 (0=cannot do; 50=moderately can do; 100=highly certain can do)

3.0 Study Findings – NRP Training

3.1 NRP/Study Participants

In June 2012, NRP was one of the components of the MD Clerkship Preparation Course – a two-week course which all medical students must successfully complete in advance of their third and fourth years of medical school (clerkship). In advance of the NRP training (and to facilitate this study), all beginning third medical students were randomly assigned to one of two instructional groups by the NRP coordinator (Table 2). Each group was facilitated by an NRP-certified instructor.

Table 2 – NRP/Study Participants & Groups

Groups	# of Students	# of Groups
Experimental (High-fidelity)	31	8 groups: • Group 1 • Group 2 • Group 3 • Group 4 • Group 9 • Group 11 • Group 12 • June 21st #2
Control (Low-fidelity)	35	9 groups: • Group 5 • Group 6 • Group 7 • Group 8 • Group 10 • Group 14 • Group 15 • Group 16 • June 21st #1

3.2 Knowledge/Skills (Megacode)

Students' attainment of the required knowledge/skills for NRP is assessed via a 'megacode' after the training component is complete. Students perform various skills during a simulated scenario while the instructor completes the NRP Megacode Assessment Checklist for each student. Five of the skills are mandatory[4] and must be scored as 'done correctly in order' (a score of 2). Table 3 lists the other megacode skills on which students are assessed. Students can score lower on these skills, but must attain the minimum score of 26 to successfully pass the megacode. The results of a Chi Square Fisher's Exact Test analyses shown in Table 3 indicates that overall, a significantly higher percentage of students using the high-fidelity manikin (95.2%) achieved a score of '2' on the majority of skills in comparison to the scores of those using the low-fidelity manikin (91.3%) (p=.003). A further analyses of each individual megacode item indicated a significant difference between high and low-fidelity groups on only one item 'dries, removes wet towels and repositions head' (p=.024); a skill on which the level of manikin fidelity would have no impact.

3.3 Satisfaction

3.3.1 Manikin Used & Training

After completing the NRP program, all students were asked to complete an evaluation survey indicating their level of satisfaction with the manikin they used for their training (ratings based on a likert scale of 1=strongly disagree to 5=strongly agree). The results of an Independent samples t-test analyses shown in Table 4 demonstrates an overall significant difference in the mean satisfaction of high fidelity vs. low fidelity participants (overall mean satisfaction of 4.59 vs. 3.56, respectively) (p<.001). Analysis of individual items also demonstrates significant differences in mean satisfaction (high vs. low) related to various components of the simulator and/or the training experience. For instance, students using the high-fidelity manikin were significantly more satisfied with the realistic feedback provided by the simulator (high fidelity mean 4.52; low-fidelity mean 2.76; p<.001). Students using the high-fidelity manikin also reported being significantly more satisfied in their abilities to clearly and accurately assess the heart rate and the degree of chest rise (p<.001 for both items). As well, students using the high-fidelity simulator were significantly more satisfied that this training would increase their confidence in dealing with a neonatal emergency in the future (p<.001).

[4] Not listed in table as there is no data to compare, i.e. all students must score a '2' to complete NRP. The five mandatory skills are: (1) checks equipment including bag, mask, & oxygen supply; (2) indicates need for positive-pressure ventilation; (3) provides positive-pressure ventilation correctly; (4) takes corrective action when heart rate not rising & chest not moving; and (5) demonstrates correct compression technique.

Table 3 – Comparison of Megacode Scores (High vs. Low)

Megacode Skill	High				Low				Sig.*
	n	0 (%)	1 (%)	2 (%)	n	0 (%)	1 (%)	2 (%)	
Asks 3 Assessment Questions (Term, Tone, Crying or Breathing)	31	0	0	100	26	0	11.5	88.5	0.052
Positions head, clears airway if necessary	31	0	0	100	26	0	7.7	92.3	0.116
Dries, removes, wet towels and repositions head	31	0	0	100	26	0	15.4	84.6	**0.024***
Requests description of respirations and heart rate	31	0	0	100	26	0	0	100	1.00
Applies pulse oximeter prove to right wrist, hand, or digit	31	3.2	0	96.8	26	0	11.5	88.5	0.104
Checks for rising heart rate and breath sounds within 5-10 breaths	31	0	6.5	93.4	26	0	3.8	96.2	0.661
Administers oxygen to meet targeted saturations using pulse oximeter & blender	31	3.2	12.9	83.9	26	0	15.4	84.6	0.637
Re-evaluates heart rate	30	0	3.3	96.7	26	0	0	100	0.348
Identifies need to start chest compressions with 100% oxygen	27	0	18.5	81.5	26	0	7.7	92.3	0.245
Demonstrates correct rate and co-ordination with ventilation	30	0	0	100	26	0	3.8	96.2	0.278
Continues/discontinues positive-pressure ventilation appropriately or weans free-O2 flow	31	0	6.5	93.5	26	0	19.2	80.8	0.143
OVERALL	**335**	**0.6**	**4.2**	**95.2**	**286**	**0**	**8.7**	**91.3**	**0.003***

**Significant at p<.05 probability level.*

Table 4 – Comparison of Student Satisfaction (High vs. Low)

Satisfaction Item	High			Low			Sig.*
	N	Mean	SD	N	Mean	SD	
The neonatal simulator provided realistic feedback (i.e. HR, BP, etc.)	31	4.52	0.508	34	2.76	1.499	<0.001*
The neonatal simulator was an effective learning tool	31	4.87	0.341	34	3.82	1.058	<0.001*
The neonatal simulator motivated me to learn	31	4.74	0.514	35	3.91	1.147	<0.001*
The neonatal simulator held my attention	31	4.74	0.445	35	3.74	1.314	<0.001*
The neonatal simulator made learning fun	31	4.74	0.514	35	3.74	1.146	<0.001*
The neonatal simulator helped me to better perform neonatal resuscitation	31	4.94	0.250	35	4.00	0.939	<0.001*
I could clearly and accurately assess the simulator's HR	31	3.87	0.957	34	2.29	1.467	<0.001*
I could clearly and accurately assess the degree of chest rise	31	4.13	0.718	34	2.59	1.373	<0.001*
It was difficult to perform neonatal resuscitation on the simulator‡	31	4.48	0.677	34	3.71	1.060	<0.001*
The simulator would be a useful training tool for medical students/residents	31	4.90	0.301	34	3.71	1.268	<0.001*
I would like to use this method of teaching and learning again in the future	31	4.81	0.402	34	3.62	1.206	<0.001*
Training with this simulator increased by confidence that I will be better prepared to deal with a neonatal emergency in the future	31	4.68	0.475	34	3.68	1.121	<0.001*
My time spent using the simulator has improved my knowledge and skills of neonatal resuscitation	26	4.77	0.430	32	4.06	1.014	<0.001*

Satisfaction Item	High			Low			Sig.*
	N	Mean	SD	N	Mean	SD	
I felt anxious about this training session because I had to use the simulator[‡]	26	4.04	1.113	32	4.25	0.880	0.422
OVERALL	**31**	**4.59**	**0.546**	**35**	**3.56**	**1.178**	**<0.001***

**Significant at p<.05 probability level.*

‡ Item was reversed scored for analysis.

3.3.2 Manikin Features

As part of completing the evaluation survey, students were asked an open-ended question to comment on the manikin features which appealed to them the most/least. Students' feedback (by group) is presented in Table 5. The majority of comments from the high-fidelity group were related to the functioning of the manikin, e.g., that they could see the cyanosis, hear the heart rate, listen for breath sounds, and look for the chest rise and how these features influenced their NRP performance. Several students also commented about the appeal of seeing the 'automatic' impact of their actions. However, students' comments regarding the high-fidelity manikin features which appealed to them the least related to technical issues with the same features, e.g., chest wall not rising, difficulty hearing the heart rate, confusing sounds, etc.

Students who used the low-fidelity manikins also commented about its realistic nature. While it did not have the same technical features as the high-fidelity version, the majority of students commented that it was realistic, it looked like a real baby (e.g., appropriate size, shape, and features), and that the positive-pressure ventilation did make the chest rise. However, what appealed to the low-fidelity group the least was the lack of an 'automatic' response from the manikin. These students were reliant on the instructor for information regarding heart rate, its tone, etc. which as some commented, took the realism out of the simulation.

Table 5 – Manikin Features Which Appealed the Most/Least (By Group)

High-Fidelity Group		Low-Fidelity Group	
Features Which Appealed the Most	**Features Which Appealed the Least**	**Features Which Appealed the Most**	**Features Which Appealed the Least**
• *Heart rate, chest rise, breathe, colour, and movement (n=6).* • *A more realistic impression of the timing of resuscitation (actually listening for and counting HR) (n=4).* • *Being able to see the real time effect of my actions (ex. my PPV working; his chest is rising, cyanosis is decreasing, tone is returning) (n=4).* • *Cyanosis, respirations, heart rate, and tone were*	• *Difficult to hear/monitor heart rate (n=5).* • *Chest wall rising not very realistic (n=3).* • *The cyanosis was hard to see and a real change of base line (n=2).* • *Fixed open mouth.* • *Had to ask for oxygen saturation.* • *Manual control & adjustment* • *Quality at heart sound – mechanical.*	• *Anatomically correct & the chest was able to rise during PPV (n=6).* • *Good size and shape (n=4).* • *Face has good practice for mask placement & seal.* • *Good to get a general idea on neonatal resuscitation.* • *It was something to practice on.* • *Looked like a real baby which made the*	• *Couldn't tell heart rate, no real oxygen sats, no variations in tone (n=7).* • *It did not provide any feedback on our resuscitation efforts. it would be much more realistic if we could visualize the changes as they occur (n=2).* • *Had to ask for breathing, time, heart rate (n=2).* • *A little unrealistic.*

High-Fidelity Group		Low-Fidelity Group	
Features Which Appealed the Most	**Features Which Appealed the Least**	**Features Which Appealed the Most**	**Features Which Appealed the Least**
all very realistic and improved our actions (n=3). • *Helped me feel better prepared for real life situation.* • *More realistic than just being told heart rate. Distinguishing sounds was an important skill to learn.* • *Operator could quickly change settings.* • *The change in heart rate and breathing really helped me feel like our actions had an effect on the status of the baby. It made me feel like a more real life situation.* • *The fact you actually had to go through assessment steps yourself and weren't just given the values*	• *Some sounds were confusing (gasp vs. cry).*	*scenario more real.* • *Skin, detail of face, and hands and feet.* • *The reality of applying this situation to an infant.*	• *Couldn't actually assess breathing or pulse on simulator.* • *Couldn't really see the chest rise.* • *Stiff head, mask fitting difficult, chest stiff making compressions difficult, can't open mouth.* • *Was obviously less anxiety provoking than it will be in real life.*

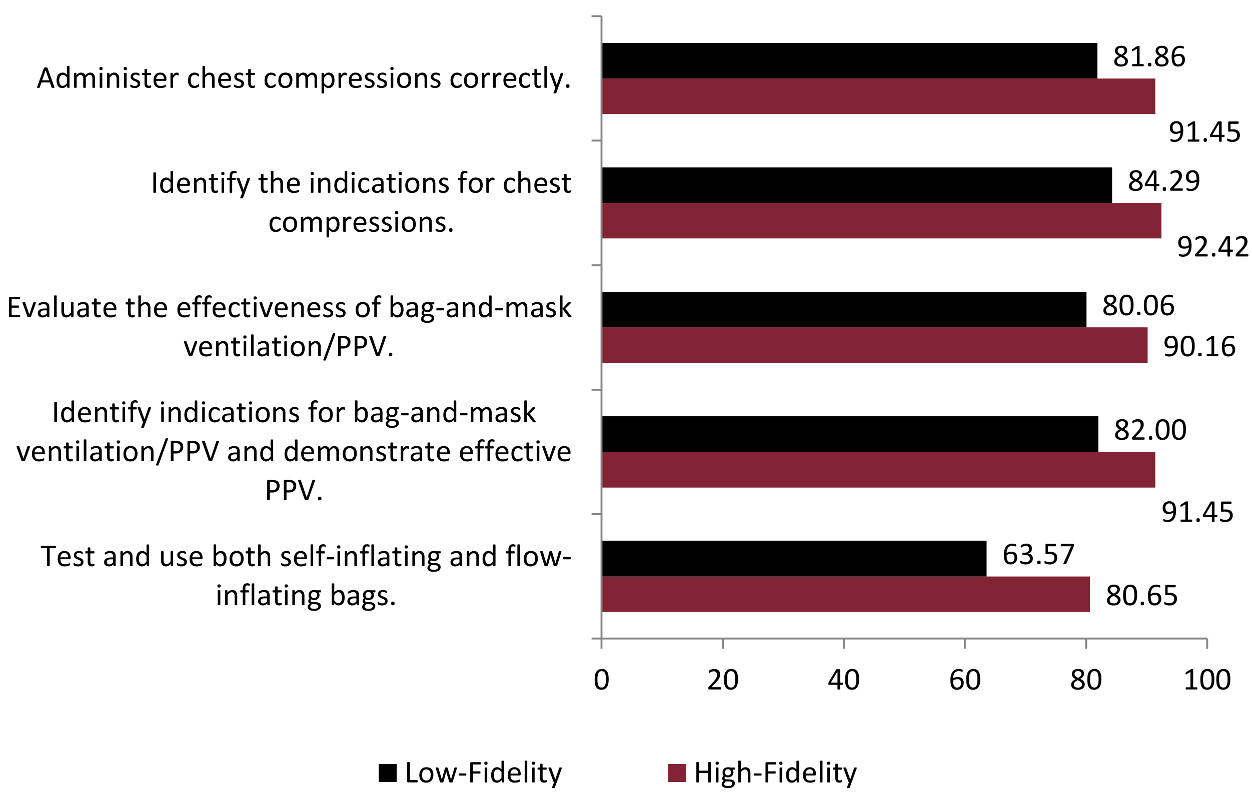
3.4 Confidence

Following their participation in the training, students were asked to rate their degree of confidence in performing several abilities, skills, and/or tasks during neonatal resuscitation, using a scale of 0=cannot at all do to 100=highly certain can do.

3.4.1 Factors Influencing Skills Performance

The results in Figure 1 summarize respondents' self-reported confidence in their ability to perform various NRP skills following their participation in the training. The results of Mann Whitney analyses of mean scores indicate significant differences in confidence for these skills between high and low-fidelity groups at the $p<.05$ probability level. Students receiving high-fidelity training reported greater confidence levels in administering chest compressions, evaluating effectiveness of bag-and-mask ventilation, testing and using self-inflating and flow-inflating bags.

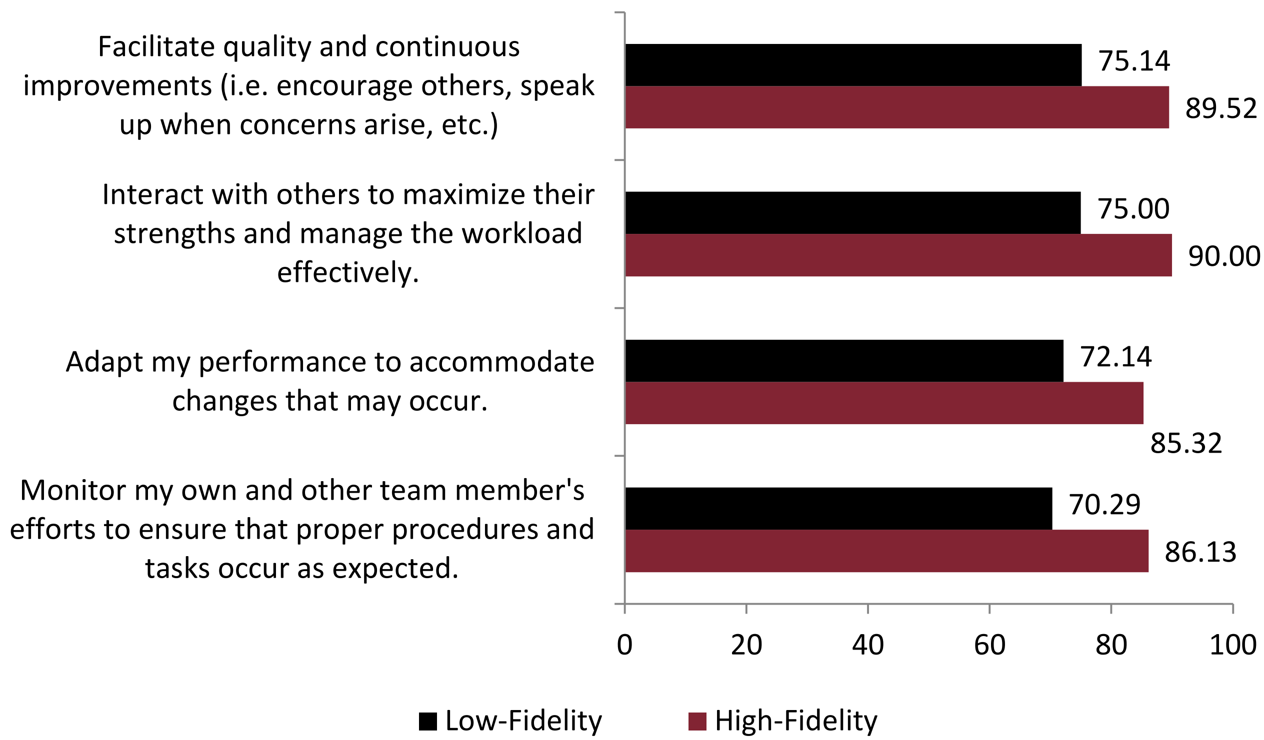
Figure 1 – Students' Self-reported Confidence to Perform NRP Skills Post-training



3.4.2 Factor Influencing Teamwork Behaviours

The results in Figure 2 summarize respondents' self-reported confidence related to various teamwork behaviours during a neonatal resuscitation. The results of Mann Whitney analyses of mean scores indicate significant differences in confidence for these behaviours between high and low-fidelity groups at the $p<.05$ probability level. Students receiving high-fidelity training reported greater confidence levels in facilitating improvements, interacting with others to manage the resuscitation, adapting performance and monitoring personal and team performance.

Figure 2 – Students' Self-reported Confidence Related to Various Teamwork Behaviours



3.5 Teamwork Behaviours

Medical students were required to participate in a teamwork simulation as part of completing the NRP training. This simulation was recorded for the purposes of a debriefing with the instructor. The scenario was approximately four minutes in duration and consisted of the following:

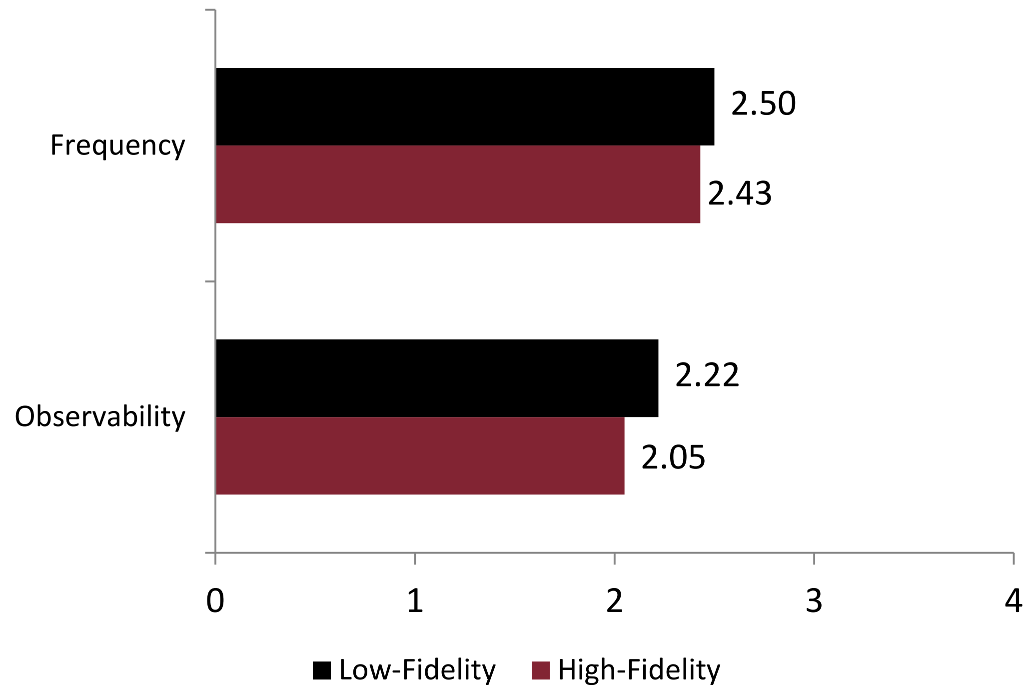
> *You are called to attend the delivery of a full-term infant to be delivered by elective C-section. There were no maternal complications. Mother is a 28 year old non-smoker, no medications or infections. Baby is delivered – has no tone.*

This signals the start of the scenario. The instructors in the low-fidelity groups provide information to the students regarding tone, cyanosis, etc. while the high-fidelity manikins should 'demonstrate' these features. Scenarios were conducted for the purposes of examining and discussing teamwork behaviours during a code. Students were not graded on these scenarios, but they were recorded for the purpose of reviewing and debriefing with the instructor.

As part of participating in the study, students consented to the release of the recorded simulation in which they participated to study investigators. The videos were provided to two independent raters (a nurse and respiratory therapist certified as NRP instructors who did not participate in the training sessions as instructors) who reviewed each video for the 'observability' and 'frequency' of several teamwork characteristics and recorded their findings using the Behavioural Markers of Neonatal Resuscitation Form (Appendix B). All videos were reviewed by both raters.

The results of an independent samples t-test analyses shown in Figure 3 demonstrate that there were no significant differences reported for 'observability' (p=.144) or 'frequency' (p=.446) of specific teamwork behaviours between the high and low-fidelity groups.

Figure 3 – Raters' 'Observability' & 'Frequency of Various Teamwork Behaviours



3.5.1 Interrater Reliability

An interrater reliability analysis using the Kappa statistic was conducted to determine the consistency of scoring amongst the raters. Kappa ranges from 0 to 1 (where numbers closer to 1 mean greater reliability). Overall, the interrater reliability for the raters was fair to moderate (mean Kappas range from 0.21 to 0.45) (Landis & Koch, 1977). There was no significant difference in interrater agreement noted for frequency of teamwork behaviours. However, there was a significant difference in interrater agreement (p=.036) for observability of teamwork behaviours for the high and low-fidelity groups. The mean Kappa for observability of the high-fidelity groups was 0.45, which suggests moderate reliability between the raters for this category.

Table 6 – Behavioural Markers of Neonatal Resuscitation Form Reliability Statistics

Case Group	Fidelity	Cohen's Kappa		Case Group	Fidelity	Cohen's Kappa	
		Observability	Frequency			Observability	Frequency
1	High	0.44	-0.08	5	Low	0.05	0.23
2	High	0.54	0.64	6	Low	0.39	0.37

Case Group	Fidelity	Cohen's Kappa		Case Group	Fidelity	Cohen's Kappa	
		Observability	Frequency			Observability	Frequency
3	High	0.3	0.25	7	Low	0.37	0.48
4	High	0.44	0.18	8	Low	0.4	0.48
9	High	0.72	0.54	10	Low	-0.03	0.32
11	High	0.32	0.57	14	Low	0.48	0.29
12	High	0.4	0.05	15	Low	0.08	0.21
'June 21 #2'	High	0.44	0.26	16	Low	-0.23	-0.11
-	-	-	-	'June 21 #1'	Low	0.39	-0.03
MEAN KAPPA	**HIGH**	**0.45***	**0.30**	**MEAN KAPPA**	**LOW**	**0.21***	**0.25**

*Inter-rater agreement differs between high and low fidelity scenarios (p=0.036)

4.0 Overall Findings

In June 2012, NRP was one of the components of the MD Clerkship Preparation Course – a two-week course which all medical students must successfully complete in advance of their third and fourth years of medical school (clerkship). In advance of the NRP training (and to facilitate this study), all beginning third year medical students were randomly assigned to one of two instructional groups by the NRP coordinator:

1. An Experimental Group who participated in NRP training and megacode assessment using a high-fidelity manikin simulator (N=31 students divided across 8 groups).
2. A Control Group who participated in NRP training and megacode assessment using a low-fidelity manikin simulator (N=35 students divided across 9 groups).

There were four (4) high-fidelity simulators used with the Experimental Group for the NRP training. Participants in the Control Group received NRP instruction using traditional low-fidelity manikins. Medical students were required to participate in and complete the NRP training and assessment components (online exam, performance skills stations, integrated skills stations which incorporated the megacode assessment, and recorded teamwork simulation). As part of participating in the study, students were asked to consent to release of the following to investigators:

- Their completed NRP Megacode Assessment Form.
- Their recorded teamwork simulation (recording is recommended as part of the NRP debriefing process) which was reviewed by two independent raters.

As part of participating in the study, students were also asked to complete:

- A Participant Evaluation Survey.
- A Neonatal Resuscitation Confidence Scale.

Ethics approval for this study was received from the Interdisciplinary Committee on Ethics in Human Research (ICEHR), Memorial University.

Prior to commencement of the study, four hypotheses were developed regarding the impact of this comparison on the experimental and control group participants. The investigators hypothesized that:

- There will be no significant differences in knowledge or megacode performance between the experimental group participants and the control group participants.
- Confidence ratings of the experimental group participants will be significantly higher than those of the control group participants.
- There will be no significant differences in team performance scores between the experimental group participants and the control group participants.
- Satisfaction scores of the experimental group participants will be significantly higher than those of the control group participants.

Overall, the study findings were consistent with the hypotheses. Students who participated in the high-fidelity NRP training reported significantly higher satisfaction (p=.001) and confidence (p=.001) scores. There were no significant differences in team performance scores, as observed by two independent raters. There was, however, a significant overall difference in knowledge and skills (p=.003), but this difference was largely attributable to performance differences on one item that was not influenced or related to a fidelity feature of the manikins - "dries, removes, wet towels and repositions head". Students from both low and high-fidelity study groups demonstrated no difference on mandatory performance items for the megacode assessment.

Knowledge/Skills (Megacode)

Overall, a significant percentage of students using the high-fidelity manikins (95.2%) achieved a score of '2' on the majority of skills when compared to the scores of those using the low-fidelity manikin (91.3%) (p=.003). Analyses of each individual megacode item however, demonstrates a significant difference between high and low-fidelity groups for only one item 'dries, removes wet towels and repositions head' (p=.024); a skill on which the level of manikin fidelity would have no impact .

Satisfaction

The study findings demonstrate an overall significant difference in the mean satisfaction scores of high vs. low fidelity participants (overall mean satisfaction of 4.59 vs. 3.56, respectively; p<.001). Analysis of individual items also demonstrates significant differences in mean satisfaction (high vs. low) related to various components of the simulator and/or the training experience. For instance, students using the high-fidelity manikin were significantly more satisfied with:

- The realistic feedback provided by the simulator.
- Their abilities to clearly and accurately assess the heart rate and the degree of chest rise.

Students were also asked to comment on the manikin features which appealed to them the most/least. The majority of comments from the high-fidelity group were related to the functioning of the manikin, i.e. that they could see the cyanosis, hear the heart rate, listen for breath sounds, and look for the chest rise and how these features influenced their NRP performance. Several students also commented about the appeal of seeing the 'automatic' impact of their actions. However, students' comments regarding the high-fidelity manikin features which appealed to them the least related to technical issues with the same features, i.e. chest wall not rising, difficulty hearing the heart rate, confusing sounds, etc. While it did not have the same technical features as the high-fidelity version, the majority of students who used the low-fidelity manikins commented that it was realistic, it looked like a real baby (i.e. appropriate size, shape, and features), and that the positive-pressure ventilation did make the chest rise. However, what appealed to the low-fidelity group the least was the lack of an 'automatic' response from the manikin. These students were reliant on the instructor for information regarding heart rate, its tone, etc. which as some commented, took the realism out of the simulation.

Confidence in Skills Performance and Teamwork

Students who participated in the high-fidelity training reported significantly higher confidence levels in their ability to perform various NRP skills and in demonstrating various teamwork behaviours post-training. Higher confidence for the high-fidelity groups was linked to skills such as:

- Identifying the indications for chest compressions.
- Administering chest compressions correctly.
- Identifying indications for bag-and-mask ventilation/PPV and demonstrating effective PPV.
- Evaluating the effectiveness of bag-and-mask ventilation/PPV.
- Testing and using both self-inflating and flow-inflating bags.

Higher confidence for the high-fidelity groups was also linked to demonstration of various teamwork behaviours, such as:

- Monitoring efforts to ensure that proper procedures and tasks occur as expected.
- Adapting performance to accommodate changes that may occur.
- Interacting with others to maximize strengths and manage the workload effectively.

- Facilitating quality and continuous improvements (i.e. encouraging others, speaking up when concerns arise, etc.).

Teamwork Behaviours

Analyses of the overall ratings of the two NRP instructors did not demonstrate any significant differences in observability or frequency of various teamwork behaviours between the high and low-fidelity groups. Interrater reliability analyses using the Kappa statistics showed overall fair to moderate interrater reliability, but moderate interrater reliability for observability of the high-fidelity groups.

5.0 Recommendations/Limitations/Future Research

The overall findings suggest that the type of manikin used for training has no significant influence on knowledge and skills performed during an NRP megacode. The most significant impact of high-fidelity training for NRP is on students':

- Satisfaction with the training experience.
- Confidence to perform NRP:
  - Specifically in areas where the manikin 'automatically' responds to correct performance of a skill (i.e. correct ventilation automatically makes the chest rise vs. the instructor telling students that the chest is rising).
  - As part of a team.

Students who participated in the high-fidelity groups reported it to be a 'great learning experience' and an 'excellent learning tool', citing that the 'hands-on experience is much more valuable than reading from a book'. Students who participated in the low-fidelity groups also reported an 'excellent experience', that the 'manikin was adequate to learn what we needed to', and it was 'much better than classroom/lecture learning'. However, students in the low-fidelity groups also reported that having 'real' oxygen saturation levels and/or being able to hear the heart rate would have been helpful.

Recommendations

- Continued use of low-fidelity simulation for basic NRP/basic resuscitation skills training.

  The ability of educational and healthcare institutions to utilize high-fidelity simulation may be limited given the required resources (e.g., costs and personnel time) to operate such manikins. The study findings demonstrate that low-fidelity simulation manikins are effective for training in basic NRP or other basic resuscitation skills. While there were significant differences in self-report satisfaction and confidence data, there were no significant and observable differences in most skill performance areas, including teamwork, which is an important aspect of resuscitation training and performance.

- Use of high-fidelity simulation for advanced resuscitation skills training and complex tasks.

  The literature supports the use of low-fidelity simulation for basic resuscitation tasks such as airway management, , but suggests that using high-fidelity simulation may have a greater impact on participants' knowledge, performance and confidence as tasks become more complex (Rodgers, Securro, & Pauley, 2009).

- Provide students, residents, and practitioners with some resuscitation training using a high-fidelity manikin if available.

  The study findings demonstrate that the fidelity level had a significant impact on medical students' overall satisfaction with this training experience. It is therefore recommended that if available, high-fidelity simulation should be accessible for resuscitation training/re-certification. If the learning experience is enjoyable, learners may be more motivated to attend the session, make time for re-certification and updates, etc.

Study Limitations

- Instructor variability – the instructors participating in this NRP training had diverse professional backgrounds and experiences (i.e. nursing, respiratory therapy, etc.), as well as diverse levels of training on high and/or low-fidelity manikins. These differences could have impacted their confidence with their assigned form of simulation and in turn, the level of instruction provided to the students.

- Generalizability of findings to health care practitioners – this NRP training was conducted with medical students with limited clinical experience and in using NRP. The results and study findings must be considered in that context.

- Limitation of the video behavioural rating form due to the length of simulation recorded – a longer simulation may have allowed for greater observance and frequency of the skills being reviewed.

Future Research

- Students in the high-fidelity groups reported greater satisfaction and confidence with the training experience. What effect might high-fidelity simulation usage have on retention of knowledge and/or skill over time?

- Repeat the study with more advanced students or residents and using advanced NRP, longer megacodes, etc. to further determine impact of fidelity used.

- Translation of findings into clinical practice and on patient care. Are there differences between low- and high-fidelity usage in NRP training on provider performance in the clinical care setting?

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Appendix A

Megacode Assessment Form

Canadian Paediatric Society / Société canadienne de pédiatrie

Megacode Assessment Form (BASIC) - Canadian Adaptation

Learner: Date:
Evaluator:
Lesson Completed: 1-4 Pass____ Re-evaluate ____

SCORING: 0=not done 1= Done incorrectly, incompletely or out of order 2= Done correctly in order

- ✓ Students must perform each of the 5 bolded items correctly
- ✓ Scenario must include 'Heart rate remains <100 beats per minute(bpm) and no chest movement' to allow demonstration of corrective action (Lesson 3)
- ✓ Scenario much include 'Heart rate remains <60 bpm despite positive pressure ventilation' to demonstrate chest compressions.
- ✓ Learner must demonstrate ventilation and chest compressions.
- ✓ Scenario with meconium-stained fluid is optional.

Lesson	Possible Points	Item	0	1	2
	No score	Asks relevant perinatal history	**No score**		
	No score	Discusses plan and assigns roles to team members	**No score**		
1	2	**Checks Equipment including Bag, Mask & Oxygen Supply**			
	2	Asks 3 Assessment Questions (Term, Tone, Crying or Breathing)			
2	**2** (optional)	(optional) If meconium is present, determines if endotracheal suction is indicated			
	2	Positions head, clears airway if necessary			
	2	Dries[1], removes wet towels and repositions head			
	2	Requests description of respirations and heart rate			
3	**2**	**Indicates need for positive-pressure ventilation**[2] (Apnea or gasping and/or heart rate<100 bpm)			
	2	Applies pulse oximeter probe to right wrist, hand or digit[3]			
	2	**Provides positive-pressure ventilation correctly** (40-60 bpm) Calls for help			
	2	Checks for rising heart rate, breath sounds within 5-10 breaths **(Instructor note: Heart rate does NOT improve)*			
	2	**Takes corrective action when heart rate not rising & chest not moving** (**M**ask readjustment; **R**eposition; **S**uction mouth & nose; **O**pen mouth; **P**ressure increase; **A**lternate airway)			
	No score	Confirms presence of chest movement and breath sounds and provides 30 seconds of effective PPV	**No score**		
	2	Administers oxygen to meet targeted saturations using pulse oximeter and blender			
	2	Re-evaluates heart rate **(Instructor note: Heart rate must remain <60 bpm)*			
	No score	Identifies option to secure airway prior to initiating compressions (i.e.: intubation)	**No score**		
4	**2**	Identifies need to start chest compressions with 100% oxygen (Heart rate <60 bpm despite 30 seconds of effective positive pressure ventilation)			
	2	**Demonstrates correct compression technique** Assess correct thumb (preferred) or finger placement & compression depth (1/3 anterior-posterior diameter of the chest)			
	2	Demonstrates correct rate and coordination with ventilation (Ask student and assistant to switch positions.)			
Closure	**2**	Continues/discontinues positive-pressure ventilation appropriately or weans free-flow oxygen			
		Student's Score Subtotals			
		Student's Total Score (add subtotals)			
		Total of all circled points (34 points maximum)			
		Performed all 5 bolded items correctly? Yes ☐ No ☐	Reevaluate ☐		
		Student attained minimum passing score? 28 points with meconium 26 points without meconium	Y Pass N Reevaluate		

1) Drying the skin does not apply to babies <28 weeks; they should be placed wet into a food-grade polyethylene bag below the neck.
2) For term infants, begin PPV with 21% oxygen; for infants <32 weeks GA, follow local protocols
3) PPV and assessment of HR are the priority and should not be unduly delayed by the application of a pulse oximeter probe

For use in Canada

Appendix B

Behavioural Markers of Neonatal Resuscitation Form[5]

[5] Adapted and used with permission of Thomas et al. (2004).

Date: _________________________ ______ (Month/Day/Year)	Observer ID: ________________ Case#: ______________

0 = None	**1 = Poor observability**	**2 = Minimum/inconsistent**	**3 = Standard observability**	**4 = Outstanding observability**
The behavior was not observed	This may be due to consistently poor audio quality or inability to determine if verbalizations were related to the behavior	There may be inconsistent audio quality or inconsistent ability to determine if verbalizations were related to the behavior	Almost all verbalizations can be understood and the observation could be used as an example of the behavior being rated	The behavior is usually explicit and clear. Would make excellent example of the behavior

1 = Rare	**2 = Isolated/minimum**	**3 = Intermittent/standard**	**4 = Consistent**
One or two rare examples of the behavior occurred	There were isolated examples of the behavior throughout the observation	There were intermittent examples throughout the observation	There were frequent/explicit examples of the behavior throughout the observation

Behavioural Markers:	**Observability 0-4**	**Frequency 1-4**	**Comments (provide examples, anchors, and definitions)**
1. Know environment (equipment check, location of code cart, who to call for help)			
2. Anticipate and plan (listen, team ‘huddles’, action plan if complications)			
3. Assume leadership role (assign leadership roles, leader articulates goals, delegates tasks, asks for input, promotes teamwork)			
4. Communicate effectively (share and verify information)			
5. Delegate workload optimally			
6. Allocate attention wisely (situation awareness, monitor actions)			
7. Use all available information (ask about prenatal, intrapartum history or newborn history)			
8. Use all available resources (know human resources, know supplies and equipment availability)			
9. Call for help when needed			
10. Maintain professional behavior (respectful, seek and offer assistance, support and promote teamwork)			

Individual Ratings	
Did this individual differ significantly from the rest of the team? If yes, how and why do you think he/she differed?	
Any Other Comments (e.g. complications, other behavioral markers, etc.)?	

Appendix C

Participant Evaluation Survey

Neonatal Resuscitation Simulator
Participant Evaluation Survey

1. Please circle your level of agreement with the following items using a scale of ***1 = Strongly Disagree to 5 = Strongly Agree.***

   The neonatal simulator…

provided realistic feedback (i.e. for heart rate, blood pressure, etc.)	1	2	3	4	5
was an effective learning tool	1	2	3	4	5
motivated me to learn	1	2	3	4	5
held my attention	1	2	3	4	5
made learning fun	1	2	3	4	5
helped me to better perform neonatal resuscitation	1	2	3	4	5

2. Please circle your level of agreement with the following items using a scale of ***1 = Strongly Disagree to 5 = Strongly Agree.***

I could clearly and accurately assess the simulator's heart rate.	1	2	3	4	5
I could clearly and accurately assess the degree of chest rise.	1	2	3	4	5
It was difficult to perform neonatal resuscitation on the simulator.	1	2	3	4	5
The simulator would be a useful training tool for medical students/residents.	1	2	3	4	5
I would like to use this method of teaching/learning again in the future.	1	2	3	4	5
Training with this simulator increased my confidence that I will be better prepared to deal with a neonatal emergency in the future.	1	2	3	4	5
My time spent using the simulator has improved my knowledge and skills of neonatal resuscitation.	1	2	3	4	5
I felt anxious about this training session because I had to use the simulator.	1	2	3	4	5

3. Which mannequin features appealed to you the most?

4. Which mannequin features appealed to you the least?

5. Did you experience any problems with the functioning of the mannequin?

6. Additional comments about your learning experience with the mannequin:

Appendix D

Neonatal Resuscitation Confidence Scale

Neonatal Resuscitation Confidence Scale

Please rate your degree of confidence in performing each of the following abilities, skills, and/or tasks during neonatal resuscitation. Rate your degree of confidence using the scale 0-100 (**0=cannot do; 50=moderately can do; 100=highly certain can do**).

0	10	20	30	40	50	60	70	80	90	100
Cannot at all					Moderately can do					Highly certain can do

Abilities	**Confidence (0 – 100)**
1. Know the equipment and personnel needed to resuscitate a newborn.	
2. Know the responsibilities and tasks of each team member.	
3. Test and use both self-inflating and flow-inflating bags.	
4. Determine if a newborn needs to be resuscitated and appropriately provide initial steps of resuscitation if indicated.	
5. Identify the indications for tracheal suctioning for the baby born through meconium.	
6. Demonstrate the role of the assistant when tracheal suctioning required.	
7. Identify the indications for pulse oximetry and demonstrate correct placement and interpretation of reading.	
8. Identify the indications for bag-and-mask ventilation/ Positive Pressure Ventilation (PPV) and demonstrate effective PPV.	
9. Evaluate the effectiveness of bag-and-mask ventilation/PPV.	
10. Identify and demonstrate the corrective actions to establish effective PPV (MR SPOA).	
11. Identify the indications for chest compressions.	
12. Administer chest compressions correctly.	
13. Coordinate chest compressions with PPV.	
14. Identify the implications for supplemental oxygen and demonstrate application of supplemental oxygen to meet targeted oxygen saturations.	
15. Describe when and why endotracheal intubation is needed during resuscitation.	
16. Use my understanding of the patient's situation to anticipate team member's needs.	
17. Monitor my own and other team member's efforts to ensure that proper procedures and tasks occur as expected.	
18. Adapt my performance to accommodate changes that may occur.	
19. Interact with others to maximize their strengths and manage the workload effectively.	
20. Facilitate quality and continuous improvements (i.e. encourage others, speak up when concerns arise).	