ORIGINAL RESEARCH

Impacts of Deliberate Practice Simulation on Neonatal Outcomes

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Keywords: Neonatal Resuscitation Program, in situ mock code, deliberate practice, simulation training, debriefing, team skills, teamwork, patient outcomes, Kirkpatrick levels

Abbreviations: Neonatal resuscitation (NR), Neonatal Resuscitation Program (NRP), deliberate practice (DP), hypoxic ischemic encephalopathy (HIE), Ronald Reagan UCLA Medical Center (RRUMC), neonatal intensive care unit (NICU), errors of omission (EOO), errors of commission (EOC), continuous positive airway pressure (CPAP), positive pressure ventilation (PPV), premature rupture of membranes (PROM), intrauterine growth restriction (IUGR), California Perinatal Quality Care Collaborative (CPQCC)

Introduction

Simulation training is the current standard for teaching neonatal resuscitation (NR) that provides mainstream education to medical trainees for Neonatal Resuscitation Program (NRP) certification. The Accreditation Council for Graduate Medical Education recommends simulation as a core didactic activity for residents and fellows.[1] A single simulation session has not shown improved performance overtime for resident trainees.[2-4] Practice is generally known to improve performance, especially coupled with opportunities for self-reflection and feedback. Deliberate practice (DP) demonstrating repetitive simulation performances have proven effective.[3,5] DP involves carrying out a task with immediate feedback, cognitive self-analysis, and repeat opportunities to refine the task performance.[6,7] Many DP studies describe significantly enhanced performance.[6,8-10] Sawyer et al. reported improved simulation efficacy and NRP performance.[11] Cordero et al. found benefits to NR team performances. McGaghie et al. found improved clinical skills with traditional non-simulated medical education training.[12,13]

The Kirkpatrick Evaluation Model defines the four levels of training evaluation and has been applied to simulation medical training in the following[14,15]:

> Level 1 (Reaction): Did students find participation in simulation valuable?
> Level 2 (Learning): Did simulation increase students' skills, knowledge, and confidence?
> Level 3 (Behavioral Change): Did students apply enhanced skills and knowledge in clinical settings?
> Level 4 (Results): Did simulation enhance patient outcomes?

Simulation to teach technical and team skills have achieved a Kirkpatrick level 4[16-19] and have decreased central line-associated bloodstream infection rates and increased return on investments.[20-23] Obstetric simulation training programs decreased rates of neonatal hypoxic ischemic encephalopathy (HIE) and shoulder dystocia.[24] A simulation-based educational program on "Helping Babies Breathe" decreased neonatal mortality.[25] However, these simulation modes that improved patient outcomes did not consist of DP, specifically as it pertains to NRP training.

Currently, a paucity of data exists to validate that DP simulation in NRP training improves patient outcomes. To facilitate broader acceptance and implementation of DP simulation in NRP training, evidence of higher effectiveness should be demonstrated in patient outcomes. We hypothesize that NRP simulation, utilizing multiple occurrences of DP, can 1) improve NRP technical performance and team skills and 2) improve patient outcomes.

Methods

Design

This prospective, observational study used a pre-and post-simulation NRP training curriculum design to evaluate and compare participating fellows' before and after training sessions (Appendix 1). Neonatology fellows served as their own control. Participants completed an annual boot camp (July 2017 and July 2018), followed by 3-4 in situ mock codes per fellow for two years. The study was conducted at Ronald Reagan UCLA Medical Center (RRUMC) at a level 4 quarternary, 22 bed neonatal intensive care unit (NICU), between July 2017 to August 2019. After each simulation session, participants received facilitated performance debriefing and feedback. The boot camp established baseline performance levels. Subsequent in situ mock codes provided repetitive opportunities for practice and evaluation. Measurements of NRP performance for each simulation session were obtained

utilizing a scoring tool (Appendix 2). Institutional Review Board exemption was obtained prior to study execution.

Participants

Nine neonatal-perinatal fellows enrolled during their 3-year training. None reported prior experiences with a neonatal-perinatal simulation boot camp. During the study, the fellows did not receive any other simulation or NRP training other than actual patient care. Those enrolled included 6 PGY-4 and 3 PGY-5 fellows. All were expected to complete the annual fellowship boot camp. During boot camp, each fellow had an opportunity to serve as a team lead in a simulation NRP scenario. For the in situ mock codes, the fellow on service served as a team leader of a multidisciplinary team. There were 5 participants (1 NICU fellow, 2 NICU nurses, 1 respiratory therapist, 1 NICU resident) per in situ mock code. Scoring for all simulation was based on team performance. All participants provided informed consent prior to start of study.

Simulation Curriculum

Annual Boot Camp

The annual boot camp, which occurred at the UCLA Simulation Center, served to provide NRP recertification at beginning of fellowship. The NRP simulation scenario served to determine the fellows' baseline performance from which their resuscitation performances in subsequent in situ mock codes were compared. The boot camp incorporated a skills station covering positive pressure ventilation (PPV), chest compressions, intubation, and umbilical lines. This was followed by 3 NRP simulation scenarios, lasting approximately 10 minutes each, with a team of 3 fellows. These scenarios utilizing Super Tory®, a high-fidelity mannequin, required demonstration of chest compressions, epinephrine, intubation, and/or normal saline bolus. These scenarios took place in a simulated delivery room, replete with radiant warmer, resuscitation equipment, and medications. The room incorporated video recording during sessions. Neonatal faculty directed scenarios behind a control room with a one-way mirror. One researcher (MPN) observed simulation but did not provide NRP guidance or treatment decision assistance.

Participant review of resuscitation performance occurred immediately post session via video playback. Study investigators were NRP instructors (MPN and NL). They facilitated 15-minute debriefings using the Good Judgement Model to elicit preliminary vocalized reactions, followed by deeper individual and team performance analysis. Debriefing concluded with take home points and performance lessons learned.[26-28]

Multiple in Situ Mock Codes

Based on 9 fellows' service schedule and NICU census, once or twice a month 10 minute in situ mock codes followed by 15-minute debriefing were conducted. A total of 36 in situ mock codes occurred between July 6, 2017 to August 5, 2019. Debriefings followed the Good Judgement Model but without video playback.[26-28] Debriefings consisted of vocalizing preliminary reactions, analyzing individual and team performance, and concluded with performance lessons learned. Nine NRP simulation scenarios incorporated use of PPV, intubation, chest compressions, epinephrine, and/or normal saline administration. Video recorded in situ mock codes used a Go-Pro Camera. Study investigator (MPN) used video recording for both boot camp and in situ mock codes for NRP scoring and performance evaluation. A low fidelity mannequin, Nasco Pediatric ALS trainer®, was used for the in situ mock codes.

Classification of NRP Errors

Errors were defined prior to study execution and relative to the contemporaneous 7th edition NRP algorithm. "Errors of omission" (EOO) were classified as interventions not completed by the resuscitation team even if indicated. "Errors of commission" (EOC) were defined as 1) interventions carried out by resuscitation team but not indicated, 2) indicated interventions conducted by resuscitation team with incorrect technical performance, or 3) indicated interventions carried out by resuscitation team at an inappropriate timeframe (i.e. greater than 5 seconds of when indicated).[29]

Neonatal Resuscitation Performance Evaluation Tool

A scoring tool to assess adherence and errors during review of NRP simulation scenarios was developed by a study researcher (MPN). The NRP evaluation tool was based upon the NRP 7th edition algorithm.[30] Another researcher (JE) reviewed the tool for content validity. The tool had a maximum total of 32 NR interventions that could be completed by the resuscitation team (Appendix 2). During review of simulation scenarios, each intervention was evaluated and scored. If an intervention was indicated and done correctly, then a checkmark was delineated for the "NRP adherence" column. If an intervention was indicated but not done by the NRP team, then a checkmark was scored for the EOO column. If an intervention was determined to be an EOC, then it would be further delineated by one of the following subset categories: 1) executed but not indicated or executed more than 5 seconds before indicated; 2) indicated but executed more than 5 seconds after indicated; or 3) executed with inappropriate technique.[29] The interventions were then summed and calculated as a percentage of the total interventions that could have been completed for that simulation scenario for each main category. Time to complete NR was also determined.

Patient Outcome Measures

Maternal and infant data, both baseline and prospective, were collected. Data included maternal age, infant sex, gestational age, birth weight, maternal complications, fetal complications, obstetrical complications, and resuscitation interventions. Infant outcomes included Apgar scores at 1 and 5 minutes, death within 12 hours of life, HIE, pneumothorax, hospital length of stay, and disposition from the hospital. Clinical data

were collected from the California Perinatal Quality Care Collaborative (CPQCC) database and patient charts and subsequently recorded in RedCap Trials.[31]

Resuscitations (simple and complex) of infants born at RRUMC and admitted to the NICU, from January 1, 2015 to July 4, 2017, were reviewed. Data from 734 cases was gathered in a baseline database. "Complex resuscitation" is defined by the need for continuous positive airway pressure (CPAP), PPV, intubation, chest compressions, epinephrine, or normal saline bolus.[29] "Simple resuscitation" includes other resuscitation, such as routine drying and stimulation, that does not include the above. Data of 697 resuscitations of infants born at RRUMC and admitted to the NICU, from July 6, 2017 to December 26, 2019, were reviewed and recorded in a prospective database.

Statistical Analysis

One-sided t-test and signed rank test were used to identify if fellows' NRP performance improved post boot camp with multiple NRP opportunities of in situ mock codes. Chi-squared test and Fisher's exact test compared the difference in pre- and post-implementation patient outcomes. All analyses were done using SAS 9.4.

Results

Deliberate Practice Simulation Results

DP performance results for 36 in situ mock codes implemented for 9 fellows were analyzed (Table 1). No statistically significant differences were noted in pre- and post-implementation group comparisons of NRP adherence scores, team skills, EOC, EOO, and resuscitation duration. EOC included providing chest compressions at the side of an intubated patient instead of at the head of bed. EOO included not intubating prior to chest compression initiation.

Neonatal Resuscitation Results

Delivery room resuscitation interventions are described for both groups in Table 2. In the post-implementation group, fellows conducted significantly more complex resuscitations (41.0% vs. 54.2%, p=<.0001). This included CPAP (29.8% vs. 43.0%, p=<.0001), PPV (25.5% vs. 32.3%, p=0.005), and intubation (6.4% vs. 9.6%, p=0.03). There were no significant group differences in epinephrine provision (0.8% vs. 1.7%, p=0.13) and chest compressions (2.3% vs. 2.6%, p=0.74) (Table 2).

Neonatal Outcomes

Pre-implementation and post-implementation groups were similar for patient outcomes (Table 3). Neither had delivery room deaths. Overall, both groups had no statistically significant differences in Apgar scores at 1 or 5 minutes, death within 12 hours of NICU admission (0.4% vs. 1.3%, p=0.07), pneumothorax, HIE, length of stay (p=0.06), or disposition from hospital (Table 3).

Maternal, Obstetrical, and Fetal Complications

Maternal, obstetrical, and fetal complications for pre- and post-implementation groups were depicted in Table 4. In the post-implementation group, we found significantly more cases of chorioamnionitis (9.0% vs. 5.3%, p=0.007), preterm labor (35.3% vs. 28.8%, p=0.009) and premature rupture of membranes (PROM) (7.3% vs. 18.7%, p=<.0001). There were more significant cases of congenital anomalies (20.4% vs. 25.0%, p=0.04) and intrauterine growth restriction (IUGR) (16.8% vs. 21.8%, p=0.006) in the post-implementation group (Table 4).

Maternal Demographics

Maternal demographics and delivery mode in pre-implementation and post-implementation groups were mostly similar (Table 5). There were 734 mothers in the pre-implementation group and 697 mothers in the post-implementation group. Overall, we found no difference in mothers with advanced maternal age (34.2% vs. 36.6%, p=0.34) or with delivery modes (cesarean section 52.2% vs. 57.0%, normal/spontaneous vaginal delivery 43.1% vs. 39.9%, or operative vaginal 4.8% vs. 3.2%, p=0.10). The mean maternal age was 32 years for both groups. A difference was noted in maternal race. More mothers designated "Other" race were in the pre-implementation group (46.4% vs. 38.8%, p=0.01) (Table 5).

Infant Demographics

Infant characteristics in pre- and post-implementation groups were similar (Table 6). No significant differences were found in birth weight, gestational age, or sex. The majority were term normal birth weight infants with no statistical difference in male to female ratio.

Discussion

In pre- and post-implementation groups, we found no differences in NRP comparisons in adherence scores, EOC, EOO, team skills, and resuscitation duration. Significantly more infants with congenital anomalies, IUGR, and PROM were in the post-implementation group. There were more opportunities for complex resuscitation (i.e. CPAP, intubation, and PPV) in the post-implementation group. Yet, we found no group differences in epinephrine and chest compressions, Apgar scores, or patient outcomes.

There was no significant decline noted in performance and team skills even though these in situ mock codes were spaced apart by about 6 months per fellow. We found no NRP decay from fellows' baseline boot camp performances. We speculate these results suggest that DP maintained fellows' NRP skills over time without decay. Prior studies show knowledge and technical decay after one NRP session.[2-4] We speculate that regular in situ mock codes could maintain NRP skills and team behavior. Studies show decline with NRP recertification once every 2 years.[2,32] Our simulation curriculum is very similar to

the American Health Association Resuscitation Quality Improvement® Program wherein a refresher program is implemented quarterly to maintain advanced life support and basic life support skills for providers with the added benefit of actual team-based practice opportunities.[33] Offering more frequent training, evaluation, and feedback than once every 2 years makes sense and could be generalized to other graduate programs. The addition of DP NRP simulation course to the clinical experience of 697 resuscitations likely prevented NRP skill decay. Although enhanced patient outcomes were not demonstrated, it is important to note that patient outcomes were not worse despite more complex resuscitations in the post-implementation group. In NICU care, the art of medicine includes consideration of prognosis of infants' primary disorders, immediate delivery room resuscitations, daily management, and future long-term outcomes of complex patients. Post-implementation data was inconclusive regarding infant illness severity and fellows' skill in emergent recognition of the need to initiate PPV and intubation. We found fellows' use of PPV and intubation significantly increased in the post-implementation group without significant differences in provision of epinephrine and chest compressions. By emphasizing effective ventilation in the form of PPV and intubation, we speculate fellows' implementation of the cornerstones of NRP could have led to their successful delivery room resuscitation attempts during delivery. This could have prevented potential escalation in cardiac arrest requiring epinephrine and chest compressions. We feel reassured that DP reinforced and maintained fellows' NRP skills.

This study has many strengths. The boot camp and the repetitive in situ mock codes are a practical simulation-based program. The frequency and multiple numbers of in situ mock codes created several DP opportunities for fellows. Also, the inclusion of complex in situ mock codes may have motivated fellows to maintain their NRP skills. Providers learn to actively apply and integrate knowledge and cognitive functions in a specific crisis management scenario. The frequent training supports fellows' need to incorporate cognitive, behavioral, and technical skills in a progressively changing situation. Conducting DP mock codes with interprofessional team members in the NICU reinforced utilization of system resources and processes. This study assessed the association between DP in NRP and patient outcomes, which has not been demonstrated before to our knowledge. Two principal investigators remained the primary researchers utilizing standardized scenarios, conducting the boot camps and in situ mock codes, and assuring the uniformity of the simulation program. The study design included consistent use of NRP 7th edition for both pre- and post-implementation periods.[30]

As an observational pre- and post-implementation study, there are confounding factors that potentially bias our results. Causal relationships cannot be accurately determined from this study. The evaluator was not blinded to the participants' post-graduate years or number of simulation sessions. Study researchers directly observed study participants that may produce observer bias. The Hawthorne effect, in which individuals, aware of being observed, modify their behavior, may have influenced group and individual actions during simulation. Adjustments were not made for any NICU quality improvement projects implemented during the study period. One quality improvement project implemented during the study period included the chronic lung injury prevention project (implementation of surfactant in the NICU). While this project may not have impacted delivery room resuscitation, it could have had an impact on patient outcomes. It is inconclusive whether this QI project led to no differences in patient outcomes between the pre-and post-implementation groups. Another quality improvement project included the prevention of neonatal hypothermia in the delivery room project (increasing delivery room temperatures to maintain neonatal temperature). This project was implemented during both the pre-and post-implementation periods. The study did not make adjustments for fellows' or NICU staff's clinical experiences gained in NRP prior to and during the study, and NICU staff did not participate in the boot camp. Team participant variations in the in situ mock codes were not controlled. However, fellows consistently served as team leaders to guide NICU staff through in situ mock codes and real patient codes.

Conclusion

The post-implementation group outcomes were no different despite caring for sicker, more medically complex infants with congenital anomalies, PROM, and/or IUGR. Outcomes based upon the daily management and prognosis of primary disorders of neonates make the impact of effective resuscitation elusive. NRP DP simulation curriculum consisting of annual bootcamps and 1-2 mock codes per month supported maintenance of fellows' skills and decay prevention in knowledge and skills throughout fellowship. The future for NRP DP simulation should include curriculum integration into neonatal-perinatal fellowship programs. Suggestions for future areas of research include conducting prospective studies to determine precise frequency of in situ mock codes. Future study of video-recorded delivery room experiences to determine the translation of simulated NRP skills into real crisis management situations should be done. Prospective multi-site randomized controlled trials examining resuscitation variability and effectiveness across NICU infant groups are needed to add to the knowledge base for future guidelines.

Conflict of interest statement

All authors indicated no financial relationships to disclose relevant to this article. Study design, data collection, analysis, interpretation, and writing of this report and/or the decision to submit this article for publication was independent of any financial source.

Acknowledgements

We thank the CPQCC team (Janella Parucha, Rebecca Amrany, Britnie Hanks, Laurie Bilgihan, Cindy Bell), NICU medical staff at RRUMC and the UCLA Neonatal-Perinatal Fellows,

UCLA Simulation Center staff members, UCLA Clinical and Translational Science Institute, and the UCLA Neonatology Division. The project described was supported by the National Center for Advancing Translational Sciences, National Institutes of Health, through grant UL1TR001881.

Table 1. Deliberate Practice Simulation Results			
	Mean, SD	**Median, IQR**	**p-Value***
NRP Adherence	4.98; 12.32	3.00; 17.00	0.18
Errors of Commission	-6.08; 13.29	-3.00; 21.50	0.24
Errors of Omission	1.48; 4.74	1.42; 4.50	0.18
Percentage of Team Skills	1.85; 10.65	0.00; 5.00	0.41
Resuscitation Duration	-0.84; 2.05	0.13; 2.00	0.21
Caption: Deliberate practice simulation performance results			
Legend: Data are presented as mean ± standard deviation or median with interquartile range * P < 0.05 SD = standard deviation, IQR = interquartile range One-sided t-test and signed rank test			

Table 1. Deliberate practice simulation performance results

Table 2. Neonatal Resuscitation Results			
	Pre-Implementation n (%)	**Post-Implementation n (%)**	**p-Value***
	n = 734	**n = 697**	
Complex resuscitation	301 (41.01)	378 (54.23)	<.0001*
Continuous positive airway pressure (CPAP)	219 (29.84)	300 (43.04)	<.0001*
Positive pressure ventilation (PPV)	187 (25.48)	225 (32.28)	0.0045*
Intubation	47 (6.40)	67 (9.61)	0.0250*
Epinephrine	6 (0.82)	12 (1.72)	0.1257
Chest compressions	17 (2.32)	18 (2.58)	0.7443
Caption: Delivery room resuscitation interventions for pre-implementation and post-implementation groups			
Legend: Data are presented as n (%) * P < 0.05 Chi-squared test and Fisher's exact test			

Table 2. Delivery room resuscitation interventions for pre-implementation and post-implementation groups

Table 3. Neonatal Outcomes			
	Pre-Implementation n (%)	**Post-Implementation n (%)**	**p-Value***
	n = 734	**n = 697**	
Apgar 1 min ≤ 5	156 (21.43)	175 (25.33)	0.0827
Apgar 5 min ≤ 5	18 (2.47)	25 (3.63)	0.2031
Death within 12 hrs of NICU admission	3 (0.41)	9 (1.29)	0.0673
Pneumothorax	27 (3.68)	38 (5.45)	0.1073
HIE	8 (1.89)	10 (2.81)	0.3957
Length of Stay			
1-7 days	391 (53.27)	336 (48.21)	
8-14 days	99 (13.49)	86 (12.34)	
15-30 days	103 (14.03)	130 (18.65)	
≥ 31 days	141 (19.21)	145 (20.8)	0.0627
Disposition from Hospital			
Home	664 (90.46)	611 (87.66)	
Transported	52 (7.08)	63 (9.04)	
Died	18 (2.45)	23 (3.3)	0.2334
Caption: Neonatal patient outcomes between pre-implementation and post-implementation groups			
Legend: Data are presented as n (%) * P < 0.05 Chi-squared test and Fisher's exact test			

Table 3. Neonatal patient outcomes between pre-implementation and post-implementation groups

Table 4. Maternal, Obstetrical, and Fetal complications			
	Pre-Implementation n (%)	**Post-Implementation n (%)**	**p-Value***
	n = 734	**n = 697**	
Pregnancy/Maternal Complications			
Group B strep	174 (30.05)	168 (29.84)	0.9378
Hypertension	159 (21.66)	173 (24.82)	0.1571
Chorioamnionitis	66 (8.99)	37 (5.31)	0.0070*
Diabetes	102 (13.9)	119 (17.07)	0.0965
Prenatal Care	728 (99.45)	690 (99)	0.3222
Obstetrical Complications			
Preterm labor	259 (35.29)	201 (28.84)	0.0090*
Preterm premature ROM	103 (14.05)	102 (14.63)	0.7535
Premature ROM before onset of labor	26 (7.28)	58 (18.71)	<.0001*
Prolonged ROM 18hr	123 (16.76)	118 (16.93)	0.9307
Malpresentation or Breech	115 (15.67)	101 (14.49)	0.5342
Bleeding Abruption Previa	83 (11.31)	66 (9.47)	0.255
Fetal Complications			
Multiple gestation	148 (20.16)	165 (23.67)	0.1085
IUGR	118 (16.08)	152 (21.81)	0.0056*
Non-reassuring fetal status	141 (19.21)	134 (19.23)	0.9941
Congenital anomaly	150 (20.44)	174 (24.96)	0.0408*
Caption: Maternal, obstetrical and fetal complications for pre- and post-implementation groups			
Legend: Data are presented as n (%) * P < 0.05 Chi-squared test and Fisher's exact test			

Table 4. Maternal, obstetrical and fetal complications for pre- and post-implementation groups

Table 5. Maternal Demographics			
	Pre-Implementation n (%)	**Post-Implementation n (%)**	**p-Value***
	n = 734	**n = 697**	
Advanced Maternal Age ≥ 35 years old (mean 32 years for both groups)	251 (34.2)	255 (36.59)	0.3447
Maternal Race			
Black	40 (5.57)	57 (8.27)	
White	272 (37.88)	279 (40.49)	
Asian	73 (10.17)	86 (12.48)	
Other	333 (46.38)	267 (38.75)	0.0129*
Delivery Mode			
Cesarean section	383 (52.18)	397 (56.96)	
Normal/spontaneous vaginal	316 (43.05)	278 (39.89)	
Operative vaginal	35 (4.77)	22 (3.16)	0.0957
Caption: Maternal demographics of mothers in pre-implementation and post-implementation groups			
Legend: Data are presented as n (%) * P < 0.05 Chi-squared test and Fisher's exact test			

Table 5. Maternal demographics of mothers in pre-implementation and post-implementation groups

Table 6. Infant Demographics			
	Pre-Implementation n (%)	**Post-Implementation n (%)**	**p-Value***
	n = 734	**n = 697**	
Infant Demographics			
Extremely low birth weight	29 (3.95)	43 (6.17)	
Very low birth weight	53 (7.22)	50 (7.17)	
Low birth weight	292 (39.78)	276 (39.6)	
Normal birth weight	360 (49.05)	328 (47.06)	0.2845
Gestational age			
Extremely preterm	22 (5.54)	39 (9.73)	
Very preterm	57 (14.36)	58 (14.46)	
Moderate preterm	80 (20.15)	77 (19.2)	
Term	238 (59.95)	227 (56.61)	0.1686
Sex			
Male	410 (55.86)	359 (51.51)	
Female	324 (44.14)	338 (48.49)	0.0989
Caption: Infant demographics			
Legend: Data are presented as n (%) * P < 0.05 Chi-squared test and Fisher's exact test			

Table 6. Infant demographics in pre-implementation and post-implementation groups

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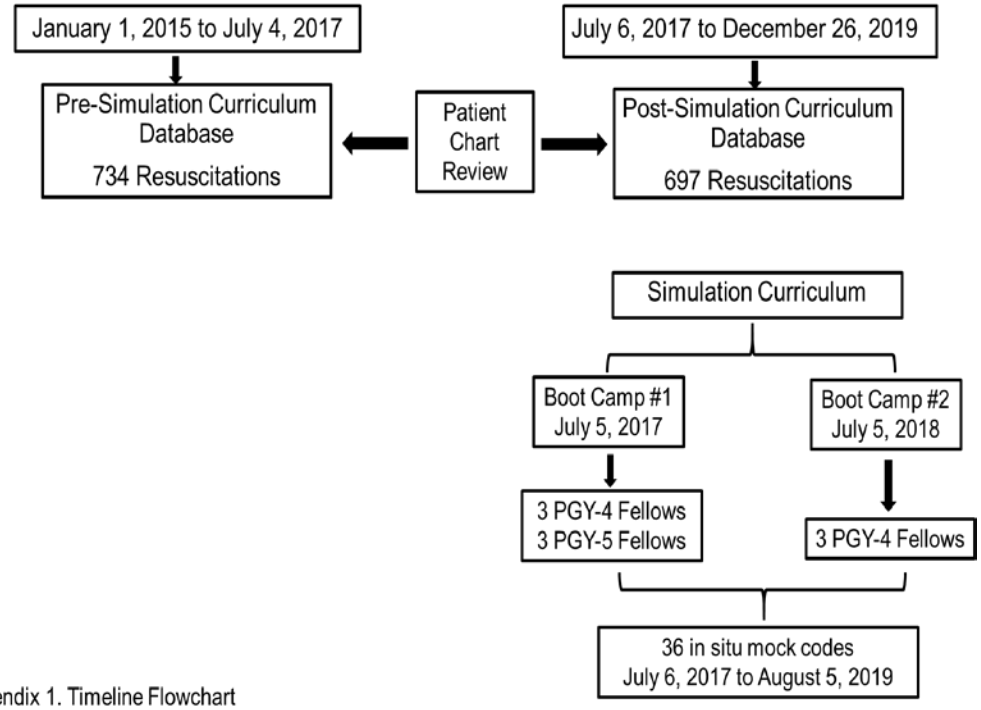

Appendix 1. Timeline Flowchart

Appendix 2. NRP Scoring Tool

		Error Subtypes		
		Omission	Commission	
Team Behavioral/Communication Skills	Performed	Indicated but not performed	Performed more than 5 seconds after indicated	Could not be determined from video
Knows environment (performs equipment check, knows location of resuscitation equipment)				
Identifes team leader				
Team leader uses available information (knows prenatal and intrapartum history)				
Team leader anticipates and plans (assigns roles and responsibilities; performs pre-resuscitation debriefing if possible)				
Communicates effectively (calls team members by name, informs team of problem or error, orders medications by name, dose, route; uses closed-loop communication; includes family members in communication as appropriate)				
Delegates workload optimally				
Team leader allocates attention wisely (maintains situational awareness; monitors each other's skill performance)				
Uses available resources (knows what personnel are available; knows what additional supplies are available and how to access them)				
Calls for additional help when needed				
Maintains professional behavior (uses respectful verbal and nonverbal communication)				