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## Simulation and education

# Characterizing prehospital response to neonatal resuscitation



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### Abstract

**Objective:** To evaluate performance of initial steps of newborn resuscitation according to the American Heart Association and American Academy of Pediatrics' Neonatal Resuscitation Program (NRP) guidelines in the prehospital setting.

**Study Design:** Observational study of 265 paramedics and Emergency Medical Technicians (EMTs) from 45 EMS teams recruited from public fire and private transport agencies in a major metropolitan area. Participants completed a baseline questionnaire assessing demographics, experience, and comfort in caring for children. Simulations were conducted April 2015 to March 2016. Technical performance was evaluated by blinded video review. NRP actions were assessed using a structured performance tool.

**Results:** Two hundred sixty-five EMS providers responded to survey questions and participated in simulations. In total, 16% reported feeling very or extremely comfortable caring for children <30 days of age (vs. 71% for children aged 12–18 years). Among 45 EMS teams participating in simulations, 22% (n = 10) dried, 18% (n = 8) stimulated, and 2% (n = 1) warmed within 30 s from arrival and 11% (n = 5) provided BMV within 60 s from arrival, as recommended by NRP. All teams provided BMV. Eighty-eight percent bagged below NRP rate recommendations and 96% bagged with tidal volume exceeding guidelines. Looking over the entire 10-min simulation for ever performing measures, 73% started to dry the baby within a median of 51 (range 0–539) seconds from arrival, 38% started to stimulate the baby within a median of 34 s (range 0–181), and 44% started to warm the baby within a median 291 s (range 27–575 s).

**Conclusions:** These data from field simulations suggest NRP steps recommended for the first minute after birth are seldom performed in a timely manner and suggests opportunities for improvement.

**Keywords:** Neonatal resuscitation, Emergency medical service, Prehospital, Newborn care

### Introduction

Annually, approximately 62,000 births occur out-of-hospital in the United States.<sup>1,2</sup> Most newborns transition successfully, however, up to 10% term and late preterm infants in the U.S. require some resuscitation to establish effective breathing and ventilation.<sup>3</sup>

Neonatal Resuscitation Program (NRP) guidelines, based on recommendations by the American Heart Association and the American Academy of Pediatrics (AAP), provides evidence-based practice guidelines that are the standard of care for infants born in the U.S. NRP provides a time-based algorithm for critical actions including establishing and maintaining normothermia by drying and warming within the first 30 s after delivery and initiating bag mask ventilation

*Abbreviations:* NRP, Neonatal Resuscitation Program; EMS, Emergency Medical Service; BMV, bag mask ventilation; EMTs, Emergency Medical Technicians; AAP, American Academy of Pediatrics; EMS-C, Emergency Medical Services of Children; FRC, functional residual capacity.

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(BMV) within the first minute if the baby has absent or poor respiratory effort.<sup>3</sup> Delays in initiating these first steps of neonatal resuscitation for the newborn infant can result in untoward consequences of cold stress and hypoxia, including hypoglycemia, acidosis, persistence of fetal circulation, brain injury, cardiopulmonary decompensation, and death.<sup>4,5</sup>

EMS responders are sometimes the first health professionals to attend a birth. Because actions taken within the first seconds to minutes after birth can make the difference between life and death or lifelong disability, it is important to understand how these are performed in the prehospital setting. The purpose of this study was to examine NRP guideline adherence in the initial steps of warm, dry, stimulate, and initiation of BMV in the prehospital setting.

## Methods

This is an observational study of EMS teams responding to a simulated neonatal resuscitation scenario. This study was conducted as part of a larger mixed-methods Children's Safety Initiative-EMS study to characterize patient safety in the prehospital setting funded by the US National Institutes of Health (NICHD R01HD062478) and approved by Oregon Health & Science University's Institutional Review Board (IRB# 00006942).

### Study population

EMS agencies were recruited through Oregon EMS Medical Director representatives and state EMS or Emergency Medical Services for Children (EMS-C) offices. Study participants were EMS teams working on the day of the simulations. Voluntary informed consent was obtained from study participants, including disclosure for video release and confidentiality agreement. The study was conducted from April 2015 to March 2016.

### Survey

All participants were asked to complete a baseline questionnaire assessing demographics, EMS experience, NRP training, and comfort in caring for children. Variables collected include level of training, years of EMS experience, time since last NRP training, and self-perceived comfort rated on a 5-point Likert-type scale of "Not at all", "Slightly", "Somewhat", "Very", and "Extremely" for children "Less than 30 days old", "Between 1 month and 1 yr old", "Between 1 and 5 years-old", "Between 6 and 11 years-old", and "Between 12 and 18 years-old". The survey was administered on paper, immediately before the simulations.

### Simulation

Teams participated in a standardized clinical scenario which involved a simulated 9-1-1 dispatch to a home for a birth in progress. EMS teams consisting of 5–7 providers responded in their own ambulances and fire trucks. They arrived to a father (played by a professional actor) holding a just delivered, cyanotic newborn manikin (Gaumard Newborn HAL<sup>®</sup> 3010; weight 3.5 kg) with poor respiratory effort. The newborn was wet with simulated birthing fluids and vernix. A mother (Gaumard Noelle<sup>®</sup> manikin) was in a nearby bed, with placenta delivered and normal vital signs. Teams were oriented to the manikin's features prior to the simulations.

Real-time feedback was provided to the team based on interventions performed. The simulation began with initial heart rate (HR) of 90 beats per minute and respiratory rate (RR) of 20 breaths/min. These vital signs were kept fixed for the first two minutes of care. If optimal care was provided (defined as warming, drying, and stimulating within the first 30 s, followed by BMV within 1 min after the birth), the baby's HR improved to >100 beats per minute, RR to 60 breaths/min, and flexed tone. If suboptimal care was provided, the baby's condition deteriorated, with HR decreasing to <60 beats per minute, and apnea, eventually leading to pulseless electrical activity, and asystolic arrest. In these situations, additional care was required to stabilize the patient: intubation, CPR, and administration of epinephrine.

All simulations were video recorded for later analysis. Videos were reviewed by an expert NRP instructor who did not participate in the design of the study or conduct simulations and was blinded to study hypotheses and the identities of the EMS agencies or participants. Teams were permitted to assign roles and responsibilities as they saw fit. Key tasks of warming, drying, stimulating, and BVM were independently reviewed by a second reviewer for added rigor. Disagreements in scoring were resolved by joint review and consensus.

### Scoring tool

A technical performance tool, modified from previously validated NRP scoring tools, measured the quality and timing of NRP activities.<sup>6,7</sup> Structured fields allowed the observer to indicate if tasks were "Not Observed", "Not Done", "Not Done Correctly". A "Notes" section allowed recording of details for each task such as "baby was warmed with wet blanket". BMV rate was scored as "Slow" (< 40 breaths/min), "Good" (40–60 breaths/min), or "Fast" (>60 breaths/min). Additionally, type of resuscitator bag used (infant, pediatric, or adult) and a clinical expert's (TH) visual assessment of percent squeeze for majority of breaths provided (<10%, 10–50%, or >50%) were recorded. Adequate ventilation with BMV was assessed by chest rise, as per NRP guidelines.

### Outcomes

The primary outcome was adherence to initial NRP steps and timing. The initial steps of warming, drying, stimulating, and initiating BMV (Supplemental Fig. 1) are thought to be of paramount importance in NRP. We defined care adhering to NRP guidelines as warming, drying, and providing stimulation within the first 30 s and BMV within 1 min of EMS arrival. Secondary outcomes included ever performing drying, warming, stimulating, and BMV during the entire 10-min simulation and quality of ventilation.

### Statistical analysis

Team-level data from simulations were analyzed using counts and frequencies. Median and range were used to describe the timing of warming, drying, stimulating, and BMV among teams that ever performed the tasks. Additionally, semi-log graphs were constructed to show the counts and frequencies of teams that performed the four tasks over time in relation to NRP time-based guidelines. To evaluate the potential association of team characteristics with NRP task performance, team-mean years at current level of training, years worked in EMS, and time passed since last NRP training were

assessed for correlation with adherence to NRP time-frame guidelines for warming, drying, stimulating, and ventilating the patient.

Statistical analyses were conducted using Stata 15 (Stata-Corp.2017.Stata Statistical Software: Release 15.College Station, TX:StataCorp LLC). All hypothesis tests were 2-sided, with a significance level of  $p$ -value  $< 0.05$ .

## Results

A total of 265 EMS providers participated in the study. Study participant characteristics are presented in Table 1. Most (85%) of EMS participants were male and white. The mean age of participants was 37 years and average years worked was 12.

### Survey

All participants responded to the baseline survey. A minority, 42 (16%) reported feeling very/extremely comfortable caring for children  $< 30$  days compared with 186 (71%) who felt very/extremely comfortable caring for children aged 12–18 years. Of EMS providers who responded to questions about NRP training, 105 (45%) never had NRP training or completed NRP training 2 or more years ago, and 128 (55%) completed NRP training within the last 2 years (Table 1).

### Simulation

A total of 45 EMS teams participated in the simulations. On average teams self-assigned a minimum of 3 providers to the baby and 1 provider to the mother. Among the teams, 10 (22%) dried, 8 (18%) stimulated, and 1 (2%) warmed the newborn within the first 30 s. Over the entire 10-min simulation, 12 (27%) never dried the infant, 28 (62%) never stimulated, and 25 (56%) never attempted to warm the infant. Of EMS teams that ever dried the newborn (73%), the median time to initiate drying was 51 s (range 0–539 s). Five (11%) teams were scored for drying “Not Done Correctly”. These teams either only dried the chest for EKG lead placement, dried only the head, or only the

face. Seventeen (38%) teams were observed stimulating the baby, with a median time of 34 s (range 0–181 s) to initiate stimulation. Stimulating was scored as “Not Done Correctly” in 67% of teams; most teams very briefly rubbed/flicked a foot, softly tapped on the chest. For teams that warmed the baby (42%), the median time was 297 s (range 27–575 s) to initiate warming. Warming was scored as “Not Done Correctly” ( $n = 3$ ; 7%) when a blanket was placed over the arm only, over the baby only (and not also under the baby to prevent heat loss), or when a wet blanket was used. Fig. 1a depicts the cumulative count of teams performing the initial NRP steps of warming, drying, and stimulating (red spaced lines at 30 s mark NRP guideline time-frame for warm, dry, and stimulate).

Fig. 1b depicts the cumulative count of teams initiating BMV (red spaced lines at 60 s mark NRP guideline time-frame for BMV). Five (11%) teams provided BMV within 60 s, as recommended by NRP. All teams performed BMV during the simulation and initiated BVM with a median time of 103 seconds (range 42–284 s) after arrival.

No teams had neonatal resuscitator bags (150 ml delivered volume, 1-hand squeeze) in the response kits provided by their agencies; all used either pediatric (450 ml delivered volume, 1-hand squeeze) or adult (600 ml delivered volume, 1-hand squeeze) bags. As shown in Table 2, 43 (96%) teams provided BMV breaths in excess of acceptable tidal volumes for a newborn. Ten (22%) teams administered volumes more than 10 times the target tidal volume for a newborn and 33 (73%) teams administered ventilation breaths 2–10 times in excess of ideal tidal volumes.

Looking specifically at BMV technique, 88% provided BMV at a rate below NRP recommendations ( $< 40$  breaths/min). Assessment for adequate ventilation with chest rise during BMV was performed by 53% of teams.

Time to warming was inversely associated with years worked in EMS ( $R = -0.54$ ,  $p$ -value = 0.02) and years worked at current level of training ( $R = -0.59$ ,  $p$ -value = 0.01) (Table 3). There were no other significant correlations between time-based NRP tasks and EMS training or experience.

## Discussion

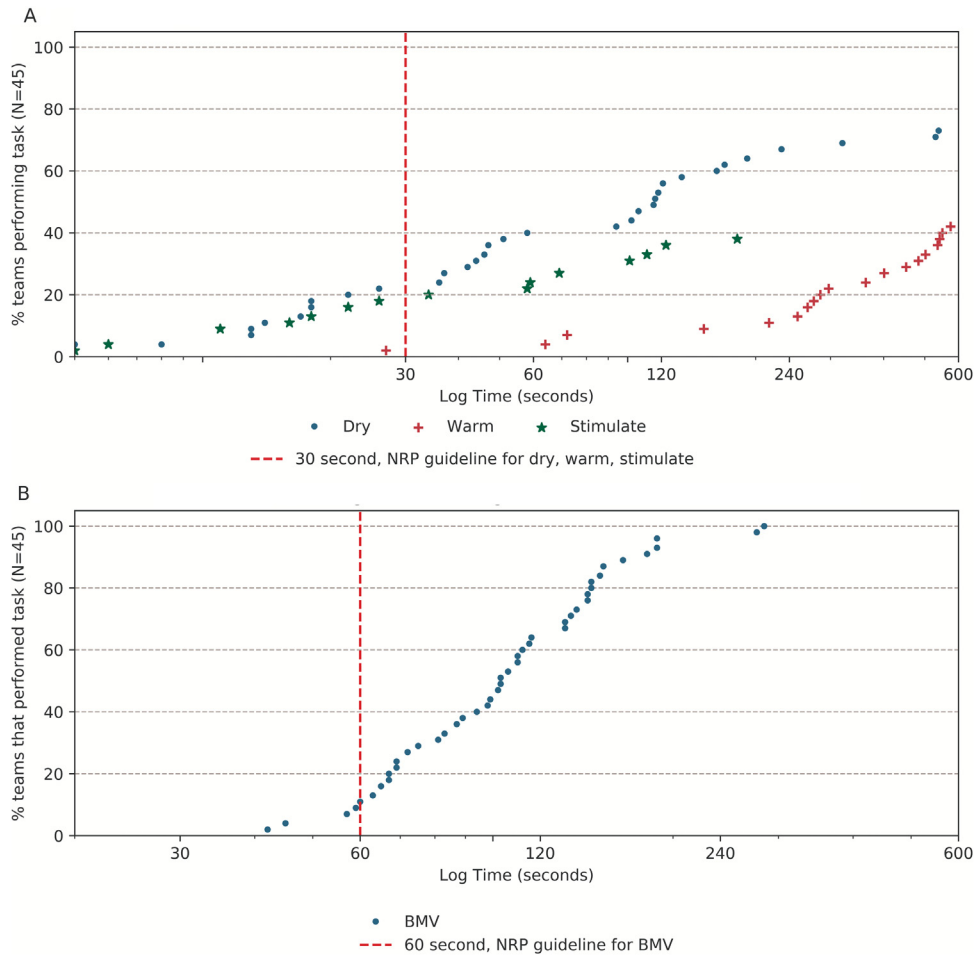
The findings of this study suggest recommended NRP activities of drying, warming, stimulating, and initiating BMV for a newborn with absent or poor respiratory effort in the first minute of birth, often do not occur or are significantly delayed in the prehospital setting. These initial steps are thought to be of utmost importance and can be life-saving.<sup>3,4,8,9</sup> NRP guidelines assume the provider is present at the time of birth and not specifically developed for the prehospital setting, where provider arrival might be significantly delayed after birth. In our scenario, EMS personnel were dispatched to a delivery in process and arrived just after birth occurred.

Our survey findings suggest most EMS personnel do not feel prepared to care for newborns. This is not surprising since pediatric calls represent only 4–10% of all EMS calls,<sup>10–13</sup> and births are rare, occurring in about 0.1%.<sup>14</sup> The infrequency of prehospital births limits exposure of EMS personnel to newborn resuscitation and proficiency. While NRP training could provide exposure to NRP guidance and timing, it is not mandatory. Outside of initial paramedic training, there is no national standard pediatric curriculum for EMS continuing education. Pediatric training is usually limited and does not routinely cover neonatal resuscitation cases.<sup>11,12,15,16</sup>

**Table 1 – EMS provider demographics and training.**

	No. (%)
Total participants	265
Age, mean (SD), years*	37 (9)
Gender male, N (%)	225 (85)
Race white, N (%)	226 (85)
Level of training, N (%)	
EMT-Intermediate	26 (10)
EMT	101 (38)
Advanced EMT	2 (1)
Paramedic	133 (50)
No answer	3 (1)
Years worked at current level of training*	9 (7)
Years worked in EMS*	12 (8)
Time past since NRP training, N(%)	
$\leq 2$ years	128 (48)
$> 2$ years	36 (14)
No training	69 (26)
No answer	32 (12)

All % are computed with 265 as denominator.  
\* Mean and SD for those who answered the question.



**Fig. 1 – (a) Timing\* of Dry, Warm, Stimulate during Neonatal Resuscitation Simulation. \* Time from arrival to initiation. (b) Timing\* of Bag Mask Ventilation (BMV) during Neonatal Resuscitation Simulation. \* Time from arrival to initiation.**

**Table 2 – Ideal vs. estimated breath volume delivered.**

Bag size used N (%)			Percent squeeze	Estimated volume
Infant (150 ml*)	Peds (450 ml*)	Adult (600 ml*)		
–	2 (4)	–	<10%	Within ideal range
–	30 (67)	3 (7)	10-50%	2–10x
–	9 (20)	1 (2)	>50%	>10x

Acceptable BMV volume is 6–8 mL/kg. Average birth weight is 3.5 kg. Ideal tidal volume is 21–28 ml.  
 \* Delivered volume, 1 hand squeeze.

**Table 3 – Correlations between team average experience/training and timing of tasks.**

	Time to dry (s) (n=33)		Time to warm (s) (n=19)		Time to stimulation (s) (n=17)		Time to BMV (s) (n=45)	
	R	p-value	R	p-value	R	p-value	R	p-value
Years at current level of training (team avg)	-0.16	0.37	-0.59*	0.01	-0.1	0.69	-0.04	0.8
Years worked in EMS (team avg)	-0.16	0.37	-0.54*	0.02	-0.36	0.89	-0.17	0.25
Recency of NRP training (team avg)	-0.04	0.82	-0.01	0.96	-0.2	0.42	0.11	0.46

\* significant at alpha = 0.05.

Studies of pediatric and family practice residents suggest NRP skills decline as early as 2–3 months.<sup>17–19</sup> This combined with our findings that NRP performance was not associated with NRP training, suggest NRP training alone may not solve this problem.

The initial steps of neonatal resuscitation are straightforward and do not require medical equipment or advanced medical training. Drying the newborn using a dry blanket, shirt or towel, stimulating the baby by rubbing its back, trunk and extremities, and warming by placing a hat on the baby and wrapping in dry blankets or similar cloth, is feasible in almost any setting and could be done by any EMS personnel, yet one-quarter of teams did not dry and over half did not warm or stimulate at all during the 10-minute simulation. These simple maneuvers are critical and failure to perform these steps can impede response to other resuscitation measures. The importance of timely initiation of basic neonatal resuscitation to improve perinatal outcomes is best exemplified by the AAP's Helping Babies Breathe™ (HBB) curriculum. This program was implemented to increase healthcare workers' awareness of the need to start the very basic steps of neonatal resuscitation - warming, drying, stimulating, and if needed, BMV - within the "Golden Minute"™ after birth.<sup>20–22</sup> This curriculum includes graphical displays for each step of neonatal resuscitation, up to assessment of heart rate after initiation of BMV, which may be helpful in the prehospital EMS setting.

We anticipated that the teams' average years of training and number of years worked in EMS would be associated with quicker times of providing the initial NRP tasks of drying, warming, stimulating, and ventilation (BMV). We also expected teams with more recent NRP training would perform the critical NRP tasks sooner upon arrival. We found that EMS experience was moderately associated with time to warming action, but not to other initial critical NRP tasks. The reasons underlying this finding are unknown. We hypothesize that experienced EMS providers are more attuned to the need to warm, and may be more creative in adapting things in their environment to this purpose. It is also possible that they simply have more hands-on experience with babies. The latter, given the low frequency of pediatric calls, raises the question of the degree to which simulation might bridge the gap.

Limiting heat loss is key to the stabilization of newborns after birth. Newly born infants lose heat quickly due to their high surface area-to-volume ratio. This unique aspect enhances the mechanisms by which heat loss occurs - evaporation of amniotic fluid from the newborn's body, convection to cooler surrounding air, radiation to cooler objects in the vicinity, and conduction through the newborn's body touching cooler surfaces.<sup>23</sup> There is a recognized association between hypothermia and neonatal morbidity and mortality, including respiratory distress, metabolic acidosis, hypoglycemia, and death.<sup>8</sup> Hypothermia increases oxygen consumption, impairs the cardiopulmonary transition from intrauterine to extrauterine life by affecting pulmonary vasomotor tone and alters acid-base homeostasis.<sup>24</sup>

While establishing and maintaining normothermia are important in the successful postnatal transition of a newborn, establishment of adequate ventilation and oxygenation are paramount. Initial stimulation of the newborn by warming and drying can overcome primary apnea. If an infant does not respond to stimulation, BMV should be initiated promptly. Effective ventilation promotes clearance of lung fluid, establishment of functional residual capacity (FRC), decrease in pulmonary vascular resistance, increase in pulmonary blood flow, and increased cardiac output. Delay in providing effective ventilation in a newborn with absent or poor respiratory effort after birth results in continued hypoxia, hypercarbia, and metabolic acidosis, which prolonged, will lead to cardiopulmonary arrest from asphyxia.<sup>4,5</sup> This contrasts to the etiology of cardiopulmonary arrest in adults, which is cardiac in origin.<sup>3</sup>

No teams completely and correctly performed BMV per NRP guidelines - by providing ventilation at a rate of 40–60 breaths/min, providing appropriate tidal volume, and assessing for chest rise. Providing suboptimal ventilation breaths can lead to inadequate response to resuscitation - i.e. heart rate that does not continue to rise appropriately with effective BMV. Although all EMS teams provided BMV, the vast majority of providers gave observed tidal volumes in excess of acceptable range. Almost one-quarter were observed to provide greater than 10 times the target tidal volume and almost three-quarters were observed to provide tidal volumes 2–10 times in excess of ideal tidal volumes. This is most likely because ambulances stock adult and pediatric bags, which due to increasing bag capacity, have a higher range of deliverable tidal volumes. Excess tidal volume which can be provided by pediatric and adult bags may increase the risk of lung injury in the newborn.<sup>8,25</sup> It can also cause pneumothorax and deterioration in the infant's clinical status, including death, if not recognized and treated. Evaluation of chest rise, performed by about 50% of EMS teams, is important for assessment of effective ventilation, but may also indicate delivery of excessive tidal volume.

In the prehospital setting, EMS providers face unique challenges that may limit the effectiveness of neonatal resuscitation interventions and adherence to NRP guidelines. In addition to the infrequency of prehospital births and the limited exposure of EMS personnel to newborn resuscitation, EMS providers face unknown patient care settings and birth environments. Furthermore, they have limited personnel on scene to medically manage both mother and infant. NRP tasks and timeframes are optimal, and mainly based on hospital births, with resuscitation team members present at delivery. In the prehospital setting, there can be delay between delivery and EMS arrival. Equipment and supplies carried by EMS providers are determined by system needs and limited by ambulance space. Due to low-frequency rates of prehospital births, there is minimal stocking of equipment and supplies specific for neonatal resuscitation.<sup>16</sup> If it is not feasible or cost effective to stock infant bags, one consideration could be to carry manometers to ensure proper inflating pressures during BMV or, at minimum, disseminate volume thresholds for neonates and appropriate percent squeeze according to resuscitator bag size. Short rapid cycle simulations or "just in time" training might be tools used for NRP training and reinforcement. Cognitive aids such as checklists with important NRP steps, could be part of all EMS toolkits so EMS providers are not expected to remember details for infrequent events. Ambulance-based telemedicine systems, with access to remote expert support, could potentially help support EMS performance in neonatal resuscitation. Reliable connectivity, cost, and user-proficiency with the technology, however, may be barriers to successful implementation.<sup>26,27</sup> NRP algorithm decision support tools on portable tablets or downloaded on mobile devices may help optimize patient care without increasing cognitive load on EMS personnel.<sup>28</sup> In addition to the above barriers of mobile technology, use of these tools may have untoward consequences, distracting and/or burdening first responders from the task at hand.<sup>29,30</sup>

There are limitations to this study. First, the make up and response of EMS is highly variable across the United States. Our study reflects Multnomah county, which has a population of >700,000. EMS response in this urban setting is simultaneous dispatch, where both fire department and private transport agencies respond to calls and there is a higher percentage of paid and ALS trained providers.<sup>31</sup> We do not know the degree to which our findings might pertain to rural settings or urban settings with different EMS composition. In our study



greater than 50% of EMS providers reported NRP training within the last 2 years. Our results, however, demonstrate recent NRP training had no association with improved performance, thus our findings may be generalizable to other EMS systems. Second, the study was performed in a simulation environment. While we used the highest levels of fidelity possible with professional actors, high fidelity simulators, dispatch and response following normal protocols, and teams using their own equipment, simulation is never able to completely replicate real-life. Certain cues such as simulated vernix and fluid on the infant, suggesting a wet newborn, might not have been as obvious to participants or teams may have disregarded this feature because it was a manikin. Third, BMV volume was based on observer's estimate of percent squeeze of the self-inflating bag as opposed to direct volumetric measurement. To augment observer reliability of the video recordings, 2 reviewers independently scored percent squeeze. We also used broadly defined categorical measures of <10%, 10–50%, and >50%. If we had used tools that directly quantified BMV volumes administered, it is likely more teams would have been scored as exceeding the particular percent volume thresholds. Fourth, we do not report on quality of heart rate assessment. However, we observed that all teams assessed initial heart rate by palpation and used more reliable methods on subsequent assessments, such as auscultation and EKG monitoring.

## Conclusions

Basic NRP skills of maintaining normothermia by drying and warming, and initiating ventilation with BMV were often delayed or not performed by EMS providers. Many of these basic steps of resuscitation can be performed by people with no or little training. The results of our study suggest there is an important opportunity to raise awareness in EMS and possibly the community at large of these simple and important actions. Furthermore, the findings of previous reports that training is not associated with better performance, coupled with rapid decline in skills following training, suggests a need to think creatively about providing cognitive aids and equipment to guide NRP compliant care in prehospital settings.

## Table of contents summary

EMS are sometimes the first health professionals at a prehospital birth. This study evaluates prehospital performance of initial steps of newborn resuscitation using NRP guidelines.

## What's known on this subject

Performance of critical initial NRP steps after birth can make the difference between life, death, or lifelong disability. Little is known about adherence to NRP guidelines in the prehospital setting.

## What this study adds

NRP steps recommended within the first minute after birth are seldom done in a timely manner in the prehospital simulation setting, suggesting an opportunity for improvement.

## Authors contribution

Dr. Trang Huynh participated in the evaluation of simulation videos, provided content expertise, wrote the primary manuscript draft, and edited the manuscript.

Ms. Amanda Schoonover participated in the design of the study, data analysis, and drafted and edited the manuscript.

Ms. Tabria Harrod participated in the design and conception of the study, and edited the manuscript.

Dr. Nathan Bahr participated in data collection, coding, validation, analysis, and visualization, and edited the manuscript.

Dr. Jeanne-Marie Guise participated in the design and conception of the study, and edited the manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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## Conflict of interest

The authors have no conflicts of interest relevant to this article to disclose.

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## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.resplu.2021.100086>.

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