



Clinical paper

Analysis and classification of errors made by teams during neonatal resuscitation[☆]



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ABSTRACT

Aim: The Neonatal Resuscitation Program (NRP) algorithm serves as a guide to healthcare professionals caring for neonates transitioning to extrauterine life. Despite this, adherence to the algorithm is challenging, and errors are frequent. Information-dense, high-risk fields such as air traffic control have proven that formal classification of errors facilitates recognition and remediation. This study was performed to determine and characterize common deviations from the NRP algorithm during neonatal resuscitation. **Methods:** Audiovisual recordings of 250 real neonatal resuscitations were obtained between April 2003 and May 2004. Of these, 23 complex resuscitations were analyzed for adherence to the contemporaneous NRP algorithm and scored using a novel classification tool based on the validated NRP Megacode Checklist. **Results:** Seven hundred eighty algorithm-driven tasks were observed. One hundred ninety-four tasks were completed incorrectly, for an average error rate of 23%. Forty-two were errors of omission (28% of all errors) and 107 were errors of commission (72% of all errors). Many errors were repetitive and potentially clinically significant: failure to assess heart rate and/or breath sounds, improper rate of positive pressure ventilation, inadequate peak inspiratory and end expiratory pressures during ventilation, improper chest compression technique, and asynchronous PPV and CC. **Conclusions:** Errors of commission, especially when performing advanced life support interventions such as positive pressure ventilation, intubation, and chest compressions, are common during neonatal resuscitation and are sources of potential harm. The adoption of error reduction strategies capable of decreasing cognitive and technical load and standardizing communication – strategies common in other industries – should be considered in healthcare.

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Introduction

Approximately 10% of all newborn infants require some assistance to begin breathing at birth, and 1% of newborns need extensive resuscitation measures to survive.¹ In 1987, the American Academy of Pediatrics and the American Heart Association launched the Neonatal Resuscitation Program (NRP) to address the need for a consistent approach to caring for newly born infants. Neonatal resuscitation requires healthcare professionals (HCPs) to work as a team to recognize and analyze a large amount of data and integrate it into useful information under intense time pressure. The complexity of this task can lead to deviations from the

NRP algorithm and poor patient outcomes. Retrospective, observational studies have shown that errors and deviations from the NRP algorithm are common. In one study, HCPs committed 152 errors in 547 NRP steps (average 27.8% error rate).² In another study of 132 resuscitations, HCPs had a 15.9–54.5% error rate, and poor communication was found to be highly correlated with noncompliance with NRP steps.³

Compared to other information-dense and high-risk fields such as air traffic control, healthcare has a limited understanding of the types of errors that occur during neonatal resuscitation. The classification of errors into categories of omission and commission was originally validated by the aviation industry as a way to facilitate error recognition.⁴ Effective interventions cannot be designed without a clear understanding of the underlying problems. Errors of commission have been found to be more easily and quickly detectable by the operator, usually through routine progress checks during or following an action. Errors of omission, on the other hand, are more likely to remain undetected because the operator has less

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reason to engage in monitoring activities in the absence of any input or intentional activity.⁴ In translating this understanding of human performance and error detection to neonatal resuscitation, determination of the most common types of errors and the frequency of each type facilitates the creation of interventions that will directly address specific gaps in error detection during such clinical activities. This study was performed to determine and characterize common deviations from the NRP algorithm during neonatal resuscitation.

Methods

Resuscitation team routines

The obstetric service at Lucile Packard Children's Hospital at Stanford (LPCH) delivers up to 300–350 infants per month. A 40-bed level IV neonatal intensive care unit (NICU) is located immediately adjacent to the labor and delivery suite. All high-risk deliveries are attended by a resuscitation team that is assembled for each delivery based on staff availability and includes at least one neonatal nurse; one neonatology fellow, neonatal nurse practitioner, or neonatal hospitalist (attending pediatrician); and one neonatal respiratory therapist. All members of the team are required to have a current NRP Provider card. Due to the ad hoc manner in which resuscitation teams were assembled, there were no routine briefings that occurred prior to each delivery.

Technical details of video recording and resuscitation

Audiovisual recordings of 250 real neonatal resuscitations were obtained from two operative delivery rooms at LPCH between April 2003 and May 2004. The operative delivery rooms were each equipped with a pressure zone microphone (model PZM-111; Crown Audio Inc., Elkhart, Indiana) and two pan-tilt, standard definition, remote control cameras (model UNI-DN18SO; Sony Corporation, Park Ridge, New Jersey). One camera was focused on the infant, and the other camera was set at a wider angle to capture the team members' actions. Resuscitation team members were responsible for starting and stopping the recordings for all resuscitations. Written informed consent was obtained from all staff who might potentially be recorded, including neonatology fellows, neonatal nurse practitioners, pediatric hospitalists, neonatal nurses, respiratory therapists, pediatric residents, medical students, and student nurses. Written informed consent was obtained from all mothers during the maternal admission process and prior to delivery by a research coordinator familiar with neonatal resuscitation. The process of audiovisual recording was approved by the Institutional Review Board at Stanford University.

A subset (23) of resuscitations involved "complex resuscitation" as defined by the need for positive pressure ventilation (PPV) with or without intubation and/or chest compressions (CC). This subgroup of resuscitations was further analyzed, as the complexity of these resuscitations and high task demand on the resuscitation teams yielded the largest number of errors and provides the greatest insight into deviations from the NRP algorithm.

Definition and classification of NRP errors

The American Academy of Pediatrics reviews and updates the NRP algorithm every five years. Errors were defined post hoc and relative to adherence to the contemporaneous 2000 NRP algorithm.¹ (Appendix A) "Errors of omission" were defined as failure of the resuscitation team to perform an intervention that was clinically indicated. "Errors of commission" were defined as (a) performance of interventions that were not indicated, (b) failure to perform an indicated intervention at the appropriate time (i.e.

within 5 s of when indicated), or (c) incorrect technical performance of an indicated intervention. Given that behavioral skills were not a part of the 2000 NRP algorithm or training, errors were defined in the context of cognitive and technical skills only.

Scoring tool

An error scoring tool for review of neonatal resuscitations was developed by one of the authors (N.Y.) based on the 2000 NRP algorithm and the NRP's Megacode Checklist.⁵ This tool was then reviewed for content validity and error classification technique by two other authors (K.Y. and L.H.). Three different symbols were used to record completion of each task performed by members of the neonatal resuscitation team. A check mark was used to indicate correct completion of a task. An "X" was used to indicate an error committed during the completion of a task, and this symbol was placed in the column associated with one of four error subtypes: (1) indicated, but not performed; (2) performed, but not indicated or performed more than 5 s before indicated; (3) performed with improper technique; or (4) indicated but performed more than 5 s after indicated. A question mark was used if it could not be determined from the video if a task was completed (i.e. unable to view on camera or recording began after such task would have been completed in the algorithm). Episodes of the same intervention were scored separately if they were stopped and then restarted (by either the same team member or a different team member). Any incorrect performance, regardless of length of episode, was scored as an error. The tasks for each resuscitation were then totaled in the following categories: "Can't Tell," "Tasks Done Correctly," "Total Number of Omissions," "Total Number of Commissions," and "Total Number of Errors" (calculated from the sum of errors of omission plus errors of commission).

Results

Two hundred nineteen healthy adult staff members consented for participation in the study. Age range, gender, and ethnicity were representative of the LPCH NICU staff at the time. Subjects ranged in age from 22–65 years. There were 50 (23%) males and 169 (77%) females. The majority were Caucasian (73%); the remaining subjects were of Asian (19%), Hispanic (7%), and African American (1%) descent. Due to the retrospective nature of this study and de-identification of the videotapes, it was not possible to determine the demographic characteristics of the study subjects in the subset of 23 complex resuscitations chosen for in-depth analysis.

Resuscitation recordings ranged in duration from approximately 5–20 min to capture the entire resuscitation. The total number of tasks that were clinically indicated if one were to adhere perfectly to the NRP algorithm (i.e. algorithm-driven tasks) for all 23 complex resuscitations were calculated. (Table 1) There were 780 algorithm-driven tasks. Of those, 136 tasks were not seen on tape and classified as "Can't Tell," leaving a total of 644 tasks that were observed to be completed either correctly or incorrectly. One hundred forty-nine tasks were completed incorrectly, for an average error rate of 23%. Of these errors, 42 were errors of omission (28% of all errors) and 107 were errors of commission (72% of all errors).

Errors of omission

Three different types of errors of omission were observed (Table 2): failure to have a cap available to place on the infant's head; failure to check equipment; and failure to auscultate the infant's heart rate and/or breath sounds during initial assessment and/or following an intervention. Of these, the most common error

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