Resuscitation Opportunities for Fellows of Very Low Birth Weight Infants in the Vermont Oxford Network

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abstract

BACKGROUND: Neonatal-perinatal medicine (NPM) fellowship programs must provide adequate delivery room (DR) experience to ensure that physicians can independently provide neonatal resuscitation to very low birth weight (VLBW) infants. The availability of learning opportunities is unknown.

METHODS: The number of VLBW (≤1500 g) and extremely low birth weight (ELBW) (<1000 g) deliveries, uses of continuous positive airway pressure, intubation, chest compressions, and epinephrine over 3 years at accredited civilian NPM fellowship program delivery hospitals were determined from the Vermont Oxford Network from 2012 to 2017. Using Poisson distributions, we estimated the expected probabilities of fellows experiencing a given number of cases over 3 years at each program.

RESULTS: Of the 94 NPM fellowships, 86 programs with 115 delivery hospitals and 62 699 VLBW deliveries (28 703 ELBW) were included. During a 3-year fellowship, the mean number of deliveries per fellow ranged from 14 to 214 (median: 60) for VLBWs and 7 to 107 (median: 27) for ELBWs. One-half of fellows were expected to see ≤23 ELBW deliveries and 52 VLBW deliveries, 24 instances of continuous positive airway pressure, 23 intubations, 2 instances of chest compressions, and 1 treatment with epinephrine.

CONCLUSIONS: The number of opportunities available to fellows for managing VLBW and ELBW infants in the DR is highly variable among programs. Fellows’ exposure to key, high-risk DR procedures such as cardiopulmonary resuscitation is low at all programs. Fellowship programs should track fellow exposure to neonatal resuscitations in the DR and integrate supplemental learning opportunities. Given the low numbers, the number of new and existing NPM programs should be considered.

WHAT’S KNOWN ON THIS SUBJECT: Neonatal-perinatal medicine fellows must obtain sufficient delivery room experience with very low birth weight and extremely low birth weight neonates before graduation. The number of experiences fellows receive is unknown.

WHAT THIS STUDY ADDS: Using the Vermont Oxford Network database, we describe the range of delivery room resuscitation and procedural experiences available to neonatal-perinatal medicine fellows during a 3-year fellowship.


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Neonatal-perinatal medicine (NPM) fellows must obtain sufficient delivery room (DR) experience with very low birth weight (VLBW) neonates before graduation. The adequacy of a fellow’s skill is assessed through twice-yearly evaluations of the entrustable professional activities (EPAs), a system of self and faculty ratings that subjectively gauge whether the fellow is progressing toward independent practice. One of the key neonatology EPAs requires fellows to become independent with providing resuscitation, including preparing for delivery, recognizing and intervening on life-threatening conditions, and managing the interprofessional teamwork. NPM fellowship programs are required to provide “patient care experiences necessary for fellows to acquire skill in delivery room stabilization and resuscitation,” but the EPAs give no guidelines around the volume of patients needed to meet this requirement.1

The optimal number of experiences needed to become proficient in any skill varies by the complexity of the skill, the individual learner, and the educational environment. DR resuscitations are complex and combine cognitive and psychomotor skills in a high-pressure environment, likely making them more difficult to master than single procedural skills. The learning curve literature is richest in the arena of surgical procedures, which have measures of success related to the time to complete a surgery, blood loss, and surgical outcomes. In general, most procedures require between 40 and 60 cases to achieve proficiency. In a systematic review of health care providers learning endotracheal intubation, ~50 experiences were needed to reach competency. Although many fellows are able to obtain a total of 50 intubation experiences during their fellowship, DR leadership and cardiopulmonary resuscitation is less common, potentially putting fellows at risk for not reaching competency within their 3 years of training. There are ~60,000 infants born at <32 weeks’ gestation in the United States annually, with most qualifying as VLBW. Many of these VLBW infants require resuscitation at birth, and their care in the DR is associated with clinically relevant outcomes, such as intraventricular hemorrhage, mechanical ventilation, and death. There are currently no data on what percentage of these births occur at hospitals with NPM fellows nor in the variation of births between NPM programs. This information would be helpful to programs as they assess their capacity to train more learners, their guidelines around who participates in resuscitations, and their supplementary learning programs, such as simulation. In this study, we use the Vermont Oxford Network (VON) database to characterize the frequency of VLBW and extremely low birth weight (ELBW) DR experiences and procedures at NPM fellowship programs.

METHODS

The VON is a voluntary worldwide community of practice dedicated to improving the quality, safety, and value of care through a coordinated program of data-driven quality improvement, education, and research. The University of Vermont’s Committees on Human Research determined that the use of data from the VON deidentified Research Repository for this analysis was not human subjects research.

Hospitals within the VON were matched to the Accreditation Council for Graduate Medical Education (ACGME)-accredited NPM fellowship program list. Only those with active fellowships during the study period were included along with any affiliated training hospitals. Hospitals with unaccredited fellowships, fellowships not included in the National Resident Matching Program, those without matched fellows during the study period, or those with fellows only for electives <4 weeks per fellow per year were excluded. Programs with >1 delivery hospital were excluded if any of their delivery hospitals did not contribute to the VON VLBW database. Fellowship program demographics, including program size and number of training sites, were collected from Main Residency Match data, the ACGME, the American Academy of Pediatrics, and public facing program websites.

In this study, we use data collected for the VON VLBW data set between 2012 and 2017. Hospitals with NICUs contributed data on VLBW infants who were 401 to 1500 g or 22 to 29 weeks’ gestation at birth. All data were collected by local staff using standard definitions. Data from all inborn, live-born infants ≥1500 g at included hospitals were analyzed. Infant demographics such as gestational age, birth weight, multiplicity, and sex were included to describe the infant population. DR experiences included VLBW births, provision of DR continuous positive airway pressure (CPAP), intubation, chest compressions of any duration, and epinephrine administration via either endotracheal tube or intravenous methods. Twins and higher-order multiples were analyzed as separate experiences. Birth experiences were reported for both VLBW infants (all weighing 400–1500 g) and for the subset of ELBW infants (only those weighing 400–1000 g).

The average numbers of VLBW and ELBW deliveries and procedures over 3 years at all training sites for each program were divided by the number of matched fellows in the program during that time frame. This
calculation estimated the highest possible mean number of cases per fellow during a 3-year fellowship period at each program, assuming every delivery was attended by 1 fellow. For each procedure, we assumed the number of cases per fellow followed a Poisson distribution centered at the observed mean cases per fellow at each program and calculated the probability that a fellow in each program would experience more than a target number of cases. We summed the probabilities for all fellows in all programs to estimate the overall percentage that would see at least the target number.

RESULTS

Of the 94 NPM fellowship programs in the United States accepting fellows between 2012 and 2017, 86 programs with 115 delivery hospitals that were members of the VON were included (Fig 1), of which 74 programs provided data for all 6 years. Program demographics are presented in Table 1. Included programs had a median of 5.8 (interquartile range [IQR] 4.3–8.6) fellows participating in their program annually during the selected study years, fewer than the median of 9.1 (IQR 7.0–11.4) fellows per year in the 8 programs not contributing to the VON. Most programs had only 1 DR hospital as a primary clinical site of training (Table 1).

The annual rate of VLBW deliveries was stable over the time period, with a mean of 10 450 infants per year. Overall, 62 699 VLBW infants were included in the analyses, with a mean gestational age of 28 completed weeks and birth weight of 1020 g and a DR mortality rate of 5.1%. Out of the larger VLBW group, 28 703 infants were ELBW, with a mean gestational age of 26 completed weeks, birth weight of 720 g, and a DR mortality rate of 10.0%. Multiple gestations represent more than one-quarter of all VLBW (28%) and ELBW deliveries (26%). Overall, 44% of the VLBW and 65% of the ELBW subset were intubated in the DR. Approximately one-quarter of included infants had both CPAP and intubation in the DR.

The mean number of potential VLBW deliveries per fellow at each program during a 3-year fellowship ranged from 14 to 214 (median: 60; IQR 44–84; Fig 2). The mean number of potential ELBW deliveries per fellow ranged from 7 to 107 (median: 27; IQR 20–39). The most common DR procedures performed on infants with VLBW per fellow at each program during a 3-year fellowship were CPAP (range: 1–131; median: 27; IQR 19–41) and intubation (range: 5–100; median: 26; IQR 17–39) (Fig 3). There were infrequent opportunities to experience chest compressions (range: 1–11; median: 3; IQR 2–4) and epinephrine administration (range: 0–8; median: 1; IQR 1–2) on VLBW infants at each program during a 3-year fellowship.

Figure 4 reveals the expected percentages of fellows who experience a range of target numbers of each DR procedure over 3 years on the basis of Poisson probability models. The number of VLBW deliveries expected per fellow varied by program size, as shown in Table 2, with smaller programs having more potential deliveries per fellow during their 3 years (P < .001). There is no difference in deliveries per fellow between programs with 1 versus those with >1 delivery hospital site (median: 56 and IQR 44–82

<table>
<thead>
<tr>
<th>TABLE 1 Included Program Demographics (N = 86)</th>
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<tr>
<td><strong>Program size, No. fellows</strong></td>
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<tr>
<td>Small (&lt;5 fellows)</td>
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<tr>
<td>Medium (5–10 fellows)</td>
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<tr>
<td>Large (&gt;10 fellows)</td>
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<tr>
<td>Program size, mean No. fellows (SD)</td>
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<tr>
<td>DR hospitals associated with fellowship, n</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<td>≥3</td>
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Figure 1
Flow diagram of fellowship programs and hospitals contributing data to the study.
versus median: 65 and IQR 47–91; \( P = .6 \).

**DISCUSSION**

There is a 10-fold variation in the availability of VLBW and ELBW deliveries and DR procedures for VLBW infants between NPM fellowship programs. Extensive DR resuscitations requiring chest compressions and epinephrine are rare at even the busiest programs, and graduating fellows are unlikely to participate in enough of these experiences to be proficient in both the psychomotor and cognitive resuscitation skills without additional exposure during training. Although a fellowship spans 3 years, most programs have between 13 and 18 months of clinical time spread over that time. Given that certain technical procedures have been previously shown to require between 40 and 60 attempts before reaching proficiency, many fellows are at risk for insufficient VLBW DR procedural experiences during their clinical time. Concorningly, this study revealed that <20% of fellows would meet a 40-experience threshold for DR VLBW intubations, and more than one-quarter of graduating fellows will not have had the opportunity to attend 40 VLBW deliveries (Fig 4), potentially leaving them with additional need for practice to reach competency.

Exposure to DR experiences is needed to achieve proficiency in both psychomotor and cognitive skills including leadership and teamwork. This study revealed that...
many fellows may have few opportunities for these experiences. Although procedures such as intubation have concrete definitions of success and failure\textsuperscript{14}, success in leading a periviable resuscitation or managing an unexpected death in the DR is harder to define. Attending neonatologists must be able to perform technical procedures as well as manage an interprofessional team. Future studies used to establish validated scales and competencies for combined DR cognitive and psychomotor skills would allow NPM fellowship programs to define target numbers of experiences for fellows. This information would also be helpful for other pediatric professionals that perform neonatal resuscitations, such as advanced practitioners, pediatric residents, and pediatricians covering delivery services.

To assess the adequacy of experiences, programs should know their annual VLBW delivery rates and what percentage of deliveries is being allocated to fellows. Programs should track individual fellow experiences via procedure logs to identify fellows at risk for insufficient training early so that an individual educational plan can be made. Programs that find that their fellows are at risk for inadequate DR experiences should look to methods to maximize learning opportunities. Programmatic structure can be used to maximize DR opportunities in lower-volume hospitals by prioritizing these experiences for fellows, potentially through changes to the coverage model, resuscitation team structure, or distribution of time spent in different clinical environments. In some situations, programs could consider external rotations in other hospitals, departments, or transport teams to supplement low procedural rates in their primary training sites. Video reviews of resuscitations along with debriefing may allow for deeper learning with existing resuscitations and reduce the overall number of experiences needed to become proficient.\textsuperscript{31,32} Outside of the

FIGURE 3
FIGURE 4
Percentage of fellows expected to participate in at least the target numbers of cases during a 3-year fellowship. A, All VLBW deliveries. B, ELBW deliveries. C, CPAP. D, Intubation. E, Chest compressions. F, Epinephrine.
clinical environment, simulations by using realistic manikins, procedural skills days, bootcamps, and crisis resource management training may all be strategies to enhance educational opportunities and competency, although these are not yet universally available.36

Managing a delivery in which an infant dies in the DR, either as a planned palliative care event or a failed resuscitation, is an integral part of practicing neonatology.36 This study reveals that ∼500 VLBW infants die in the DR per year at the participating fellowship sites, slightly fewer than the number of NPM fellows in training any given year. All fellows should have opportunities to lead families and teams through these difficult decisions and events, making these simulations especially important to include in NPM fellowship training. NPM fellows may require additional training to ensure they are prepared to communicate effectively with families anticipating, at risk for, or experiencing the death of a very preterm infant in the DR.37

In this study, we were able to ascertain the data for the majority of but not all NPM training programs in the United States and were limited to published match data to ascertain the number of fellows per program. Fellows entering their program outside the match would lead the presented data to be biased toward overestimating the number of experiences and procedures per fellow. Additionally, many programs have other learners and providers, such as neonatal nurse practitioners, physician assistants, neonatal hospitalists, and pediatric residents, who cover some percentage of deliveries without fellows, which will additionally bias the results toward overestimating the maximum number of experiences and procedures available for each fellow. Conversely, programs with electives at delivery hospital sites that were not in the VON or were <4 weeks in duration may have more experiences and procedures than reported. Deliveries of multiple-gestation infants represent another area of limitation, because they were counted as 2 separate occurrences. Although in some resuscitations of multiples a single fellow may participate in the care of both infants, many times separate teams care for each infant, and if a second fellow is not part of that team, this would again bias toward overestimation. Resuscitations of term and near-term infants are additional opportunities for fellows to build on their psychomotor and cognitive skills in DR management. Because the majority of our limitations are biased toward overestimating the number of experiences a fellow might see in fellowship, the concerns raised about adequacy of training remain significant.

This study represents the largest cohort of NPM fellowship programs’ data on VLBW deliveries and use highly reliable VON data to avoid reporting bias found in case logs.15 With this information, we provide valuable insight into the current state of VLBW resuscitation training for neonatology fellows and highlight the need for fellow-level procedural tracking, strong educational environments, and supplemental procedural training opportunities. Individual programs should consider examining their own VON data, fellow call schedules, guidelines on distribution of procedures between providers, and educational practices to determine if they are providing adequate opportunities for their learners and continuing education for their experienced providers and neonatologists. Additionally, hospitals hiring newly graduated neonatologists may need to provide additional support to ensure their new hires have had adequate exposure to the DR to independently care for VLBW infants as well as lead and teach others the skills of DR resuscitation.

At a larger level, this study reveals that many programs are at risk for providing suboptimal DR training experiences to their fellows. Individual programs, as well as the ACGME, may wish to carefully evaluate the DR environment before expanding their complement of fellows or opening new fellowship or advanced practitioner training programs. The number of NPM training slots currently exceeds the number of applicants and has been steadily increasing in the past decade, with 62 slots (30% increase) added since 2009 when NPM joined the match.24 In addition, many pediatric residencies have decreased the amount of time spent in the NICU, meaning new NPM fellows will have fewer neonatal resuscitation experiences when they enter fellowship training. During this same time frame, the rate of VLBW births has remained relatively steady at ∼1.4%, meaning there are fewer of these high-risk patients per fellow every year.16 As the field of neonatology moves forward, consideration should be given to how many new neonatologists are needed to care for these infants.38

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<tr>
<th>Program Size</th>
<th>Median (IQR)</th>
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<tr>
<td>&lt;5 fellows</td>
<td>81 (62–122)</td>
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<tr>
<td>5–10 fellows</td>
<td>51 (44–74)</td>
<td>&lt;.001</td>
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<tr>
<td>&gt;10 fellows</td>
<td>47 (36–55)</td>
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**TABLE 2 VLBW Delivery Information by Program Size per Fellow (N = 86)**
CONCLUSIONS
Rates of VLBW and ELBW DR experiences and procedures are highly variable among NPM fellowship programs, and some key, high-risk events, such as DR cardiopulmonary resuscitation, are rare at all programs in the United States. Fellowship programs should make efforts to know their own DR experience availability and track fellow experiences to guide their training approach, including supplemental learning strategies. Further studies of the learning curve for DR procedural and leadership skills would be helpful in setting goals for fellowship experiences, guiding clinical-service schedules, and setting up simulation programs. On a national level, consideration should be given to the continuation and expansion of NPM training programs.

ACKNOWLEDGMENTS
We thank our colleagues who submit data to the VON on behalf of infants and their families. Participating centers are listed in Supplemental Table 3.

ABBREVIATIONS
ACGME: Accreditation Council for Graduate Medical Education
CPAP: continuous positive airway pressure
DR: delivery room
ELBW: extremely low birth weight
EPA: entrustable professional activity
IQR: interquartile range
NPM: neonatal-perinatal medicine
VLBW: very low birth weight
VON: Vermont Oxford Network

Dr Gray conceptualized and designed the study, coordinated and supervised data collection, drafted the initial manuscript, and reviewed and revised the manuscript; Dr Brei contributed to study design and data collection and reviewed and revised the manuscript; Ms Greenberg conducted initial analyses and interpretation of analyses and reviewed and revised the manuscript; Ms Umoren contributed to study design and reviewed and revised the manuscript; Drs Horbar, Edwards, and Ehret contributed to study design and interpretation of analyses and reviewed and revised the manuscript; Dr Ringer interpreted analyses of the study and critically reviewed the manuscript for important intellectual content; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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