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Research Article

Which Airway and Vascular Access Procedures Should New Neonatal Resuscitation Program Trainees be taught? -

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ABSTRACT

Background and Objectives: Endotracheal intubation and umbilical venous catheter (UVC) placement are currently the preferred methods for obtaining an advanced airway and emergent vascular access in neonatal resuscitation. Laryngeal Mask Airway (LMA) and Intraosseous Needle (IO) insertion may be less complicated for inexperienced providers. We compared time to placement for Endotracheal Tube (ETT) and UVC versus LMA and IO in a high-fidelity simulated neonatal resuscitation environment.

Methods: Twenty-seven fourth-year medical students viewed a video on four skills (ETT, LMA, IO, UVC) and completed a brief guided practice of each skill on a low-fidelity mannequin immediately before being randomized to an ETT/UVC or LMA/IO intervention in a standardized, simulated delivery room scenario. Time to placement, success in placement, the number of attempts, and critical errors were documented. Participants' prior experience and confidence with each skill were surveyed afterward.

Results: The median procedure time for the LMA/IO intervention was 106 seconds shorter than ETT/UVC ($p = 0.009$). Success rates were higher for LMA and IO compared to ETT and UVC, although they did not reach statistical significance. Median time to place an LMA successfully was 108 seconds shorter than ETT ($p < 0.001$).

Conclusions: In this pilot study, LMA/IO placement was significantly faster thanETT/UVC placement, primarily due to the speed of LMA insertion. Inexperienced providers could benefit from utilizing LMA and IO in neonates requiring emergent airway and vascular access.

Keywords: Neonatal resuscitation; Intubation; Medical simulation; Vascular access; Airway, NRP, LMA, IO, ETT, UVC

ABBREVIATIONS

ETT: Endotracheal Tube; IO: Intraosseous Needle; LMA: Laryngeal Mask Airway; NRP: Neonatal Resuscitation Program; SBME: simulation-Based Medical Education; UVC: Umbilical Venous Catheter

INTRODUCTION

Although 10% of newborns require some assistance to begin breathing, less than 1% require extensive resuscitative measures [1-3]. The NRP emphasizes Endotracheal Intubation (ETT) when an advanced airway is required and favors emergent Umbilical Venous Catheter (UVC) placement for volume expansion or emergent medications [4].

Most NRP providers do not routinely perform endotracheal intubation, and novices are often unsuccessful or require multiple attempts [5-7]. Lack of expertise in this area is a growing problem. Multiple factors contribute to limited opportunity to gain real-world experience: restriction of trainee duty hours, Accreditation Council for Graduate Medical Education and Residency Review Committee guidelines for the number of rotations in NICUs, increased use of other professionals for these tasks, and shortened retention time for skills learned [8]. Even individuals who do intubate with some frequency often take longer than NRP recommends for placing an ETT [9]. The Laryngeal Mask Airway (LMA) is an alternative for ventilating neonates effectively [10-12].

If bradycardia persists despite adequate ventilation, vascular access is considered [3]. However, emergent umbilical venous access to deliver fluids or medications is another infrequently performed technique that requires a high level of skill to successfully execute. Intraosseous Needle (IN) insertion requires less skill and can result in rapid vascular access [13,14]. IO infusion is safe, effective, and can elicit a clinical response to medications similar to Intravascular (IV) administration in the pediatric population, including neonates and very low birth weight infants [15,16].

High-fidelity simulation training of such tasks provides valuable learning experiences that are difficult to obtain in real life. Simulation-Based Medical Education (SBME) offers a safe environment in which learners can make mistakes without harm, while accommodating learners' schedules, customized needs, and provide repetition as needed.

Time is of the essence in the delivery room resuscitation of a critically ill newborn. Although studies have evaluated these procedures individually for time to and ease of placement, we hypothesized that the combination of LMA and IO would be faster than the combination of ETT and UVC in less experienced providers. This study compared the time to achieve an advanced airway and obtain emergent vascular access in a standardized, simulated delivery room scenario.

MATERIALS AND METHODS

Participants

Indiana University School of Medicine fourth-year medical students who were enrolled in an elective pediatric rotation and had successfully completed an NRP course were eligible for inclusion in this study. This four-hour course was conducted two days prior to the study. The course included practice on low-fidelity mannequins in the skills stations as well as practice with high fidelity mannequins during the integrated skills station. The students all passed NRP's didactic online exam prior to the course.

Students spanning two academic years were offered the opportunity to participate in this study: 31 in 2012 ("Year One") and 17 in 2013 ("Year Two"). Because this was a pilot study, the sample size was a convenience sample based on the availability of the medical students in the elective rotation.

Setting and Equipment

The sessions were held at the Simulation Center at Fairbanks Hall, Indiana University School of Medicine. The scenario was conducted in two identical rooms designed to re-create two fully functional delivery rooms. SimNewB (Laerdal Medical Corp; Wappingers Falls, NY) high-fidelity neonatal mannequins were utilized.

Study Procedures

On the day of the study, each student went into a "skills station room," where an experienced neonatal provider first showed a video of one of the four procedures (LMA, ETT, IO, or UVC), then guided the student through performing that procedure on a task trainer using all necessary equipment. For ETT and LMA placement, the Laerdal Neonatal Intubation Trainer was utilized, and for the UVC and IO placement the Laerdal Newborn Anne was used, both Laerdal Medical Corp; Wrappingers Falls NY. Then the student moved to a second instructor who showed another video and guided the student through that procedure. This was repeated for all four procedures. The total time spent in the skills station room was 30 minutes.

After completing the four videos and practicing on the task trainers, each participant selected an opaque envelope that randomized him or her to a set of interventions: either LMA plus IO or ETT plus UVC. Immediately after randomization, the participant entered the simulation delivery room, blinded to the intervention until the scenario began and a tray next to the infant warmer was uncovered, revealing the tools available for use.

A standardized simulated scenario of a maternal placental abruption was utilized. Both rooms ran identical simulated scenarios with three embedded participant team members: a team leader, a nurse, and a respiratory therapist. The team leaders, who evaluated the participants as the scenario took place, were attending neonatologists with extensive experience in delivery room management and SBME.

When the participant entered the simulation room, the delivery room team leader provided the participant with a brief standardized history, reporting that the baby had a heart rate of 40 and was receiving bag-mask ventilation and chest compressions. The student was then asked to first establish an advanced airway and then obtain emergent vascular access. If the student asked a question about a procedure, the only response given was, "Do the best you can."

Total procedure time (LMA + IO or ETT + UVC) was set at a maximum of 10 minutes. Participants were allowed a maximum of three attempts for the airway procedure. If they were unsuccessful after three attempts, their time was censored for that procedure. Students who failed to obtain an advanced airway after three attempts were directed to attempt vascular access. The simulation was stopped when the student had obtained vascular access and started to infuse a fluid bolus, or at 10 minutes, whichever came first.

Each scenario was videotaped for review, data collection, and analysis. Additionally, the team leader collected data in real time utilizing a scoring sheet (Appendices 1 & 2). The participants then completed a post-scenario survey to assess their experience and perceived confidence with each skill (Appendix 3). As compensation for the participant's time, a $10 gift card was given upon receipt of the completed survey.

Assessment

The primary outcome was time to establish an advanced airway and emergent vascular access (total procedure time for LMA + IO or ETT + UVC). Secondary outcomes were correct device placements for airway and vascular access, the n

umber of attempts needed to achieve an advanced airway, the frequency of performing a critical error during vascular access, and participant confidence.

Definitions of parameters assessed:

1. Combined airway and vascular access parameters -
   a. Total procedure time = time to complete LMA + IO or ETT + UVC
2. Airway parameters -
   a. Total airway management time = the time the participant first picked up airway tools to confirmation of placement
   b. Airway procedure time
      i. For ETT = the time the laryngoscope blade entered the mouth until its removal on the final attempt
      ii. For LMA = the time the LMA entered the mouth to the time the cuff was inflated on the final attempt
   c. Confirmation = participant's request for a team member to check for bilateral breath sounds or chest rise
   d. Success for ETT = confirmation as defined above plus the evaluator's assessment of correct placement in the trachea via direct laryngoscopy at the end of the simulation
   e. Success for LMA = confirmation as defined above plus the evaluator's reassessment of correct placement via bilateral breath sounds or chest rise confirmed at the end of the simulation
3. Vascular access parameters –
   a. Total vascular access management time = the time the participant's hand first picked up the access equipment to the time the bolus was correctly attached for use
   b. Success for IO or UVC = IO or UVC in place with a bolus of normal saline correctly attached and ready for infusion

Evaluations for the skills of ETT, LMA, and UVC were adapted from the 6th edition NRP textbook [3] (ETT, p. 207; LMA, p. 208; UVC, p. 234) and the IO skill checklist was adapted from The Atlas of Procedures in Neonatology [17].

A post-scenario survey was administered to assess each participant's prior experience with delivery room resuscitation and the four technical skills evaluated. Participants were asked to rate their confidence in each skill on a 5-point Likert scale, with a score of 1 being not at all confident and 5 being extremely confident.

Statistical Analysis and Institutional Review

Statistical significance was set at $p \leq 0.05$. Log-rank tests were used to compare times for each procedure and number of attempts listed in Tables 1 and 2.

Successful placement of the airway device and emergent vascular access, the incidence of critical errors when attempting to obtain vascular access, and participant confidence in each procedure was compared between the LMA/IO and ETT/UVC groups using Fisher's exact tests. Exact binomial 95% confidence intervals were calculated.

Institutional Review Board (IRB) approval from the Indiana University School of Medicine was obtained prior to enrollment of any participants and written informed consent was obtained from all participants.

RESULTS

Twenty-seven students (56%) agreed to participate: 17 in Year One, 10 in Year Two.Of the 27 participants, 14 were randomized to the LMA/IO group and 13 to the ETT/UVC group.

Combined Time to Obtain an Advanced Airway and Gain

Vascular Access

The total procedure time for the LMA/IO group was significantly less than the ETT/UVC group ($p = 0.009$). The median (95% C.I.) total procedure time for the LMA/IO group was 220 (197,248) seconds, while the median (95% C.I.) time for the ETT/UVC group was 326 (259, 535) seconds.

Airway

Both the median airway procedure time and the total airway management time were significantly shorter using the LMA compared to the ETT (19 vs 119 seconds and 88 vs 196 seconds, respectively). More participants were successful with LMA than ETT (12 vs. 9); however, that result was not statistically significant (Table 1).

Vascular Access

Time to obtain vascular access using the IO was notably less than the UVC (198 vs. 235 seconds, respectively); however, this was not statistically significant. Twelve people in each group successfully obtained vascular access (Table 2). We identified two types of critical errors during the vascular access procedure: (1) failure to flush the tubing, catheter or stopcock; and (2) failure to clear air from the bolus, tubing, catheter, or stopcock. The frequency of those errors was virtually the same between both groups.

Survey

No participants had significant prior experience with delivery room resuscitation or the four technical skills. Participant confidence did not significantly differ between the groups for any of the procedures (Table 3).

DISCUSSION

This study examines practices for life-saving procedures that are performed infrequently in delivery rooms. We demonstrate how fourth-year medical students with virtually no prior experience in LMA placement can have a high success rate of success in performing this procedure during simulated neonatal resuscitation. Additionally, successful placement of the LMA can be accomplished in significantly less time than placement of an ETT. Finally, the successful placement of the combination of LMA and IO can be accomplished in significantly less time than ETT and UVC.

In a newborn with respiratory distress in the delivery room, every second count until a patent airway is established, and infants can decompensate quickly during intubation attempts [18]. NRP teaches endotracheal intubation as the preferred method for obtaining an advanced. However, endotracheal intubation is a time-intensive, complex procedure, challenging to master for those who do not perform it routinely [9,13,14]. The NRP suggests considering the use of an LMA as an alternative to ETT if intubation is unsuccessful or not feasible. Currently, there is insufficient evidence for LMA use in newborns weighing < 2000 g, delivered at < 32 weeks' gestation or in the setting of meconium-stained newborns who are not vigorous [2].

Table 1: Securing an Airway: LMA compared to ETT.

Metric	LMA (n = 14)		ETT (n = 13)		
	Median	95% C.I.	Median	95% C.I.	*p* value
Number of attempts	1	(1,2)	2	(1,NE[a])	0.11
Airway procedure time (sec)	19	(15,25)	119	(16,207)	0.002
Total airway management time (sec)	88	(65,102)	196	(110,342)	< 0.001
	N (%)	95% C.I.	N (%)	95% C.I.	*p* value
Success[b]	12 (86)	(57,98)	9 (69)	(39,91)	0.39

ETT: Endotracheal Tube, LMA: Laryngeal Mask Airway
[a]Because 4 of the 13 students were unsuccessful after the maximum 3 attempts, their time was censored. Thus, the upper limit is not estimable (NE).
[b]Success = correct device placement plus confirmation of bilateral breath sounds or chest rise

Table 2: Securing Vascular Access: IO compared to UVC.

Metric	ION (n = 14)		UVC (n = 13)		
	Median	95% C.I.	Median	95% C.I.	*p* value
Time to obtain access (sec)	198	(160,215)	235	(206,253)	0.10
	N (%)	95% C.I.	N (%)	95% C.I.	*p* value
Success[a]	12 (86)	(57,98)	12 (92)	(64,100)	> 0.99
Critical error[b]	8 (57)	(29,82)	9 (69)	(39,91)	0.64

ION: Intraosseous Needle, UVC: Umbilical Venous Catheter
[a]Success = correct device placement plus confirmation of bilateral breath sounds or chest rise
[b]Critical error = any of the following: failure to flush tubing, catheter, stopcock; failure to clear to clear air from the bolus, tubing, catheter or stopcock

Table 3: Participant Confidence for each Procedure (post-simulation).

Metric	LMA/ION group (n = 14)		ETT/UVC group (n = 13)		
	N (%)	95% C.I.	N (%)	95% C.I.	*p* value
LMA	10 (71)	(42,92)	10 (77)	(46,95)	> 0.99
ETT	10 (71)	(42,92)	7 (54)	(25,81)	0.44
ION	7 (50)	(23,77)	5 (39)	(14, 68)	< 0.70
UVC	8 (57)	(29,82)	7 (54)	(25,81)	> 0.99

ETT: Endotracheal Tube, ION: Intraosseous Needle, LMA: Laryngeal Mask Airway, UVC: Umbilical Venous Catheter
Confidence = a rank of 4 (very confident) or 5 (extremely confident) on a 5-point Likert scale

Primary Endpoint

The NRP recommends that endotracheal intubation is completed within approximately 30 seconds [3]. In this study, the airway procedure time using endotracheal intubation was 119 seconds, almost four times longer than recommended. This was likely due to the group's inexperience and prolonged laryngoscopy while navigating the complex steps necessary for successful intubation. In our study, the LMA insertion time of 19 seconds greatly decreased the length of time the infant did not receive ventilation. LMA placement eliminates the need for laryngoscopy, a cause of intubation failure in trainees [9]. The shorter procedure time supports LMA placement as a less complex procedure that can be executed with a high rate of success by novice users. As a secondary endpoint, our success rate of 69% with ETT is comparable to O'Donnell's results of a 62% success rate. Interestingly, O'Donnell's results reflected an admixture of residents, inexperienced and experienced physicians in live delivery situations [18]. Our results suggest an ease of use that may be clinically significant for providing faster effective ventilation in less experienced providers.

In similar fashion, IO insertion provides easier and more rapid vascular access compared to UVC placement, particularly in those who do not frequently perform newborn resuscitation [19]. In our study, the median procedure time to obtain IO access was 197.5 seconds, compared to 235 seconds for UVC. Although that difference was not significant on its own, a statistically significant difference existed for vascular access combined with airway procedure time. Thus, in this study, if an LMA and IO were used instead of ETT and UVC, 106 seconds could be saved. More than 1.5 minutes of life-saving ventilation and fluid resuscitation could make a difference in a neonate's long-term outcome. Additionally, in situations where only one advanced provider is present, the time saved by placing an LMA could potentially be used to obtain vascular access.

Multiple studies have illustrated the efficacy of IO insertion in infants [16,20-22]. Compared to all other forms of pediatric and infant vascular access, IO access is safer, associated with fewer complications, faster to place, and requires less practice to master, even if used infrequently [19]. Our results of IO access taking a median 37 seconds less to obtain than UVC compares favorably with Rajani's result of 46 seconds' difference in IO versus UVC when physicians performed neonatal simulations [14].

Secondary Endpoints

We defined success for obtaining an advanced airway as (1) correct placement (ETT in the trachea or LMA inflation) plus (2) confirmation of bilateral breath sounds and/or chest rise. Using those criteria, 12 of the 14 LMA placements were deemed successful, compared to 9 of the 13 in the ETT group.

One person correctly placed the LMA without seeking confirmation. However, confirmation speaks to patient safety as well as teamwork, so that last step of asking a team member to confirm the open airway by checking for breathing sounds or chest rise was an integral part of our definition of successful placement. Thus, that one person's LMA effort was not counted as "successful." Clinically, a patient could improve with a correctly placed airway device that has not been confirmed.

All but one participant was successful in obtaining vascular access. One person attempting UVC was unsuccessful. A potentially lethal complication of obtaining vascular access is the introduction of air into the circulatory system, leading to an air embolus. Our study defined those events as critical errors, which included failure to flush air bubbles from catheter tubing, stopcocks, and fluid boluses. Our study showed no statistical difference in the incidence of critical errors for IO versus UVC placement.

Strengths and Limitations of the Study

This study has many strengths. Its homogenous cohort (fourth-year medical students, all studying to be pediatricians) had virtually no previous delivery room resuscitation experience but was highly vested in learning the skills. All delivery room conditions, equipment, simulations, and teaching scripts for all instructors were identical. The amount of time spent in practicing in the skills station under the instructor's guidance was the same between all groups in both years. Also, the skills practice immediately preceded the simulation for the participants in each of the two years.

One limitation of the study is that it randomized a convenience sample; however, in this population of inexperienced learners who were invested in the material, we anticipate any potential differences in sampling or outcomes would have been minimal.

Despite all the standardization built into the study, two deviations occurred, both with the Year Two group: a new instructor at one skill station, and a technical malfunction in the IO video. The first deviation was minimized because of the standardized teaching script. The lack of IO video was compensated by the experienced instructor reading the video's transcript and personally demonstrating the procedure as depicted in the malfunctioning video. Notably, the lack of IO video in this group did not lead to a statistically significant difference in IO placement time compared to the Year One group (Table 2).

By choice, we utilized full-term SimNewB mannequins because their higher fidelity offered more lifelike features that those of preemie mannequins. This might limit the generalizability of our results to a premature infant population, however, LMA and IO may not be appropriate in many preterm infant populations.

By design, we did not debrief the students after their simulation experience. That eliminated a potential confounder: students did not know what they did right or wrong, so they could not influence other students one way or another. Students also were kept separated from each other for the duration of the simulation. Under normal circumstances, video-assisted debriefing would have commenced immediately after the simulation, which would have included discussion of all critical errors. Such debriefing is known to increase the educational effect [23].

Our participants had a single facilitated learning session for each skill before they began the simulated scenario of placenta abruption. We did not attempt to repeat the simulation to see if procedure times would decrease with repetition. We expect that they would, as seen in the work by Sawyer regarding multiple simulations of neonatal resuscitation [23].

During our simulation, each participant was asked to obtain an advanced airway prior to attempting vascular access. If a participant could not correctly intubate the infant, that might have led to a higher emotional stress response that could have decreased the person's performance while trying to obtain vascular access. Because four of the 13 students in the ETT/UVC group were unable to successfully open an airway after three attempts, a stress response could have contributed to longer UVC times. One of the 13 students could not attain ETT or UVC access.

Additionally, although all airway and vascular access equipment were readily available on a tray at the bedside, the participants were responsible for opening the packaging themselves. The difficulty with opening the packages was noted at times. This may have prolonged the simulated scenario; whereas, in the clinical environment, team members would assist with preparing the equipment.

We did not ensure that participants could correctly do the procedures before putting them in the simulated scenario, as correctness of steps was a secondary outcome. However, the correctness speaks to confidence. Results of the Likert-scale survey we conducted indicated that 71% of all participants felt "very" or "extremely" confident of their LMA or ETT skills after the simulation. Regarding IO vs. UVC, 50% and 57% of participants, respectively, felt "very" or "extremely" confident of those skills afterward. Change in self-confidence is not a true proxy for change in real-life outcomes; however, self-confidence does contribute to persistence in achievement.8

There are variable estimates to the number of times intubation must be performed to become proficient. In at least one study, it was found that at least 200 intubation attempts are required to reach a success rate of 95% [24]. This further supports our position that LMA is a viable and effective alternative for any practitioner infrequently involved in neonatal resuscitation. The sooner a patient airway is obtained, the fewer complications a newborn will likely have.

We chose a simulation setting for this study. The American Academy of Pediatrics 2010 Special Report – Neonatal Resuscitation states that the use of simulation may enhance the performance of healthcare professionals in the clinical setting [2]. There is evidence that simulations do improve clinical outcomes in numerous healthcare arenas, including prescribing medicines [25], managing pain [26], and uncovering latent safety issues in NICUs [27]. Additionally, reviews of SBME research indicate that SBME generalizes to clinical settings [28].

FUTURE DIRECTIONS

This study describes neonatal resuscitation simulation as a research methodology that indicates inexperienced NRP providers can perform the life-saving techniques of LMA and IO with a high rate of success. Further studies are warranted on this topic: (1) studying a larger population, (2) studying performance on solely airway management, (3) comparing fourth-year medical students' performance to that of residents who still have limited neonatal resuscitation experience, and (4) assessing practitioners in the community who do not perform neonatal resuscitation often. We feel further studies will support the findings of our pilot study and hope that the NRP will formally consider LMA and IO as viable alternatives for use by inexperienced or infrequent neonatal resuscitation providers.

CONCLUSION

SBME can provide much-needed training in a safe environment, particularly in light of the limited amount of clinical time physicians-in-training spend in NICUs. For complex and infrequently used procedures, simulation-based training may offer more opportunity than real-life situations for teaching, learning, and refining relevant skills. In particular, LMA and IO skills can enable inexperienced providers to successfully execute vital skills that can aid newborns in distress, as demonstrated in this study.

FINANCIAL DISCLOSURES

This study was funded internally. The LMAs were donated by LMA North America (a division of Teleflex). None of the authors have any financial relationships relevant to this article to disclose.

CONTRIBUTIONS TO THIS STUDY

BB: Conceptualized the study, participated in the study, reviewed and edited the manuscript, approved the final manuscript as submitted

RP: Designed the study, wrote the protocol and obtained IRB approval, did data collection and input, reviewed and edited the manuscript, approved the final manuscript as submitted.

CJ: Conducted the statistical analysis, reviewed and edited the manuscript, approved the final manuscript as submitted

EW: Participated in the study, reviewed and edited the manuscript, approved the final manuscript as submitted

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