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Airway emergency management in a pediatric hospital before and during the COVID-19 pandemic

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ABSTRACT

Objective: Children's hospitals frequently care for infants with various life-threatening airway anomalies. Management of these infants can be challenging given unique airway anatomy and potential malformations. Airway emergency management must be immediate and precise, often demanding specialized equipment and/or expertise. We developed a Neonatal-Infant Emergency Airway Program to improve medical responses, communication, equipment usage and outcomes for all infants requiring emergent airway interventions in our neonatal and infant intensive care unit (NICU).

Patients and methods: All patients admitted to our quaternary NICU from 2008 to 2019 were included in this study. Our program consisted of a multidisciplinary airway response team, pager system, and emergency equipment cart. Respiratory therapists present at each emergency event recorded specialist response times, equipment utilization, and outcomes. A multidisciplinary oversite committee reviewed each incident.

Results: Since 2008, there were 159 airway emergency events in our NICU (~12 per year). Mean specialist response times decreased from 5.9 ± 4.9 min (2008–2012, mean ± SD) to 4.3 ± 2.2 min (2016–2019, $p = 0.12$), and the number of incidents with response times >5 min decreased from 28.8 ± 17.8% (2008–2012) to 9.3 ± 11.4% (2016–2019, $p = 0.04$ by linear regression). As our program became more standardized, we noted better equipment availability and subspecialist communication. Few emergency situations (n = 9, 6%) required operating room management. There were 3 patient deaths (2%).

Conclusions: Our airway safety program, including readily available specialists and equipment, facilitated effective resolution of airway emergencies in our NICU and multidisciplinary involvement enabled rapid and effective changes in response to COVID-19 regulations. A similar program could be implemented in other centers.

1. Introduction

Unique anatomy can complicate neonate and infant airway management [1,2], and unexpected airway emergencies arise frequently in neonatal intensive care units. Further, management of neonates delivered at quaternary children's hospitals with complex airway issues can demand "on call" multidisciplinary teams [3]. Timely airway emergency interventions are necessary and life-saving.

We developed a multidisciplinary Neonatal-Infant Emergency Airway Program to facilitate rapid airway interventions. An oversight committee reviewed all incidents. Collaboration with Otolaryngology and Anesthesia teams facilitated management of bedside airway procedures and rare cases that required operating room interventions. These emergency procedures underwent important changes in response to the COVID-19 pandemic. Herein we present our longitudinal experiences, finding specialized equipment availability and usage, subspecialist response times, and retrospective oversight to have facilitated consistently rapid interventions and optimal outcomes. As NEAR4Kids

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and NEAR4Neos collaborative programs have improved pediatric airway management [4,5], our findings may similarly help improve clinical airway emergency responses.

2. Materials and methods

2.1. Patients

Patients admitted to our quaternary neonatal and infant intensive care unit (NICU) were included in this study, which was deemed exempt from oversight by the Children's Hospital of Philadelphia Institutional Review Board.

3. Methods

Our Neonatal-Infant Emergency Airway Program included a multidisciplinary response team and specialized equipment to facilitate management for any patient in our NICU who experienced an airway emergency (Fig. 1 and Table 1). A hospital-wide notification system alerted relevant personnel to event locations by a single pager phone button push. Activation typically occurred in response to anticipated or experienced difficulty in securing an artificial airway (e.g., after an unplanned extubation). In patients suspected to have difficult airways, a sign placed at the bedside indicated that initial intubation attempts were to be made by the most experienced practitioner present. In most cases, this was a Neonatology Attending physician.

Once activated, respiratory therapists brought specialized equipment to bedside, including flexible fiberoptic laryngoscopes, Benjamin laryngoscopes, a variety of endotracheal tubes and sizes, laryngeal mask airways (LMAs), and surgical airway equipment (Table 1). Nurses retrieved emergency code carts, including intravenous access equipment, medications, and other supplies. Minimum personnel present at each event after emergency response activation included an Attending Neonatologist, respiratory therapist, nurse, an ENT and/or Anesthesiologist. C-MAC video laryngoscopy is the standard of care for all intubations in our NICU. Attempts were made to sedate and paralyze patients with intravenous atropine, fentanyl, and vecuronium prior to the first intubation attempt, although the emergent nature of many events and/or difficulties with bag-mask ventilation often precluded premedication.

In response to COVID-19, we also made available a separate cart equipped with extra N95 masks, eye protection, gloves, hand sanitizer, and gowns for all responding personnel. All personnel donned full personal protective equipment (PPE), since airway interventions were considered aerosol generating procedures. Rapid COVID-19 tests were performed for all new admissions for airway issues, as well as semi-

Table 1
Personnel and equipment present and available at all Airway Emergency Responses.

Personnel
Neonatology – Attending and Fellow Physicians, Nurse Practitioners, Nursing Staff
Otolaryngology – Attending, Fellow, and Resident Physicians
Anesthesia – Attending, Fellow, and Resident Physicians
Respiratory therapists
Airway Equipment
Direct laryngoscopy handles and blades (size 00, 0, 1)
Video laryngoscopy handles, blades, and monitors (size 0, 1)
Benjamin laryngoscopes
Flexible fiberoptic laryngoscopes and monitor tower (2.2 mm, and 2.8 mm with suction)
Endotracheal Tubes (2.0, 2.5, 3.0, 3.5, 4.0)
Alligator forceps (large, small)
Tracheostomy surgical set with neonatal and pediatric size tracheostomy tubes
Laryngeal mask airways (traditional and intubating LMAs, sizes 1, 1.5)
Nasopharyngeal airways (sizes 6.5–8.5)
Other equipment
Hospital-wide notification system and phones
Personal protective equipment (gowns, gloves, N95 masks, surgical masks)
Viral filters for in-line use (15 mm inner diameter, 22 mm outer diameter)

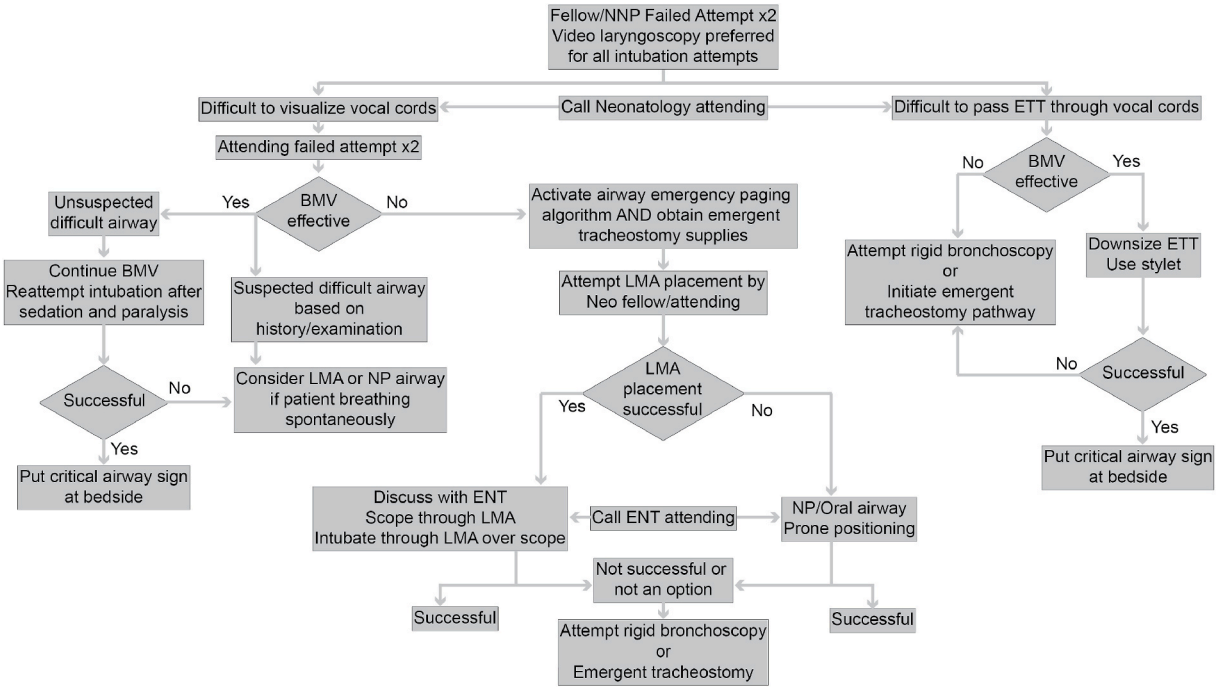

Fig. 1. Neonatal Airway Emergency Response algorithm flow sheet. Initial steps assume management by neonatology team, including Fellow, Neonatal Nurse Practitioner (NNP) and/or Neonatology Attending physician. In patients with suspected difficult airways, initial intubation attempts were made by the most experienced practitioner (typically a Neonatology Attending). Our standard of care was to sedate and paralyze patients prior to intubation, if able. Video laryngoscopy was the standard of care for intubation attempts. If initial attempts failed, an emergency response page was sent to Otolaryngology (ENT) and Anesthesia teams. LMA, laryngeal mask airway. NP, nasopharyngeal airway. BMV, bag mask ventilation. ETT, endotracheal tube.

elective diagnostic airway procedures, such as nasopharyngeal laryngoscopy. Patients were presumed positive until negative testing was confirmed.

Respiratory therapists or nurses present during each event recorded response times, communication, equipment utilization and outcome after each event on Emergency Response tracking forms (Supplemental Fig. 1). Events and forms were analyzed by a multidisciplinary Airway Safety Monitoring team, comprised of NICU, ENT and Anesthesia physicians, as well as respiratory therapists, to address clinical complications or systemic problems. Given event infrequency and severity, we believe we have recorded all events over the past decade.

4. Results

We separated and analyzed our findings into three epochs to monitor statistical trends. Initial data was collected for these events from 2008 to 2012. From 2013 to 2015, standardized measures were enacted and procedures became streamlined. Since 2016, our airway emergency response program has been well established. The number of events has remained constant at ~12 per year (Fig. 2A). Clinical characteristics for patients managed in the course of these events varied widely, from weights under 1 kg to greater than 4 kg, and with diagnoses ranging from differences in neonatal airway anatomy, to subglottic stenosis, to severe congenital facial masses and upper airway malformations.

A critical aspect of our program was rapid response and presence of subspecialists and equipment. Average time to first subspecialist arrival decreased, but not to statistical significance (Fig. 2B). We also tracked "delayed" subspecialist responses (>5 min), reasoning that it should take under 5 min to arrive at an acute event from anywhere in our hospital. Events with delayed subspecialist responses dropped dramatically (29 ± 18% 2008–2012 vs 20 ± 18%2013–2015 vs 9 ± 11% 2016–2019, Fig. 2C, $p = 0.04$ by linear regression). Delayed responses also decreased when analyzed on an annual basis ($p = 0.04$, Supplemental Fig. 2). Safety and assuredness afforded by consistently rapid responses were clinically meaningful.

Since program establishment, subspecialists and emergency equipment were present at every event. Specialized equipment usage has remained consistent over time, with flexible fiberoptic laryngoscopes and Benjamin laryngoscopes being the equipment most often utilized to resolve emergency events (Supplemental Fig. 3A). Successful intubations were most frequently performed by ENT, although in many cases the NICU or Anesthesia Attending physicians were able to intubate in situations where initial attempts by a NICU fellow or front line clinician failed (Supplemental Fig. 3B). Few events (n = 9, 5.7%) required management in an operating room. In these cases, use of rigid bronchoscopy helped to secure airways. Review of these and other events highlighted a need for a 2.2 mm flexible fiberoptic laryngoscope to be included with our airway emergency cart. There were 3 patient deaths (1.9% overall), 2 of which were clinically ascribed to airway issues. In the 2 airway-related deaths, patient size, severity of airway malformations, and/or parental preferences precluded surgical airway placement. Multidisciplinary review of these events did not identify related system failures to necessitate changes in team organization or infrastructure.

The interdisciplinary collaboration promoted through our program was also critical in quickly and effectively adjusting procedures in response to the COVID-19 pandemic. Universal NICU admission screening, and standardized upper and lower respiratory tract sampling for intubated patients, enabled rapid identification of all COVID-19-positive patients. Given the likelihood of an 'aerosol-generating procedure' (i.e., intubation) at each emergency event, personnel at emergency events were limited to the Anesthesia Attending, ENT Resident/Fellow, Neonatology Attending and Fellow, Respiratory Therapist, and 1–2 Neonatology Front Line Clinicians. Extra nurses, physicians and front line clinicians were asked to leave. All staff present wore fit-tested N95 masks, eye protection, and gowns and gloves donned and doffed per institutional personal protective equipment (PPE) policies. PPE and viral filters are now included in separate carts that were brought to all airway emergency events. Limited personnel were involved with COVID-19-positive airway interventions to limit exposure to these aerosol-generating procedures. Video laryngoscopic intubation was strongly preferred for these patients, as this allowed the greatest physical distance between the patient and providers.

5. Discussion

Challenges associated with neonatal and infant airways are well described [2,3]. Our Emergency Airway Program facilitated consistently prompt management for all infants in our NICU who experienced airway emergency events. As our program became standardized, we might have expected increased event frequency. Instead, events remained consistent over time. We attributed this finding to prevalent use of video laryngoscopy in the past 2–3 years, which likely avoided some airway emergencies. Improved multidisciplinary communication may have also avoided some events. For example, the Emergency Airway Program team was notified prior to certain events, such as the birth of infants

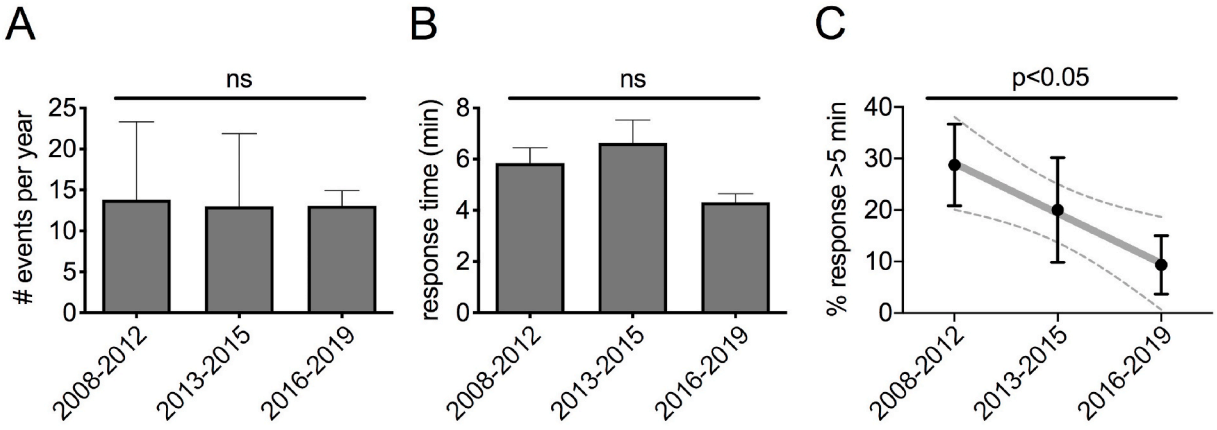

Fig. 2. Airway Emergency Response events and response times over the study period.
A. The number of Airway Emergency Response events per year over the study duration. ns, no significant difference ($p = 0.98$ by one-way ANOVA).
B. Subspecialist response arrival times after Airway Emergency Pager System activation over the study duration. ns, no significant difference ($p = 0.053$ by one-way ANOVA).
C. The percentage of delayed subspecialist responses (arrival >5min after Airway Emergency Pager System activation) over the study duration. $p = 0.036$ by linear regression.

with known airway malformations by scheduled induction or cesarean section in our Special Delivery Unit. Planned events were not included in this manuscript.

Our tracking system also enabled us to identify equipment most useful for successfully resolving airway emergencies. A 2.2 mm flexible fiberoptic laryngoscope was not initially included with our specialized airway equipment. However, after program inception, this was clearly the dominant bronchoscope used in both diagnosis and airway access for most patients. We therefore include a 2.2 mm flexible fiberoptic laryngoscope in our budget process and make it available during all emergency events.

This was an observational study based on a decade of experience. Airway emergency data were not systematically captured or evaluated prior to creation of this program. The relatively infrequent nature of these events limited our ability to demonstrate statistically significant differences between epochs, although the reliability of equipment and subspecialist personnel were clinically meaningful. The special patient population served in our quaternary NICU may limit the generalizability of our results, but we hope that our experience helps foster development of similar programs in other children's hospitals. Response times, equipment availability, and patient outcomes are key quantitative metrics with which to judge program success.

Our institution opened a Center for Fetal Diagnosis and Treatment in 1995. We have since experienced tremendous growth, evaluating and caring for more than 25,000 patients from 70 countries. Similarly, our institutional Neonatal Airway Safety Program, enacted in 2004, now handles 100–200 clinical airway management referrals per year. Many of these complex patients require expert airway management, necessitating a multidisciplinary team with collective experience treating fetuses and infants with congenital airway anomalies. Caring for patients with complex or specialized airway needs has further emphasized the importance of our Emergency Airway Program, which was implemented to support all patients in our NICU. Subspecialist cooperation and equipment availability that was streamlined through our Airway Safety Program experience has proven useful in managing these patients at delivery and throughout hospitalization.

Our program has created a safer care environment based on utilization of available expertise. Airway management programs are necessary at specialized birth centers and NICUs care for a growing number of infants with prenatally recognized airway anomalies. Multidisciplinary oversight and event reviews helped manage complications and systemic problems as they arose during program development, and facilitated rapid and effective adaptations in response to changing circumstances (e.g., the COVID-19 pandemic). Our hospital has now enacted a multidisciplinary Airway Emergency Response Committee to oversee and standardize equipment and responses in these challenging situations hospital-wide. We hope our experiences with our program will help others establish similar programs in other settings.

The COVID-19 pandemic allowed the multidisciplinary team to rethink PPE needs and our response practices to optimize safety and minimize the spread of aerosol generating contamination. Although robust data are not available for COVID-19-positive events, key changes in equipment and response practices described herein will be most important for other hospitals to implement a similar program.

6. Conclusions

Establishment of an Airway Safety Program enhanced tracking and resource utilization in our quaternary children's hospital. Subspecialist response times and equipment availability were streamlined as a result of this program. In many cases, expert users and specialized equipment were necessary to resolve life-threatening situations. Revising our protocols related to aerosol generating procedures in response to the COVID-19 pandemic was valuable for our institution. Similar programs could optimize management of clinically challenging airway emergency events in other hospital settings.

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Declaration of competing interest

The authors have no relevant conflicts of interest to disclose.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijporl.2020.110458.

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