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Breathing Easier: Decreasing Tracheal Intubation-associated Adverse Events in the Pediatric ED and Urgent Care

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Abstract

Introduction: Tracheal intubation is a high-risk procedure in the pediatric emergency department (PED) and pediatric urgent care (PUC) settings. We aimed to develop an airway safety intervention to decrease severe tracheal intubation-associated adverse events (TIAEs) by decreasing process variation. **Methods:** After gathering baseline data on TIAE, an interdisciplinary team underwent a mini-Delphi process to identify key drivers for decreasing severe TIAE rates. We launched a 4-part airway safety bundle that included: (1) color-coded weight-based equipment chart, (2) visual schematic of airway equipment, (3) recommended medication dosing, and (4) safety checklist across a single, tertiary PED and 5 satellite community PUCs/PEDs. Multiple plan–do–study–act cycles were undertaken, and results were monitored using statistical process control charts. Charts were restaged when special cause variation was achieved. This study aimed to decrease the severe TIAE rate from a baseline of 23% in the tertiary site and 25% in the community sites to <15% within 12 months and to sustain these outcomes for 6 months. **Results:** During the study period, we noted decreased rates of severe TIAE in both the PED and PUC setting during the intervention period, and we have sustained this improvement for more than 6 months in all sites with no associated change in balancing measures. **Conclusions:** Implementation of an airway safety bundle over a wide geographic area and among personnel with variable levels of training is possible and has the potential to decrease severe TIAE across multiple clinical settings. *(Pediatr Qual Saf 2019;4:e230; doi: 10.1097/pq9.0000000000000230; Published online November 19, 2019.)*

INTRODUCTION

Rapid sequence intubation (RSI) is considered the definitive airway management for critically ill pediatric patients. Despite this, RSI is performed infrequently and is associated with adverse outcomes in multiple clinical settings.[1–11] Intubations performed in the emergency department (ED) and urgent care (UC) settings are subject to suboptimal communication, varying personnel experience, and unstable patient conditions resulting in significant process variation.[12–14]

Poor patient outcomes are associated with increased process variability, increased time to intubation (TTI), and increased number of intubation attempts.[15] National quality metrics for RSI include TTI, tracheal intubation-associated adverse events (TIAEs), and first-pass intubation success rate. Published pediatric ED (PED) TIAE rates range between 20% and 61%,[16–20] and first-pass intubation success rates are between 26% and 85%.[17,20–24] TIAEs are also correlated with increasing numbers of intubation attempts,[17,24] which result in increased duration of mechanical ventilation, longer critical care unit stays, and increased mortality.[2,18,21–23,25] Although pediatric intensive care unit-based databases, such as the National Emergency Airway Registry for Children (NEAR-KIDS), exist and track metrics of pediatric tracheal intubation, no such database exists for PEDs or community EDs/pediatric UCs (PUCs). The result is that there are few data-driven quality initiatives to create safer advanced airway management

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Preliminary data were presented as a poster at American Association of Pediatrics National Conference and Exhibition, Chicago, IL, 2017, and at Pediatric Academic Society, Baltimore, MD, 2019.

Supported by Clinical Operations Effectiveness and Patient Safety Small Grants Program.

Supplemental digital content is available for this article. Clickable URL citations appear in the text.

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To cite: Neubrand TL, Alletag M, Woods J, Mendenhall M, Leonard J, Schmidt SK. Breathing Easier: Decreasing Tracheal Intubation-associated Adverse Events in the Pediatric ED and Urgent Care. Pediatr Qual Saf 2019;6:e230.

Received for publication March 20, 2019; Accepted October 5, 2019.

Published online November 19, 2019.

DOI: 10.1097/pq9.0000000000000230

techniques in these settings, and the resulting impact on clinical care and patient outcomes is not known.[14,26,27]

Although our baseline for severe TIAE falls in the low end of published PED TIAE rates, we postulated that by standardizing practice and increasing provider comfort with this infrequent procedure, we could further decrease the rate of severe TIAE in both the PED and PUC setting. This report describes the development and implementation of a unique 4-part airway safety bundle in both a tertiary care PED and 5 affiliated community PED/PUC sites. This study aimed to decrease the severe TIAE rate from a baseline of 23% in the tertiary site and 25% in the community sites to < 15% within 12 months and to sustain these outcomes for 6 additional months.

METHODS

Study Site

We conducted this quality improvement initiative across a single, academic tertiary PED and 5 satellite community PUCs/PEDs within a single university-affiliated children's hospital regional care system. All sites shared the same protocols, electronic health record (EHR), pathways, and formulary. At all sites, a pharmacist within the pediatric health system reviewed and approved orders continuously through the EHR. The tertiary site is an American College of Surgeons Level 1 verified pediatric trauma center with a PED in a free-standing academic children's hospital. It has approximately 90,000 visits yearly and is staffed with pediatric emergency medicine physicians 24 hours daily. The 5 community sites consist of 2 PEDs and 3 PUCs, with approximately 80,000 additional annual visits. The community sites are staffed with a combination of pediatric emergency medicine physicians, pediatricians, and advanced practice providers. Critically ill patients in the community sites require transfer to the tertiary site, 15–60 minutes away by ground transportation.[28] The regional pediatric care network, consisting of the community sites, has a robust quality and process improvement culture as evidenced by a local quality review board, a team of data analysts devoted to extracting data from the EHR for programmatic monitoring, and active participation in quality and safety committees.

Interventions

After analyzing baseline data (December 2015 to May 2016), a multidisciplinary team consisting of physicians, nurses, respiratory therapists, and pharmacists, used a mini-Delphi methodology to identify key drivers (Fig. 1) in which intervention was likely to result in decreased rates of severe TIAE. We defined severe/major TIAE as cardiac arrest, death, hypotension, laryngospasm, pneumothorax, pneumomediastinum, hypoxia <80%, and direct airway injury, in concordance with the NEAR-KIDS registry.[18] These severe events were distinguished from nonsevere/minor TIAE, which we defined as right mainstem intubation with immediate recognition, esophageal intubation with immediate recognition, emesis without aspiration, lip/dental trauma, or hypoxia with SpO_2 80%–90%. Nonsevere/minor TIAEs were not a target for intervention in our study.

After a literature review and 3 rounds of in-person meetings, the team reached a consensus for targets of intervention. These included (1) airway equipment reorganization to minimize user error (**see figure, Supplemental Digital Content 1**, which shows the photograph of color-coded airway equipment organization, **http://links.lww.com/PQ9/A141**); (2) creation of a visual schematic and weight-based equipment chart to decrease equipment variability (**see figure, Supplemental Digital Content 2**, which shows the visual schematic and weight-based equipment chart for airway supplies, **http://links.lww.com/PQ9/A141**); (3) a standardized medication ordering/dosing sheet to decrease medication underdosing (**see figure, Supplemental Digital Content 3**, which shows the standardized medication dosing and ordering sheet, **http://links.lww.com/PQ9/A141**); and (4) a safety checklist (**see figure, Supplemental Digital Content 4**, which shows the airway safety checklist, **http://links.lww.com/PQ9/A141**) to decrease process variability. This airway safety bundle was introduced to the tertiary site in May 2016 and to the community sites in April 2017. Before the introduction, all clinical staff members were educated on the problem of TIAE during in-person staff meetings and via emailed presentations. For the 2 weeks before the rollout of the airway safety bundle, the new process was discussed during daily safety huddles, during staff meetings, and during weekly pharmacy and respiratory therapy educational initiatives. We presented the airway safety bundle to all newly hired nurses, respiratory therapists, and EMTs during their new employee orientations, and physicians were updated every 6 months on project interval data, both individually, and as a group. Additionally, pediatricians in the community sites received in-person airway refresher courses every 6 months that included airway mannequin training, didactics on airway management, and emphasis on the use of the airway safety bundle. An online video was developed and made internally available to all pediatricians in the community sites to further describe the airway safety bundle and the airway resources available in those locations.

Data Collection

Baseline data and study data were collected retrospectively at all sites via a review of electronic medical records and resuscitation documents on a structured form. Variables collected included: patient demographics, indications for intubation, time and dose of sedatives and paralytics administered, time to successful intubation, number of intubation attempts, intubating provider demographics, and type and timing of adverse events (Table 1). These data were managed using a REDCap (Research Electronic Data Capture) database.[29] We defined an intubation attempt as any laryngoscopy or attempted

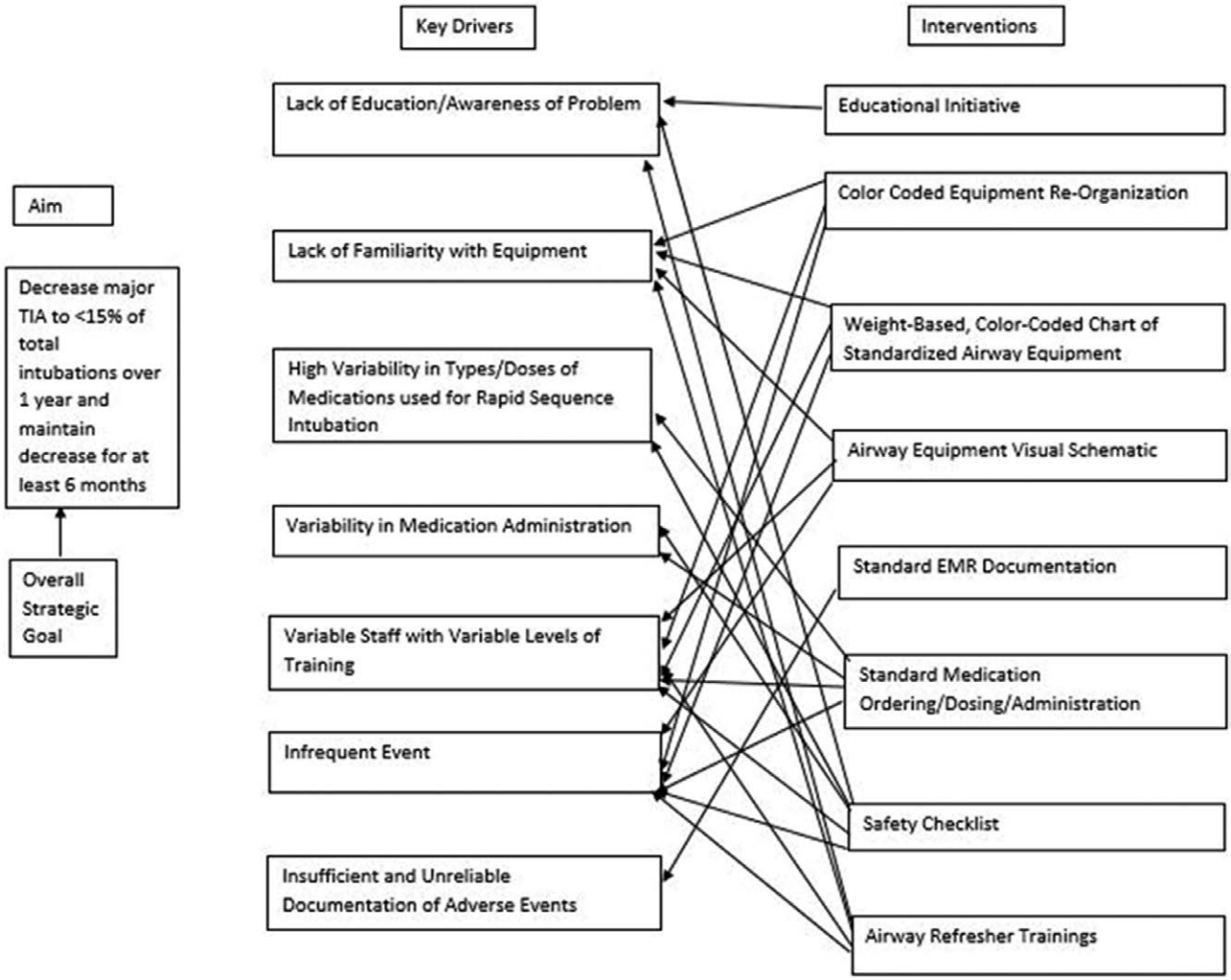

Fig. 1. Key driver diagram.

placement of an endotracheal tube. Successful intubation was one in which the endotracheal tube was confirmed to be in the trachea by noting at least one of the following: symmetric chest rise, symmetric breath sounds, color change on colorimeter or appropriate placement on chest x-ray. Video review became available at the tertiary site in December 2018, but video access was limited to 2 resuscitation rooms and was only available in 2 individual cases. We used the same structured data collection form, whether video or chart review was being utilized for data collection.

Outcomes of Interest

The primary outcome measure was the proportion of intubations that had an associated severe TIAE, as defined earlier, in concordance with the NEAR-KIDS database.[11,18,23,30] The process measures included the rate of compliance with recommended intubation-associated medication dosing and the use of the standardized procedure documentation in the EHR, which included documentation of compliance with the airway safety bundle. We considered compliance with the airway safety bundle "complete" only if its use was documented in the EHR and if there was compliance with the recommended medication dosing. Our balancing measures included failed intubations requiring anesthesia or critical care transport team intervention, percentage of time trainees (resident or fellow) performed the first intubation attempt, and TTI. TTI was defined as the time from the administration of the first medication used for RSI to the time of successful intubation.

Data Analysis

Patients initially intubated by an anesthesiologist or by the critical care transport team were excluded from the analysis. Tracheal intubation adverse events in the tertiary site and the community sites were plotted over time using control charts (P-charts and G-charts) created with Excel macros designed and maintained by our institution's Center for Clinical Effectiveness. We reviewed statistical process control charts for special cause variation, and the P-charts were restaged when 10 of 11 or 8 consecutive points were above or below the centerline.[31] Patient characteristics, process measures, and balancing measures were described for

Table 1. Patient Characteristics, Balancing Measures, Process Measures at Baseline, throughout the Study Period, and during the Maintenance Period

	Baseline (n = 43)	Study Period (n = 66)	Maintenance (n = 72)
Patient characteristics			
Age, y	2.2 (0.5–13.6)	2.5 (0.6–7.7)	3.6 (0.5–14.2)
Weight, kg	14.3 (7.0–35.4)	13.0 (7.1–28.0)	20.7 (7.8–48.0)
Male	28 (65%)	41 (62%)	34 (47%)
Balancing measures			
Failed intubation requiring anesthesia or critical care transport team to intervene	4 (9%)	9 (14%)	7 (10%)
Trainee is first to attempt intubation	25 (58%)	36 (55%)	56 (78%)
TTI, min	6 (4–9)	4 (3–7.5)	3.5 (2–9)
Process measures			
Standardized documentation*	n/a	100%	100%
Compliance with medication dosing recommendations	17 (50%)	35 (65%)	39 (63%)

Data are presented as n (%) or median (interquartile range). Data were missing for weight (n = 3), TTI (n = 12), and compliance with medication dosing recommendations (n = 12).
*Once standardized documentation was implemented, it was the only option.
n/a, not applicable.

the baseline, study intervention, and maintenance periods. A statistician completed the statistical analysis using SAS v. 9.4 (SAS Institute, Cary, NC). The local Organizational Research Risk and Quality Improvement Review Panel approved the study as nonhuman subjects research.

RESULTS

In the 6-month "baseline period" at the tertiary site between December 2015 and May 2016, before our intervention, there were 26 intubations included for analysis. During the intervention period (June 2016–June 2017), there were 41 intubations, and in the maintenance phase (July 2017–July 2018), there were 68 intubations. At the community sites, the "baseline period" occurred from December 2015 to January 2017 and included 17 intubations in both the PEDs and the PUCs. The intervention period (February 2017–February 2018) included 25 intubations, and the maintenance phase (March 2018–December 2018) included 4 intubations. Of the 46 intubations in the community sites, 30 (65%) occurred in the community PED and 16 (35%) occurred in the PUCs.

After the implementation of the airway safety bundle, we noted a decrease in severe TIAE in both the community sites (Fig. 2) and the tertiary site (Fig. 3) during the intervention

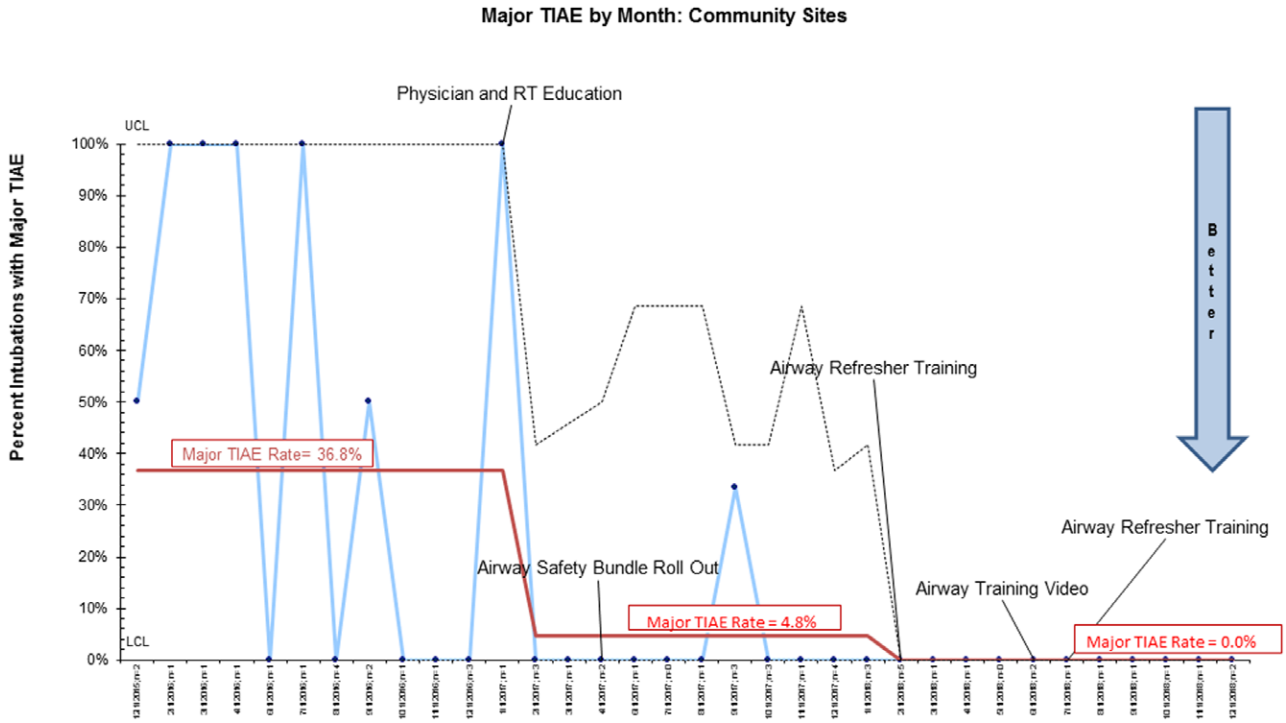

Fig. 2. P-chart demonstrating decrease in severe TIAE rate in community sites over time.

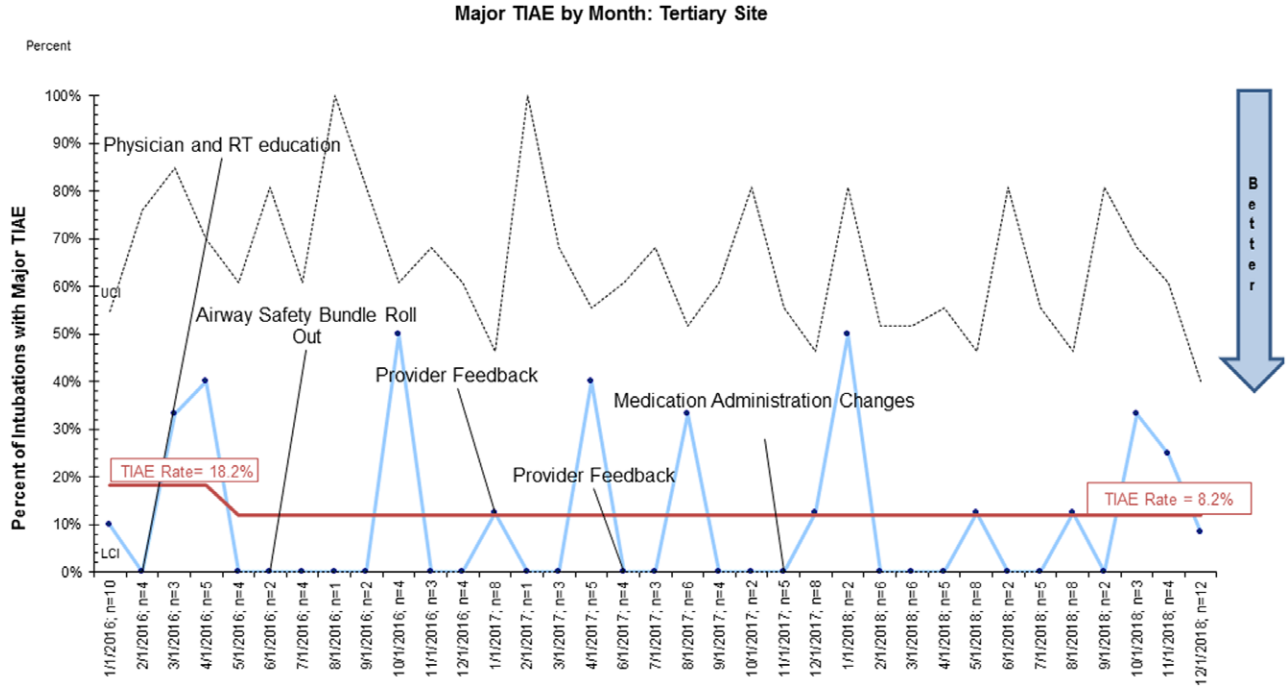

Fig. 3. P-chart demonstrating decrease in severe TIAE rate in tertiary site over time.

period. The improvement in TIAE was sustained for the 6-month maintenance period at all clinical sites.

We also noted a progressive increase in the number of intubations without major TIAE between successful intubation attempts in the community sites (Fig. 4) but not in the tertiary site (Fig. 5). Nonsevere TIAE did not significantly change after the implementation of the airway safety bundle at either the tertiary site (50.0% versus 33.6%, $P = 0.14$) or the community sites (50.0% versus 38.5%, $P = 0.43$). The most common TIAE experienced at both the tertiary and community sites was hypoxia.

Our balancing measures of intubations by trainees and rescue intubations were not affected by the initiation of the airway safety bundle (Table 1). We did note a decrease in TTI during the study period and the maintenance period. The overall utilization rate of the airway safety bundle was 64% in both the tertiary and the community sites, as demonstrated by compliance with the recommended

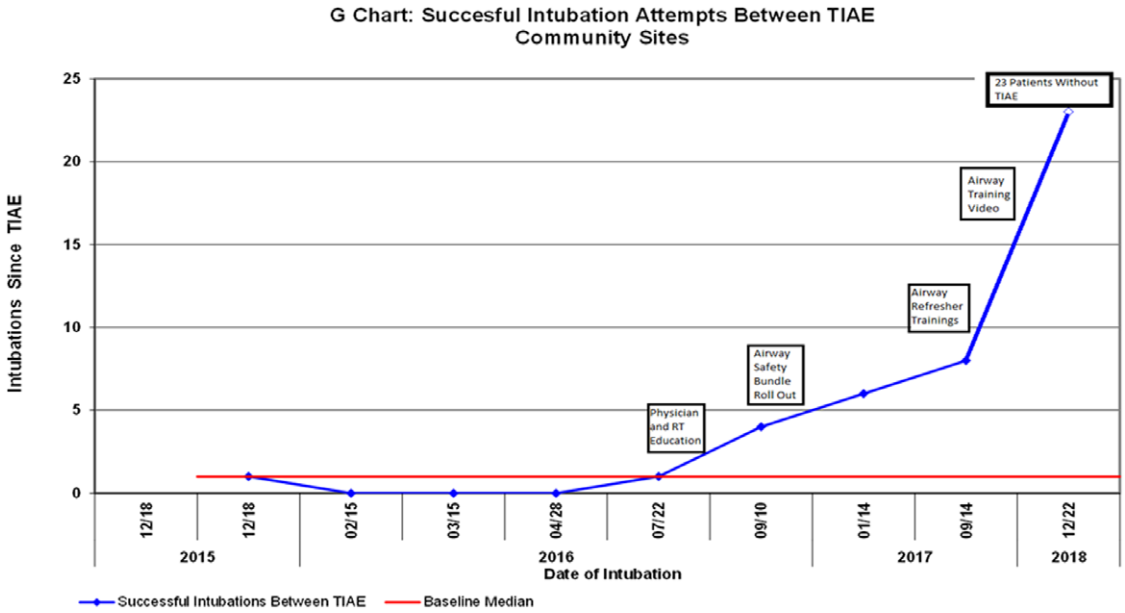

Fig. 4. G-chart demonstrating increased number of intubations between severe TIAE at the community sites.

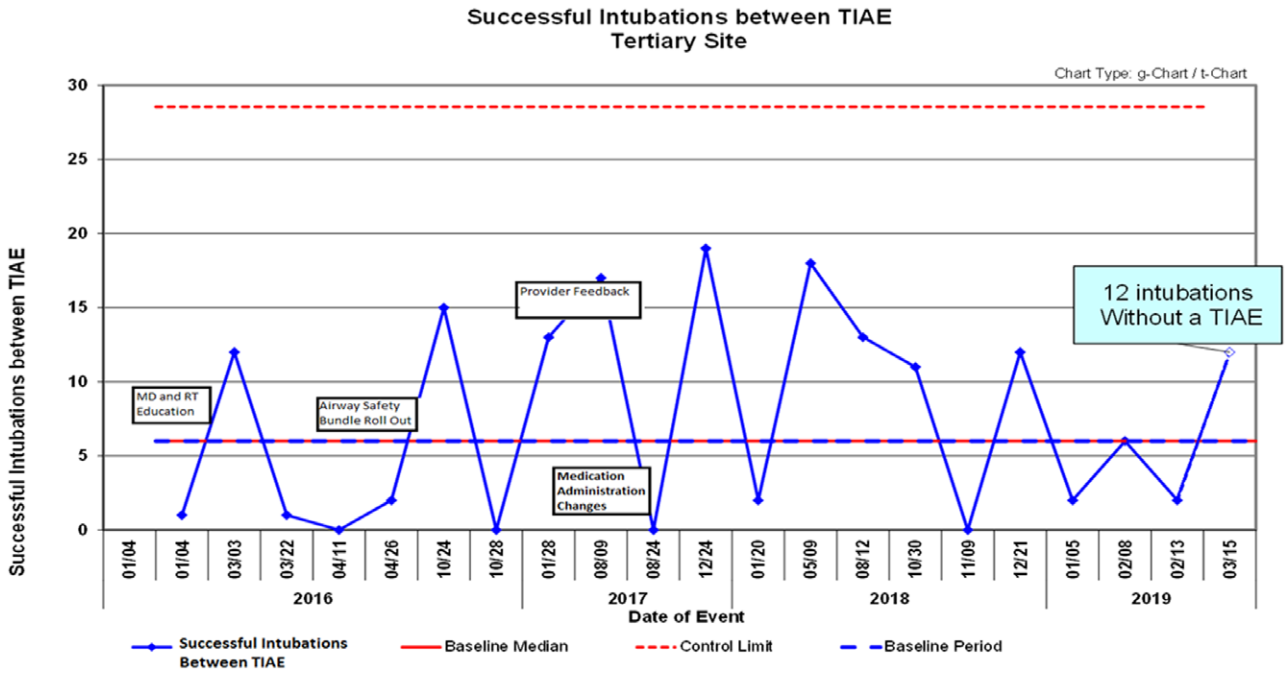

Fig. 5. G-chart demonstrating number of intubations between severe TIAE at the tertiary site.

medication dosing regimen and documentation of use in the standardized procedure electronic documentation.

DISCUSSION

Airway safety bundles have been described for use in the PED in the past.[13] However, their overall effect on patient-level outcomes is not well described. Further, no studies describe the effects of the introduction of an airway safety bundle in both an academic, tertiary ED and a group of affiliated, community UC and EDs. In this study, we deployed an airway safety bundle across a network of pediatric ED/UC sites and found a decrease in severe TIAE across all practice environments and among staff with variable levels of training and experience. We attribute this decrease to the adoption of the airway safety bundle and to increased compliance with recommended medication dosing and administration times. We further speculate that the development of an online educational video describing the airway safety bundle, in combination with airway refresher courses, helped to maintain this decrease in TIAE in the community sites over time.

Prior studies describe low first-pass intubation success rates among pediatricians in community UC and EDs.[32] As tertiary care children's hospitals expand into community EDs, and as pediatric readiness becomes increasingly important in general EDs, it will be vital to establish protocols to provide maximal support to pediatricians practicing in settings that do not provide anesthesiology services. We believe that airway safety bundles, including safety checklists, standardized airway equipment and medication recommendations, and the use of supraglottic airway devices, may decrease some of the risk associated with critical airway management in community PED/PUCs.

Our findings do have limitations. We conducted this study across a single PED and PUC network with shared EHRs and with a strong culture of quality improvement. This culture likely contributed to high rates of uptake and acceptability of the airway safety bundle among PED and PUC staff. Implementation of a similar initiative may be more difficult at other institutions where quality initiatives do not receive the same level of institutional support. Further, there is no national airway management registry for PEDs, so a comparison of our quality metrics with other institutions is limited. There are also no nationally recognized protocols for reducing the risk of TIAE in the PED. Because we introduced multiple interventions simultaneously, it may be that the components of our airway safety bundle did not contribute equally to the resulting decrease in severe TIAE. Finally, given the relative rarity of pediatric endotracheal intubation in the PED and PUC setting, the baseline data and subgroup sizes of our P-charts may be too small to indicate a change in the frequency of severe TIAE conclusively.

In our study, approximately 50% of patients experienced some TIAEs. Although this rate is higher than TIAE rates reported from the ICU setting,[2,13,20,30] it is consistent with rates of reported adverse events in the PED setting.[5,8,32] Although we did note decreased rates of severe TIAE, rates of nonsevere TIAE in our study did not decrease. It may be that by including hypoxia (any SpO_2 < 90%) as an adverse event in our dataset, we overestimated the number of patients experiencing a nonsevere TIAE. Although we did not make any distinction between brief

and sustained duration of hypoxia, we did distinguish between hypoxia as a severe TIAE (SpO_2 < 80%) and as a nonsevere TIAE (SpO_2 80%–90%). We do not know the clinical significance of SpO_2 of 80%–90% during intubation, and because hypoxia was the most common type of severe and nonsevere TIAE, this could have resulted in a high total TIAE of unclear significance.

Furthermore, we cannot determine whether our intervention impacted each specific type of severe TIAE in the same way. At the time of initiation of our project, there was no mechanism to directly track the use of the airway safety bundle electronically in the medical record. This barrier resulted in our need to use alternate data as a proxy to measure the use of the airway safety bundle. In this case, we used compliance with recommended medication dosing and use of the standardized procedure documentation, which included self-reporting of use of the airway safety bundle. Because we noted an increase in the use of both recommended medication dosing and standardized documentation after implementation of the airway safety bundle, we believe these proxies were reliable indicators of its use. Finally, because the scope of our study did not include long-term follow-up of patient outcomes, we do not know how the nonsevere TIAE affected patient morbidity.

CONCLUSIONS

After initiation of an airway safety bundle across a network of tertiary and community PEDs/PUCs, we saw a decrease in severe TIAE. Implementation of the bundle was feasible and adopted across a wide geographic distribution with multiple providers of varying training and experience levels. As more tertiary children's hospitals expand into affiliated community-based emergency and UC settings, standardized processes will be required to provide care to critically ill patients across varying practice settings. Further study, ideally in multicenter populations, is needed to determine whether the achievements are generalizable to the wider PED/PUC or general ED setting.

ACKNOWLEDGMENT

Assistance with the study: Joan MacKenzie.

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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