JOURNAL OF SURGICAL RESEARCH • MARCH 2021 (259) 276–283

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Assessment of Nonroutine Events During Intubation After Pediatric Trauma

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ARTICLE INFO

Article history:
Received 4 December 2019
Received in revised form
28 August 2020
Accepted 22 September 2020
Available online 1 November 2020

Keywords:
Child
Wounds and injuries
Intubation
Intratracheal
Medical errors

ABSTRACT

Background: Intubation in the early postinjury phase can be a high-risk procedure associated with an increased risk of mortality when delayed. Nonroutine events (NREs) are workflow disruptions that can be latent safety threats in high-risk settings and may contribute to adverse outcomes.
Materials and methods: We reviewed videos of intubations of injured children (age<17 y old) in the emergency department occurring between 2014 and 2018 to identify NREs occurring between the decision to intubate and successful intubation ("critical window").
Results: Among 34 children requiring intubation, the indications included GCS≤8 ($n = 20$, 58.8%), cardiac arrest ($n = 6$, 17.6%), airway protection ($n = 5$, 14.7%), and respiratory failure ($n = 3$, 8.8%). The median duration of the "critical window" was 7.5 min (range 1.4-27.5 min), with a median of six NREs per case in this period (range 2-30). Most NREs ($n = 159$, 61.9%) delayed workflow, with 31 (12.1%) of these delays each lasting more than one minute. Eighty-seven NREs (33.9%) had a potential for harm but did not lead to direct patient harm. The most common NREs directly related to the intubation process were poor positioning for intubation ($n = 23$, 8.9%) and difficulty passing the endotracheal tube ($n = 5$, 1.9%), with most being attributed to the anesthesiologist performing the intubation ($n = 51$, range 0-7).
Conclusions: Workflow disruptions related to nonroutine events were frequent during pediatric trauma intubation and were often associated with delays and potential for patient

Author contributions statement: EA and RB conceived the study, and RB, IM, and AS obtained the grant funding for this research. EA and MA collected and analyzed study data. RB, AT, and KO were involved in the development of the data classification scheme. MC conducted the statistical analysis included in the study. EA, MA, KO, and RB drafted the manuscript, and all authors contributed substantially to its review. RB takes responsibility for the paper as a whole.

Presentations: This subject was presented in the Scientific Forum at the American College of Surgeons Clinical Congress 2019 in San Francisco, CA, on October 28, 2019.

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https://doi.org/10.1016/j.jss.2020.09.036

harm. Interventions for improving the efficiency and timeliness of the critical window should focus on adherence to intubation protocol and improving communication and teamwork related to tasks in this phase.

Introduction

Establishing and maintaining an airway are essential for ensuring adequate oxygenation and ventilation after critical injury.[1] Endotracheal intubation may be required in this setting because of severe cognitive impairment, cardiac arrest, airway obstruction, hypoventilation, or hemorrhagic shock.[2] Delays in securing an airway worsen respiratory decompensation and increase the urgency to intubate.[3] Intubation can also lead to life-threatening complications, such as worsening hypoxia and hemodynamic instability, highlighting the importance of the efficiency and timeliness of this procedure.[4,5] External distractions, team errors, and technical skills of the physician can increase the likelihood of complications when intubation is performed urgently.[5,6] Given the impact of delayed intubation, an understanding of the variability in the intubation sequence and how workflow variability disrupts and delays this process is needed for developing improvement strategies.

Nonroutine events (NREs) are a broad class of events that deviate from the ideal course of care, whether or not contributing to adverse outcomes.[7,8] Analysis of NREs has been applied in several settings for identifying aspects of human performance that influence outcomes.[7-10] A previous study identified NREs during pediatric trauma resuscitations, showing that these events are frequent and may represent latent safety threats.[10] This study mostly included lower acuity trauma evaluations that required a range of interventions.

The goal of this current study was to identify and classify NREs during resuscitations of severely injured children who required intubation after arrival in the emergency department (ED). Our long-term goal is to identify workflow disruptions that can be prevented or mitigated during intubation after pediatric injury.

Materials and methods

Setting

Children's National Hospital is a level 1 pediatric trauma center that serves the Washington D.C. metropolitan area, treating about 600 injured children annually as trauma activations based on institutional and regional triage criteria. Patients with lower acuity injuries are triaged as trauma "stat," while those with higher acuity injuries are triaged as trauma "stat attending." The team required for "stat" activations includes a surgical coordinator (pediatric surgery fellow or senior resident), ED attending, the lead nurse responsible for documentation, bedside surgical surveyor (junior resident or nurse practitioner), bedside nurses, respiratory therapists, an anesthesiologist, and an X-ray technician. Required team members for a "stat attending" also include a surgical attending and a critical care physician. Trauma activations are video recorded for quality improvement and secondary use in research. The audio-video recording system provides views from overhead and the foot of the bed. The Children's National Hospital Institutional Review Board approved this study.

Selection of participants

We conducted a retrospective, observational study of injured children (<17 y old) who underwent intubation during their trauma resuscitation from November 2014 to July 2018. During this time, 52 patients were intubated as part of their initial resuscitation. Three patients were excluded because consent could not be obtained for video review, and 15 were excluded due to absent or poor quality video. Patients were included in the study only if consent for video review was obtained. Thirty-four patients were included in the study, including 20 males (58.8%) and 14 females (41.2%).

Study design

From the trauma registry, we obtained patient demographics, initial vital signs, Glasgow coma score (GCS), mechanism of injury, injury severity score (ISS), Abbreviated Injury Scale (AIS) injury profile, triage level "stat" or "attending," and final ED, and hospital disposition. We collected the time of day, day of the week, and the roles of team members using video review and the medical record. We defined significant physiological disturbances as initial vital signs falling more than two standard deviations outside age-appropriate norms.[11-13] We classified indications for intubation as severe cognitive impairment (GCS $\leq$8), cardiac arrest, airway protection, respiratory failure, or severe hemorrhagic shock.[2] We assigned the GCS$\leq$8 category only when occurring outside the setting of cardiac arrest or respiratory failure. We classified patients intubated for altered mental status with a GCS >8 or for whom airway protection was required because of their injuries as "airway protection."

We created a data dictionary to define NREs potentially occurring during trauma resuscitations based on the ATLS protocol, previous work identifying NREs during trauma resuscitation, and expert opinion.[1,10] Definitions were modified, and additional NREs were included in the dictionary during pilot coding. Two physicians were trained to classify NREs based on these definitions using the videos of five resuscitations not included in this study. These reviewers achieved 82% agreement in their initial identification of NREs in the resuscitations analyzed in the study. To manage variations in coding, the two reviewers reconciled differences in NRE coding and together viewed the videos again to verify the final NRE coding. The reviewers documented the team role most associated with each NRE occurrence. We defined NREs as related to the “leadership team” if attributable to the surgical attending, surgical coordinator, ED attending, or lead nurse. Other role assignments included the surgical surveyor, bedside nurse (a role filled by one to three nurses or technicians), respiratory therapist (a role filled by one or two respiratory therapists), anesthesiologist, emergency medical services (EMS) technician (a role filled by up to four EMS technicians), X-ray technician, patient, and family members.

We divided resuscitations into phases structured around the intubation process for analysis. We defined the time from team assembly (when at least two members of the team were present) until patient arrival as the “prearrival” phase. At our institution, the prearrival discussion is directed by a checklist used by the team leader and includes a review of the patient’s age, estimated weight, mechanism, of injury, and any other prearrival information provided by EMS. If the patient is known to be severely injured with a diminished GCS, this discussion may include a review of the reasons for possible intubation. Vials of medications used for rapid sequence intubation are pulled before arrival for all patients. The period between patient arrival and the decision to intubate was defined as the “preintubation decision phase” phase. When the decision to intubate was made before patient arrival, we used the arrival times as the time of the decision to intubate. We defined the period between the decision to intubate until the end of successful laryngoscopy as the “critical window,” and the period from the end of laryngoscopy until patient departure as the “postintubation” phase. We assigned NREs to each phase based on their time of occurrence. Team member absence from the entire resuscitation was assigned to the first phase where their presence was required, while late arrival was assigned to the phase of arrival because of distraction associated this event. The reviewers assigned NREs as related to airway management if directly involving a step required for securing and maintaining the airway by intubation regardless of the phase in which it occurred.

The reviewers then independently designated NREs within the “critical window” based on the potential severity of impact and on any associated time expense. Differences in these designations were resolved by consensus. We used a previously described classification of patient impact, assigning “minor” to an NRE if the potential for harm was low (e.g., stethoscope not available for auscultation) and “major” if the potential for harm was high (e.g., no chest compressions performed when indicated).[14] We assigned the delay associated with each NRE as “none,” “momentary,” for delays shorter than one minute, and “moderate” for delays greater than one minute.[9,15]

Following the review of the pilot and coded resuscitations, the final data dictionary included 119 unique NRE types (Appendix). Using a three-step modified Delphi approach, three additional physicians reviewed each NRE and classified each as a process event if related to the action or inaction of team members. Process events were further classified as errors of commission, omission, or selection.[10,16] Errors of the commission were defined as events where an incorrect action was taken to address a goal, errors of omission as events occurring when no action to address a goal occurred despite the action being required, and selection errors as suboptimal ordering and choice of actions among potential options. Nonprocess events were defined as factors that occur outside of the team’s control, including external events, actions of nonteam members, and equipment malfunction or unavailability.

Analysis

We used the intraclass correlation coefficient and a two-way mixed, single measures model to evaluate interrater reliability for reviewer assessments of NRE severity and associated delay. Differences between coded and noncoded resuscitations were assessed using the Wilcoxon rank-sum test and Fisher exact test where appropriate. Because of the non-normal distribution of NREs and time of phases between cases, we described these variables using medians and interquartile ranges. We calculated the rate of NREs in each phase by dividing the number of NREs per phase by the total time of the phase across all resuscitations. We compared the “critical window” length between cases based on indication and whether the decision to intubate was made before arrival using the Wilcoxon rank-sum test and multivariate linear regression. We evaluated the associations between the number of “critical window” NREs and the indication and decision to intubate before arrival using a Poisson regression model that included an offset variable that normalized the time intervals to model rates. We defined significance at a $P < 0.05$ level. We performed these analyses using SAS 9.4 (Cary, NC)

Results

Characteristics of study subjects

The final dataset included 34 patients (Table 1). Twenty-six patients were injured by blunt mechanism (76.5%), and two (5.9%) by penetrating mechanism. The remaining six patients (17.6%) were triaged as trauma activations based on prehospital report but had no injuries identified during their resuscitation or subsequent hospital stay. These patients were classified as “medical,” and the final diagnoses included asthma exacerbations and cardiac arrest of unknown etiology. Most patients met the definition of major trauma, with a median ISS of 16 (IQR 20.8, range 0-50). Serious injuries (AIS $\geq$3) to the head and neck ($n = 22$, 64.7%) were most common, followed by the thoracic region ($n = 6$, 17.6%). Seven patients sustained a serious injury to more than one body region (20.6%). Five patients (14.7%) arrived at the ED without prior notification of the team. Daytime ($n = 18$, 59.9%) and weekday trauma activations ($n = 21$, 61.5%) were more common than those occurring after hours.

Twenty-six patients (76.5%) presented with 38 instances of significant physiological disturbance in their initial vital signs, including hypotension ($n = 6$), hypertension ($n = 13$), bradycardia ($n = 7$), and tachycardia ($n = 12$). The patients’ initial GCS had a median value of 6 (IQR 4.8, range 3-15). The most common indication for intubation was GCS$\leq$8 ($n = 20$, 58.8%), followed by cardiac arrest ($n = 6$, 17.6%), airway protection ($n = 5$, 14.7%), and respiratory failure ($n = 3$, 8.8%). The team decided to intubate eight patients (23.5%) before arrival based on prehospital information. These patients included the six

Table 1 – Summary statistics.

Variable	Coded resuscitations ($n = 34$)	Noncoded resuscitations ($n = 18$)	P-value
Age (yrs), avg. (SD)	5.6 (4.9)	5.9 (4.4)	0.57
Female, no. (%)	14 (41.2)	6 (33.3)	0.77
Mechanism, no. (%)			
Blunt	26 (76.5)	16 (88.9)	
Penetrating	2 (5.9)	2 (11.1)	0.14
Medical	6 (17.7)	0 (0)	
Injury severity score (ISS), median (IQR)	16 (5-26)	14.5 (9-21)	0.92
AIS ≥3, no. (%)			
Head and neck	22 (64.7)	11 (61.1)	1.00
Face	1 (2.9)	0 (0)	1.00
Thorax	6 (17.6)	3 (16.7)	1.00
Abdomen and pelvic contents	0 (0)	2 (11.1)	0.11
Extremities and pelvic ring	3 (8.8)	3 (16.7)	0.40
External	0 (0)	0 (0)	
Indication for intubation, no. (%)			
GCS ≤8	20 (58.8)	9 (50.0)	
Cardiac arrest	6 (17.6)	0 (0)	
Airway protection	5 (14.7)	7 (38.9)	0.02
Respiratory failure	3 (8.8)	0 (0)	
Severe hemorrhagic shock	0 (0)	2 (11.1)	
Trauma activation characteristics, no. (%)			
Arrival without prior notification	5 (14.7)	2 (11.1)	1.00
Night	16 (47.1)	10 (55.6)	0.77
Weekend	13 (38.2)	11 (61.1)	0.15
Mortality, no. (%)			
Died in emergency room	4 (11.8)	0 (0)	0.29
Hospital death	6 (17.6)	1 (5.6)	0.40

patients intubated for cardiac arrest and two for GCS≤8. Four patients intubated for cardiac arrest died during their trauma resuscitation, and another two (one each with GCS≤8 and cardiac arrest) died during their hospital stay. Thirty-two patients were intubated on the first attempt. The remaining two patients required a second laryngoscopy before successful intubation. To evaluate whether "coded" resuscitations were biased toward any attribute, we compared the included patients ($n = 34$) to other patients who were also intubated during the study period who were not included because of the absence of consent or adequate video ($n = 18$). The only significant difference between coded ($n = 34$) and noncoded ($n = 18$) resuscitations was the distribution of indications for intubation (Table 1).

Main results: nonroutine events

Phase: overall

We identified 723 NREs between all 34 cases (Appendix), with a median of 19.5 NREs per resuscitation (range 10-41 per resuscitation, Table 2). We observed 101 NREs (84.9%) among the 119 NRE types in the data dictionary. The median duration of the 34 resuscitations was 43.7 min (range 23.1-107.2 min). NREs occurred at a rate of 0.6 NREs per minute. More NREs were classified as process events ($n = 508$, median 13, range 5-32 per resuscitation) than nonprocess events ($n = 215$, median 5, range 2-16 per resuscitation). Among the process events, the most frequent were a deviation from protocol ($n = 34$, 4.7%) and inadequate communication requiring clarification ($n = 32$, 4.4%). The most frequent nonprocess events were phone calls and pages interrupting team members ($n = 41$, 5.7%) and the absence of the surgical attending during the resuscitation ($n = 20$, 2.8%). Ninety-three NREs (12.9%) were directly related to the process of airway management. NREs were most often attributable to the bedside nurse ($n = 141$, median 3.5, range 0-13 per resuscitation), followed by the surgical surveyor ($n = 110$, median 2.5, range 0-11 per resuscitation). Factors external to the process, individuals outside the room, or equipment malfunction accounted for 133 NREs (18.4%, median 3.5, range 1-10 per resuscitation).

Phase: prearrival

The "prearrival" phase did not occur in one resuscitation because of insufficient time for team assembly before patient arrival. Among the remaining resuscitations, the "prearrival" phase had a median duration of 10 min (range 0.1-46 min). Nineteen NREs occurred during this phase (Appendix) at a rate of less than 0.1 NREs per minute. Nonprocess events ($n = 11$,

Table 2 – Distribution of nonroutine events among 34 resuscitations with intubation.

Variable	Median (interquartile range)				
	All phases	Before patient arrival*	Preintubation decision†	Critical period	Postintubation
Nonroutine events	19.5 (15.3-25.8)	0 (0-1)	3 (0-7.8)	6 (4.3-10)	8 (6-10)
Process events					
Commission	4 (3-6)	0 (0-0)§	0 (0-1)	1 (0.3-2)	2 (1-3)
Omission	4 (3.3-7)	0 (0-0)	1 (0-1.8)	1 (1-2.8)	2 (1-3)
Selection	4.5 (3.3-6.8)	0 (0-0)	1 (0-2.8)	2 (1-3)	1 (0.3-2.8)
Nonprocess events	5 (4-8.8)	0 (0-1)	1 (0-3)	2 (1-3)	2 (1.3-3)
Airway management NRE	2 (1-3.8)	0‡	0 (0-0)	1 (0.3-2)	1 (0-1)
NREs by team role					
Leadership	2 (2-3)	0 (0-0)	0 (0-0.8)	1 (0-2)	1 (0-2)
Anesthesiologist	1.5 (1-3)	0	0 (0-0)	1 (1-2)	0 (0-1)
Surgical surveyor	2.5 (1-4)	0 (0-0)	1 (0-2)	0.5 (0-2)	0.5 (0-1)
Bedside nurse	3.5 (2-6)	0	0 (0-1)	1 (0-2)	2 (1-2.8)
Respiratory therapist	2 (1-4)	0	0 (0-1)	0 (0-1)	1 (0.3-2)
X-ray technician	0 (0-0)	0	0	0	0 (0-0)
EMS technician	1 (0-1)	0 (0-0)	0 (0-1)	0 (0-0)	0
Other personnel	0 (0-0)	0	0	0 (0-0)	0 (0-0)
Entire team	0 (0-0)	0	0 (0-0)	0 (0-0)	0 (0-0)
Patient	1 (0-1)	0	0 (0-0)	0 (0-0)	0.5 (0-1)
Parent	0 (0-0)	0	0 (0-0)	0 (0-0)	0 (0-0)
Equipment/external	3.5 (2-5)	0 (0-1)	0 (0-1)	1 (0-2)	2 (1-2)

* Phase did not occur in one resuscitation.
† Phase did not occur in eight resuscitations.
‡ 0 indicates no observed events.
§ 0 (0-0) indicates events occurring with a low frequency with a median and interquartile range of 0.

median 0, range 0-3 per "prearrival" phase, Table 2) were more common than process events ($n = 8$, median 0, range 0-1 per "prearrival" phase). The most frequent process events included crowding by nonteam members ($n = 5$, 26.3%) and lack of prearrival notification ($n = 4$, 21.1%). NREs during this phase were only attributed to the surgical surveyor ($n = 3$), EMS technician ($n = 3$), or leadership ($n = 1$) with the remaining NREs related to individuals and not on the team, factors external to the process, or equipment malfunction ($n = 12$).

Phase: preintubation decision

The "preintubation decision" phase did not occur in eight resuscitations because the decision was made before patient arrival. Among the remaining 26 resuscitations, this phase lasted a median of 4.3 min (range 0.9-58 min) and included 149 NREs (median 3, range 0-22 per "preintubation decision" phase, Appendix). NREs in this phase occurred at a rate of 0.7 NREs per minute. Process events ($n = 105$, median 2, range 0-16 per "preintubation decision" phase, Table 2) were more common than nonprocess events ($n = 44$, median 1, range 0-6 per "preintubation decision" phase). The most common process events were deviation from protocol ($n = 14$, 9.4%) and failure to stabilize the cervical spine ($n = 10$, 6.7%), while the most common nonprocess events were phone calls and pages ($n = 8$, 5.4%), and late arrival of the surgical surveyor ($n = 4$, 2.7%). Six NREs were directly related to airway management, including failure to set up or apply the nonrebreather mask ($n = 5$, 83.3%) or the end-tidal CO_2 monitoring system ($n = 1$, 16.7%). Most NREs in this phase were related to the surgical surveyor ($n = 42$) or bedside nurse ($n = 28$).

Phase: critical window

The "critical window" lasted a median of 7.5 min (range 1.4-27.4 min). The duration of this phase was shorter when the decision to intubate was made before than after patient arrival (median 2.2 min, range 1.3-10 versus median 8.1 min, range 3.6-27.4, $P < 0.001$). This phase was longer among patients intubated for airway protection (median 11.0, range 8.2-27.4 min) than for those intubated for cardiac arrest (median 1.7, range 1.4-5.8 min, $P = 0.004$), but was similar to those intubated for GCS≤8 (median 7.6, range 3.6-16.2 min, $P = 0.07$) or respiratory failure (median 7.4, range 6.4-9.9 min, $P = 0.14$). In a multivariate model controlling for an indication for intubation, we no longer observed a difference in the length of the "critical window" based on whether the decision to intubate was made before or after arrival ($P = 0.70$, data not shown).

The "critical window" included 257 NREs with a median of six NREs (range 2-30) per "critical window" phase (Appendix). During this phase, NREs occurred at a rate of 0.9 NREs per minute. Controlling for different lengths of the "critical window" between patients, we observed neither an association between the number of NREs and the timing of the decision to intubate in relationship to patient arrival nor between the number of NREs and indication for intubation (all $P > 0.05$). Process events ($n = 181$, median 4.5, range 0-24 per "critical window" phase, Table 2) were more common than nonprocess events ($n = 76$, median 2, range 0-6 per "critical window" phase). The most common process events were poor patient positioning for intubation in which the patient was repositioned by the anesthesia provider to ensure access to the airway ($n = 23$, 8.9%) and deviation from the protocol ($n = 13$, 5.1%). The most common nonprocess events were pages and phone calls ($n = 16$, 6.2%) and the need to upgrade to a higher level of trauma activation ($n = 13$, 5.1%). Fifty-three NREs (20.6%) were directly associated with airway management, including poor patient positioning for intubation ($n = 23$) and difficulty passing the endotracheal tube ($n = 5$). Most NREs in this phase were attributed to the anesthesiologist ($n = 51$, median 1, range 0-7). Minor NREs ($n = 170$, median 4.5, range 1-21) were more common than major NREs ($n = 87$, median 2, range 0-9). NREs associated with a momentary delay ($n = 128$, median 3, range 0-13 per "critical window" phase) were more common than those associated with either a moderate delay ($n = 31$, median 0, range 0-4 per "critical window" phase) or no delay ($n = 98$, median 2, range 0-13 per "critical window" phase). The reviewers achieved interrater reliability for assessments of the severity of 0.76 ($P < 0.001$) and associated delay of 0.83 ($P < 0.001$) for NREs in this phase.

Phase: postintubation

The "after intubation" phase was the longest phase (median 18.7, range 10.2-55.8 min) and included 298 NREs (median 8, range 3-18 per "postintubation" phase, Appendix). NREs in this phase occurred at a rate of 0.4 NREs per minute. Process events ($n = 214$, median 5, range 1-13 per "postintubation" phase, Table 2) were more common than nonprocess events ($n = 84$, median 2, range 0-5 per "postintubation" phase). The most frequent process events were inadequate sedation requiring additional sedation to prevent endotracheal tube dislodgement ($n = 26$) and excessive noise in the room, requiring a team member to request silence ($n = 15$). The most common nonprocess events were the absence of the surgical attending ($n = 18$) and phone calls or pages ($n = 17$). Thirty-four NREs (11.4%) were related to airway management, including difficulty securing the endotracheal tube ($n = 11$), slow ventilation using a bag-valve mask ($n = 8$), and repositioning of the endotracheal tube ($n = 8$). Most NREs were related to the bedside nurse ($n = 68$), followed by the respiratory therapist ($n = 49$).

Discussion

We observed that nonroutine events are frequent during pediatric trauma resuscitations requiring intubation and have the potential to lead to delays and cause patient harm. The rate of NREs differed across the phases of the resuscitation, being highest in the "critical window" and lowest in the "prearrival" phase. Several processes and environmental factors may contribute to these observed differences, including the frequency and complexity of required tasks, the vulnerability of each phase to NREs, differences in the potential impact of external factors, and the team member associated with NREs. We did not observe an association with the overall number of NREs and either the timing of the decision to intubate or indication for intubation. This finding may indicate that NREs may not be context-dependent but related more generally to trauma resuscitation or the intubation process.

Most NREs were associated with the team's action or inaction in all phases except the prearrival phase. Process events classified as errors of omission and selection errors had a similar proportion overall and were more common than errors of commission in the "preintubation decision," "critical window," and "postintubation" phases. In contrast, process events classified as selection errors were more common than other error types in the "critical window." Although process flexibility may be needed because of patient condition or provider preference during the "critical window," this finding reflects the importance of task order and dependency required for successful airway management.[2,17,18] The types of process events within each of these classifications differed across phases, with those related to airway management most frequently occurring in the "critical window." NREs related to airway management were also observed in the "preintubation decision" phase during the preparation for intubation and in the "postintubation" phase when tasks related to managing the secured airway occurred. Although most previous work has emphasized the importance of errors related to the intubation process, these observations show that critical aspects of airway management also occur outside of the "critical window" and are vulnerable to variability.

Although NREs unrelated to the actions of the team were less frequent, this class represented over a quarter of all NREs observed. Differentiating process events from nonprocess events is useful for developing interventions to prevent or mitigate the effects of NREs. Although process events may be amenable to interventions focused on team (e.g., simulation training, checklists, and real-time decision support), NREs associated with factors unrelated to the process may be better addressed with system improvements (e.g., ensuring personnel availability, appropriate prearrival notification, and functioning equipment). The absence of a surgical attending is a common NRE identified in the presented cases. Quality improvement initiatives at our instruction are focused on improving attending attendance by providing earlier notification to surgeons in this role. Strategies designed to eliminate or reduce external distractions are needed to address the most common type of NRE that we observed, that is, phone calls and pages. These options include silencing the communication devices or leaving these devices outside the room for someone else to address. External distractions can increase the occurrence of errors during procedures and the number of deviations from protocol, supporting the benefit of interventions focused on this class of NREs.[19]

NREs were more often associated with an individual role rather than the team. Most were attributable to the bedside nurse, reflecting the number of tasks performed by this role (e.g., nasogastric tube placement, intravenous catheter placement). The roles associated with NREs also differed among each phase, likely related to which roles were present and executing the most frequent and critical tasks. For example, NREs during the "prearrival phase" were associated with the surgical surveyor, EMS technician, or leadership roles, those most often present when the team was assembling. In contrast, most NREs in the "critical window" were associated with the anesthesiologist whose role is assigned to airway management and intubation at our hospital. Although trauma resuscitation is a multidisciplinary process, these findings show that interventions to improve the process of intubation also should be targeted at specific roles.

NREs were frequently associated with the potential for patient harm in the "critical window." Because no NRE could be directly linked to an adverse event in this study, this class of NRE can be described as "near-miss" events that represent latent safety threats. The circumstances associated with near-miss events may be similar to those related to errors that lead to adverse outcomes, supporting the study of NREs for identifying the optimal approach for improving performance beyond what can be found using root-cause analysis and other traditional methods.[20] NREs during the "critical window" were most often associated with a delay–a potential safety threat given the urgency of intubation in this setting. Even when not associated with an observed temporal disruption, NREs categorized as interruptions can increase mental fatigue and situational stress.[21] These interruptions may lead to premature task termination and less frequent task completion.[22-24]

Our study findings have several similarities to and differences from the findings of previous studies. The approach to ascertain NREs has varied in previous studies, including administration of surveys to providers after completion of the event, real-time observation, video review, or a combination of these methods.[7,9,10,25,26] An advantage of using video review is the ability to observe the event from multiple views and to perform reviews more than once. A previous study of pediatric intubations in the ED described the advantages of video review for identifying variations in the intubation not observable with other methods.[27] Our finding that NREs are common has also been found in other high acuity settings.[9,10,28] In these settings, several factors increased the likelihood of NREs, including fast pace, reliance on multidisciplinary coordination of concurrent tasks, and high patient acuity. The finding that NREs have the potential for patient harm but often do not cause harm has been described.[7,10] NREs, however, may be associated with adverse events, showing that these events can propagate to the patient and are not only latent sources of harm.[19,29] The predominance of external distractions as a category of NREs has also been observed, as has the finding that NREs frequently lead to process delays.[9,30]

Our study has several limitations. First, this study was performed at a single institution, potentially limiting generalizability. Although assessment at other institutions will be needed to validate our findings, the frequency and impact of NREs have been common findings in NRE analyses in similar settings. Second, the identification of NREs relied on the subjective assessment of physician raters. We used several strategies to minimize this bias, including formalization of the review process, independent and simultaneous video review, and repeated evaluation. Third, our findings are based on the review of a sample of pediatric trauma resuscitations in which we found differences in the indication for intubation between those included and not included during the study period. Confirmation of our results in a larger population of injured children and adults will be needed to confirm the generalizability of our observations. Finally, although we observed that many NREs had potential for harm, we did not find that any led to an adverse event. Confirmation of the impact of NREs will require a large-scale study in which these events can be linked with more rarely occurring adverse events.

Conclusions

Endotracheal intubation during trauma resuscitation is a time-sensitive intervention that can be associated with complications and adverse patient outcomes when delayed. Our study findings confirm that NREs are frequent, contribute to delays, and pose latent safety threats during the most critical phase of intubating injured children. Similar to other studies of NREs in high acuity settings, our study highlights the benefits of qualitative and quantitative analysis of NREs for identifying process variability and its impact.[7-10] A key deliverable of our study is a description of NRE types that can be extended for use in other domains. Recent studies have highlighted the limits of education and simulation training as strategies for improving performance during trauma resuscitation.[31,32] To address these limitations, several complementary strategies have been proposed, including checklists and real-time decision support.[33-35] Our findings provide a framework for identifying strategies that can best address process variability based on the type, associated role, and impact of NREs.

Disclosure

All authors have no conflicts of interest to report.

This work was supported by the National Institutes of Health (award R01LM011834) and the National Science Foundation under grant number IIS-1763355.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jss.2020.09.036.

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