Factors that impact second attempt success for neonatal intubation following first attempt failure: a report from the National Emergency Airway Registry for Neonates

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ABSTRACT

Objective To determine the factors associated with second attempt success and the risk of adverse events following a failed first attempt at neonatal tracheal intubation.

Design Retrospective analysis of prospectively collected data on intubations performed in the neonatal intensive care unit (NICU) and delivery room from the National Emergency Airway Registry for Neonates (NEAR4NEOS).

Setting Eighteen academic NICUs in NEAR4NEOS.

Patients Neonates requiring two or more attempts at intubation between October 2014 and December 2021.

Main outcome measures The primary outcome was successful intubation on the second attempt, with severe tracheal intubation-associated events (TIAEs) or severe desaturation (≥20% decline in oxygen saturation) being secondary outcomes. Multivariate regression examined the associations between these outcomes and patient characteristics and changes in intubation practice.

Results 5805 of 13 126 (44%) encounters required two or more intubation attempts, with 3156 (54%) successful on the second attempt. Second attempt success was more likely with changes in any of the following: intubator (OR 1.80, 95% CI 1.56 to 2.07), stylet use (OR 1.65, 95% CI 1.36 to 2.01) or endotracheal tube (ETT) size (OR 2.11, 95% CI 1.74 to 2.56). Changes in stylet use were associated with a reduced chance of severe desaturation (OR 0.74, 95% CI 0.61 to 0.90), but changes in intubator, laryngoscope type or ETT size were not; no changes in intubator or equipment were associated with severe TIAEs.

Conclusions Successful neonatal intubation on a second attempt was more likely with a change in intubator, stylet use or ETT size.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Neonatal intubation is a common procedure in the neonatal intensive care unit (NICU) and delivery room and has a high rate of first attempt failure and a risk of severe adverse events.

⇒ Current practices and factors affecting second attempt success for neonatal intubation following a failed first attempt are not known.

WHAT THIS STUDY ADDS

⇒ In the majority of second attempts, no changes were made to any of the intubator, laryngoscope type (direct vs video laryngoscope), stylet use or endotracheal tube size.

⇒ Second attempt success is associated with a change in any of the intubator, stylet use or endotracheal tube size; none is associated with severe adverse events.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This large retrospective study provides information on the efficacy and safety of specific practice changes following a failed first attempt at neonatal intubation, which might assist in the design of guidelines for the management of failed intubation attempts in the NICU and delivery room.

INTRODUCTION

Neonatal tracheal intubation (TI) is a vital procedure performed in neonatal intensive care units (NICUs) and delivery rooms that carries significant risks due to procedure-related adverse events.[1] First attempt TI procedural failure is reported amongst up to 40% of experienced senior medical staff and 70% of junior medical staff.[2] Potential harms include intraventricular haemorrhage, neurodevelopmental impairment and death.[1 3 4]

Clinicians consider multiple personnel and equipment choices to use during TI attempts to improve the chance of TI success. The effects of physician training level, stylet use, premedication and family presence on first attempt success rates have been examined.[2 5–8] An increased number of attempts is

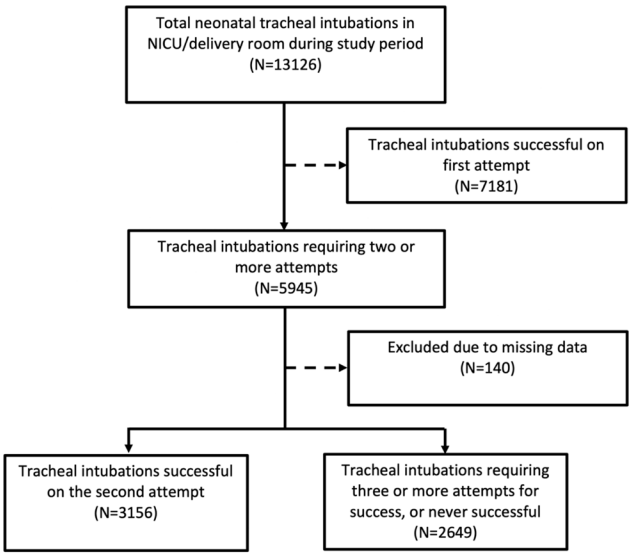

Figure 1 Study flow diagram. NICU, neonatal intensive care unit.

associated with an increased risk of adverse events,[8 9] but no study has explored the factors associated with subsequent TI success following a failed first attempt for neonates. Previous studies on second attempt outcomes in adults found that changing to a more senior intubator and rapid sequence induction increased second attempt success; however, neonatal-specific data are lacking.[10–12] Intubator experience levels, available equipment and intubation guidelines are rarely standardised across NICUs; thus, guidance on the factors that could aid decision-making in this environment is required.

Addressing this, we performed a retrospective cohort study of the National Emergency Airway Registry for Neonates (NEAR4NEOS) database aiming to (1) determine the frequency of changes in intubator and equipment between attempts following a failed first attempt at neonatal TI; and (2) determine the factors associated with an increased chance of a successful second attempt and the factors associated with severe adverse events and severe oxygen desaturation.

METHODS

Study design

This was a retrospective cohort study using prospectively collected data from the multicentre NEAR4NEOS, involving 18 NICUs in the USA, Canada, Europe and Australia.[1] All participating centres obtained a waiver of informed parental consent to use patient data.

Data collection

Data on TIs between October 2014 and December 2021 were included. Each centre collected data on patient, intubator and practice characteristics, as well as outcomes for each TI encounter, using a NEAR4NEOS data collection form with standardised operational definitions.[1] Data collected by local clinical team members immediately following the procedure were entered into a secured, password-protected Research Electronic Data Capture (REDCap) system hosted by the data coordinating centre at the Children's Hospital of Philadelphia (Philadelphia, USA).

Inclusion and exclusion criteria

All TI encounters in the NICU or delivery room requiring more than one attempt to achieve successful TI were included; encounters that only involved one attempt or ended with placement of a laryngeal mask were excluded.

Definitions

NEAR4NEOS defines a TI encounter as the sequence of events leading to placement of an endotracheal tube (ETT) for a specific infant at a specific time. An attempt begins with insertion of a laryngoscope or other device into the patient's mouth or nose and ends when the device is removed or the ETT is placed. A difficult airway is defined as any of the following: known history of difficult airway, widest mouth opening/thyromental space less than three patient fingers, airway obstruction, midface hypoplasia, micrognathia, cleft palate or limited neck extension.[13] For this study, a change in intubator is defined as a change in either the discipline (neonatology/general paediatrics/anaesthetics/ear, nose and throat/surgery/respiratory therapy/other) or experience level (attending/trainee/nurse practitioner/physician assistant/hospitalist) of the person attempting TI between the first and second attempts. Change in laryngoscope is defined as a change in the laryngoscope type (direct or video-assisted) between the first and second attempts. Change in stylet use is defined as either the insertion or removal of an ETT stylet between the first and second attempts. Change in ETT size is defined as a change in the internal diameter size of the ETT between the first and second attempts. None of the participating NICUs had a standardised protocol to specify changes in intubator or equipment between attempts; changes were made at the local team's discretion.

Outcome measures

The primary outcome was second attempt success, defined as successful TI following a failed first attempt within the same encounter. Secondary outcomes were severe tracheal intubation-associated events (TIAEs) and severe oxygen desaturation, according to NEAR4NEOS operational definitions. Severe TIAEs were defined as the occurrence of any of the following during TI: cardiac arrest, oesophageal intubation with delayed recognition, hypotension requiring therapy, cardiac compressions <1 min, laryngospasm, pneumothorax or direct airway injury. Severe oxygen desaturation was defined as ≥20% absolute decrease in oxygen saturation during the encounter from the highest level recorded immediately prior to the first TI attempt.

Statistical analysis

Summary statistics (median, IQR and proportion) were calculated for patient, intubator and practice characteristics. Wilcoxon rank-sum test was used to analyse differences between non-parametric variables and Fisher's exact test was used to analyse associations between categorical variables. The data set was then randomly split using a 1:1 ratio into training and testing subgroups. Variables describing patient characteristics and TI processes (such as premedication use and location) as well as changes in intubator or equipment were included in multivariate regression models. These models used penalised lasso regression to shrink the absolute value of the coefficients and therefore automatically eliminate variables which were not significant contributors from the final regression and then model the primary and secondary outcomes; the model was trained on the training subgroup and then tested on the testing subgroup. Corresponding ORs and 95% CIs were presented. The predictive

Table 1 Patient and practice characteristics stratified by second attempt outcome

Characteristic	Successful second attempt (n=3156)	Unsuccessful second attempt (n=2649)	P value*
Gestational age at birth, weeks, median (IQR)	28 (25–35)	28 (25–33)	<0.01
Age in days, median (IQR)	1 (0–25)	2 (0–24)	0.18
Weight at intubation, g, median (IQR)	1540 (890–2801)	1344 (840–2500)	<0.01
Sex (male), n (%)†	1853 (59)	1488 (56)	0.15
Intubation within NICU, n (%)	2322 (74)	2067 (78)	<0.01
Comorbidities, n (%)			
Sepsis	182 (6)	152 (6)	1.0
Congenital heart disease	230 (7)	152 (6)	0.02
Congenital anomaly requiring surgery	355 (11)	181 (7)	<0.01
Airway anomaly	140 (4)	128 (5)	0.49
Neurological impairment	184 (6)	134 (5)	0.20
Acute respiratory failure	1973 (63)	1814 (68)	<0.01
Chronic respiratory failure	513 (16)	441 (17)	0.70
Surgery/procedure for acquired disorder	128 (4)	122 (5)	0.33
Intubation indication, n (%)			
Oxygen failure	804 (25)	708 (27)	0.28
Procedure	205 (6)	177 (7)	0.79
Ventilation failure	749 (24)	696 (26)	0.02
Frequent apnoea and bradycardia	452 (14)	463 (17)	0.001
Upper airway obstruction	88 (3)	83 (3)	0.44
Therapeutic hyperventilation	5 (<1)	1 (<1)	0.23
Neuromuscular weakness	4 (<1)	6 (<1)	0.53
Emergency drug administration	15 (<1)	10 (<1)	0.69
Unstable haemodynamics	94 (3)	65 (2)	0.23
Absent protective airway reflexes	19 (<1)	11 (<1)	0.36
Surfactant administration	797 (25)	752 (28)	0.007
DR - routine practice for diagnosis	108 (3)	54 (2)	0.001
DR - clinical indication	660 (21)	475 (18)	0.005
Reintubation after unplanned extubation	248 (8)	139 (5)	<0.01
Other	131 (4)	109 (4)	0.99
Airway clearance	7 (<1)	8 (<1)	0.61
Difficult airway, n (%)	765 (24)	761 (29)	<0.01
Difficult mask ventilation‡, n (%)	369 (12)	365 (14)	0.04
Premedications used, n (%)			
No sedation or paralysis	1484 (47)	1219 (46)	0.46
Paralysis only	19 (1)	31 (1)	0.32
Sedation only	386 (12)	535 (20)	<0.01
Sedation and paralysis	1255 (40)	876 (33)	<0.01

*Wilcoxon rank-sum test for continuous variables; Fisher's exact test for categorical variables.
†Sex unknown in 15 neonates.
‡259 recorded as 'N/A'.
DR, delivery room; N/A, not available; NICU, neonatal intensive care unit.

performance of the resulting models was calculated using the testing data set and described using area under the receiver operating characteristic curve (AUC) values. Statistical analysis was performed using R, with a p value <0.05 considered significant.

RESULTS

Patient, intubator and practice characteristics

Among 13 126 TIs performed during the study period, 5805 (44%) required at least two attempts and had complete data. Successful TI occurred on the second attempt in 3156 (54%) of these (figure 1). The proportions of overall TIs contributed by the 18 centres ranged from 0.76% to 17.6%.

Infants successfully intubated on the second attempt were larger and more commonly intubated in the delivery room (table 1). Intubator and practice characteristics for failed first attempts at TI are shown in table 2. The most common discipline was neonatology (n=4211, 73%); medical trainees (n=2976, 51%) were most likely to perform the first attempt, followed by nurse practitioners (n=1307, 23%) and attending physicians (n=244, 4%). The oral route was used in 5569 (96%) of failed first attempts. Direct laryngoscopy and stylets were used in 4429 (76%) and 4348 (75%) failed first attempts, respectively.

Factors associated with second attempt success

In most TI encounters (3855, 66%), neither the intubator nor the equipment was changed between the first and second attempt. Change in intubator was the most common change between the first and second attempt, occurring in 1064 encounters (18%),

Table 2 Intubator and practice characteristics for failed first attempts at intubation

Characteristic	Failed first attempt (n=5805)
Intubator discipline, n (%)	
Neonatology	4211 (73)
General paediatrics	1088 (19)
Anaesthetics	31 (<1)
Ear, nose and throat	26 (<1)
Surgery	96 (2)
Respiratory therapy	277 (5)
Other	75 (1)
Intubator experience level, n (%)	
Attending	244 (4)
Trainee	2976 (51)
Hospitalist	150 (3)
Nurse practitioner	1307 (23)
Physician assistant	459 (8)
Unknown	669 (12)
Intubation route, n (%)	
Oral	5569 (96)
Nasal	205 (4)
Other/unknown	31 (<1)
Laryngoscope type, n (%)	
Direct	4429 (76)
Video	1342 (23)
Other/unknown	34 (<1)
Stylet used, n (%)	4348 (75)
Premedication used, n (%)	
No sedation or paralysis	2638 (45)
Paralysis only	36 (1)
Sedation only	938 (16)
Sedation and paralysis	2193 (38)

followed by change in ETT size (548, 9%), stylet use (9%; 370 stylet added, 134 removed) or laryngoscope type (110, 2%) (table 3). Two or more changes occurred simultaneously in 244 (4%) TI encounters, but this did not increase success beyond just making one change (OR 1.19, 95% CI 0.89 to 1.62). Attending physicians were more likely than others to change equipment (OR 2.24, 95% CI 1.67 to 2.97). On univariate analysis, second attempt success was more likely with any change in intubator, stylet use or ETT size (all p<0.001), but not with a change in laryngoscope type (p=0.33). These three factors remained significantly associated with second attempt success on multivariate modelling (table 4): change in intubator (OR 1.80, 95% CI 1.56 to 2.07), change in stylet use (OR 1.65, 95% CI 1.36 to 2.01) and change in ETT size (OR 2.11, 95% CI 1.74 to 2.56). The presence of a difficult airway (OR 0.77, 95% CI 0.68 to 0.87) or intubating within the NICU rather than the delivery room (OR 0.78, 95% CI 0.68 to 0.91) were associated with a reduced chance of success on second attempt.

Table 4 Multivariate lasso regression model for second attempt success*

Characteristic†	OR	95% CI
Change of intubator	1.80	1.56 to 2.07
Change of stylet use	1.65	1.36 to 2.01
Change of ETT size	2.11	1.74 to 2.56
Premedication use - sedation and paralysis	1.28	1.12 to 1.46
Premedication use - sedation only	0.69	0.59 to 0.82
Difficult airway	0.77	0.68 to 0.87
Intubation in NICU	0.78	0.68 to 0.91

*n=3156; the model's area under the curve value was 0.64 (95% CI 0.62 to 0.66).
†Postmenstrual age and age in days were highly correlated with current weight and were therefore removed to avoid multicollinearity. The following variables were non-significant and excluded from the final model: change of laryngoscope, gestational age, current weight, patient sex and difficult mask ventilation.
ETT, endotracheal tube; NICU, neonatal intensive care unit.

Factors associated with severe TIAEs and severe oxygen desaturation

Serious TIAEs occurred in 316 (5%) TIs requiring two or more attempts. The occurrence of severe TIAEs was not associated with a change in intubator, stylet use, ETT size or laryngoscope (table 5). Increasing gestational age at birth (OR 0.97, 95% CI 0.95 to 0.99) and combined use of sedation and paralysis (OR 0.60, 95% CI 0.46 to 0.78) were associated with a reduced occurrence of a severe TIAE, while difficult mask ventilation (OR 2.93, 95% CI 2.30 to 3.75) was associated with an increased occurrence.

Severe oxygen desaturation occurred in 3354 (58%) TIs requiring two or more attempts. On multivariate analysis (table 6), change in stylet use (OR 0.74, 95% CI 0.61 to 0.90) and increasing gestational age (OR 0.96, 95% CI 0.95 to 0.97) were associated with a reduced occurrence of severe desaturation, while difficult mask ventilation (OR 1.41, 95% CI 1.23 to 1.63), combined use of sedation and paralysis (OR 1.87, 95% CI 1.63 to 2.15), use of sedation alone (OR 1.74, 95% CI 1.47 to 2.07) and being intubated within the NICU (OR 2.74, 95% CI 2.36 to 3.19) were associated with increased occurrence. Change in ETT size, intubator or laryngoscope type was not associated with severe desaturation.

DISCUSSION

This is the largest multicentre study to examine specifically the practices involved in TI after a failed first attempt in neonates. First attempt failure was common in our population, occurring in 44% of all TIs.[1 14 15] Second attempt failure rate was similarly

Table 3 Univariate associations between changes in practice and second attempt outcome

Practice change*	Changed on second attempt, n (%)	Successful TI on second attempt, n (%)	OR (95% CI)†	P value
Change of intubator	1064 (18)	700 (66)	1.79 (1.55 to 2.06)	<0.01
Change of ETT size	548 (9)	382 (70)	2.06 (1.70 to 2.51)	<0.01
Change of stylet use	504 (9)	337 (67)	1.78 (1.46 to 2.17)	<0.01
Change of laryngoscope type	110 (2)	65 (59)	1.22 (0.82 to 1.83)	0.33

*No change occurred in 3855 (66%) TIs; of these, 1863 (48%) were successful on the second attempt.
†Fisher's exact test.
ETT, endotracheal tube; TI, tracheal intubation.

Table 5 Multivariate lasso regression model for severe TIAEs*

Characteristic†	OR	95% CI
Gestational age (weeks)	0.97	0.95 to 0.99
Difficult mask ventilation	2.93	2.30 to 3.75
Premedication use - sedation and paralysis	0.60	0.46 to 0.78

*n=316; TIAE data collected at the level of overall TI encounter rather than attempt. The model's area under the curve value was 0.65 (95% CI 0.60 to 0.70).
†Postmenstrual age and age in days were highly correlated with current weight and were therefore removed to avoid multicollinearity. The following variables were non-significant and excluded from the final model: change of intubator, change of ETT size, change of stylet use, change of laryngoscope, current weight, patient sex, difficult airway, intubation in NICU and premedication use - sedation only.
ETT, endotracheal tube; NICU, neonatal intensive care unit; TI, tracheal intubation; TIAE, tracheal intubation-associated event.

high, at 46%. There was no change in intubator or equipment for the second attempt in most encounters. Since second attempt success increased following some changes, these findings suggest the approach for second attempts could be optimised by making changes after the first failed attempt, rather than deferring changes until multiple failed attempts. The infrequency of change in intubator or equipment may reflect a lack of clear guidance following a failed first attempt in TI protocols.[16 17] The low rate of change in laryngoscope type may reflect a lack of availability of video laryngoscopy (VL) as well as a lack of confidence and training in its use.[18] While the described changes were uncommon, other changes in practice not recorded in the NEAR4NEOS registry may have occurred between attempts, such as the use of external laryngeal manipulation or neck rolls.

Second attempt success increased when changing the intubator, stylet use or ETT size. Seniority was associated with increased first attempt TI success in the NEAR4NEOS registry.[1 2] Our study accords with these findings, although more research is needed to understand what factors may influence the clinical team to change intubator between attempts and whether there are specific scenarios where such changes are advantageous. Second attempt success also increased with combined sedation and neuromuscular blockade during the TI encounter but reduced with the use of sedation alone, consistent with previous NEAR4NEOS data on first attempt success.[19]

Stylet use has previously been shown not to influence the chance of first attempt success.[5 6] However, unlike the first TI attempt, the intubator has obtained direct knowledge of the specific airway anatomy to optimise the second attempt. They may then be able to use this knowledge to consider whether stylet use may or may not be beneficial for that specific airway, potentially explaining the increased success related to either adding or removing a stylet for the second attempt. With adequate preprocedural preparation, changing either stylet use and/or ETT size is a relatively simple and quick intervention to introduce into an intubation encounter with minimal training. Clinicians should nevertheless consider what effect smaller ETT size may have on tube leak and ventilation.

Table 6 Multivariate lasso regression model for severe desaturation*

Characteristic†	OR	95% CI
Change of stylet use	0.74	0.61 to 0.90
Gestational age (weeks)	0.96	0.95 to 0.97
Difficult mask ventilation	1.41	1.23 to 1.63
Premedication use - sedation and paralysis	1.87	1.63 to 2.15
Premedication use - sedation only	1.74	1.47 to 2.07
Intubation in NICU	2.74	2.36 to 3.19

*n=3354; severe desaturation data collected at the level of overall TI encounter rather than attempt. The model's area under the curve value was 0.68 (95% CI 0.66 to 0.70).
†Postmenstrual age and age in days were highly correlated with current weight and were removed to avoid multicollinearity. The following variables were non-significant and excluded from the final model: change of intubator, change of laryngoscope, change of ETT size, current weight, patient sex and difficult airway.
ETT, endotracheal tube; NICU, neonatal intensive care unit; TI, tracheal intubation.

The majority of first and second attempts were performed with direct laryngoscopy. Change in laryngoscope type was rare and did not increase the chance of second attempt success. Several studies have suggested benefits to VL as a training tool for less experienced neonatal staff, although evidence regarding broader settings and experience levels is less clear.[7 20–22] A Cochrane systematic review of VL use in neonates reported increased success for the first attempt at TI, but no overall reduction in the number of TI attempts, with modest sample sizes and moderate to very low quality evidence.[23] A more recent study from the NEAR4NEOS registry did not find any independent association between VL use and first attempt success.[24] As both primary VL use and changing to VL for the second attempt were uncommon, our study was underpowered to make meaningful conclusions about the effects of VL on second attempt success. Large prospective trials would assist in delineating the role of VL in neonatal TI. Given the increasing use of VL as a training tool and the recent development of smaller blades better suited to premature infants, there is potential that TI success using VL may increase as individuals and institutions develop expertise.[18]

After adjusting for other patient and practice characteristics, a change in intubator did not alter the occurrence of either a severe TIAE or severe desaturation within the overall TI encounter. This finding may provide reassurance that allowing less experienced intubators to perform a second attempt does not increase the risk of a severe TIAE as defined in this study. Practice changes over time have reduced TI training opportunities,[25] provoking concerns that trainees at completion may only achieve modest levels of competency at performing and troubleshooting TI.[26–28] Each TI attempt is a valuable training opportunity, but the need to facilitate procedural learning must be balanced with the safety of allowing a trainee to attempt the procedure. Our data on adverse outcomes on second attempts support the practice of allowing less experienced intubators to proceed with a second attempt following a failed first attempt if deemed safe to do so, and the lower chance of success and the specific risks and clinical indication for intubation for that infant are considered. The efficacy and safety of more than two attempts by the same intubator were not assessed and warrant further exploration.

Our study has limitations. The separate effects of different directions of change in intubator or equipment were not analysed. The rationale for changing or not changing intubator or equipment is unknown. Data on TIAEs and desaturation were collected at the level of TI encounter or course, rather than each attempt, meaning that the direction of any association between practice changes and these outcomes is not certain. The modest AUC values for the multivariate predictive models may reflect the impact of important unmeasured factors on the outcomes. Data on each TI attempt were self-reported by the medical staff performing the TI, but standard NEAR4NEOS operational definitions aim to minimise reporting bias. Finally, data in this study were collected from academic NICUs, limiting generalisability to smaller centres where team resources and processes may be different.

CONCLUSION

Changes in intubator, ETT size or stylet use were all associated with a greater chance of a successful second TI attempt, and clinical teams should consider making one or more of these changes following a failed first attempt, instead of repeating the attempt in an identical manner. Changing laryngoscope type was uncommon and had no observed effect when performed. Changing stylet use was associated with a lower chance of severe desaturation, but none of the examined changes was associated with any reduction in severe TIAEs. These findings may help inform revised protocols for how to manage a second attempt at TI following a failed first attempt, and support finding an optimal balance between maximising success and safety while retaining valuable real-world training opportunities for less experienced intubators.

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Data availability statement Data are available upon reasonable request. Individual subject data collected during the study and statistical analysis will be available beginning at 12 months and ending 5 years after article publication to researchers who provide a methodologically sound proposal with approval by the NEAR4NEOS Manuscript Oversight Committee. Data will be available for analysis to achieve aims in the approved proposal. Proposals should be directed to buffmanH@chop.edu; to gain access, data requestors will need to sign a data access agreement approved by the Children's Hospital of Philadelphia.

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