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Open and percutaneous pediatric tracheostomy: comorbidities and in-hospital mortality

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Abstract

Background Tracheostomy procedures are used to establish a surgical airway in patients when non-invasive methods fail to offer adequate support. In pediatric patients, this procedure is relatively rare, and data on patients is scarce, limiting the ability of physicians to contextualize patient outcomes and identify those most at risk. This can be crucial, as research has shown that early tracheostomy in pediatric patients may improve clinical outcomes. The objective of this study is to characterize the comorbidities of pediatric patients undergoing open and percutaneous tracheostomies and examine their association with in-hospital mortality, as well as to compare patient demographics and comorbidity frequency between the two approaches. The 2016 Kids' Inpatient Database was used to identify patients younger than 21 with ICD-CM-10 codes for open or percutaneous tracheostomies to determine demographic characteristics and identify the most frequent comorbidities in these patient cohorts.

Results A weighted total of 5229 cases were analyzed. Congenital cardiopulmonary defects, newborn respiratory diseases, and traumatic lung or brain injury were the most common comorbidities for tracheostomy patients. In open tracheostomies, there was an increased likelihood of in-hospital mortality in patients aged less than one (OR = 2.2; 95% CI, 1.6–3.0) and in patients with atrial septal defects (OR = 1.9; 95% CI, 1.5–2.5), patent ductus arteriosus (OR = 2.5, 95% CI, 2.0–3.3), bronchopulmonary dysplasia (OR = 2.1; 95% CI, 1.6–2.8), and acute kidney injury (OR = 5.6, 95% CI, 4.3–7.2). Trauma-related comorbidities were more common in patients who underwent percutaneous procedures and were not associated with an increased likelihood of mortality. Patient age < 1 was associated with an increased risk of in-hospital mortality in both the open (OR = 2.2; 95% CI, 1.6–3.0) and percutaneous (OR = 2.3, 95% CI (1.3–3.9) approaches.

Conclusion There are many indications for pediatric tracheostomy, and patients often present with complicated disease profiles and complicated courses of care. Broadly, we found that congenital cardiopulmonary defects were associated with a higher likelihood of in-hospital patient mortality, especially in younger patients undergoing an open-approach procedure. Patients undergoing a percutaneous-approach procedure were more likely to have trauma-related comorbidities such as pneumothorax or brain hemorrhage that were not associated with in-hospital mortality.

Keywords Tracheostomy, Pediatrics, Socioeconomic status, Congenital birth defects, Pediatric surgery

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Background

Tracheostomy procedures are used to establish a surgical airway in patients when non-invasive methods fail to offer adequate support [1]. In pediatric patients, this procedure is relatively rare [2]. Tracheostomies occur in less than 1.5% of ventilated children, compared with 10–24% of ventilated adults [3]. The procedure is classically performed using either an open approach (OT) or a percutaneous approach (PT) as described in Watters et al. [4].

Due to its infrequency in pediatric care, data on patient profiles are scarce, which could limit the ability of physicians to identify pediatric patients most at risk for tracheostomy, as well as comorbidities that may complicate hospital care or infer mortality risk. Pediatric patients with tracheostomies have a threefold greater morbidity and mortality compared to adult patients [5]. Research has shown that early tracheostomy in children on mechanical ventilation may improve medical outcomes [6]. Given the benefit of early tracheostomy and the level of care and preparation required for this procedure, identifying pediatric patients at risk is of high clinical importance.

Pediatric tracheostomy patients regularly present with complicated disease profiles and prolonged hospitalizations, often requiring long-term, complex care after discharge [4]. Caregivers must be well-prepared and well-resourced for routine care of their child's tracheostomy tube and identification of medical emergencies [7]. However, in a survey of 220 tracheostomy caregivers, McCormick et al. found that only 48% felt "very prepared" to treat their patient at the time of discharge, 11% did not receive emergency training, and 14% sought emergent care within one week of discharge [8]. The financial, emotional, and physical burdens of post-tracheostomy childcare can be detrimental to caregivers, and a better understanding of patient risk factors, comorbidities, and complications may help providers better support patient families [9].

This study uses a national database to characterize the most common comorbidities within pediatric tracheostomy patients and explores their association with in-hospital mortality, as well as compare patient demographics and common comorbidities between OT and PT patients. It also examines overall in-hospital mortality rates for pediatric tracheostomy patients and explores associations between age, gender, and mortality.

Methods

Our study examined nationwide pediatric hospitalizations in 2016 with the Kids' Inpatient Database (KID), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality, which provides national estimates of hospital inpatient stay for patients younger than 21 years of age [10]. The HCUP has many contributing partners [11]. Boston Medical Center and Boston University Medical Campus Institutional Review Board did not require approval or exemption, as the KID is a public database, and research with publicly available data does not meet the definition of human subject research at our institution under 45 CFR 46. Data were obtained from the most recent KID, which provides data on nationwide inpatient discharges in 2016.

Patients with International Classification of Diseases, 10th Revision, Procedure Coding System codes corresponding to OT and PT procedures were included in our analysis. The International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) codes for these procedures, as well as diagnoses of concurrent medical problems in these patients, were used to collect data [12]. To demonstrate national estimates, we applied discharge weights provided in the KID to each discharge data value. Stratifying variables used to produce discharge weights were geographic region, urban/rural location, teaching status, bed size, ownership, and children's hospital [11]. Statistical analysis in this study was performed using SPSS Statistics (v 26; IBM corp).

After separating patients who had undergone OT or PT from the overall KID cohort, the most prevalent ICD-10-CM diagnosis codes among these patients were identified to examine the prevalence of different comorbidities. This was repeated in a separate cohort containing OT and PT patients who died during their hospitalization. Odds ratios (ORs) and 95% confidence intervals (CIs) were used to determine associations between individual comorbidities and likelihood of patient death during hospitalization.

Binary logistic regression models were used to assess if patient age or gender was associated with in-hospital mortality. ORs and CIs were used to describe associations between these patient characteristics and clinical outcomes. The statistical significance of variables within the regression models was determined with a Wald chi-square test ($p < 0.05$).

Results

Patient demographics

There were 6,266,285 weighted pediatric hospitalizations in the 2016 KID. We identified 4004 OT procedures and 1225 PT procedures. Prevalence rates within the database population for OT and PT were 2.56 and 0.78 per 100,000 patients, respectively. The mean and median ages of patients undergoing OT and PT were 7.4 and 3.0 years and 11.7 and 16.0 years, respectively.

Forty-two percent of OT patients were under 1 year old, and 50.4% of 1-year-old patients were neonates, defined by the KID as patients admitted within 28 days

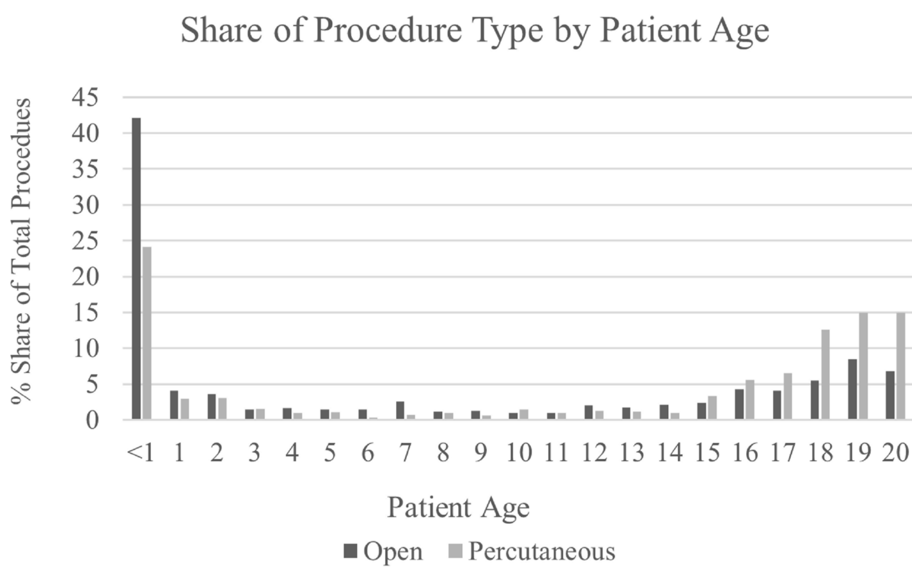

Fig. 1 Percentage share of procedure type by patient age, OT, and PT

Table 1 Patient sex and percentage share of procedure cohort, OT and PT approaches

	Open ($n=4004$) N, share of patient cohort (%)[a]	Percutaneous ($n=1225$) N, share of patient cohort (%)
Sex		
Male	2429 (60.7)	817 (66.9)
Female	1572 (39.3)	408 (33.1)

[a] 3 patients in this cohort did not have listed information on sex

Table 2 Multivariate OR analysis comparing patient age and sex with in-hospital mortality for OT and PT

	Open		Percutaneous	
Variable	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Age				
< 1	2.22 (1.63–3.02)	.000	2.26 (1.32–3.85)	.003
Neonates	1.67 (1.23–2.23)	.001	1.51 (0.74–3.09)	.262
1–5	0.79 (0.47–1.31)	.351	0.44 (0.13–1.51)	.193
6–10	0.68 (0.35–1.30)	.242	0.51 (0.09–2.98)	.452
11–15	1.07 (0.64–1.77)	.804	0.85 (0.30–2.39)	.759
16–20	–[a]	–	–[a]	–
Sex				
Male	–[a]	–	–[a]	–
Female	0.79 (.472–1.31)	.558	1.80 (1.11–2.92)	.018

[a] Reference value

of birth (Fig. 1). Patients younger than one accounted for 24% of those undergoing PT, and 58% of patients were between the ages of 15–20 (Fig. 1). Male patients made up the majority of our patient cohort, representing 60% of OT procedures and 66% of PT procedures (Table 1).

Patient mortality

Table 2 shows the relationship between in-hospital mortality and patient age and sex, using OR analysis. Three hundred eleven (7.8%) patients undergoing OT died during their hospitalization. There was an increased likelihood of in-hospital mortality in patients younger than 1 year old (OR = 2.22; 95% CI = 1.63–3.02). In the cohort of patients younger than one, neonatal age was further associated with an increased likelihood of mortality compared to those older than 28 days of life (OR = 1.67; 95% CI = 1.23–2.26) (Table 2).

Seventy-four PT patients (6.0%) died during their hospitalization. Patients younger than 1 year old (OR = 2.26; 95% CI = 1.32–3.85) had an increased likelihood of in-hospital mortality. Female PT patients (OR = 1.739; 95% CI = 1.07–2.81) also had an increased likelihood of in-hospital mortality (Table 2).

Additionally, we examined which comorbidities were most common among patients undergoing OT and PT procedures, as well as whether they were associated with an increased or decreased likelihood of in-hospital mortality. These findings are shown in Tables 3 and 4, respectively.

Discussion

Given the infrequency of tracheostomies in younger patients, a large database was useful in examining demographic trends and comorbidities. To our knowledge, no studies exist that so broadly examine patient

Table 3 Prevalence of comorbidities in OT patients and their association with in-hospital mortality using OR analysis

Diagnoses	Share of patient cohort (%)	Share of patients with in-hospital mortality (%)	OR (95% CI)
Atrial septal defect (Q21.1)[a]	813 (20.30)	99 (31.83)	1.94 (1.51–2.51)
Atelectasis (J98.11)	789 (19.71)	50 (16.08)	0.77 (0.56–1.05)
Acute tracheitis without obstruction (J04.10)	707 (17.66)	43 (13.83)	0.73 (0.52–1.02)
Bronchopulmonary dysplasia originating in the perinatal period (P27.1)	591 (14.76)	79 (25.40)	2.12 (1.61–2.77)
Patent ductus arteriosus (Q25.0)	573 (14.31)	87 (27.97)	2.56 (1.97–3.34)
Acute post-hemorrhagic anemia (D62)	524 (13.09)	31 (9.97)	0.71 (0.49–1.05)
Respiratory failure of newborn (P28.5)	502 (12.54)	74 (23.79)	2.38 (1.80–3.15)
Anemia of prematurity (P61.2)	472 (11.79)	53 (17.04)	1.60 (1.17–2.19)
Acute kidney failure, unspecified (N17.9)	405 (10.11)	103 (33.12)	5.56 (4.27–7.24)
Pleural effusion, not elsewhere classified (J90)	319 (7.97)	30 (9.65)	1.26 (0.84–1.87)
Pulmonary hypertension, unspecified (I27.20)	319 (7.97)	46 (14.79)	3.09 (2.27–4.22)
Respiratory distress syndrome of newborn (P22.0)	297 (7.42)	44 (14.15)	2.24 (1.59–3.19)
Persistent fetal circulation (P29.3)	256 (6.39)	59 (18.97)	4.15 (3.02–5.71)
Ventricular septal defect (Q21.0)	247 (6.17)	36 (11.58)	1.90 (1.31–2.76)
Transient neonatal thrombocytopenia (P61.0)	226 (5.64)	33 (10.61)	2.15 (1.46–3.18)
Traumatic pneumothorax, initial encounter (S27.0XXA)	186 (4.65)	1 (0.01)	0.06 (0.01–0.44)
Congenital hypoplasia and dysplasia of the lung (Q33.6)	136 (3.40)	28 (9.00)	3.28 (2.13–5.06)
Bloodstream infection due to a central venous catheter (T80.211A)	105 (2.62)	31 (9.97)	5.29 (3.42–8.19)

[a] Corresponding ICD-10-CM code for listed diagnosis

Table 4 Prevalence of comorbidities in PT patients and their association with in-hospital mortality using OR analysis

Diagnoses	Share of patient cohort (%)	Share of patients with in-hospital mortality (%)	OR (95% CI)
Acute post-hemorrhagic anemia (D62)[a]	308 (25.14)	14 (18.92)	0.68 (0.38–1.25)
Atelectasis (J98.11)	228 (18.61)	13 (17.57)	0.92 (0.50–1.72)
Pneumonitis due to inhalation of food and vomit (J69.0)	196 (16)	9 (12.16)	0.71 (0.35–1.46)
Atrial septal defect (Q21.1)	146 (11.92)	19 (25.68)	2.79 (1.60–4.84)
Traumatic pneumothorax, initial encounter (S27.0XXA)	130 (10.61)	4 (5.41)	0.46 (0.17–1.29)
Glasgow coma scale score 3–8 (R40.243)	125 (10.2)	4 (5.41)	0.49 (0.17–1.36)
Acute kidney failure, unspecified (N17.9)	122 (9.96)	11 (14.86)	1.63 (0.84–3.20)
Other fracture of the base of the skull, initial encounter for closed fracture (S02.19XA)	121 (9.88)	4 (5.41)	0.50 (0.18–1.41)
Acute tracheitis without obstruction (J04.10)	118 (9.63)	9 (12.16)	1.32 (0.64–2.73)
Bilateral contusion of lung (S27.322A)	112 (9.14)	6 (8.11)	0.87 (0.37–2.05)
Cerebral edema (G93.6)	111 (9.06)	13 (17.57)	2.29 (1.22–4.31)
Subarachnoid hemorrhage w/loss of consciousness (S06.6X9A)	104 (8.49)	1 (1.35)	0.13 (0.02–1.01)
Traumatic subdural hemorrhage w/loss of consciousness (S06.5X9A)	103 (8.41)	1 (1.35)	0.14 (0.02–1.02)
Pleural effusion, not elsewhere classified (J90)	98 (8.00)	3 (4.05)	0.47 (0.15–1.52)
Anoxic brain damage, not elsewhere classified (G93.1)	93 (7.59)	7 (9.46)	1.29 (0.57–2.90)
Patent ductus arteriosus (Q25.0)	85 (6.94)	13 (17.57)	3.31 (1.73–6.31)
Bronchopulmonary dysplasia originating in the perinatal period (P27.1)	78 (6.37)	11 (14.86)	2.88 (1.45–5.72)
Unilateral contusion of the lung (S27.321A)	69 (5.63)	1 (1.35)	0.21 (0.03–1.59)
Ventricular septal defect (Q21.0)	56 (4.57)	11 (14.86)	4.29 (2.11–8.69)

[a] Corresponding ICD-10-CM code for listed diagnosis

comorbidities and their associations with in-hospital mortality for both OT and PT in pediatric patients, as well as compare patient demographics and comorbidities for these procedures. Our results show OT as the more commonly chosen approach in younger patients, with PT becoming more prevalent in ages 15–20. Though PT has gained substantial evidence in adult populations for its safety, efficacy, and cost-effectiveness compared to OT in recent years [13, 14], comparative data between the two procedures is sparse in pediatric populations.

Historically, PT was not often utilized in airway management of pediatric patients because the small, mobile characteristics of the trachea were thought to make this approach dangerous [15]. There has also been concern that bronchoscopic guidance during the procedure could compromise ventilation [15]. A 2019 retrospective study comparing the two approaches in pediatric patients showed PT to be a feasible approach in children, with endoscopic guidance recommended for the control of intra-procedural complications. This same study showed no differences in intra-operative complications between OT and PT, with long-term complications being more common in OT patients, indicating PT can be a suitable option in the airway management of some children [16]. However, data on the safety and efficacy of PT in patients aged 0–5 years old is sparse, and studies with longer follow-ups and higher patient counts may be needed to determine the lowest age for its safe performance [2].

PT patients were of a higher median age than OT, largely due to the increased prevalence of PT in patients aged 15–20. One possible explanation for this finding is the increased risk of trauma-related injury within this age cohort, particularly in male patients [17]. Table 3 shows brain hemorrhages, skull fractures, and coma were relatively common comorbidities in PT patients, with a prevalence of 8–10% depending on the diagnosis code examined. Acute post-hemorrhagic anemia, potentially a sign of rapid blood loss, occurred in approximately 25% of PT patients. Research in the adult population has shown PT to be a successful intervention in patients with brain [18] and spinal cord injury [19]. Additionally, a 2013 study on critically injured trauma patients found PT to have a lower risk of surgical site infection when compared to OT [20]. Currently, no evidence or guidelines broadly favors one surgical approach versus the other, so our findings align with current literature showing procedure choice is often the result of surgeon preference [21]. They were analyzed separately to define prevalence, demographics, and comorbidities more precisely in each approach, given the lack of current studies comparing the techniques in pediatric patients.

Our analysis revealed in-hospital mortality rates that are consistent with previous values from studies utilizing KIDs from 2000 to 2012 [2]. Although technique has not changed much over the previous two decades, there have been significant evolutions in indications, complications, and technological advances [22], although this does not seem to have led to a significant decline in in-hospital mortality. One possible explanation is the increase in indications for tracheostomy in pediatric patients due to better survival of premature infants and those suffering from severe congenital anomalies, creating a patient cohort that may have a higher baseline risk for mortality than the cohort of 20 years ago [23]. Our analysis also found associations between patient age, gender, and procedure mortality that have been noted in prior literature [24], with the additional finding of neonatal age further increasing the likelihood of in-hospital mortality. Tables 2 and 3 show congenital heart defects, acute respiratory pathologies, and traumatic lung or brain injury were the most common comorbidities, with congenital cardiopulmonary defects having the greatest association with in-hospital mortality.

Previous literature has noted increased mortality in tracheostomy patients with congenital heart disease but has not examined mortality rates for each specific defect [24]. Although ventricular septal defects are the most common congenital heart defect in the general pediatric population [25], we identified atrial septal defect as the most prevalent within pediatric tracheostomy patients. A 2018 study showed that patients with atrial septal defects were also more likely to have bronchopulmonary dysplasia, a comorbidity also found to be associated with in-hospital mortality [26]. We found bronchopulmonary dysplasia and atrial septal defects were both twice as likely to be found in the younger cohort of OT patients, indicating that neonate patients with combined cardiac and pulmonary defects may be at the highest risk for in-hospital mortality following tracheostomy procedures.

Acute kidney injury (AKI) was also associated with a higher likelihood of in-hospital mortality. We found no prior study examining the connection between AKI and mortality among tracheostomy patients. In a study conducted by Youseff et al., predisposing factors to AKI included mechanical ventilation, particularly in newborn populations whose comorbidities include respiratory distress syndrome [27]. A separate study examining pediatric patients with postoperative AKI found these patients had an increased rate of tracheostomy and a longer duration of postoperative ventilation [28]. It follows that tracheostomy patients who develop AKI during their hospitalization may represent those with more severe respiratory distress, increasing mortality risk.

Follow-up

When compared to other research examining demographic trends and comorbidities within pediatric tracheostomies, our large sample size increases the external validity and generalizability of our findings. To our knowledge, our study is the first to use an inpatient database to broadly examine the prevalence of specific comorbidities among pediatric tracheostomy patients and determine their association with in-hospital mortality. These findings may assist clinicians with risk stratification in a complicated patient population and inform clinical assessments of patient prognosis based on which comorbidities are present. Although indications for pediatric tracheostomy have increased in recent decades [23], procedure risk remains high both intra- and postoperatively. Continued research to explore safety improvement strategies decrease in-hospital mortality and post-procedural complications would prove beneficial, as there exists high variability in tracheostomy care protocols in the literature [23]. Establishment of a standardized post-procedural care protocol and exploring the barriers caregivers may face in caring for tracheostomy tubes at home may help decrease or provide context to post-operative complications.

Study limitations

While we were able to find associations between patient demographics, comorbidities, and in-hospital mortality, the ultimate cause of patient death is not available within the KID, which limits our ability to investigate direct connections between these data elements and patient mortality.

Furthermore, while comparing outcomes based on procedure approach would be a reasonable goal of this study, selection bias regarding the decision to perform OT or PT limits the veracity of any possible conclusions, as current literature shows that procedure choice is often based on provider preference [20]. Additionally, detailed information on the course of care is not available within the KID, limiting us from directly linking patient comorbidities to the chosen approach.

The limitations of the KID also prevent us from identifying the precise indication for any procedure, as well as the severity of the patient's condition. Categorizing outcomes by indication, rather than the comorbidities listed for each patient, would allow us to align preoperative condition more precisely with postoperative outcomes. It would also allow us to more precisely examine variations in outcomes within certain comorbidities, such as examining whether the severity of a congenital heart defect was associated with greater in-hospital mortality.

Conclusions

Our analysis showed that comorbidities for pediatric tracheostomy patients are commonly related to congenital cardiopulmonary defects and traumatic injury. Broadly, we found that congenital cardiopulmonary defects were associated with a higher likelihood of in-hospital patient mortality. Our analysis also shows younger, male patients may also be at higher risk for post-procedural mortality. While trauma-related injuries are more common in patients undergoing percutaneous tracheostomy, they are not associated with increased in-hospital mortality. Qualitative research investigating post-procedural complications and caregiver experience with at-home tracheostomy care may provide additional context for these findings and offer further information to guide inpatient care for this complex patient population. Studies utilizing individual case reports instead of a large patient database, with the ability to examine the full course of patient care, may provide clearer answers as to how these comorbidities impact the recovery of respiratory function in pediatric patients.

Abbreviations

CI	Confidence interval
OR	Odds ratio
OT	Open tracheostomy
PT	Percutaneous tracheostomy
KID	Kids' Inpatient Database
HCUP	Healthcare Cost and Utilization Project
ICD-10-CM	International Classification of Diseases, 10th Revision, Clinical Modification
AKI	Acute kidney injury

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Authors' contributions
JS developed the study hypothesis and design and had a primary role in the study organization, statistical analysis, manuscript drafting, and interpretation of data. DOD had significant input on the study design and substantial assistance in the organization and statistical analysis of data and manuscript editing. DH contributed substantial assistance in the organization and interpretation of data, as well as the writing of the manuscript. ER had substantial contributions to the organization and interpretation of data, review of literature, and editing of the manuscript. KD contributed substantial assistance to the organization and writing of the manuscript, as well as review of literature. SF had substantial contributions to the organization of data, manuscript editing, and literature review. JL helped develop the study hypothesis and design, had a major role in data presentation and interpretation, and contributed significantly to manuscript writing and editing. All authors read and approved the final manuscript, agreeing to be accountable for all aspects of the work.

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Availability of data and materials
The datasets generated and/or analyzed during the current study are available in the Kids' Inpatient Database repository, 2016 edition, available publicly at https://www.hcup-us.ahrq.gov/kidoverview.jsp.

Declarations

Ethics approval and consent to participate
To conduct this study, Boston Medical Center and Boston University Medical Campus Institutional Review Board did not require approval or exemption, as the KID is a public database, and research with publicly available data does not meet the definition of human subject research at our institution under 45 CFR 46.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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