Title: Prior Cardiac Surgery is Independently Associated with Decreased Survival following Infant Tracheostomy

Authors: Elizabeth Rosner D.O.[1], Christopher W. Mastropietro M.D.[2]

Affiliations:

[1]Children's Hospital of Michigan / Wayne State University, Department of Pediatrics, Division of Critical Care Medicine, Detroit, MI, United States of America

[2]Riley Hospital for Children / Indiana University School of Medicine, Department of Pediatric, Division of Critical Care Medicine, Indianapolis IN, United States of America

Contributor's statement:

Elizabeth Rosner, D.O, was the principal investigator for this study, substantially contributing to study design, acquisition of data, analysis and interpretation of data, and manuscript preparation. Dr. Rosner has approved this manuscript for submission.

Christopher Mastropietro, MD, was the faculty mentor for this study, responsible for study conception and design, analysis and interpretation of data, and manuscript revision. Dr. Mastropietro has approved this manuscript for submission.

All work was performed at Children's Hospital of Michigan, Detroit, MI

Corresponding Author:

Christopher W. Mastropietro, MD
Associate Professor of Pediatrics, IU School of Medicine
Medical Director of the Cardiovascular ICU, Riley Hospital for Children
Indianapolis, IN 46202
Phone: 317-944-5165
E-mail: cmastrop@iupui.edu

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Abstract

Introduction: Previous reports have demonstrated that prior cardiac surgery is independently associated with in-hospital mortality after infant tracheostomy. We aimed to determine if these infants would continue to be at increased risk for death following hospital discharge.

Methods: A retrospective review was performed on patients < 2 years of age who recovered from tracheostomy in the pediatric intensive care unit at our institution between 1/2007-12/2011, with follow-up to 12/2013. Survival to one year following tracheostomy was the primary outcome variable for the study. Multivariate Cox regression analysis was then performed to determine independent risk factors for death after infant tracheostomy.

Results: Forty-two patients met inclusion criteria, 18 of which had undergone prior cardiac surgery. Twenty-six patients (62%) were alive at one year post-tracheostomy. Age at tracheostomy, concomitant genetic abnormalities or prematurity, and ventilator dependence at discharge were not statistically different between survivors and those who died. Patients who died however were more likely to have had cardiac surgery prior to tracheostomy [11 (69%) vs. 7 (27%), *P*=0.008] and had longer hospital length-of-stay [median 3.4 months (interquartile range: 2.6-4.6) vs. 2.2 months (interquartile range: 1.1-3.5), *P*=0.045]. Multivariate Cox regression analysis revealed only prior cardiac surgery to be independently associated with decreased survival after tracheostomy (hazard ratio 4.7, 95% confidence intervals: 1.3-16.4; *P*=0.017).

Conclusion: Prior cardiac surgery is independently associated with decreased survival within one year following tracheostomy. Clinicians and families of infants with prior cardiac surgery in whom tracheostomy after cardiac surgery is deemed necessary should consider this risk when planning long-term care.

Key Words: Tracheostomy; pediatric; ventilators, mechanical; chronic lung injury; cardiac surgical procedures; heart defects, congenital

Introduction

Infants who require tracheostomies for long-term respiratory management often have additional co-morbidities such as gastroesophageal reflux, developmental delay, chronic lung disease, and congenital or acquired heart disease. Some of these latter children also have, in addition to their underlying heart defect, other risk factors for the need for tracheostomy associated with their surgical repair or palliation procedure. Examples of such risk factors include vocal cord or diaphragmatic paresis/paralysis, tracheobronchomalacia resulting from chronic airway compression from cardiac structures, or chronic lung disease from complicated preoperative and postoperative courses. Several institutions have reported their experiences with pediatric patients requiring tracheostomy following cardiac surgery.[1-3] These reviews have reported a mortality rate of 34-47%, significantly higher than the mortality rates reported in non-cardiac surgical populations.[4-6] Two large multi-institutional studies performed by Berry and colleagues demonstrated increased risk of in-hospital mortality following tracheostomy in children with congenital heart disease, the majority of which had undergone cardiac surgical repair or palliation.[7,8] To our knowledge, no study to date determined whether or not tracheostomy following pediatric cardiac surgery continues to be associated with poorer outcomes following hospital discharge relative to patients who require tracheostomy in association with other disease processes. Our aim was to examine outcomes in infants who undergo tracheostomy at our institution and identify factors that may negatively impact their survival. We hypothesized that infants who require tracheostomy following cardiac surgery would continue to have an increased risk of death following hospital discharge, despite similar post-tracheostomy care providers and parental education protocols to patients requiring tracheostomy in association with other illnesses.

Methods

Study Population

This study was approved by the institutional review boards of Wayne State University and the Detroit Medical Center. We performed a retrospective review of the medical records for all children less than two years of age who required a tracheostomy and recovered from the procedure in the pediatric intensive care unit (PICU) at Children's Hospital of Michigan from January 2007 to December 2011 with follow-up through December 2013. Patients who recovered from tracheostomy in the neonatal intensive care unit, none of whom would have undergone prior cardiac surgery, were excluded to ensure similar care and education for all patients after tracheostomy. Additionally, at the time of study design, we were aware that, with the exception of one 15 year old child all children who underwent tracheostomy after cardiac surgery at our institution during our study period were less than two years of age. Patients greater than two years of age were therefore excluded to limit study heterogeneity.

Children's Hospital of Michigan is a 260-bed tertiary care center located in Detroit serving a diverse urban population. The pediatric cardiovascular surgeons perform approximately 250-300 operations per year on patients with congenital heart lesions at all levels of complexity. The postoperative care of these patients is managed together by the cardiovascular surgeons and pediatric intensive care physicians. When tracheostomy placement is being considered for a patient in our PICU, a pediatric pulmonologist and pediatric otolaryngologist, if not yet involved in the patient's care, are consulted. The decision for tracheostomy is based on a patient's clinical course (e.g. multiple failed extubation attempts, inability to wean from mechanical ventilation), results of direct laryngobronchoscopy and multi-disciplinary discussions involving the pediatric intensive care team, pediatric pulmonologists and otolaryngologists, and the patient's family.

Tracheostomy Preparation and Education

The families of patients requiring tracheostomy meet with the otolaryngology nursing staff, pediatric pulmonologist, and social worker prior to the procedure to discuss and plan the immediate and long term care of the patient. After the tracheostomy has been performed by a pediatric otolaryngologist, the primary caregiver from the family as well as a second caregiver undergoes educational training that includes cardiopulmonary resuscitation. The caregivers are given printed educational materials for use as a reference once they are at home that include information on suctioning, daily tracheostomy care, changing the tracheostomy tube, and cardiopulmonary resuscitation. The caregivers are also provided with a 20-minute video demonstrating each of these aspects of tracheostomy care. Two caregivers must do hands-on education and demonstrate that they can perform each of these tasks efficiently. After completing the training each caregiver must stay in-hospital for at least one 12-hour period where they alone provide all of the care for their child. If the patient requires home mechanical ventilation, the training also involves ventilator teaching by the respiratory therapists from the medical equipment company. Caregivers must be able to show how to assemble the ventilator prior to being discharged For patients with only a tracheostomy, the teaching is typically completed in as few as 8-10 days. For patients who require home mechanical ventilation, teaching and making the home ventilator-ready takes at least one month from the time the tracheostomy is performed. For these patients, transfer from the ICU to the pediatric pulmonology service occurs when patients are hemodynamically stable on consistent ventilator support. At this point in their course, the pediatric pulmonologists assume primary care of these patients and continue to direct ventilator management after hospital discharge. Only patients who are ventilator-dependent have access to 8-12 hours of home nursing care per day. This education program is similar to others that have been described previously and follows the guidelines for discharging a patient with a tracheostomy from the American Thoracic Society. [9-11]

Data Collection and Analysis

Data collected from the patient's course prior to tracheostomy included: age at admission, sex, weight, diagnoses cardiac surgical procedure (if applicable), indication for tracheostomy, co-morbidities, including prematurity (defined as less than 36 weeks gestation), age at tracheostomy, duration of hospital stay prior to tracheostomy, duration of ventilator-dependence prior to tracheostomy, and number of attempts at extubation. We also recorded Pediatric Index of Mortality-2 (PIM-2) score at ICU admission, which is a validated and commonly used scoring system for rating the severity of medical illness for children. [12] Data collected after tracheostomy included: duration of time from tracheostomy to hospital discharge or in-hospital death, ventilator support at time of discharge, duration of time from tracheostomy to death or the end of the study period, and location and circumstances of death.

Data are represented as mean with standard deviation for normally-distributed continuous variables, median with interquartile range for skewed continuous variables, and absolute counts with percentages for categorical variables. Bivariate analyses comparing who died within one year after tracheostomy placement to patients who survived using t-tests for normally-distributed continuous variables, Mann-Whitney U tests for skewed continuous variables, and chi-square tests for categorical variables. The primary outcome variable was the study was death at 1-year post-tracheostomy. A Cox proportional hazards regression analysis was performed to determine independent risk factors for mortality within one year of tracheostomy. Variables with $P \leq 0.1$ on bivariate analysis comparing patients who died to patients alive at one year were considered for the multivariate model. Additional bivariate analyses comparing patients with tracheostomy and a history of prior cardiac surgery to those without a history of prior cardiac surgery were performed. Kaplan-Meier survival curves for patients with prior cardiac surgery and without prior cardiac surgery were generated and compared using log rank test. The

program used for the initial statistical analyses was Stata® IC/13.0 (StataCorp LP, College Station, TX). A biostatistician then confirmed all statistical analyses using SAS v9.3 (SAS Institute, Cary, NC), and also tested the proportional hazards assumption using SAS's phreg procedure, which computed the p-value of a Kolmogorov-type supremum test. These tests were based on a sample of 10,000 simulated residual patterns and had a non-significant p-value > 0.05.

Results

Forty-two patients were included in the study. Eighteen of these patients (43%) had a history of prior cardiac surgery, while no patients had cardiac surgery after tracheostomy. The most common indications for tracheostomy were tracheobronchomalacia (n=17) and extrathoracic airway obstruction (n=19). Other indications for tracheostomy included neuromuscular weakness, pulmonary hypertension, chronic lung disease, diaphragmatic paresis, and central hypoventilation. Median number of extubation attempts for all patients was 1, with a range of 0 to 6 attempts. In other words, some patients never met criteria for extubation while others underwent multiple attempts before tracheostomy was pursued.

Twenty-six patients (62%) were alive one year after tracheostomy. Characteristics of survivors and patients who died are compared in Table 1. Patients who died within one year following tracheostomy had a significantly longer cumulative hospital stay (i.e. from ICU admit to death or discharge after tracheostomy) and were more likely to have had cardiac surgery. The results of a Cox regression survival analysis are provided in Table 2. History of prior cardiac surgery and cumulative hospital stay, the two variables found to be significantly different in our bivariate analysis of survivors versus non-survivors at one year after tracheostomy, were included in the regression model. Only cardiac surgery had a significant effect on death, such that patients undergoing tracheostomy after cardiac surgery were nearly 5 times more likely to die within one

year after tracheostomy as compared to patients requiring tracheostomy in association with other disease processes.

Patient characteristics of patients with a history of prior cardiac surgery are compared to patients without cardiac surgery in Table 3. Patients with a history of prior cardiac surgery were significantly younger, were more likely to have tracheobronchomalacia as the underlying indication for their tracheostomy, and were more likely to be ventilator dependent at hospital discharge. None of these three variables however, when added to the Cox proportional hazards regression model, independently impacted survival or appreciably altered the results provided in Table 2 (data not shown). More detailed characteristics of those patients who underwent tracheostomy after cardiac surgery and who underwent tracheostomy in association with other diagnoses are provided in Table 4 and 5, respectively. Four more patients died between one year after insertion of their tracheostomies and the end of the study period, three of which had a history of prior cardiac surgery. In Figure 1, a Kaplan-Meier curve shows the survival up to 2 years following tracheostomy, comparing patients requiring tracheostomy after cardiac surgery to those patients requiring tracheostomy not in association with cardiac surgery. Survival is markedly decreased in those patients who underwent cardiac surgery, log rank test P=0.002. The majority of patients in both of these groups survived to hospital discharge, 16 of 18 (89%) in patients with prior cardiac surgery and 23 of 24 (96%) in patients without, P=0.567. Mortality after discharge however, was significantly higher in those patients who underwent cardiac surgery, 12 of 16 (75%), as compared to those who did not, 5 of 23 (22%), P-value<0.001. In fact, all patients with systemic-to-pulmonary artery shunts (for single ventricle anatomy or Tetralogy of Fallot) died after hospital discharge within one year of tracheostomy insertion.

Overall, there was 102.5 person years of follow-up throughout the study period, 27.4 person-years in patients who underwent cardiac surgery and 75.1 person-years in patients without a

history of cardiac surgery. The incidence rates for overall and post-discharge mortality in patients with a history of cardiac surgery were 5.1 per 10 person years and 5.0 per 10 person-years, respectively; in contrast, the incidence rates for overall and post-discharge mortality in patients without cardiac surgery were 0.8 per 10 person-years and 0.7 per 10 person-years, respectively.

Of the patients with prior cardiac surgery who survived to hospital discharge, 7 of 16 (35%) died acutely either at home or in the emergency department after having a sudden cardiopulmonary arrest at home, while 3 of 23 non-cardiac surgical patients (9%) died in similar acute circumstances, P=0.06. Median time from discharge to death for the seven infants with a history of cardiac surgery was 27 days (range: 2 days – 51 months). All of these patients had electrocardiograms (ECG) and echocardiograms just prior to discharge. One of the seven patients with a history of cardiac surgery who died acutely at home had moderate atrioventricular valve regurgitation, one patient had moderate pulmonary valve insufficiency, and one patient had intraventricular conduction delay on ECG and was discharged home on amiodarone. Event histories provided by the parents of these infants were available for all seven patients. For four infants, the family simply reported that they found their children unresponsive, and upon arrival of medical personnel, the children were found to be pulseless. One patient reportedly had normal vital signs just before a nurse left the home, then found later in the day to be cold and cyanotic by the mother, who called 911. Another patient reportedly became uncomfortable “during a breathing treatment,” for which the mother called the on-call respiratory therapist because she thought “something was wrong with the ventilator.” She was instructed to Ambu®-bag ventilate the patient and call 911, but the infant decompensated further by the time emergency medical personnel arrived and was pronounced dead at an outside emergency department. The last patient who died acutely was reported to have been coughing and “turned blue,” for which the home nurse changed the tracheostomy tube but no

clinical improvement occurred. Upon arrival of emergency medical personnel, the infant was cyanotic with absent vital signs. Autopsy reports were available for four of these seven infants. No autopsy report found evidence of a cardiovascular cause of death such as shunt occlusion, conduit obstruction, or ventricular outflow tract obstruction.

Discussion

This report demonstrates that prior cardiac surgery is independently associated with decreased survival in infants within one year of requiring tracheostomy. This study is consistent with previous studies that report a high mortality rate in patients undergoing tracheostomy in association with cardiac surgery. [1-3] To our knowledge, this is the first study to demonstrate that this increased risk, as compared to a population without cardiac surgery with similar care and caregiver education after tracheostomy, persists following discharge from the hospital. In fact, at our institution, in-hospital mortality was not statistically different between these two cohorts, and the survival disadvantage observed in patients with prior cardiac surgery did not become apparent until after hospital discharge. Additionally, our study provides important information regarding the timing and location of death for these infants, revealing that a considerable portion of the deaths in patients undergoing tracheostomy after cardiac surgery occurred at home or in the emergency department following cardiopulmonary arrest at home, some within days after discharge.

In a large cohort of children with various illnesses requiring tracheostomy with home mechanical ventilation, Edwards and colleagues reported mortality in 47 of 228 patients, and half of these mortalities were described as unexpected.[13] Neither congenital heart disease or a history of pediatric cardiac surgery was examined as potential risk factors for mortality in this study. On the other hand, many of the deaths in this study were described as “cardiac” in nature and the majority of the unexpected deaths were considered to not be related to the tracheostomies

themselves but rather to the progression of the patients' underlying disease processes. Based on the histories available for the sudden unexpected deaths in our cohort, some of the events may have been triggered by mechanical complications but the end results were more likely to be related to the underlying disease burden of each patient. Indeed, the high mortality rates observed in children following cardiac surgery seen in our study as well as at other institutions[1-3] are most likely due to the cumulative discharge morbidities present in this patient population. Infants requiring tracheostomy after cardiac surgery by definition have some degree of both respiratory and cardiac disease. For many patients, residual cardiac disease remains following surgery. For example, patients with Tetralogy of Fallot continue to have right ventricular diastolic dysfunction for months to years following repair.[14] Infants undergoing cardiac surgery often have abnormalities in other organ systems that are less common in infants with primarily respiratory disease. For example, many often suffer concomitant neurologic and renal injuries during and after surgery related to exposure to cardiopulmonary bypass and post-operative hemodynamic instability.[15,16] As a result of all of the aforementioned co-morbidities, these patients likely have less reserve as compared to other patients and therefore less likely to tolerate respiratory complications that may occur at home such as a mucus plug or dislodgment of their artificial airway.[17] The higher rate of home mechanical ventilation in patients with cardiac surgery, though not independently associated with mortality, does mandate a much higher level of care for many of these infants and should not be dismissed as a possible contributing factor. Caregivers of patients requiring home mechanical ventilation must not only know how to care for the tracheostomy tube but also understand the complexities of how to use, maintain, and troubleshoot a mechanical ventilator.[18] As the level of care for the patient increases, so does the level of stress and likelihood of complications.

Due to the poor outcomes associated with tracheostomy in cardiac surgical patients reported in this study and others, the option of tracheostomy should be thoroughly discussed and

alternatives should be considered if possible. On the other hand, if there is no alternative to tracheostomy or it is decided by the team caring for a patient and family that tracheostomy is the best option, a more extensive discharge education plan and closer home monitoring program may be warranted. Berry and colleagues previously reported that extended hospital stays post-tracheostomy in children requiring home mechanical ventilation did not affect survival, though this study did not examine the effect of extended hospital stays on the subset of patients with prior cardiac surgery.[7] In our study however, patients who died were more likely to have longer postoperative stays than those who survived. We therefore speculate that the duration of stay following tracheostomy may be less important than the discharge teaching and education provided to the children's caregivers during this time period. Considering the high mortality rates that have been consistently reported in infants and children with a history of prior cardiac surgery, the development of consensus guidelines on parental counseling and discharge planning procedures specific to this patient population seems warranted. A national database of all infants undergoing tracheostomy could also be helpful, with the goal of further identifying patient characteristics that can differentiate optimal from poor candidates for the procedure.

Our study has limitations inherent to its retrospective design. For example, more detailed information on the causes of death would have been helpful. Further, our study represents the results of a single center's experience, which may not be generalizable to all centers. The high mortality rates seen in our study however are similar to the previously published mortality rates at other centers.[1-3] The single center nature of the study also ensures that post-operative care and parental education was similar for all patients. Another study limitation concerns our decision to exclude infants who underwent tracheostomy placement and tracheostomy recovery in the neonatal intensive care unit at our institution. While this decision was made to limit variation in the care and education received by the patients and their families following tracheostomy placement, we acknowledge that this exclusion could bias our results by

eliminating a number of complex infants without a history of cardiac surgery from our study. A multi-centered study in which the location of post-tracheostomy care (i.e. neonatal versus pediatric intensive care unit) is included as a potential confounding variable should be pursued to confirm our results. Lastly, the small number of patients in our study limits both the precision of its statistical design and the number of potential confounding variables that could be identified and analyzed.

Conclusion

Prior cardiac surgery was independently associated with decreased survival in infants requiring tracheostomy, the majority of which occurred after hospital discharge within one year of the procedure. With this knowledge, every effort should be made to optimize each patient's underlying cardiac physiology before proceeding with tracheostomy. This increased risk of mortality should also be thoroughly discussed with families of infants in whom tracheostomy after cardiac surgery is considered. Caregivers of these children should not only be aware of increased risk of mortality following discharge but also for the risk of sudden catastrophic events that can occur at home.

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Table 1. Patient Characteristics Based on Status at 1-Year Post-Tracheostomy

Variables[a]	Survived (n=26)	Died (n=16)	P-value
Age at ICU admission (months)	7.6 (5.9)	6.2 (5.7)	0.475
Male sex	17 (65%)	8 (50%)	0.324
Prematurity	10 (38%)	3 (19%)	0.180
Chromosomal abnormalities	11 (42%)	5 (31%)	0.475
Pediatric Index of Mortality-2 at ICU admission[b]	3.3 (1-8.9)	2.1 (1.7-4)	0.612
History of cardiac surgery	7 (27%)	11 (69%)	0.008
Tracheobronchomalacia	9 (35%)	8 (50%)	0.324
Extrathoracic airway obstruction	13 (50%)	6 (38%)	0.429
Extubation attempts (*N*)	1.5 (1.5)	1.9 (1.8)	0.368
Age at Tracheostomy (months)	8.5 (5.7)	7.5 (5.6)	0.590
ICU admission to tracheostomy placement (days)[b, c]	27 (15-52)	32 (26-70)	0.087
Tracheostomy to discharge or death (days)[b]	32 (20-46)	47 (35-60)	0.117
Cumulative Hospital Length of stay (months)[b]	2.2 (1.1-3.5)	3.4 (2.6-4.6)	0.045
Ventilator-dependent at discharge or death	16 (62%)	12 (75%)	0.808
Age of primary caregiver (years)	26 (6.7)	28 (8.6)	0.441

[a] Continuous variables are represented as mean (standard deviation), categorical data are listed as n (%) unless otherwise noted; [b] Represented as median (interquartile range); [c] Represents pre-tracheostomy duration of mechanical ventilation; Statistical significance set at $P<0.05$.

Table 2. Cox Proportional Hazards Regression Analysis

Variable	Hazard Ratio	95% Confidence Intervals	*P*-value
Prior cardiac surgery	4.7	1.3 – 16.4	0.017
Cumulative hospital stay[a]	0.9	0.70 - 1.16	0.428

[a] ICU admission-to-tracheostomy plus tracheostomy-to-discharge or in-hospital death

Table 3. Characteristics of Patients with a History of Cardiac Surgery Prior to Tracheostomy Insertion Compared to Patients with No History of Prior Cardiac Surgery

Variables[a]	Cardiac surgery (n= 18)	No cardiac surgery (n= 24)	P-value
Age at ICU admission (months)	1.8 (1.2-7.3)	8.1 (3.4-14.2)	<0.001
Male sex	9 (50%)	16 (67%)	0.276
Prematurity	3 (17%)	10 (42%)	0.104
Chromosomal abnormalities	7 (39%)	9 (38%)	0.927
PIM-2 at ICU admission[c]	2.2 (1.8-3.6)	3.3 (0.9-10.4)	0.875
Tracheobronchomalacia	13 (72%)	4 (16%)	<0.001
Extrathoracic airway obstruction	15 (63%)	(22%)	0.013
Extubation attempts (*N*, range)	1.5 (0-6)	1 (0-5)	0.466
Age at tracheostomy (months)	3.6 (2.4-9)	9.4 (4.5-15.5)	0.025
ICU admission to tracheostomy placement (days)[b]	46.5 (30-81)	17.5 (13-30)	<0.001
Tracheostomy to discharge / death (days)	53.6 (35-75)	28.5 (19-44)	0.002
Cumulative hospital length of stay (months)	4.3 (3.3-6.2)	1.6 (0.9-2.4)	<0.001
Ventilator-dependent at discharge or death	17 (95%)	11 (46%)	0.001
Mortality prior to hospital discharge	2 (11%)	1 (4%)	0.567
Mortality at 1 year after tracheostomy	12 (67%)	5 (21%)	0.008

[a] Continuous variables are represented as median (interquartile range) unless otherwise noted, categorical data are listed as *N* (%); [b] Represents pre-tracheostomy duration of mechanical ventilation; [c] Pediatric Index of Mortality-2 [12]; Statistical significance set at $P<0.05$.

Table 4. Patients Who Required Tracheostomy after Cardiac Surgery

	Cardiac Defect / Primary Surgery	Tracheostomy Indication(s)	Co-Morbidities	Overall Outcome
1	Aortic coarctation, VSD / Definitive repair	Left bronchomalacia, neuromuscular weakness	Trisomy 18	Alive
2	TA / RV-to-PA conduit	Tracheobronchomalacia	Prematurity DiGeorge syndrome	Alive 30 months after tracheostomy, lost to follow-up
3	Critical PS / Transannular patch	Persistent glottic edema	Prematurity	Alive
4	ASD, VSD, aortic root deviation / ASD- VSD closure, PA-plasty	Tracheobronchomalacia Pulmonary hypertension	Hydrocephalus Anoxic encephalopathy	Died after readmission, 9.3 months after tracheostomy
5	AVSD / Definitive repair	Bronchomalacia	Trisomy 21 Complete heart block	Died after readmission, 3.7 months after tracheostomy
6	VSD / PA banding	Tracheomalacia	Chromosome 3p deletion Imperforate anus	Died after readmission, 6.9 months after tracheostomy
7	TOF, absent PV/ Definitive repair	Bronchomalacia		Died at home, 18 month after discharge
8	DORV, TGA, PS / RV-to-PA conduit	Tracheobronchomalacia	Hydrocephalus	Died at home, 3 days after discharge
9	TA – RV-to-PA conduit	Tracheobronchomalacia	Choanal atresia Rib abnormalities	Died at home, 27 days after discharge

ASD: atrial septal defect; *AVSD:* atrioventricular septal defect; *DORV*: double outlet right ventricle; *PA*: pulmonary artery; *PS*: pulmonary stenosis; PV: Pulmonary valve; *RV*: right ventricle; *TA*: truncus arteriosus; *TGA*: transposition of the great arteries; *TOF*: tetrology of Fallot; *VSD*: ventricular septal defect

Table 4. Patients Who Required Tracheostomy after Cardiac Surgery

	Cardiac defect / Primary Surgery	Tracheostomy Indication(s)	Co-Morbidities	Overall outcome
10	TOF with AVSD / Definitive repair	Severe subglottic stenosis	Down syndrome Complete heart block	Died during initial admission, 2 months after tracheostomy
11	TOF, Pulmonary atresia, MAPCAs / Systemic-to-PA shunt	Tracheobronchomalacia	Hydrocephalus	Died at home, 2 days after discharge
12	PA, Unbalanced AVSD / Unifocalization, Systemic-to-PA shunt	Right bronchomalacia		Died at home, 5 days after discharge
13	PA, Ebstein's / Systemic-to-PA shunt, fenestrated closure of TV	Tracheobronchomalacia	Hepatic dysfunction	Died after readmission, 4 months after tracheostomy
14	TOF / Systemic-to-PA shunt	Right bronchomalacia Left bronchial stenosis	Prematurity Tracheoesophageal fistula	Died at home 11 months after discharge
15	DORV /Damus-Kaye-Stansel procedure, Systemic-to-PA shunt	Chronic lung disease	Chromosome 8 anomaly Ventriculoperitoneal shunt	Died during initial admission, 4 months after tracheostomy
16	TA, IAA / Heart transplant	Subglottic stenosis	Pulmonary hypertension DiGeorge syndrome	Died at home 51 months after discharge
17	TA / Heart Transplant	Tracheomalacia		Alive
18	HCM / Heart transplant	Severe left bronchomalacia	Pectus carinatum	Died after readmission, 3 months after tracheostomy

AVSD: atrioventricular septal defect; *DORV*: double outlet right ventricle; *HCM*: hypertrophic cardiomyopathy; *IAA*: interrupted aortic arch; *MAPCAs*: major aortopulmonary collateral arteries; *PA*: pulmonary artery; *RV*: right ventricle; *TA*: truncus arteriosus; *TOF*: tetrology of Fallot; *TV:* tricuspid valve; *VSD*: ventricular septal defect

Figure 1 - Kaplan-Meier Survival Curve

Survival after tracheostomy after cardiac surgery (solid line) is significantly lower than patients with tracheostomy in association with other disease states (dashed line), log rank test *P*=0.0015.