Early tracheostomy in severely burned pediatric patients: 16-year experience at a tertiary burn center in China

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Abstract

Background: A tracheostomy is a lifesaving procedure in severely burned pediatric patients. Because of the complex operative procedures, higher incidence of complications, pulmonary infections and mortality, tracheostomy in pediatric patients has always been controversial, especially for children < 3 years of age. Our study aimed to describe the characteristics of severely burned pediatric patients who had a tracheostomy and to identify the risk factors associated with complications related to tracheostomies, so as to provide assistance and suggestions for the airway management of such patients.

Method: Severely burned pediatric patients (aged ≤15 years of age) who had a tracheostomy between 1 January, 2004 and 31 December, 2019 were retrospectively reviewed. The following data were collected: age; gender; total burn surface area (TBSA); burn mechanism; inhalation injury; indication for tracheostomy; time from injury to tracheotomy; duration of ventilation; duration of tracheostomy, tracheotomy-related complications; and prognosis.

Results: Sixty-five severely burned pediatric patients with tracheostomies were reviewed in this study, 70.6% were < 3 years of age. The 0-3 year age group had the largest number of tracheotomies and the highest incidence of tracheostomy-related complications. Tracheotomy-related complications occurred in 15 patients (23.1%); seven, and eight were early and late complications, respectively. There was no significant relationship between the risk factors that were analyzed and early complications, but TBSA%, ventilation time, and duration of tracheostomy were significantly related to late complications. Multivariate linear regression analysis indicated that age, TBSA%, inhalation injury, and ventilation time were independent variables influencing the duration of tracheostomy. Decannulation was carried out successfully in 96.7% (58/60) of surviving patients. Age (B = −0.011, p = 0.008), TBSA (B = 1.5, p = 0.006), inhalation injury (B = 1.07, p = 0.004), and ventilation time (B = 1.081, p = 0.000) were independent risk factors influencing the duration of tracheostomy. Five patients died (7.7%); no children died from tracheotomy-related complications.

Conclusion: Early tracheostomy is a relatively safe and effective method for airway management in severely burned children; however, patients < 3 years of age should be evaluated for tracheostomy with greater caution due to the severity of the complications.

Introduction

With the advances in intensive care medicine, fluid resuscitation, and wound repair, the overall mortality of burn patients is declining; however, respiratory failure remains one of the major causes of death subsequent to a burn injury [1]. Establishing and maintaining a safe and stable airway is a key step in the management of severely burned pediatric patients [2]. Endotracheal intubation and tracheostomy are two of the most commonly used methods of airway management for critically ill children with burns. Compared to adults, the respiratory system of children is immature and the ability to compensate is poor. Severely burned pediatric patients are more likely to develop respiratory obstruction after burns [3].

Additionally, severely burned pediatric patients often have varying degrees of face and neck burns, and inhalation injuries, which significantly increase the difficulty of tracheal intubation. Intubation in these patients is often impossible because of airway edema after adequate fluid resuscitation. In addition, children with severe burns often require prolonged mechanical ventilation. Therefore, tracheostomy has become an important choice for airway management in severely burned pediatric patients.

Tracheostomies are often performed in patients in whom establishing and maintaining endotracheal intubation is difficult, or patients with large surface area burns or severe inhalation injury (IHT) patients who require long-term mechanical ventilation or pulmonary toilet [4]. Because of the difference in anatomic and physiologic features between children and adults, tracheostomies in children are often associated with higher morbidity and mortality. Indeed, the younger the patients, the greater the risk [5, 6]. Complication rates from tracheostomies in children vary from 10–55% [7]. Due to the lack of evidence-based guidelines and expert consensus for the establishment of artificial airways in severely burned pediatric patients, the clinical decisions are mainly based on the experience of physicians, thus tracheostomies in pediatric burn patients has always been controversial.

The vast majority of tracheostomies in our study were performed between 2004 and 2013. Under the relatively backward economic and medical conditions, and the lack of monitoring equipment at the time, selecting a safe, effective, and economical airway management method was essential for severely burned pediatric patients. Therefore, the purpose of our study was to describe the characteristics of severely burned children with tracheostomies and to identify risk factors associated with tracheostomy-related complications and the duration of tracheostomy to provide assistance and suggestions for airway management in such patients. At the same time, our results may also serve as a reference for airway management of severely burned pediatric patients in developing countries with poor health status and a lack of monitoring equipment.

Methods

Medical records for severely burned pediatric patients in burn ICU of Guangzhou Red Cross Hospital of Jinan University who had tracheostomies between 1 January 2004 and 31 December 2019 were retrospectively reviewed. The burn ICU referral criteria were as follows: (1) ≤ 15 years of age and TBSA ≥ 15%; and (2) ≤ 15 years of age and TBSA < 15%, but at high risk for acute upper airway obstruction, such as oropharyngeal burns, deep facial and neck burns, and IHTs. The following demographic data were obtained: age; gender; TBSA%; burn mechanism; IHT; indication for tracheostomy; time from injury-to-tracheotomy; duration of mechanical ventilation; duration of tracheostomy; tracheotomy-related complications; and prognosis. All tracheostomies were performed in the operating room with the child intubated under general anesthesia after receiving informed consent from the parents.

Most of the tracheostomies in our department were performed by the same senior physician (Dr. Xiaojian Li). The tracheotomy procedures were as follows: First, a shoulder roll was placed under the patient's shoulders to make the trachea more superior. Second, a vertical skin incision was made with careful

dissection of the strap muscles. If the thyroid isthmus was encountered, the thyroid isthmus was retracted upward, thus fully exposing the trachea. An inverted T-shaped tracheal incision over the 3rd and 4th rings was made. Third, a tracheotomy tube was inserted into the trachea and the trach plate was sutured to the skin. Finally, the shoulder roll was removed and the ties were safely fastened such that only one finger fit between the tie and the skin. If mechanical ventilation was required, the conventional modes of synchronized intermittent mandatory ventilation or continuous mandatory ventilation were initially used in these patients. Patients with IHTs were treated by a protocol involving a nebulized budesonide inhalation suspension and ipratropium bromide inhalation solution. Second- and third-degree burn wounds were excised 3–5 days after injury and covered with a porcine xenograft, and then autografting was performed weekly until all wounds were closed.

For the statistical analysis, SPSS (version 22) was used. Continuous data are presented as the mean ± standard deviation or median (25th–75th percentile). Continuous variable comparisons between two groups were analyzed with Mann–Whitney tests for two groups and Kruskal–Wallis tests for ≥ 3 groups. Chi-square or Fischer's exact test was used for dichotomous variables. Multivariate linear regression analysis was performed to analyze risk factors that influenced the duration of tracheostomy. A P value < 0.05 was set as the measure for statistical significance. This study was approved by the Ethics Committee of Guangzhou Red Cross Hospital of Jinan University.

Results

A total of 1349 critically ill burned children were admitted to the Department of Burn ICU at Guangzhou Red Cross Hospital of Jinan University between1 January, 2004 and 31 December, 2019. Sixty-five patients (4.8%) had tracheotomies and were included in this study. Forty-three patients (66.2%) were male and 22 patients (33.8%) were female. The mean age of the patients with tracheostomies was 45 months with a range from 3 months–15 years. Most tracheostomies were performed in the 0–3 year age group (58.5%; Fig. 1).

Hot liquid scalding was the most common injury. Thirty-seven patients (56.9%) were scalded by hot liquid, 23 (35.4%) were burned by fire, three (4.6%) were injuried by high voltage electricity, and two (3.1%) were burned by other means. The median TBSA was 39.5% ± 24.5%. Thirty-six patients (55.4%) underwent laryngoscopy or bronchoscopy at the time of admission. Twenty patients (30.7%) were diagnosed with IHT and 51 (78.5%) needed mechanical ventilation. Upper airway obstruction (existing or anticipated) was the primary indication for tracheotomy. Thirty-eight tracheostomies (58.5%) were performed for upper airway obstruction and the remaining 27 tracheostomies (41.5%) were performed for respiratory insufficiency requiring mechanical ventilator support. The common causes of upper airway obstruction were oropharyngeal burns, deep facial and neck burns, and IHTs. Twenty-one patients had emergent tracheotomies due to acute upper airway obstruction after burns, whereas 44 patients had prophylactic tracheotomies. Sixty-one (93.8%) patients had tracheotomies without intubation and four patients (6.2%) were orotracheally-intubated first and later converted to a tracheotomy. The time from injury-to-performing a tracheostomy was 34.3 ± 54.1 h, the mean duration of a tracheostomy was 16.9 ±

12.3 days, the mean ventilation time was 16.4 ± 11.3 days, and the mean duration of intensive care was 40.3 ± 63.2 days. Twenty-two patients (33.8%) developed pneumonia during the ICU stay. Decannulation was carried out successfully in 96.7% (58/60) of surviving patients; 55 patients succeeded on primary decannulation attempts and three patients succeeded on the second attempt. Five patients (7.7%) died; all from disease-related progression, with no tracheotomy-related deaths during the study period (Table 1).

Table 1

Demographics of tracheotomy severely burned pediatric patients.

	N	Studied group
Age (mean ± SD)(months)	65	45.1 ± 42.7
Sex (%)		
Male	43	66.2%
Female	22	33.8%
TBSA% (median, 25–75 percentile)	65	35.5(20–60)%
III% (median, 25–75 percentile)	65	17.5(0–40)%
Burn mechanism		
Flame	23	35.4%
Hot liquid	37	56.9%
Electrical	3	4.6%
Other burn factors	2	3.1%
IHT	20	30.7%
Indication for tracheotomy		
Upper airway obstruction	42	64.6%
Assisted ventilation	23	35.4%
Mechanical ventilation	51	78.5%
Time of injury to placement of tracheostomy (h)	65	34.3 ± 54.1
Ventilation time (days)	51	16.4 ± 11.3
Duration of tracheostomy (days)	65	16.9 ± 12.3
Length of ICU stay (days)	65	40.3 ± 63.2
Pneumonia	22	33.8%
Tracheotomy complications	17	23.1%
Decannulation	58	89.2%
Died	5	7.7%
TBSA: total burn surface area, IHT: inhalation injury		

Tracheotomy-related complications occurred in 15 patients (23.1%); seven patients (10.7%) had early tracheotomy complications, including three patients with tracheostomy site bleeding (all of these hemorrhages were minor), one with a pneumothorax, and three with subcutaneous emphysema. Eight patients (12.4%) had late tracheotomy complications, including two patients with tracheomalacia, three with post-decannulation tracheocutaneous fistulas, and three with tracheal granulomas (Table 2). The 0–3 year age group had the highest incidence of tracheostomy complications; 12 patients (70.6%) were < 3 years of age (Fig. 2). There were no accidental decannulations. Two patients who developed tracheomalacia were discharged with a tracheostomy tube in place. Twenty-three tracheostomy patients were followed up for 3 months–8 years after discharge. No tracheostomy-related complications occurred in other patients during follow-up. Two patients who developed tracheomalacia could not be contacted because their telephone numbers were not recorded.

Table 2
Tracheotomy related complications.

Tracheotomy related complications	N	Studied group
Early tracheotomy complications	7	10.7%
Wound bleeding	3	4.6%
Pneumothorax	1	1.5%
Subcutaneous emphysema	3	4.6%
Late tracheotomy complications	8	12.4%
Tracheomalacia	2	3.1%
Postdecannulation tracheocutaneous fistula	3	4.6%
Tracheal granulomas	3	4.6%

We first analyzed the risk factors which influenced the incidence of early tracheotomy complications by univariate analysis. The results indicated that factors, including age, gender, TBSA%, burn mechanism, IHT, and time of tracheostomy; however, mechanical ventilation had no significant correlation with early tracheotomy complications ($p > 0.05$; Table 3). Then, we analyzed the factors which influenced the incidence of late tracheotomy complications. The results indicated that late tracheotomy complications were significantly associated with TBSA% ($p = 0.001$), ventilation time ($p = 0.000$), and duration of tracheostomy ($p = 0.000$; Table 4).

Table 3
Factors associated with the occurrence of early complications related to tracheostomy in severely burned pediatric patients

		Early complications n = 8(12.3%)	Non- early complications n = 57(87.7%)	P
Age				0.51
0–3 years		6(12.9)	34(87.1)	
3–6 years		1(8.3)	11(91.7)	
6–9 years		0(0)	6(100)	
9–12 years		0(0)	3(100)	
12–15 years		1(25)	3(75)	
Gender				1
	Male	5(11.6)	38(88.4)	
	Female	3(13.6)	19(86.4)	
TBSA% `(χ ± SD)		53.9 ± 26	38.6 ± 24.6	0.11
IHT				0.706
	Yes	2(10)	18(90)	
	No	6(13.3)	39(86.7)	
Mechanical ventilation (days)				0.799
	Yes	6(11.8)	45(88.2)	
	No	2(14.3)	12(85.7)	
Burn mechanism				0.465
Flame		3(13)	20(87)	
Hot liquid		4(10.8)	33(89.2)	
Electrical burn		0(0)	3(100)	
Other burn factors		1(50)	1(50)	

TBSA: total burn surface area, IHT: inhalation injury

	Early complications n = 8(12.3%)	Non- early complications n = 57(87.7%)	P
Time of injury to placement of tracheostomy (h)	31.3 ± 47.8	40.6 ± 61.8	0.849
TBSA: total burn surface area, IHT: inhalation injury			

Table 4
Factors associated with the occurrence of early complications related to tracheostomy in severely burned pediatric patients

		late complications n = 9(13.8%)	Non- late complications n = 56(86.2%)	P
Age				0.576
0–3 years		7(17.5)	33(82.5)	
3–6 years		1(8.3)	11(83.3)	
6–9 years		1(16.7)	5(100)	
9–12 years		0(0)	3(100)	
12–15 years		0(0)	4(100)	
Sex				1
	Male	6(11.6)	37(88.4)	
	Female	3(13.6)	19(86.4)	
TBSA% ˋ(χ ± SD)		68.2 ± 24.6	34.9 ± 21.9	0.001
IHT				0.706
	Yes	2(10)	18(90)	
	No	6(13.3)	39(86.7)	
Mechanical ventilation				0.209
	Yes	9(17.6)	42(82.4)	
	No	0(0)	14(100)	
Ventilation time (days)		37.2 ± 8.6	10.4 ± 11.2	0.000
Burn mechanism				0.314
Flame		5(21.7)	18(78.3)	
Hot liquid		3(8.9)	34(91.2)	
Electrical burn		1(33.3)	2(66.7)	
Other burn factors		0(0)	2(100)	

TBSA: total burn surface area, IHT: inhalation injury

	late complications n = 9(13.8%)	Non- late complications n = 56(86.2%)	P
Time of injury to placement of tracheostomy (h)	18.9 ± 15.2	41.3 ± 62.1	0.711
Duration of tracheostomy (days)	38.3 ± 11.6	13.6 ± 8.4	0.000
TBSA: total burn surface area, IHT: inhalation injury			

Multivariate linear regression analysis was performed to analyze risk factors that influenced the duration of tracheostomy. Variables, such as age, gender, TBSA%, burn mechanism, IHT, ventilation time, and the time from injury-to-tracheostomy were included in the analysis. Age (B = − 0.011, p = 0.008), TBSA% (B = 1.5, p = 0.006), IHT (B = 1.07, p = 0.004), and ventilation time (B = 1.081, p = 0.000) were independent risk factors that influence the duration of tracheostomy. The duration of tracheostomy was longer if the patient was younger, the TBSA% was greater, the IHT was more serious, or the ventilation time was longer (Table 5).

Table 5
Multivariate linear regression analysis for the risk factors that influencing the duration of tracheostomy.

Variable	B	Standard error	P
Age	-0.011	0.004	0.008
Sex	11.4	12.6	0.281
TBSA	1.5	0.47	0.006
Burn mechanism	4.36	15.1	0.724
Inhalation injury	1.07	0.353	0.004
Ventilation time	1.081	0.017	0.000
Time from injury to tracheostomy	-0.006	-0.461	0.647
TBSA: total burn surface area			

Discussion

Severely burned children are prone to develop acute upper airway obstruction, especially after adequate fluid resuscitation. One reason for this finding was the anatomy and physiologic characteristics of the

patients. Another was related to the burn mechanism, as most of the burns were facial and neck burns, and IHTs. Therefore, establishment of a safe and effective airway is essential for the treatment of these patients. In view of the complexity and high incidence of complications, tracheostomy in pediatric patients has always been controversial [8, 9]. Recent studies have shown that early tracheostomy in critically burned pediatric patients is safe and effective. Early tracheostomy provides a stable airway and improves mechanical ventilation management, and the incidence of tracheotomy site infections and pneumonia is also extremely low [3–4, 10–11].

Compared with a tracheotomy, tracheal intubation has the advantages of being simple and rapid with fewer complications. Therefore, most physicians choose tracheal intubation as a better way to establish an artificial airway in the early stage of burns in children; however, tracheal intubation also faces many problems in the treatment of pediatric burns, as follows: (1) Children's vocal cords are anatomically forward, thus aggressive fluid resuscitation for patients with IHTs, and oropharynx and supraglottis burns aggravate airway edema and make intubation difficult. (2) Children’s tracheas are relatively short; body position changes during surgery and dressing changes increase the risk of endotracheal tube dislodgement or accidental decannulation. (3) Children's airways have a small inner diameter and therefore only a relatively narrow tracheal tube can be placed, resulting in increased airway resistance, particularly in patients with IHTs, and significant increases in airway secretions, which can easily lead to endotracheal tube obstruction. (4) Children cannot tolerate prolonged intubation and immobility; in most cases, sedation and neuromuscular blockade are required to prevent accidental extubation, and the use of these drugs can also cause corresponding complications [3]. At the same time, prolonged tracheal intubation can significantly increase the incidence of airway complications. Therefore, the airway management method should be individualized to the patient's clinical course, especially in younger children.

There are two main indications for tracheotomy in children with severe burns: (1) acute upper airway obstruction; and (2) requirement for long-term ventilation support [10]. Most of the tracheostomies were done for upper airway obstruction in our study (58.5%), which is similar to other reports [4]. For early airway management in severely burned pediatric patients, we primarily chose tracheostomy rather than tracheal intubation, which is inconsistent with guidelines and protocols at other institutions [4, 12]. For early airway management, we primarily chose tracheostomy rather than tracheal intubation in severely burned pediatric patients, which is inconsistent with guidelines and other institutions. Most of the tracheotomies in our study were performed between 2004 and 2013. At that time, economic and medical conditions were very poor, and the monitoring equipment in our department was limited. Tracheotomy was considered to be an economic, safe, and effective airway management method to achieve satisfactory results. Our findings may serve as a reference for airway management of children with severe burns in developing countries with poor medical conditions and lack of monitoring equipment. In recent years, with the improvement in nursing and monitoring conditions in our department, we selected tracheal intubation instead of tracheostomy in the early airway management of younger children with oropharyngeal, facial, and neck burns. This study demonstrated that tracheal intubation is also safe and effective in early airway management for young patients. Previous reports also found that prolonged

airway management in severely burned children can also be accomplished by tracheal intubation [13]; however, other reports also found that long-term (> 10 days) tracheal intubation increase the incidence of tracheal stenosis in severely burned pediatric patients [11, 14]. Our study indicated that most tracheotomy-related complications occurred in children 0–3 years of age. This finding may be related to the immature structure of the respiratory tract in this age group, patients more prone to developing airway obstruction after burns, and patients in whom it was more difficult in performing a tracheostomy. Therefore, airway management in the 0–3 year age group should be carefully considered unless there are clear indications for tracheostomy, such as an inability to intubate or patients who require long-term respiratory support; otherwise, tracheal intubation may be a preferred choice in these patients.

Decannulation was carried out successfully in 96.7% of surviving patients. This result is similar to other reports of pediatric burn patients, and higher than non-trauma pediatric patients [4, 10, 15–17]. This may be related to the duration of tracheostomy in trauma, since it is shorter in pediatric patients than in non-trauma pediatric patients, as we know the duration of tracheostomy is an important factor affecting the success rate of decannulation. Five patients (7.7%) died; all from disease related progression with no tracheotomy-related deaths in the study period. This result is similar to previous reports and once again confirmed that tracheostomy in critically ill burned children is safe and effective [3–4, 10].

Complications related to tracheotomy are traditionally classified into two types: early (within the first 7 days of surgery); or late (> 7 days of surgery) [18]. The incidence of tracheotomy-related complications in children varies widely in the literature (3–84%) [19–24]. Fifteen patients (23.1%) had a tracheostomy-related complication in our study (seven and eight early and late complications, respectively). With the exception of two patients who developed tracheomalacia and who were discharged with the tracheostomy tube in place, most of the complications resolved, and no patients died from complications of the tracheostomy. In our study we did not identify any risk factors associated with early complications of the tracheotomy, but TBSA%, ventilation time, and the duration of tracheostomy were closely related to late complications. Early complications may be related to the skills of the operating physicians. Due to our limited number of case and no comparisons, we cannot draw a clear conclusion. Some experts suggest that children's tracheostomy should be performed by experienced physicians whenever possible [3]. Due to the close relationship with ventilation time, duration of tracheostomy, and the occurrence of late tracheotomy-related complications, we should take effective measures to shorten the ventilation time and decannulate as early as feasible to reduce complications related to the tracheotomy.

Our study indicated that age, TBSA%, IHT, and ventilation time were independent factors influencing the duration of tracheostomy. The duration of tracheostomy will be longer if the patient is younger, the TBSA% is greater, the IHT is more serious, or the ventilation time is longer. Another study also showed that the duration of tracheostomy is negatively correlated with age [25]; however, a recent study of pediatric burn patients found that the duration of tracheostomy is mainly related to the TBSA%, but not to age [10]. The difference between their conclusions and our conclusions may be mainly related to the different ways in which patients were grouped by age. Previous research showed that early decannulation can reduce complications related to tracheostomy, the negative emotional impact on the patient and their

parents, and the economic burden of the family and the healthcare system [15, 26–28]. Due to the lack of a standard decannulation protocol for children with severe burns, we had to use decannulation methods for patients with other diseases. This reduced the success rate of decannulation and prolonged the tracheostomy time. Therefore, guidelines and decannulation protocols for severely burned pediatric patients are urgently needed.

Conclusion

Early tracheostomy is a relatively safe and effective method for airway management in severely burned children; however, patients < 3 years of age should be carefully considered for severe tracheostomy-related complications. Late tracheostomy-related complications in critically burned pediatric patients were significantly associated with ventilation time and duration of tracheostomy. The duration of tracheostomy will be longer if the patient is younger, the TBSA% is greater, the IHT is more serious, or the ventilation time is longer.

Declarations

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Author Contributions

BC and XjL conducted the study design. LyC, WbT, YC, QF, and SZ acquired the study data. BC, ZhL, and FK performed the statistical analysis and interpretation of data. BC, XjL, ZZ and XhZ drafted the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Our study received approval from the ethics committee of Guangzhou Red Cross Hospital

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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Figures

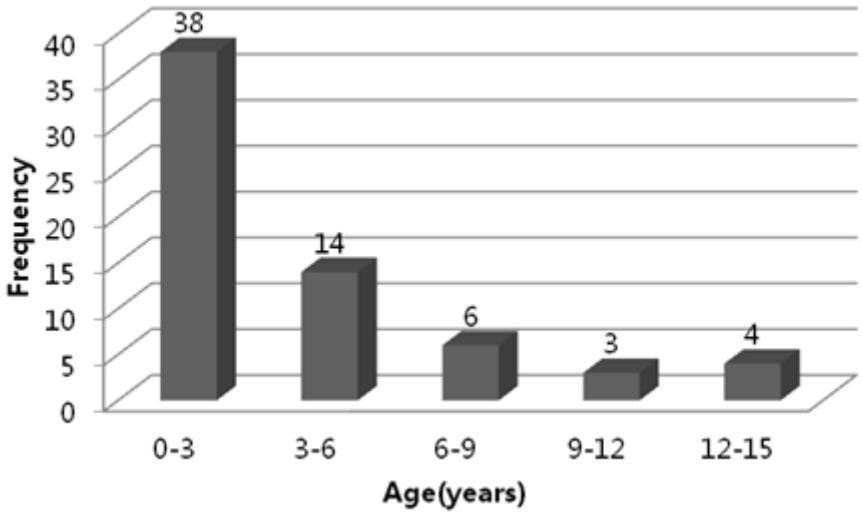

Figure 1

Age distribution of the patients underwent tracheostomy.

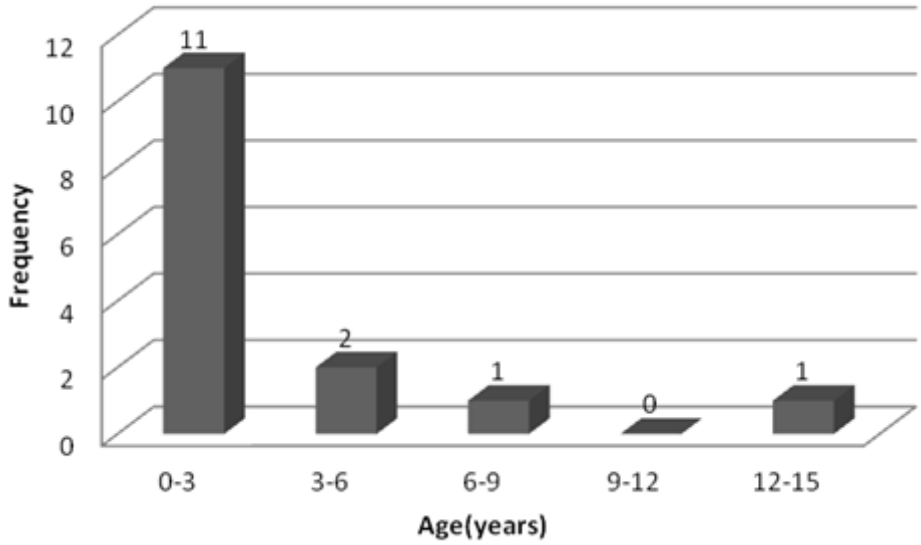

Figure 2

Age distribution of the complications related to tracheostomy.