Outcomes of heliox use in children with respiratory compromise– A 10 years single institution experience

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ABSTRACT

Objective: Heliox, a mixture of helium and oxygen, has been shown to improve laminar airflow and decrease airway resistance in children and adults. The objectives of this study are to evaluate the short-term outcomes of heliox use in children with upper airway obstruction and to identify variables associated with a need for surgical intervention.

Methods: A retrospective cohort study of children who received heliox for respiratory distress between 2012-2022 in a tertiary-care children's hospital.

Results: A hundred and thirty-eight heliox treatments were recorded in 119 patients, age 34.1±46.4 months old. Twelve (10.1%) patients were excluded due to a history of airway reconstruction or tracheostomy cannulation prior to heliox initiation at current admission. Of the remaining 107 patients, 61 (57.0%) underwent tracheostomy placement, airway reconstruction, or palliative care. Demographics, mean gestational age, and age at heliox treatment were similar between the groups. Patients who were recommended a definitive airway surgical intervention were more likely to have secondary airway lesions (p<0.0001), be enteral feed dependent (p<0.0001), and have other significant comorbidities (p<0.0001). Cumulative use of heliox over 47 hours was associated with a 6.2-fold increased risk of needing a tracheostomy tube placement or airway reconstruction (95% CI 2.56-14.13, p<0.0001). Multivariate regression analysis identified neuromuscular disease, intracranial neuropathology, and cumulative time of heliox to be associated with a need for tracheostomy or airway reconstruction.

Conclusions: Heliox may be used as a temporizing agent in children with upper airway obstruction. Patients who require heliox for more than 47 hours, especially if other comorbidities are present, should be considered for definitive airway intervention.

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INTRODUCTION

Heliox is a gas mixture of helium and oxygen that is used clinically to improve airflow in children and adults with airway obstruction. The theoretic benefits of heliox are derived from its physical properties as they relate to fluid dynamics. Specifically, the low density of helium may lower the resistance of airflow in obstructed airways and convert turbulent airflow into a more efficient laminar flow.[1,2] Thus, heliox may result in decreased work of breathing and improved ventilation in patients with airway obstruction.

Several small cohort studies have investigated the therapeutic utility of heliox in children with respiratory compromise. The limited, conflicting data suggests that heliox may improve work of breathing and gas exchange, be used as a temporizing method until the obstruction subsides, and even prevent the need for intubation in children with bronchiolitis or asthma exacerbations.[1,3-11] In upper airway obstruction, heliox has demonstrated some success in improving respiratory distress in children with croup and post-extubation stridor.[1-3,12] The potential benefit of heliox in children with laryngeal edema and upper airway obstruction secondary to non-croup etiologies has resulted in mixed findings.[3,4]

Although heliox is a safe intervention without any direct known adverse effects, overutilization of heliox may result in high costs for both the patient and the health system, extended lengths of stay, and delayed definitive care. We aimed to investigate the short-term outcomes of heliox use in children with upper airway obstruction. Secondarily, we aimed to identify variables associated with a need for definitive surgical interventions in patients who received heliox.

METHODS AND MATERIALS

Data was collected from the electronic medical records of all patients younger than 18 years old who underwent heliox treatment between 2012 and 2022. Hospitalizations were excluded from outcome analysis if the patient had a history of airway reconstruction or prior tracheostomy cannulation. Patient records were examined to identify each time heliox was initiated and discontinued during the same hospital admission. The amount of time spent on heliox was calculated for each individual heliox treatment and summed together to the closest hour. The relationship between need for definitive airway intervention and variables of interest was modeled with multivariable logistic regression to attain risk-adjusted odd ratios an 95% confidence intervals. Patients who were recommended definitive airway intervention but opted for palliative care were categorized with patients who underwent definitive airway intervention. Covariates included (based on p-value <0.02 on comparison of baseline characteristics): the presence of genetic anomaly or syndrome, bronchopulmonary disease (BPD), hypotonia or neuromuscular disease, secondary airway lesion, intracranial neuropathology, congenital heart disease, enteral feed dependence, use of systemic steroids, age and cumulative time for heliox use.

RESULTS

119 patients were placed on heliox therapy during 138 hospital admissions. The patients, aged 2.8 ± 3.9 years old, came from medically complex backgrounds.

Patient outcomes following heliox treatment

Outcomes were analyzed in 107 patients during 121 hospital admissions. 38 (35.5%) patients (44 hospitalizations), underwent definitive airway intervention 12.26 ± 16.83 weeks following heliox treatment on average. An additional 13 (12.1%) patients (16 admissions) were recommended definitive airway intervention but elected to forgo tracheostomy placement in preference of palliative care.

Factors associated with the need for definitive airway surgery

Table 1 summarizes patient characteristics and hospitalization data by need for definitive airway surgical intervention. **Figure 1** depicts the cumulative time spent on heliox in patients by need for definitive airway surgical intervention. Patients who required tracheostomy or airway reconstruction underwent a mean of 160 ± 265.1 hours on heliox therapy compared to a mean of 35 ± 32 hours in those who did not (p=0.0004). Length of hospital stay, from heliox initiation to either discharge or definitive surgical intervention, was significantly higher in those who required definitive airway intervention (93 ± 90 days vs. 8.95 ± 11.1 days, p<0.0001). Multivariate regression analysis identified neuromuscular disease, intracranial neuropathology, and cumulative time of heliox to be associated with a need for tracheostomy or airway reconstruction. The presence of neuromuscular disease and intracranial neuropathology carried a respective 4.63-fold (95% CI 1.16-21.2, p=0.035) and 6.76-fold (95% CI 1.27-54.5, p=0.033) increased risk of requiring definitive airway surgery. Utilizing the Yuden method (**Figure 2**), an optimal threshold of 47 hours (sensitivity 0.52, specificity 0.84) spent on heliox was identified. Need for heliox over 47 hours was associated with a 6.2-fold increased risk of requiring tracheostomy or airway reconstruction (95% CI 2.56-14.13, p<0.0001). Heliox treatment longer than 5 days had a specificity of 0.98 and positive predictive value of 0.94 in predicting a need for definitive airway intervention.

Table 1. Characteristics by Definitive Surgical vs Medical Treatment

Characteristic	Definitive airway surgery		No definitive airway surgery		P-value
Patients, n (%)	51	(0.48)	56	(0.52)	-
Comorbidities, n (%)	50	(0.98)	38	(0.68)	**<0.0001**
Enteral feed dependence (any)	48	(0.94)	29	(0.52)	**<0.0001**
Genetic or syndromic disorder	30	(0.59)	13	(0.23)	**<0.0001**
BPD/PH	13	(0.25)	11	(0.20)	**0.02**
Asthma	4	(0.08)	16	(0.29)	**0.0009**
Neuromuscular disorder/hypotonia	42	(0.82)	18	(0.32)	**<0.0001**
Intracranial pathology	35	(0.68)	11	(0.20)	**<0.0001**
Seizures	25	(0.49)	11	(0.20)	**0.002**
Congenital heart disease	20	(0.39)	10	(0.18)	**0.01**
Secondary airway lesions	47	(0.92)	19	(0.34)	**<0.0001**
Hospital admissions, n (%)	**60**	**(0.50)**	**61**	**(0.50)**	-
Stridor, n (%)	54	(0.90)	46	(0.75)	**0.002**
Heliox use					
Age at heliox (years), Mean (SD)	2.40	(4.18)	2.79	(3.75)	0.35
Cumulative time (hr), Mean (SD)	160.4	(265.1)	35	(32.40)	**0.0004**
Re-intubated after heliox, n (%)	37	(0.62)	7	(0.12)	**0.0003**
Indications for heliox use, n (%)					
Status Asthmaticus	0	(0.00)	9	(0.15)	**0.0028**
Status Epilepticus	3	(0.05)	5	(0.08)	0.7
Respiratory Infection (any)	16	(0.27)	25	(0.41)	0.12
Upper airway obstruction	41	(0.68)	22	(0.36)	**0.0005**
Length of stay (days), Mean (SD)	93	(90.0)	8.95	(11.10)	**<0.0001**

Figure 1. Patient cumulative time on heliox by medical definitive surgical vs medical treatment

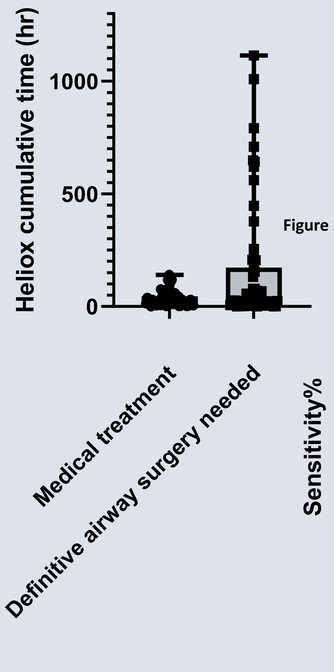
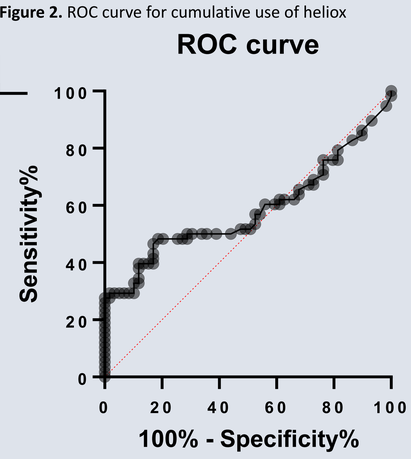


Figure 2. ROC curve for cumulative use of heliox



DISCUSSION

Our study showed that overall, about 50% of patients who received heliox for any indication and for any amount of time were recommended a definitive airway surgical intervention. Multivariant regression analysis identified neuromuscular disease, intracranial neuropathology, and cumulative time of heliox to be associated with a need for tracheostomy or airway reconstruction. Specifically, cumulative use of heliox over 47 hours was associated with a 6.2-fold increased risk of needing airway reconstruction or tracheostomy. Ninety-seven percent of patients who received heliox for more than 5 days during the same admission required definitive airway surgery.

Overutilization of heliox is associated with high costs, prolonged admission in the ICU, significant respiratory therapy staffing needs, and delays the definitive care for the patient. Our data demonstrates that patients who were recommended a tracheostomy or LTR spent a significantly longer amount of time on heliox therapy and length of stay. This suggest that continuing heliox in preference of pursuing other treatment options may significantly delay the definitive care that is needed. Therefore, early identification of patients who will likely require definitive airway intervention is of utmost importance. Our data suggest that a need for heliox for 47 hours, is associated with a higher likelihood of needing surgical intervention. Other risk factors that should be taken in account are neuromuscular disease and known neuropathology. Almost 100% of children who required heliox for more than five days during the same admission required definitive airway intervention.

CONCLUSIONS

Children with non-croup/asthma upper airway obstruction may benefit from the use of heliox to bridge a short period of airway obstruction. Overutilization of heliox is associated with extended lengths of stay and delayed definitive care. The use of heliox over 47 hours and comorbidities like neuromuscular disease and intracranial neuropathology are associated with higher likelihood of need for definitive surgical airway intervention.

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