Flexible Fiberoptic Bronchoscopy in Non-ventilated Children in Pediatric Intensive Care Unit: Utility, Interventions and Safety

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Abstract

Objective: To study the utility of flexible fiberoptic bronchoscopy (FFB), and its effects on oxygenation and hemodynamics in children while on respiratory assist devices.

Materials and methods: The data of non-ventilated patients who underwent FFB during their stay in the PICU from January 2012 to December 2019 was retrieved from medical, nurses, and bronchoscopy records. The study parameters, demography, diagnosis, indication, and findings of FFB and interventions done after FFB, were noted, and also the oxygenation and hemodynamic parameters before, during and 3 hours after FFB.

Results: Data from the first FFB of 155 patients were analyzed retrospectively. About 54/155 (34.8%) children underwent FFB while on HFNC. About 75 (48.4%) patients were on conventional oxygen therapy (COT) before FFB. There were 51 (33%) patients who had received mechanical ventilation and were extubated successfully. The 98 (63.2%) children had primary respiratory diseases. Stridor and lung atelectasis were indications for FFB in 75 (48.4%) cases and the commonest bronchoscopic finding was retained secretions in the airways. Based on the FFB findings, 50 medical and 22 surgical interventions were done. The commonest medical and surgical interventions were changes in antibiotics (25/50) and tracheostomy (16/22) respectively. There was a significant fall in SpO_2 and a rise in hemodynamic parameters during FFB. All these changes were reversed after the procedure with no consequences.

Conclusion: Flexible fiberoptic bronchoscopy is a useful tool to diagnose and guide interventions in non-ventilated pediatric intensive care unit (PICU). There were significant but transient changes in oxygenation and hemodynamics with no serious consequences.

Keywords: Airway assessment, Bronchoalveolar lavage, Diagnostic Procedure, Flexible bronchoscopy, Pediatric intensive care unit.

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Highlights

Flexible fiberoptic bronchoscopy (FFB) is a useful diagnostic and therapeutic tool in critically ill, non-ventilated children in the PICU. The FFB-guided interventions have a high yield. It is a safe procedure but there are significant but reversible changes in the hemodynamics and oxygenation status of patients during the procedure.

Introduction

Wood and Fink were the pioneers who popularized the use of FFB in pediatrics.[1] Most of the previous studies and reports included a cohort of non-critical ambulatory patients or those admitted to the pediatric wards.[2–6] There are few reports on FFB done in critically ill children in pediatric intensive care unit (PICU) settings.[7–10] Majority of previous publications had included ventilated and non-ventilated PICU patients as a single study cohort. The risk of procedure-related complications is more in ventilated patients as compared to no-ventilated cases.[7,8] So bronchoscopy-related complications were not highlighted exclusively in non-ventilated sick children. The sick children in PICU often require non-invasive respiratory assist devices like high flow nasal cannula (HFNC), non-invasive ventilation (NIV), and conventional oxygen therapy (COT) and many of them need diagnostic and therapeutic FFB.[7] So, performing FFB in these children is a challenge. There is the paucity of published literature on the use of FFB in patients receiving non-invasive respiratory assistance.[11] Also there is the scarcity of published studies on FFB-related alterations in oxygenation and hemodynamics.[12–15] This retrospective study was conducted with the objectives to study the uses of FFB and the effects of the procedure on oxygenation and hemodynamics in children.

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Materials and Methods

This retrospective study was conducted from January 2012 to December 2019 in the twelve-bedded PICU of the multispecialty teaching hospital. Institutional Ethics and Research Committee approval were obtained and consent waiver was also granted considering the type of study.

Equipment

We used different size bronchoscopes, 2.8 mm outer diameter (OD) (BF-XP160F Evis Exera, Olympus, Japan), 3.8 mm OD (BF-3C Evis Exera, Olympus, Japan) and 4.8 mm OD (BF-P160 Evis Exera, Olympus, Japan) depending on the age and size of the patient. For neonates and infants 2.8 mm OD, for young children, 3.8 mm OD and for older children 4.8 mm OD bronchoscopes were used.[16]

Procedural Sedation and Monitoring

All bronchoscopies were done at the bedside in the PICU. All patients were kept fasting for 3 hours prior to the procedure. Intravenous ketamine (1 mg/kg) was used for sedation. A multiparameter monitoring was used to monitor cardiopulmonary status before, during, and after bronchoscopy.

Procedure

The team for FFB included one pediatric critical care fellow, one trained technician, two critical care nurses besides a pediatric bronchoscopist. One nurse was responsible for monitoring and recording the hemodynamic and oxygenation parameters while another nurse was for the supply of drugs and normal saline (0.9%) for bronchoalveolar lavage (BAL). Critical care fellow was responsible for the sedation administration, instillation of saline for BAL, and post-procedure monitoring and management of the child. Bronchoscopy setup was done by a PICU technician. He was also responsible for restraining the child's head during the procedure.

Bronchoscopy was performed via nasal route while the bronchoscopist was standing at the head end of the patient. Advanced airway management equipments were kept ready at the bedside. The nose was decongested with oxymetazoline (0.025%) nasal drop before the procedure. Fractional inhaled oxygen (FiO_2) was increased by 10% during FFB in children receiving HFNC with age-appropriate optiflow cannula (AIRVO2, Fisher and Paykel, Auckland, New Zealand) at a flow rate of 2 L/kg. If needed, FiO_2 was adjusted to maintain $SpO_2 \geq 92\%$. Those patients receiving NIV as respiratory assistance were shifted to HFNC for bronchoscopy. In all patients, before starting the procedure, SpO_2 was ≥92% was ensured with acceptable work of breathing. Supplemental oxygen was provided to all other children with OxyMask (OK-1125-8I, Southmedic Canada) to maintain $SpO_2 \geq 92\%$. Oral suction was done just prior to the introduction of a bronchoscope. Bronchoalveolar lavage was collected in a mucus extractor which was connected between the bronchoscope and central suction (70–80 cm H_2O). The site of BAL was selected on the basis of radiological findings in a recent chest radiographs and on the presence of inflammation and secretions in the airways. Aliquots of 3 mL saline for babies weighing <5 kg, 5 mL for children between 5 and 10 kg, 7.5 mL for 11–20 kg, and 10 mL for patients weighing >20 kg were used for lavage.[17]

About 1% lidocaine was instilled in the airways through "Spray and proceed technique" through the working channel of the bronchoscope. Lidocaine was sprayed at the level of the glottis before entering through the vocal cords, upper trachea, main carina, and bronchi. The anatomy and dynamics of the larynx, subglottis, trachea, main carina, bronchi, and segments were evaluated as the bronchoscope was negotiated through airways. Bronchoscopy was concluded after BAL if indicated. Enteral feeding was restarted 3 hours after the procedure unless it was contraindicated. As per PICU policy, a chest radiograph was done within 4–6 hours to assess any post-procedure changes. All the procedures were video recorded and saved on CD ROM.

Data Collection

The study parameters were retrieved from the bronchoscopy database and from medical and nurse's charts. The following data were recorded for each patient demography, the time interval between admission in the PICU and FFB, clinical diagnosis, indication and findings of bronchoscopy, the microbiology of BAL, and medical or surgical interventions done on the basis of FFB findings. Oxygenation and hemodynamic parameters before, during, and 3 hours after FFB were recorded. HR, RR, systolic (SBP), diastolic (DBP) and mean blood pressure (MAP), and SpO_2 were recorded for all enrolled patients and FiO_2 was also recorded for patients receiving HFNC during the procedure.

Diagnostic FFB was defined as those procedures where the primary aim was to assess airway anatomy, patency, and dynamics or to obtain diagnostic BAL specimens for respiratory tract infection and parenchymal diseases. Bronchoscopies done to open blocked airways and large-volume lavage in specific clinical conditions were defined as "Therapeutic" FFBs. The FFB findings and/or BAL were considered positive when the procedure clinched the diagnosis that explained the patient's clinical condition or that resulted in treatment change.[18] Incomplete or complete resolution of lung collapse in chest radiograph done after FFB was attributed to FFB. We only recorded the presence of a significant amount of thick mucoid, mucopurulent, or frankly purulent secretions as a positive finding. Oxygen saturation/Fractional inhaled oxygen (SF ratio) was calculated for patients on HFNC.[19] All foreign bodies lodged in the airway were removed through a rigid bronchoscope under general anesthesia in an operation room.

The continuous parameters were presented as mean ± SD and categorical variables were presented as percentages. The oxygenation, and hemodynamic parameters pre-FFB, during-FFB, and post-FFB for 155 children were compared using repeated measures ANOVA with a Greenhouse-Geisser correction. Comparisons between specific time points (pre versus post-FFB; pre versus during FFB; during versus post-FFB) were done for OxyMask and HFNC using multiple paired *t*-tests with Bonferroni correction to keep type I error at 5%. The p-value < 0.05 was considered significant. Statistical analysis was done using SPSS 23.0 (IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.).

Results

There were 6205 PICU admissions from January 2012 to December 2019. Out of which 2242 (36.1%) children required invasive mechanical ventilation, 1495 (24.1%) NIV, and 1042 (16.8%) needed HFNC during their stay in the PICU. High flow nasal cannula was installed in our unit in 2016. Bronchoscopy data of 155 patients were analyzed. The age ranged from 1 month to 18 years. The time gap between admission to PICU and the first FFB ranged from 1 hour to 70 days. About forty-three (27.7%) children were on HFNC before FFB. Eleven patients receiving NIV with nasal or facemask interface were taken on HFNC to perform FFB. A total of 54/155 (34.8%) children underwent FFB while on HFNC. About seventy-five (48.4%) patients were on COT before FFB. There were 51 (33%) patients who had received mechanical ventilation and were extubated successfully. About four children were tracheostomized, two had Guillain Barre syndrome, and one each of organophosphorus poisoning and super-refractory seizures. Flexible fiberoptic bronchoscopy was done in 101 (65.2%) patients with supplement oxygen with OxyMask (Table 1). No patient was electively admitted to PICU for FFB.

Table 1: Basic characteristic of study population (*N* = 155)

Parameter	*Frequency*
Age[a]	9 (4,24)
Male[b]	114 (73.5)
Time gap (hrs)[c]	50 (18,168)
Route of FFB	
Nasal	155 (100)
FFB on respiratory assistance	
HFNC	54 (34.8)
Oxygen only	101 (65.2)
Pre-FFB CXR	
Normal	55 (35.5)
Atelectasis	47 (30.2)
Consolidation	13 (8.4)
Non-homogenous infiltration	30 (19.3)
Lung hyperinflation	6 (3.8)
Collapse-consolidation	3 (1.9)

[a]median with IQR; [b]frequency with percentage; [c]time gap between admission in pediatric intensive care unit and bronchoscopy; CXR, chest x-ray; FFB, fiberoptic flexible bronchoscopy; HFNC, high flow nasal cannula

Table 2: Medical and surgical diagnosis

Respiratory diseases (98)	*Heam-oncology disorders* (4)
Upper airway (15)	Leukaemia (3)
Congenital (12)	HLH (1)
Vocal cord palsy (2)	*Genetic diseases* (4)
Vallecular cyst (2)	*Liver/GI disorders* (7)
Subglottic stenosis (3)	GERD (4)
Laryngomalacia (4)	TEF (2)
Laryngeal web (1)	FHF (1)
Acquired (3)	*Trauma/Poisoning* (3)
Postextubation stridor (2)	TBI (2)
Foreign body (1)	OP poisoning (1)
Lower airway/lung (83)	*Cardiac diseases* (11)
Pneumonia (35)	Acyanotic CHD (6)
Bronchiolitis (10)	Cyanotic CHD (4)
LTB/WALRI (4)	Cardiomyopathy (1)
Tuberculosis (3)	*Septicemia* (12)
Persistent wheeze (5)	*Central nervous system* (12)
Suspected FB (6)	Seizure disorder (3)
Persistent cough (4)	Meningoencephalitis (2)
Persistent atelectasis (2)	Encephalopathy (6)
Chronic lung disease (7)	Stroke (1)
CLM (4)	*Peripheral nervous system* (4)
Alveolar hemorrhage (2)	Guillain Barre syndrome (3)
Tracheal mass (1)	Spinomuscular atrophy (1)

CHD, congenital heart disease; CLM, congenital lung malformation; FB, foreign body; FHF, fulminant hepatic failure; GERD, gastroesophageal reflux disease; HLH, hemophagocytic lymphohistiocytosis; LTB, laryngo-tracheobronchitis; OP, organophophorus; TBI, traumatic brain injury; TEF, tracheoesophageal fistula; WALRI, wheeze associated lower respiratory infection

Thirty-nine (25.2%) patients with surgical diagnosis underwent FFB while the rest of the cases had a medical conditions (Table 2). The majority of children had primary respiratory system disease (98/155, 63.2%). Congenital airway anomalies accounted for 80% of cases of upper airway diseases. Non-resolving pneumonia or bronchopneumonia was the diagnosis in the majority of respiratory diseases (35/98, 35.7%). One child had lipoid pneumonia with acute respiratory failure after oil ingestion and needed therapeutic lavage. There were six cases of cystic fibrosis and two children had bronchopulmonary dysplasia. Congenital lung malformation included three cases of congenital lobar emphysema and one child had congenital cystic adenomatoid malformation.

Stridor and lung atelectasis were indications for FFB in 75 (48.4%) cases. The commonest finding was retained respiratory secretions (37/155, 23.8%). Retained secretions were associated with inflamed airways in a few patients (Table 3). Extrinsic airway compression was seen in four cases. Cardiopulmonary angiography clinched the diagnosis and the children underwent surgery with complete recovery.

The commonest indication of FFB in post-mechanical ventilation cases was post-extubation stridor (26/51, 51%) while atelectasis was present in 14 cases. Subglottic membrane, circumferential or incomplete, was present in 10 cases. In seven of these cases, the membrane was ruptured with the negotiation of the bronchoscope and resulting in marked improvement in stridor. Thick retained secretions or mucus plugs and bronchial granulation tissue were present in 11 cases with atelectasis.

Based on the FFB findings, 50 medical and 22 surgical interventions were done (Table 3). The frequent medical interventions were up gradation (*n* = 19) or de-escalation (*n* = 6) of antibiotics and initiation of systemic steroids (*n* = 19). Eight children underwent surgical tracheostomy under general anesthesia. Total or partial lobar atelectasis was present in 47 (30.3%) chest radiographs prior to FFB. There was a complete or partial resolution of atelectasis in 30 (63.8%) radiographs done after the procedure.

Bronchoalveolar lavage (BAL) was sent in 113 (72.9%) patients. The microbiological yield was obtained in 33 (29.2%) the samples. *Pseudomonas aeruginosa* was the commonest organism (39.3%) followed by *Klebsiella pneumoniae* (21.2%), *Acinetobacter baumanii* in six, and *Staph aureus* in three cultures. While *Achromobacter xylosoxidans*, *Stenotrophomonas maltophilia, Escherichia coli*, *Candida albicans, Candida glabrata, and Mycobacterium tuberculosis* were grown in one each. Polymicrobial growth was obtained in three samples.

Majority of children had normal blood pressure for their age at the time of FFB. Nine children were on low-dose single inotrope (epinephrine 0.05 mcg/kg/min) and four cases were on antihypertensive medications with controlled blood pressure at the time of FFB. There were significant changes in SpO_2, HR, RR, SBP, DBP, and MAP during FFB in the study cohort (Table 4). Significant increases in HR and RR were present in all age groups. As compared to pre-and post-FFB, the significant increases in SBP, DBP and MAP were present during a procedure in under five children (p-value < 0.001). Rising trends in SBP, DBP, and MAP were present in patients >5 years of age but these did not reach statistical significance. All these changes were reversed after a procedure with no adverse consequences.

Table 3: Flexible bronchoscopy indications, findings and interventions (*N* = 155)

Indication	*Finding*	*Intervention*
Atelectasis (*n* = 37)[a]	Retained secretions (21)	Antibiotics change (6)
	Inflamed airways with thick retained secretions (8)	Anti-reflux measures (2)
	Airway malacia (2)	Jejunal feed (1)
	Cheesy material in airways (1)	Home ventilation (1)
	Foreign body (1)	ATT (1)
	Granulations in airways (1)	Foreign body removal with RB (1)
	Normal (4)	Systemic steroid (1)
		Antibiotics change (2)
Stridor (*n* = 38)	Vallecular cyst (2)	Endoscopic marsupialization (2)
	Subglottic membrane/granulation (13)	Laser removal (5)
	Severe subglottic stenosis (2)	Systemic steroid (8)
	Laryngomalacia (5)	Tracheostomy (2)
	Laryngeal edema (5)	Tracheostomy (3)
	Vocal cord palsy (2)	Laryngeal surgery (2)
	Airway malacia (2)	Systemic steroids (5)
	Extrinsic airway compression (1)	Antibiotics change (1)
	Inflamed airways (2)	Tracheostomy (2)
	Foreign body aspiration (1)	Pulmonary angiography (1)
	Tracheal mass (1)	Antibiotics change (1)
	Normal (3)	Systemic steroids (1)
		Foreign body removal with RB (1)
		Excision and Tracheoplasty (1)
Diagnostic broncho-alveolar lavage (13)	Granulations in airways (1)	Antibiotics change (3)
	Mucopurulent secretions (6)	Antifungal therapy (1)
	Blood stained fluid (2)	
	Normal (4)	
Weaning failure (2)	Extrinsic compression main carina (1)	Cardiac angiography (1)
	Mucopurulent secretions (1)	Antibiotics change (1)
Oxygen dependence (7)	Mucopurulent secretions (3)	Antibiotics change (1)
	Tracheal origin RUL (1)	Systemic steroids (1)
	Segmental malacia (1)	Antibiotics change (1)
	Edema of arytenoids (1)	
	Inflamed airways with thick retained secretions (1)	
Persistent cough (4)	Bulky arytenoids, inflamed airways (1)	Anti-reflux measures (1)
	Normal (3)	
Non-resolving pneumonia (25)[a]	Mucoid mucopurulent secretions (10)	Antibiotics change (3)
	Inflamed lower airways (6)	Antifungal therapy (1)
	Airways malacia (4)	Reflux scan (1)
	Extrinsic compression (2)	Anti-reflux scan (1)
	Cheesy material in airway (1)	Antibiotics change (3)
	Vocal cord palsy (1)	Pulmonary angiography (1)
	Granulation tissue in bronchus (1)	CECT chest (1)
	Normal (3)	ATT (1)
		ATT (1)
		PEG (1)
		Tracheostomy (1)
		Systemic steroids (1)

(Contd...)

Table 3: *(Contd...)*

Indication	*Finding*	*Intervention*
Airways assessment (11)	Suprastomal granulation (1)	Granulation removal (1)
	Laryngeal cleft grade II, with bulky arytenoids (1)	Laryngeal surgery (1)
	LUL bronchomalacia (3)	Lobectomy (3)
	Non-patent TEF (2)	Gastric pull-up Gastric pull-up surgery (2)
	Extrinsic compression trachea (1)	Cardiac angiography (1)
	Subglottic stenosis (1)	Decannulation deferred (1)
	Normal (2)	
Persistent wheeze (5)	Airway malacia (2)	Antibiotics change (1)
	Inflamed airways with mucus plugs (2)	Systemic steroid (1)
	Laryngeal cleft grade I with retained secretions (1)	
Suspected foreign body (13)	Thick retained secretions (3)	Antibiotics change (2)
	Subglottic granulation (1)	Systemic steroid (1)
	Foreign body (5)	Foreign body removal with RG (5)
	Inflamed airways with mucus plugs (1)	Antibiotics change (1)
	Normal (3)	
Non-resolving pneumonia (25)[a]	Mucoid/mucopurulent secretions (10)	Antibiotics change (3)
	Inflamed lower airways (6)	Antifungal therapy (1)
	Airways malacia (4)	Reflux scan (1)
	Extrinsic compression (2)	Anti-reflux scan (1)
	Cheesy material in airway (1)	Antibiotics change (3)
	Vocal cord palsy (1)	Pulmonary angiography (1)
	Granulation tissue in bronchus (1)	CECT chest (1)
	Normal (3)	ATT (1)
		ATT (1)
		PEG (1)
		Tracheostomy (1)
		Systemic steroids (1)
Airways assessment (11)	Suprastomal granulation (1)	Granulation removal (1)
	Laryngeal cleft grade II, with bulky arytenoids (1)	Laryngeal surgery (1)
	LUL bronchomalacia (3)	Lobectomy (3)
	Non-patent TEF (2)	Gastric pull-up surgery (2)
	Extrinsic compression trachea (1)	Cardiac angiography (1)
	Subglottic stenosis (1)	Decannulation deferred (1)
	Normal (2)	
Persistent wheeze (5)	Airway malacia (2)	Antibiotics change (1)
	Inflamed airways with mucus plugs (2)	Systemic steroid (1)
	Laryngeal cleft grade I with retained secretions (1)	
Suspected foreign body (13)	Thick retained secretions (3)	Antibiotics change (2)
	Subglottic granulation (1)	Systemic steroid (1)
	Foreign body (5)	Foreign body removal with RG (5)
	Inflamed airways with mucus plugs (1)	Antibiotics change (1)
	Normal (3)	

[a]represent frequency; ATT, anti-tubercular treatment; LUL, left upper lobe; PEG, percutaneous endoscopic gastrostomy; RB, rigid bronchoscope; RUL, right upper lobe; TEF, tracheoesophageal fistula

The pre-bronchoscopy SpO_2 was significantly higher in the OxyMask group as compared to the HFNC group (p-value = 0.0002). In comparison of OxyMask and HFNC groups, the mean percentage fall in SpO_2 during FFB from pre-procedure value was –2.86 ± 3.72% and –3.12 ± 7.52% (p-value = 0.56). Similarly, rise in HR in OxyMask and HFNC groups during the procedure from pre-FFB values was (11.97 ± 10.65%; 13.1 ± 13.24%; p-value = 0.53), RR (23.2 ± 21.3%; 25.8 ± 15.4%; p-value = 0.09)

Table 4: Comparison of hemodynamic and oxygenation parameters in study cohort underwent fiberoptic bronchoscopy patients

Parameter	*Pre FFB*	*During FFB*	*3 hour Post FFB*	P^a	P^b	P^c
OxyMask^{TM} (*n* = 101)						
SpO_2	96 ± 2.2	93.3 ± 3.9	96.5 ± 2	<0.0001	<0.0001	0.09
HR	124.9 ± 20.3	138.6 ± 20	123.2 ± 18	<0.0001	<0.0001	0.55
RR	38.9 ± 10.7	N47 ± 11.6	37.8 ± 9.2	<0.0001	<0.0001	0.43
SBP	95 ± 17.3	100.3 ± 18.5	93.3 ± 16.7	0.03	0.005	0.47
DBP	57.8 ± 13.4	61.6 ± 14.1	57 ± 11.7	0.05	0.01	0.69
MAP	71.4 ± 14.5	76.7 ± 14.6	70.6 ± 13.7	0.01	0.002	0.07
HFNC (*n* = 54)						
FiO_2	0.41 ± 0.08	0.64 ± 0.09	0.39 ± 0.1	<0.0001	<0.0001	0.25
SpO_2	94.5 ± 2.5	91.6 ± 1.7	95.6 ± 3.1	<0.0001	<0.0001	0.04
SF ratio	240 ± 53.9	147 ± 29.2	253.6 ± 62.8	<0.0001	<0.0001	0.22
HR	120 ± 16	134 ± 19	119.3 ± 17.4	<0.0001	0.0001	0.92
RR	38.9 ± 8.6	48.5 ± 10.4	37.3 ± 7.9	<0.0001	<0.0001	0.31
SBP	96.5 ± 16	103 ± 19.9	94.3 ± 13.9	0.06	0.009	0.44
DBP	58.6 ± 12	63.6 ± 14	59 ± 11.6	0.04	0.07	0.82
MAP	72.3 ± 13.7	76.9 ± 16	71 ± 11.9	0.11	0.03	0.59

[a], indicates *p*-value between pre FFB and during FFB; [b], indicates *p*-value between during FFB and 3 hours post FFB; [c], indicates differences between pre and 3 hours post FFB; DBP, diastolic blood pressure (mmHg); FiO_2, fractional inhaled oxygen; HR, heart rate (/min); MAP, mean arterial pressure (mmHg); RR, respiratory rate (/min); SBP, systolic blood pressure (mmHg); SF, saturation/FiO_2

SBP (6.2 ± 11.6%; 6.85 ± 12.3%; *p*-value = 0.34), DBP (8.1 ± 17.9%; 9.2 ± 15.6%; *p*-value = 0.5) and MAP (6.37 ± 14.7; 6.7 ± 13.3; *p*-value = 0.51).

There was minor procedure-related bleeding in 14 (9%) patients. There were 26 children had a reduction in $SpO_2 \leq 88\%$ during the procedure which was treated with an increase in FiO_2 or oxygen flow. Only in seven instances, bronchoscope was withdrawn temporarily due to a transient fall in $SpO_2 < 85\%$ and subsequently, all procedures were completed. There were no complications like arrhythmia, seizures, and cardiopulmonary arrest. In only two cases the dose of inotrope was increased after FFB. Post-procedure fever ≥38°C was recorded in 19 (12.2%) cases in the first 24 hours of FFB.

Discussion

The present study demonstrated the utility of FFB in non-ventilated children admitted to PICU. FFB was required for varied indications and its findings helped in planning the medical and surgical interventions. Our study also showed the safety profile of FFB in critically ill children. The changes in the oxygenation and hemodynamics during bronchoscopy were significant but transient and without any consequences.

The transnasal route was used for FFB in all our patients including four tracheostomized cases. In tracheostomized patients, the nasal route allowed us to assess upper airways with easy maneuverability of the bronchoscope and provide secure and open airway to patients during the procedure. In many critically ill patients, alternative routes are selected depending on the clinical situation. These include via endotracheal tube, tracheostomy, and laryngeal mask airway.[6,20] A major disadvantage of using alternative routes is an inability to examine upper airway structures and dynamics.

Many patients in the PICU are on respiratory assist devices like HFNC and NIV to manage their hypoxemia and to reduce the work of breathing. FFB through the nasal route was possible with small size bronchoscopes even in infants with HFNC on flow.[11] Pediatric size bronchoscopy compatible NIV interfaces are not available in India.

Eleven of our cases were on bilevel positive airway pressure (BIPAP) mode prior to FFB. They were shifted to HFNC at a flow rate of 2 L/kg with FiO_2 optimization to achieve $SpO_2 \geq 92\%$. HFNC had been beneficial in preventing desaturation during FFB in adult patients with acute hypoxic respiratory failure as compared to COT.[21,22] Non-invasive ventilation was significantly more effective than HFNC in adult patients with moderate to severe hypoxemia.[23,24] In a randomized trial on 103 children, HFNC was superior to a conventional nasal cannula with significantly less fall in SpO_2 and reduction in absolute risk. Moderate hypoxemia, $SpO_2 < 90$ was significantly less in the HFNC group but the occurrence of severe hypoxemia was the same in the two study groups.[11]

The majority of our patients had a primary diagnosis of respiratory disease, particularly lower respiratory infections including non-resolving pneumonia. The characteristics of study population vary with place of origin of the study, unit specialty and availability of expertise. In some studies, predominantly post-operative cardiac and airway reconstruction patients were included.[7,8,10,18]

Stridor and atelectasis were the indications in almost half the patients in our study. The incidence of postextubation stridor in PICU varied from 2.5% to 25%.[25] There were 26 patients with postextubation stridor in our study and many of these patients had subglottic membrane or granulation tissue as a cause of stridor. Thin membranes were ruptured during the passage of the bronchoscope resulting in marked improvement in stridor.

In our study retained secretions in airways were the commonest cause of atelectasis. Out of 37 lung atelectasis, retained secretions without airway inflammation on FFB were present in 20 cases. In 17/20 cases, atelectasis resolved as compared to 6/17 cases in which airway inflammation and secretions (*p*-value = 0.006) were present. The probable reason was the clearing of mechanical block caused by

thick secretions with FFB but airway mucosa inflammation could not be resolved. Similar to our results, re-expansion of the lung in chest radiograph after FFB was reported in over 75% of cases after FFB.[18,26]

The prevalence of suspected foreign bodies as an indication for FFB varied from <1 to 28.5%.[2,20] In the present study, the foreign body was localized in 5 out of 13 suspected cases. An alternative diagnosis was made with FFB and medical interventions were done. So rigid bronchoscopy under general anesthesia was saved in these patients.

The bronchoscopy positivity rate was 85.6% in our study. Bronchoscopic findings and BAL results led to alterations in the medical treatment and surgical interventions in 96 (61.9%) patients. The high positivity rate of bronchoscopy was reported in previous studies.[7,8,18] Kabra et al. reported low positivity of 54%.[27] Our BAL positivity rate was comparable to that reported previously.[3,7]

Definition for desaturation had been widely variable in prior studies from 65% to 90%.[20,28] There were no procedure-related life-threatening complications in our study. Our attempt was to maintain $SpO_2 \geq 92\%$ during FFB. Risk of desaturation is common particularly whilst the bronchoscope is in the mid-trachea. This may occur despite oxygen supplementation, particularly in infants and young children with low oxygen reserves.[4] The rise in HR, RR, SBP, DBP, and MAP during bronchoscopy was reported previously in adults during the passage of bronchoscope through the trachea and with BAL.[12,14,29,30] The hemodynamic changes are due to sympathetic stimulation and release of plasma norepinephrine caused by the movement of the bronchoscope and suctioning.[13] Bar-Zohar and Sivan reported a statistically significant fall in SBP and DBP in children admitted to PICU during FFB.[26] The fall in blood pressure was related to premedication and intravascular fluid status. So, it is important to assess intravascular fluid status in sick children. Selection of premedication drugs should be done on the basis of the hemodynamics and fluid status of patients to avoid hemodynamic complications.

There are a few limitations and strengths in our study. The major limitations are the retrospective design and heterogeneous study cohort. The disease severity was not taken into consideration. We used only SpO_2 and not PaO_2 as an oxygenation parameters. We did not time the changes in hemodynamic and oxygenation parameters during the passage of the bronchoscope through airways and during BAL. More importantly for a clinician, we did not study the influence of FFB-directed interventions on outcomes like the length of stay in the PICU and hospital and duration of antibiotics and resolution of infections, and survival. Our study illustrated the changes in oxygenation and hemodynamics during bronchoscopy in critically ill, non-ventilated patients admitted in the PICU. The data and results were not influenced by the presence of non-critical cases or mechanically ventilated children. Detailed changes in hemodynamics have not been reported previously. FFB was successfully done in children on HFNC.

Conclusion

FFB was a useful tool to diagnose and guide interventions in non-ventilated patients in the PICU. Bronchoscopy resulted in significant but transient changes in oxygenation and hemodynamics with no serious consequences.

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