

# Flexible Fiber-optic Bronchoscopy-directed Interventions in Children with Congenital Heart Diseases

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## ABSTRACT

**Objective:** In children, pulmonary and cardiac diseases are closely associated, and their integrated evaluation is important. Flexible fiber-optic bronchoscopy (FFB) can be used for both diagnostic and therapeutic purposes in pediatric cardiac intensive care units (PCICU). The objective of this study was to evaluate the utility of FFB in children with congenital heart disease (CHD).

**Materials and methods:** A retrospective, descriptive study was conducted at a tertiary care center in pediatric patients who underwent FFB in PCICU over a period of 6 years (2012–2017).

**Results:** Total 71 bronchoscopies were done in 58 patients with CHD with median age and weight of 2.5 months and 3.4 kg, respectively. Total of 20 different cardiac lesions were present among patients who underwent FFB. While 38 (53.5%) and 30 (42.3%) procedures were performed in pre-op and postoperative patients, respectively, 3 intraoperative bronchoscopies were also performed. The main indications for FFB were persistent atelectasis (42/71), prolonged oxygen requirement (13/71), stridor (8/71), and suspected airway anomaly (6/71). Tracheobronchitis was the commonest bronchoscopy finding (51/71, 71.8%) followed by tracheobronchomalacia (27/71, 38.3%). Cause of stridor detected in 7/8 cases. Associated preoperative and postoperative respiratory complications were detected and necessary interventions were done. These included slide tracheoplasty (5/58), tracheostomy (5/58), antibiotic change based on bronchoalveolar lavage (BAL) cultures (11/71), and continued positive pressure ventilation (4/71). Nonconsequential complications were transient hypoxemia (10/71), bleeding (2/71), and transient bradycardia (1/71).

**Conclusion:** Bedside FFB is a safe and a valuable diagnostic tool that also helps in guiding interventions in children with cardiac diseases.

**Keywords:** Airway anomalies, Bronchoalveolar lavage, Congenital heart disease, Flexible fiber-optic bronchoscopy, Interventions, Pediatric intensive care.

*Indian Journal of Critical Care Medicine* (2020); 10.5005/jp-journals-10071-23419

## INTRODUCTION

Children with congenital heart diseases (CHD) often have coexisting airway anomalies leading to airway obstruction.<sup>1,2</sup> Flexible fiber-optic bronchoscopy (FFB) can be performed at the bedside and provide plenty of useful information for managing such patients, preoperatively and postoperatively. The objectives of our study were to investigate the utility of FFB in children suffering with CHD and to study the effect of bronchoscopic findings on management decisions in the pediatric cardiac intensive care unit (PCICU).

## MATERIALS AND METHODS

### Study Population

Medical records of 58 patients with CHD who underwent FFB in seven-bedded PCICU at a tertiary care multispecialty hospital from January 2012 to December 2017 were reviewed after obtaining permission from the institutional ethics committee. Diagnosis of CHD was made by the pediatric cardiologists based on clinical and echocardiography findings. The need and final decision for FFB was on the discretion of the treating cardiologist and cardiac surgeon.

Bronchoscopies were performed at the bedside or in a dedicated bronchoscopy procedure room after obtaining an informed consent from the parents and care-taking guardians. Intraoperative bronchoscopies were performed in cardiac operating rooms. Oxymetazoline (0.025%) nasal drop was instilled in both nostrils before the procedure. Children were sedated with intravenous ketamine (1 mg/kg) or midazolam (0.1 mg/kg). Bronchoscopy was done using a broncho videoscope (Olympus, Model number BF-XP160F) of size 2.8 mm with 1.2 mm working channel and a

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**How to cite this article:** Sachdev A, Chhawchharia R, Gupta D, Gupta N, Joshi R, Agarwal N. Flexible Fiber-optic Bronchoscopy-directed Interventions in Children with Congenital Heart Diseases. *Indian J Crit Care Med* 2020;24(5):340–343.

**Source of support:** Nil

**Conflict of interest:** None

ultrathin bronchoscope (Olympus, Model number BF-N20) of 2.2 mm outer diameter with no working channel. The procedure was performed transnasally or through an endotracheal tube with continuous ECG and oxygen saturation monitoring. Oxygen by a simple mask was delivered continuously during transnasal bronchoscopy. The FFB was performed by a pulmonologist (AS) and other members of team including cardiac intensivist, bronchoscopy technician, intensive care and pulmonology fellows, and nurse.

The anatomy and dynamics of laryngeal structures including arytenoids, epiglottis, and vocal cords were studied. During the procedure, 1% lidocaine was instilled by the "Spray and proceed

technique" through the working channel. After negotiating the vocal cord, the subglottis, trachea, and bronchi were evaluated anatomically and functionally. All along the lower airways, the bronchial mucosa and the airway pattern were studied. In patients who required bronchoalveolar lavage (BAL), normal saline was instilled (1 mL/kg) in affected areas and fluid aspirated was sent for the microbiological analysis. All procedures were recorded and stored electronically.

**Data Collection**

Patient characteristics, including age, gender, weight, route of FFB, size and type of the endotracheal tube, primary cardiac disease, and preoperative or postoperative status were recorded. Medical records were reviewed for the indications of bronchoscopy, radiological findings, bronchoscopic findings, BAL yield, and complications during the procedure. We also recorded the results of interventions (medical or surgical) executed by the cardiologists post-bronchoscopy.

**Statistical Analysis**

The categorical data are presented as number and percentages and quantitative variables are expressed as median with range.

**RESULTS**

A total of 71 FFB were done in 58 patients with CHD over a period of 6 years (2012–2017). Nine patients required FFB twice, while two patients underwent bronchoscopy three times. The median age of patients was 2.5 months (range 1 day–12 years) and median weight was 3.4 kg (range 2–24 kg) (Table 1). Out of 58 patients, 40 (69%) were males. While 44 (62%) procedures were done transnasally, 27 (38%) were done via an endotracheal tube while patient was being mechanically ventilated.

Thirty-three patients had cyanotic congenital heart diseases (CCHD) and 25 patients had acyanotic congenital heart disease (ACHD). Among these, ventricular septal defect (VSD) (8/51) and transposition of great arteries (TGA) (9/51) were most common lesions in acyanotic and cyanotic heart diseases, respectively. Detailed distribution of various CHD is shown in Table 2. While 38 (53.5%) and 30 (42.3%) procedures were performed precardiac surgery and postcardiac surgery, respectively, 3 bronchoscopies were performed intraoperatively (cardiac repair with slide tracheoplasty).

**Indications of FFB**

The main indications for FFB in cardiac patients were lung collapse (42/71), prolonged oxygen requirement (13/71), stridor (8/71),

and suspected airway anomaly (6/71). Airway anomalies were suspected clinically on the basis of clinical features like noisy breathing, dysmorphism, and radiological abnormality. Three intraoperative bronchoscopies were performed to demonstrate resolution of airway abnormality during slide tracheoplasty. From the procedures that were done preoperatively (38), 21 procedures in 18 patients were done for persistent atelectasis, 7 for prolonged ventilation, 4 patients had stridor, and 6 patients were suspected to have airway anomalies. The common indications amongst postoperative patients were persistent atelectasis (20), persistent oxygen requirement (6), and stridor (4).

**Bronchoscopy Findings**

Definitive anomaly was detected in 49/71 procedures (69%) and 38 procedures had multiple findings. Tracheobronchomalacia was the most common airway anomaly encountered in 38% procedures (27/71), majority of which were diagnosed preoperatively (16/38). Tracheobronchitis was the most common bronchoscopy finding (51/71, 71.8%). The extrinsically compressed airway was seen in 16.9% of procedures (12/71) and 10/58 patients. Other airway anomalies detected were the abnormal branching of airway (9/71), vocal cord paresis (4/71), subglottic stenosis (4/71), two cases each of bronchus suis and laryngomalacia and one case of complete tracheal rings.

The causal relation between the bronchoscopy findings and indication of FFB was evaluated. Tracheobronchitis (33),

**Table 2:** Distribution of congenital heart diseases

		Type of heart disease, n (%)	
		ACHD 25	CCHD 33
Left to right shunt		With high PBF	
VSD	8	Persistent truncus arteriosus	1
PDA	2	TAPVR	5
Complete AV canal defect	2	TA	4
VSD + PDA + MS	1	DORV + VSD	2
VSD + PDA + PPHN	1	TA + VSD	1
Proximal AP Window	1	TA + PDA	1
VSD + Anm great vessels	3	DORV + COA + VSD	
Obstructive lesions		HLHS	1
COA	6	HLHS + Anm great vessels	1
AS	1	TGA	9
		With low PBF	
		TOF	4
		PA	2
		PA + dextrocardia	1

ACHD, acyanotic CHD; VSD, ventricular septal defect; PDA, patent ductus arteriosus; AV, atrioventricular; MS, mitral stenosis; PPHN, persistent pulmonary hypertension; Anm, anomalous; COA, coarctation of aorta; AS, aortic stenosis; CCHD, cyanotic CHD; PBF, pulmonary blood flow; TAPVR, total anomalous pulmonary venous return; TA, tricuspid atresia; DORV, double outlet right ventricle; HLHS, hypoplastic left heart syndrome; TGA, transposition of great arteries; TOF, tetralogy of Fallot; PA, pulmonary atresia

**Table 1:** Demographic data

Variable	n (%)
Age (months)	2.5 (1 day–12 years)*
Weight (kg)	3.4 (2–24)*
Gender (male)	40 (69)
Route of bronchoscopy	
Nasal	44 (62)
Endotracheal	27 (38)
Time of procedure	
Preoperative	38 (53.5)
Postoperative	30 (42.3)
Intraoperative	3 (4.2)

\*Median (range)

tracheobronchomalacia (17), and extrinsic compression of bronchus (5) were responsible for persistent atelectasis in 42 patients. One case each of subglottic stenosis, vocal cord paresis, and tracheitis had stridor preoperatively, while postoperatively, stridor was encountered in three patients with subglottic stenosis, one with tracheitis and one with tracheobronchomalacia. A comparison of preoperative and postoperative bronchoscopic findings is shown in Table 3.

**Microbiological Results**

Bronchoalveolar lavage was performed in 53 (74.6%) procedures and sent for cultures. Positive cultures were obtained in only 7/53 samples (13.2%). Acinetobacter species was grown in three, Pseudomonas aeruginosa in two, Klebsiella pneumoniae and Candida in one procedure each.

**Flexible Fiber-optic Bronchoscopy—Guided Interventions**

Based on the FFB findings, interventions were advised in 38/71 (53.5%) procedures. Based on the BAL culture results, clinical criteria of ventilator-associated pneumonia and severity of airway inflammation as observed on bronchoscopy antibiotic change were suggested in 11 instances (15.5%). Bronchoscopy was done more than once in 15.7% (8/51) cases of tracheobronchitis for therapeutic BAL. Continued positive pressure ventilation (PPV) was advised in one case of tracheobronchomalacia and three cases of extrinsically compressed bronchus. Further investigation with CT angiography thorax was advised in 10 cases of extrinsically compressed bronchus to rule out anomalous vasculature. Main causes of airway compression were dilated right main pulmonary artery (5), dilated right main pulmonary artery with circumflex aorta (1), dilated left pulmonary artery (2), dilated left atrium (1), and circumflex aorta (1). Surgical interventions were undertaken in 10 cases (14.1%). Tracheostomy was done in five (8.6%) cases, three cases of subglottic stenosis, one case of tracheomalacia, and one case of vocal cord paresis. Slide tracheoplasty was done in five (8.6%) cases, four cases of extrinsically compressed bronchus, and one case of complete tracheal rings. Three FFB with ultrathin bronchoscope were performed intraoperatively to confirm resolution of airway compression after tracheoplasty in a case of complete tracheal rings and two cases of extrinsically compressed bronchus. Various interventions undertaken as a result of FFB findings are summarized in Table 4.

**Table 3:** Comparison of preoperative and postoperative bronchoscopic findings

Bronchoscopic findings	Preoperative (n = 38)	Postoperative (n = 30)
Laryngomalacia	2 (5.3)*	0
Subglottic stenosis	1 (2.6)	3 (10)
VC palsy	1 (2.6)	3 (10)
Complete tracheal rings	1 (2.6)	0
Tracheobronchitis	25 (65.8)	25 (83.3)
TB malacia	16 (42.1)	11 (36.7)
Abn branching	6 (15.8)	3 (10)
EC of airways	12 (31.6)	0
Bronchus suis	2 (5.3)	0

\*Figures in number and percentage in parentheses; VC, vocal cord; TB, malacia, tracheobronchomalacia; Abn, abnormal; EC, extrinsic compression

**Complications**

Out of 71 procedures, 58 procedures (81.7%) were tolerated well and no complications were noted. Complications noted were transient hypoxemia (10/71), bleeding (2/71), and transient bradycardia (1/71). These complications were short-lived not requiring particular medications or resuscitative measures and did not alter the natural course of the illness in any patient. None of the complications had any long-term sequelae.

**DISCUSSION**

Congenital heart disease is often associated with airway anomalies due to close anatomic proximity of cardiac and respiratory structures.<sup>1-3</sup> Flexible bronchoscopy allows the anatomic and functional assessment of the airway in patients with CHD at the bedside, before or after cardiac repair. Robotin et al.<sup>4</sup> employed FFB in all patients suspected to have airway obstruction as first-line tool and found it to be 100% accurate in establishing diagnosis. While preoperative detection of airway obstruction allows surgical corrective measures during cardiac repair, postoperative detection helps in improving outcome and prognosis. Knowledge of coexisting airway anomalies is vital for better management of these patients. This study adds information about preoperative and postoperative indications of FFB and its role during surgery and in the management postoperative complications in CHD patients.

A wide spectrum of cardiac lesions is reported in this study including both cyanotic and acyanotic CHDs. Although number of patients with complex and simple CHD were equal (29 cases each), patients with complex CHD required multiple bronchoscopies. Airway assessment was done prior to surgical repair in nearly half of the patients. Lee et al.<sup>1</sup> reported similar profile of CHDs in their study. These results were reciprocated by Cerda et al.<sup>5</sup> in their study

**Table 4:** Interventions guided by flexible fiber-optic bronchoscopy

Indications	Findings	Interventions
Stridor (n = 8)	Subglottic stenosis (4)	Tracheostomy (3)
	Laryngomalacia (1)	Slide tracheoplasty (1)
	Tracheobronchitis (1) Vocal cord paresis (1)	Antibiotic change (1)
Atelectasis (n = 42)	Airway malacia (17)	Prolonged PPV (4)
	Tracheobronchitis (33)	Antibiotic change (4)
	Extrinsic compression (5)	Slide tracheoplasty (1) Advanced investigation (5)*
Prolonged ventilation requirement (n = 13)	Airway malacia (5)	Tracheostomy (2)
	Tracheobronchitis (9)	Antibiotic change (5)
	Extrinsic compression (3) Vocal cord paresis (2)	Advanced investigation (3)*
Suspected airway anomalies (n = 6)	Extrinsic compression (3)	Slide tracheoplasty (3)
	Complete tracheal ring (1)	Advanced investigations (3)*

Numbers in parentheses represent frequency

\*CT, pulmonary angiography



who found no correlation between pulmonary disorder and type of cardiac lesion.

Among six different indications for FFB, most common were persistent atelectasis and persistent oxygen requirement, which included persistent invasive or noninvasive ventilation (NIV). These indications have been reported in several other pediatric series, as well as previous reports on cardiac patients.<sup>3,5-7</sup> Airway anomalies could be detected successfully in 69% of procedures with airway malacias being most common in our study. Lee et al. reported a diagnostic yield of 92% in their series of 52 cardiac patients with airway obstruction while Chapotte et al. reported 71% diagnostic yield.<sup>1,2</sup> The exact magnitude of airway problems in cardiac patients is still unknown as not all children with CHD undergo FFB assessment. In our study, tracheobronchitis was most frequently encountered FFB finding, though most common airway anomaly was tracheobronchomalacia.

Airway obstruction due to tracheobronchomalacia, tracheobronchitis, as well as extrinsic compression of airway is often witnessed with CHD and these were the cause for persistent atelectasis in our study as well. While most of the cases with airway malacias and airway compression were diagnosed preoperatively, 1 case with extrinsic compression of airway and 11 cases with tracheobronchomalacia were diagnosed after cardiac repair. Airway obstructions may not always be clinically evident in the preoperative period. Children with coexisting airway anomalies may become symptomatic in postoperative period due to intraoperative handling of airway and vascular structures, mechanical ventilation, or postoperative sepsis.<sup>8,9</sup> Only endotracheal vision can help evaluate severity of airway edema and trapped secretions.<sup>10</sup> In our study, 51 procedures found tracheobronchitis as the cause for obstruction or worsening of existing anatomical obstruction.

Bronchoscopy was useful in determining postoperative complications like vocal cord palsy (3), subglottic stenosis (3), tracheobronchitis (25), and tracheobronchomalacia causing persistent atelectasis leading to difficult weaning from the ventilation support. One case each of laryngomalacia, congenital subglottic stenosis, congenital vocal cord palsy, and tracheomalacia presented with stridor preoperatively was diagnosed by FFB.

In our study, FFB had contributed in management of children in (36/71) 50.7% of procedures. This is comparable with Wood's general series of 1,000 procedures, where contribution of FFB was in 76% of procedures.<sup>11</sup> Another general series of 200 FFB by Godfrey et al.<sup>6</sup> estimated this percentage to be 90.5%. Persistent atelectasis was managed by BAL and prolonged PPV. Based on BAL culture reports and degree of airway inflammation, antibiotic change was advised. Findings of FFB suggested change of management from conservative to surgical at an early stage in 10 cases. This included tracheostomy (5/71) and slide tracheoplasty (5/71). Cerda et al.<sup>5</sup> reported 5.8% cases where FFB findings proposed surgery. Intraoperative bronchoscopy was done in three cases, during slide tracheoplasty to demonstrate to surgeon the extent of tracheal abnormality before incision of trachea and to confirm resolution of airway obstruction and visual assessment of the airway lumen at the end of the corrective procedure.

Although very safe, FFB may present few complications like hypoxemia, bleeding, hemodynamic alterations like bradycardia, or

sometimes post-bronchoscopy fever.<sup>7,12</sup> In our study, complications were noted in only 19% patients. These complications are reported earlier mainly in ICU settings by Nussbaum and Bar-Zohar and Sivan.<sup>13</sup>

## CONCLUSION

Bedside FFB in children with CHD is a safe and an efficient tool with various diagnostic and therapeutic implications especially in children with symptoms suggestive of airway obstruction.

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