Rigid Bronchoscopic Placement of Fogarty Catheter as a Bronchial Blocker for One Lung Isolation and Ventilation in Infants and Children Undergoing Thoracic Surgery: A Single Institution Experience of 27 Cases

Sunil Kant Kamra¹ · Ashwin Ashok Jaiswal² · Amrish Kumar Garg² · Manoj Kumar Mohanty³

Received: 11 December 2015 / Accepted: 5 October 2016 / Published online: 15 October 2016
© Association of Otolaryngologists of India 2016

Abstract One-lung ventilation (OLV) is a challenging task in infants and children as few techniques are possible because of narrow anatomy. The aim of this study is to evaluate and experience lung isolation with Fogarty catheters as a bronchial blocker placed by rigid bronchoscope for OLV in infants and children with lung pathologies requiring surgical management in an industrial hospital. This study is a prospective study carried out in J.L.N. Hospital and Research Centre, Bhilai (CG), from January 2011 to December 2014. The study was designed to place Fogarty catheter for achieving OLV using rigid bronchoscope in children. The patient and anaesthesia characteristics, placement and positioning of Fogarty catheters, intraoperative course, complications and recovery of the patient were studied. The data were then compared with the relevant and available literature. Over the study period of 4 years, 27 cases were included, out of which 22 (81.48 %) cases had suppurative lung disease,

three cases (11.11 %) had hydatid cyst of the lung, whereas one case (3.7 %) each of congenital lobar emphysema and congenital cystic adenomatoid malformation of the lung, respectively. In all cases general anaesthesia was provided using single lumen endotracheal tube and one lung ventilation achieved by parallel placement of Fogarty catheter as a bronchial blocker with rigid bronchoscope. The surgical management included thoracotomy with decortication in 21 cases, thoracotomy with excision of hydatid cyst in 3 cases, video-assisted thoracoscopic surgery, thoracotomy with left upper lobectomy and thoracotomy with left lower lobectomy in one case each, respectively. There were no major intraoperative and postoperative complications. There was no mortality in our study. We conclude that rigid bronchoscope can be safely and effectively used to place Fogarty catheter in main bronchus in infants and children for achieving OLV.

Keywords Fogarty catheters · Bronchial blocker · Bronchoscopy · One-lung ventilation (OLV)

✉ Ashwin Ashok Jaiswal
ash1978jaiswal@gmail.com

Sunil Kant Kamra
kamrasunilkant@gmail.com

Amrish Kumar Garg
drakgarg19@yahoo.co.in

Manoj Kumar Mohanty
manoj65us@yahoo.com

¹ Department of Anaesthesia, J.L.N. Hospital and Research Centre, Bhilai, CG, India

² Department of ENT and Head Neck Surgery, J.L.N. Hospital and Research Centre, Sector 9, Bhilai, Dist. Durg, CG 490009, India

³ Department of Paediatric Surgery, J.L.N. Hospital and Research Centre, Bhilai, CG, India

Introduction

One lung ventilation (OLV) was not practiced in children till the late years of twentieth century. Prone position and lung retraction were adopted to facilitate lung surgery in children. The complexity of OLV in pediatric patients is more because of limited available techniques and experience [1]. With passing years, interests are gearing towards practicing OLV in children more to gain benefits like a ‘quiet’ surgical field with adequate exposure and avoidance of contamination of the normal lung [2]. Today ballooned catheters like Arndt, Univent tubes and Fogarty catheter are used as bronchial blockers to achieve OLV. Close

familiarity with equipments used for OLV as well as bronchoscopy and respiratory tract anatomy is important for successful OLV. As the institute did not possess the fiberoptic paediatric bronchoscope, a rigid bronchoscope was used to guide placement of Fogarty catheter. We present our experience of placement of Fogarty catheter as a bronchial blocker using rigid bronchoscopy for OLV conducted in infants and children with lung pathologies requiring surgical management over a period of 4 years for various indications in an industrial hospital.

Materials and Methods

The study was conducted in Jawaharlal Nehru Hospital and Research Centre, Bhilai (CG) over a period of 4 years from January 2011–December 2014. The study included a total 27 cases comprising of infants and children below 14 years of age with lung pathologies requiring the one lung ventilation for surgical management. All parents were informed in detail regarding the study and informed consent was taken for their children voluntary participation in the study. All candidates were subjected to a detailed history taking and clinical examination was performed including a general systemic examination. Radiological examination including X-ray chest and high resolution computed tomography scan (HRCT) thorax was done to know the status of lung parenchyma, disease status as well as the bronchial anatomy. After a detailed preoperative case study, OLV in specific bronchus and Fogarty catheter (2–7fr) was decided. Tracheal and bronchial diameter as well as approximate distance of carina from angle of mouth was assessed. This helped us to decide the size of Fogarty to be used and its approximate distance from bronchus to the angle of mouth.

All children were premedicated with inj. Atropine (0.01 mg/kg). After ascertaining mask ventilation all children were paralysed with inj atracurium (0.5–0.6 mg/kg) following induction with IV propofol (2–3 mg/kg).

The chosen size Fogarty catheter was placed in the trachea and bronchus with tilt of neck on either side at an approximate measured length. Rigid ventilating bronchoscope of appropriate size was inserted to place and/or to confirm the placement of Fogarty catheter in the chosen bronchus at about 1 cm from carina and the balloon was inflated with recommended amount of air. Forceps was utilized for correct placement of Fogarty and Rigid bronchoscope was withdrawn after placement. Lung isolation and proper positioning of the blocker in the correct mainstem bronchus were confirmed by auscultation, before and after lateral positioning of the patient and length of Fogarty at angle of mouth was noted. All patients were intubated with single lumen endotracheal tube. The balloon was inflated again with the

recommended amount of air and goahead for surgery was given (Fig. 1a–f). The balloon was deflated and reinflated as and when asked by the surgeon to know and avoid parenchymal/bronchial leaks. After definitive surgery balloon was deflated and lungs were inflated.

Respiratory parameters such as peripheral arterial oxygen saturation (SpO₂), and end-tidal carbon dioxide tension (EtCO₂) were monitored during two lung ventilation (TLV) and after initiation of OLV in supine and lateral position. Intraoperative and postoperative complications were noted. Variables recorded included size of Fogarty catheter used, size of bronchoscope used, size of endotracheal tube used, time taken for placement, the number of times the bronchoscope was used and successful placement (as determined by an independent observer). The data were then compared with the relevant and available literature.

Observation and Results

In the study period of 4 years, a total 27 cases including infants and children with lung pathologies requiring surgical management were reviewed. The year-wise distribution of cases is shown in Fig. 1g. The following characteristics were taken into consideration.

Patient Characteristics

Age Distribution

In our study, out of 27 cases, most common age group was 2–4 years accounting for 29.62 % (8) of cases whereas 14.81 % (4) of cases were seen in the age group of 0–1 years (Table 1). The youngest patient was 3 months old while the oldest one was of 13 years of age. The overall mean age was found to be 4.67 ± 3.61 years while it was 4.89 ± 3.96 years in males whereas 4.57 ± 2.64 years in females (Fig. 1h).

Sex Distribution

There were 19 boys and 8 girls out of the 27 cases providing a male predominance with a sex ratio of 2.375:1 (Fig. 1h).

Anesthesia Characteristics

The one lung ventilation was provided in all 27 cases with right sided ventilation in 12 cases and left sided ventilation in 15 cases (Table 2). The peripheral arterial oxygen saturation monitoring revealed a mean SpO₂ of 98.93 % during two lung ventilation and 95.3 % during one lung ventilation in supine position and 94.44 % in lateral

Fig. 1 Clinical photograph showing the placement method steps. **a** Step 1—Induction of anaesthesia. **b** Step 2—chosen size Fogarty catheter is placed in the trachea and bronchus with tilt of neck on either side at an approximate measured length. **c** Step 3—rigid ventilating bronchoscope of appropriate size is inserted. **d** Step 4—confirmation of the placement of Fogarty catheter in the chosen

bronchus with manipulation of Fogarty. **e** Step 5—forceps is utilized for correct placement of Fogarty catheter at about 1 cm from carina. **f** Step 6—the balloon is inflated with recommended amount of air under bronchoscopic vision. **g** Year-wise distribution of cases. **h** Age and sex distribution

position. These fall in Spo2 though statistically significant (p value 0.00001) was clinically not significant. In three patients oxygen saturation was down to 85 % which was

promptly treated. The end tidal carbon dioxide monitoring revealed a mean ETCO₂ of 31.67 mmHg during two lung ventilation and 39.26 mmHg during one lung ventilation in

Table 1 Endotracheal tube, bronchoscope and Fogarty catheter characteristics (n = 27 cases)

Sr. no.	Age group (years)	No. of cases	Size of ETT (mm)	Size and type of bronchoscope (mm, rigid)	Size of Fogarty catheter (fr)
1	0–1	4	3	3	3
2	1–2	3	3.5	3	3
3	2–4	8	4	4	3
4	4–6	4	4.5	4	3, 4
5	6–8	5	4.5, 5	4	4
6	8–10	1	5.5	4	5
7	10–13	2	6	5	5

supine position and 40.04 mmHg during lateral position (Table 3). The differences in ETCO₂ though statistically significant (p value 0.00001) was within acceptable normal range. Three children showed a rise in ETCO₂ to >45 mmHg which was managed. The comparison and correlation between Spo₂ and ETCO₂ in these groups is shown in Table 4.

Rigid Bronchoscopy Characteristics

Of the 27 cases rigid bronchoscope of sizes 3, 4 and 5 mm depending on the age of patient was used to place and/or for confirmation of correct placement of Fogarty catheter (Table 1). The mean time for placement of Fogarty catheter was 4.48 min by rigid bronchoscopy. In all the 27 children the bronchoscope was used for single time however only one child required a repeat bronchoscopy due to displacement of Fogarty catheter while lateral decubitus positioning of the patient.

Fogarty Catheter Characteristics

The Fogarty catheter was placed in left bronchus providing a left bronchial blockade with selective collapse of lung on left side in 12 cases whereas in right bronchus providing a right bronchial blockade with selective collapse of lung on right side in 15 cases (Table 2). The Fogarty catheters of sizes 3fr, 4fr and 5fr were used in accordance with age of the patients (Table 1). In all 27 cases the Fogarty catheter was placed extra-luminal i.e. parallel placement outside the endotracheal tube by rigid bronchoscope. Size of Fogarty catheter was chosen after assessing the diameter of trachea and bronchus (X-ray) and diameter of inflated balloon of Fogarty.

Table 2 One lung ventilation, bronchial blockade with selective lung collapse, indications, surgical management and complications (n = 27 cases)

Sr. no.	Characteristic	No. of cases
1	One lung ventilation	
	Right	12
	Left	15
	Total	27
2	Bronchial blockade with selective lung collapse	
	Right	15
	Left	12
	Total	27
3	Indications	
	Suppurative lung disease (Empyema thoracis)	22
	Right	13
	Left	8
	Bilateral	1
	Pulmonary Hydatid cyst	3
	Right	1
	Left	2
	Congenital lobar emphysema	
	Left upper lobe	1
	Congenital cystic adenomatoid malformation of lung	
	Bilateral lower lobe	1
	Total	27
4	Surgical management	
	Thoracotomy with decortication	21
	Right	13
	Left	8
	Video assisted thoracoscopic surgery (VATS)	
	Right	1
	Thoracotomy with excision of hydatid cyst	3
	Right	1
	Left	2
	Thoracotomy with left upper lobectomy	1
	Thoracotomy with left lower lobectomy	1
	Total	27
5	Complications	
	During positioning	
	Displacement of Fogarty catheter	1
	Intra operative	
	↓ in Spo ₂	3
	↑ in ETCO ₂	3
	Arrhythmia	1
	Post operative	
	Laryngeal Oedema	1
	Convulsion	1
	Ventilatory support	1

Table 3 SPO2 and ETCO2 parameters during TLV, OLV and lateral position

Sr. no.	Groups	Mean (%)	(%)	<i>p</i> value
1	SPO2 (TLV)	98.93	1.11	0.00001 significant difference in SPO2 level in 3 groups
2	SPO2 (OLV)	95.3	3.02	
3	SPO2 (LAT)	94.44	3.25	
Sr. no.	Groups	Mean	SD	<i>p</i> value
1	ETCO2 (TLV)	31.67	2.45	0.00001 significant difference in SPO2 level in 3 groups
2	ETCO2 (OLV)	39.26	4.49	
3	ETCO2 (LAT)	40.04	5.35	

Table 4 Comparison between SPO2 and ETCO2 parameters during TLV, OLV and lateral position

Sr. no.	Comparison between 2 groups	<i>p</i> value
1	Between SPO2 (TLV) and SPO2 (OLV)	<i>p</i> = 0.0001 significant
2	Between SPO2 (TLV) and SPO2 (LAT)	<i>p</i> = 0.0001 significant
3	Between SPO2 (OLV) and SPO2 (LAT)	<i>p</i> = 0.32 not significant
4	Between ETCO2 (TLV) and ETCO2 (OLV)	<i>p</i> = 0.0001 significant
5	Between ETCO2 (TLV) and ETCO2 (LAT)	<i>p</i> = 0.0001 significant
6	Between ETCO2 (OLV) and ETCO2 (LAT)	<i>p</i> = 0.56 not significant

Indications for Surgery and OLV

Suppurative lung disease 22 cases (81.48 %), Hydatid cyst of lung 3 cases (11.11 %), one case (3.7 %) each of congenital lobar emphysema and congenital cystic adenomatoid malformation of lung respectively were the indications for OLV and Surgery. The further details are as in Table 2.

Surgical Management

Out of the 27 cases, the surgical management included thoracotomy with decortication, excision, and lobectomy as well as video assisted thoracoscopic surgery (VATS). Table 2.

Complications

There were no major intraoperative and postoperative complications seen in our study. During lateral decubitus positioning of the patient in one patient displacement of the Fogarty catheter occurred leading to desaturation hence the balloon was deflated and replacement of the Fogarty catheter was done under rigid bronchoscopic guidance. Intraoperatively, in one case of congenital cystic adenomatoid malformation, arrhythmia occurred while separating the left lower lobe from the pericardium which was managed immediately. Post operatively, laryngospasm was seen in one patient while one patient with bilateral empyema required ventilator support for a period of 48 h. One episode of convulsion was seen in a patient with

bilateral congenital cystic adenomatoid malformation (Table 2). There was no evidence of collapse or injury to trachea or bronchus postoperatively.

Outcome

Surgical outcome was overall good. There was no mortality seen in our study.

Discussion

Surgical interventions, including video-assisted thoracoscopic surgeries, are increasingly being performed in the neonatal and pediatric populations. Achieving one lung ventilation (OLV) has posed a unique challenge to anesthesiologists for many years. A review of the past literature shows various continually evolving techniques and methods, yet no gold standard has ever been attained. Each of the available methods of lung isolation has its strengths and weaknesses. The choice of technique for each individual case depends on interplay of several factors such as: indication for OLV, concurrent patient problems, available equipment and skill/training of the anesthesiologist. The ABCs of lung isolation described by Peter Slinger as *A* anatomy (know the anatomy); *B* bronchoscopy (Skill); and *C* chest imaging (to know the airway status) must be adhered to [3, 4].

Balloon-tipped bronchial blockers (BB) remain the 'technique of choice' in paediatric patients, under the age

of 6 years [5, 6]. The catheter or blocker may be placed within or outside the ETT. Its position can be checked by auscultation, the image intensifier or by bronchoscopy either flexible or rigid. With an inflated blocker balloon, the airway is completely sealed, providing more predictable lung collapse and better operating conditions than with an ETT in the bronchus. A potential problem is dislodgement of the blocker balloon into the trachea. A recent study reported that bronchial blocker cuffs produced lower “cuff-to-tracheal” pressures than double lumen tubes [7]. The current use of bronchial blocker technology, supported by scientific clinical evidence, dictates that bronchial blockers should be available in any service that performs lung separation techniques. Double lumen tubes (DLT) are a Gold standard of One Lung Ventilation in adults but non availability of DLT of smaller size (<26F) forced anesthesiologists to look for alternative means of OLV in children below the age of 6 years and so Fogarty catheter placement in either bronchus using a bronchoscope is practiced widely.

The Fogarty occlusion embolectomy catheter (Edwards Lifesciences, Irvine, CA), invented by Dr. Thomas J. Fogarty in the late 1940s, is a device designed specifically to be used as a vascular tool; however, there are well documented reports of its use in successful bronchial blockade to achieve lung isolation [8]. In 1969 Vale [9] and Lines [10]; both described the use of a Fogarty catheter to control ventilation to the operated lung. It is an effective bronchial blocker used in adults as well as children. It is positioned under direct vision, is inexpensive and reusable [11]. The Fogarty catheter has an incorporated stylet that can be reshaped at the distal end to facilitate its guidance into the left mainstem bronchus.

Choice of appropriate size of Fogarty catheter or the technique of lung isolation/ventilation that is chosen for use during paediatric surgery relates to the age and size of the patient [6]. As early as 1969, Vale and Lines already described the use of Fogarty embolectomy catheter for lung isolation in small children and suggested appropriate size selection for this age group [9, 10]. Tan and Tan–Kendrick, measured right and left bronchus of 250 children aged 2 days–16 years old using computed tomograms (CT) of the thorax and correlated it with the patient’s age and weight, in order to create a guide to size selection of the Fogarty catheter. From this study, they found out that the age, but not the weight, of the patient is a good predictor of the main bronchial diameters. They recommended the use of a 3 Fr Fogarty catheter up to the age of 4 years and a 5 Fr catheter for 5–12 years old. They also perceived that the balloon pressure exerted by the larger catheter on the bronchial wall might be lower. Since embolectomy catheters can exert high pressure on the airway, it is worth knowing that by using incremental volumes of air in

inflating the balloon until the seal is achieved will be helpful in preventing untoward effects of having high pressures [12]. It is worth noting that using 0.1 ml incremental volumes of air will help achieve a just seal volume. In our study we used Fogarty catheters of three sizes i.e. 3fr, 4fr and 5fr (Fig. 2a–d) taking into consideration the specifications regarding the Fogarty catheters as provided by Edwards Lifesciences (Table 5).

Placement methods include blind techniques and direct visualization techniques such as rigid bronchoscopy, fibreoptic flexible bronchoscopy and fluoroscopy. Placement of a Fogarty catheter can be accomplished outside or within a SLT blindly and with the help of rigid or fiberoptic bronchoscope (FOB) [13–16]. Fogarty catheter placement inside the SLT using two FOB adapters connected in a series has been described for using a separate port for the FOB and the Fogarty catheter [17]. Alternatively, a Fogarty catheter can be placed by passing through the hole made in a SLT and the FOB through a SLT adapter [18]. Placement of a Fogarty catheter outside the tracheal tube can be achieved by direct visualization of the bronchus using a rigid bronchoscope, but the use of this technique may prolong laryngoscopy and bronchoscopy [14–16], Fogarty catheter placement can be facilitated by inserting it into the trachea before intubation with a SLT or along the side of the SLT after intubation [13]. Although it does not create additional potential for disconnection and leaks in the breathing circuit, it may increase the time for instrumentation of the larynx and the trachea. Alternatively, isolation of the lung can be achieved by placement of a bronchial blocker or a Fogarty catheter from outside the SLT with the help of a FOB [19].

Mohan et al. [20] described the successful placement of a Fogarty catheter for one-lung ventilation through a SLT using the single diaphragm of an adapter for both the FOB and the Fogarty catheter. In our study we utilized rigid bronchoscopy for placement of Fogarty catheter in 27 cases. In all cases Fogarty was placed extraluminally i.e. outside the endotracheal tube by parallel placement. When compared fibreoptic bronchoscopy is found to be more beneficial due to better vision and ease in insertion even in lateral position, however during rigid bronchoscopy ventilation can be continued even during procedure as well as Fogarty catheter can be manipulated for placement in either bronchus using foreign body forceps.

Among the other Modern bronchial blockers, The Univent Tube (Uniblocker) was the first modern BB reported in 1982 by Inoue et al. [21] and was termed as the “Univent” tube (Fuji Systems, Tokyo, Japan). The Univent tube was modified in 2001, to the system that is currently available, which is termed the “Torque Control Blocker Univent” (TCB). The use of the Arndt wire-guided endobronchial (WEB) blocker (Cook) was first reported in 1999

Fig. 2 Photograph showing **a** Fogarty catheters of different sizes 3fr, 4fr and 5fr. **b** Fogarty catheters with their respective maximum capacity. **c** Fogarty catheters of size 3fr and 5fr with inflated balloon.

d Bronchoscopic view showing left bronchial blockade with inflated balloon of 3fr Fogarty catheter

Table 5 Fogarty catheter characteristics (Edwards Lifesciences)

Sr. no.	Catheter French size (mm)	2F 0.67	3F 1.00	4F 1.33	5F 1.67	6F 2.0	7F 2.3
1	Maximum liquid capacity (ml)	N/A	0.2	0.75	1.5	2.0	2.5
2	Maximum gas capacity (ml)	0.2	0.6	1.7	3.0	4.5	5.0
3	Diameter of inflated balloon (mm)	4	5	9	11	13	14
4	Maximum French size of deflated balloon (mm)	3.4 F 1.13	4.3 F 1.43	5.0 F 1.67	6.0 F 2.0	7.0 F 2.3	8.0 F 2.7

[22]. For children, the Arndt Endobronchial Blocker is only suitable if the ETT to be used is greater than 4.5 mm internal diameter, as the available 5 Fr catheter has a diameter of 2.5 mm and requires a small bronchoscope of at least 2.2 mm for positioning [23, 24]. The Cohen Flex-tip endobronchial blocker (Cook) was first reported in 2005

[25]. Coopdech bronchial blocker, by Smith Medical, Rosmalen, NL, has a preformed angulation at the distal tip to aid placement in the desired bronchus [26, 27]. EZ blocker, by AnaesthetIQ, Rotterdam, NL, is a Y shaped bronchial blocker with two distal extensions to be placed in both main stem bronchi [28].

Fig. 3 **a** X-ray chest PA view showing right-sided empyema thoracis. CT scan thorax, **b** coronal view, **c** sagittal view and **d** axial view showing right sided empyema thoracis (pyopneumothorax) with partial collapse with consolidation right lower lobe

Hammer and colleagues have published extensively on OLV in the pediatric population. They have achieved OLV through multiple methods from single-lumen ETT, uninflated tube, double-lumen ETT, to Fogarty embolectomy catheter used as a bronchial blocker, and AEBs [6, 29]. Although clinical reports of comparison with other blockers are lacking, there is a large series of >200 cases by a single author in which the Fogarty occlusion catheter was preferentially used for a left-sided thoracic surgery with apparently positive results [13]. There are also some

isolated reports of use in patients with difficult airways requiring OLV [30–33].

Stephenson and Seefelder [34] reported a method of performing OLV through extraluminal placement of the 5 Fr AEB in infants younger than 24 months. They were successful in separating lung ventilation in 23 (88.5 %) of their patients: 6 had a body weight greater than 10 kg. Similarly, the AEB was also described for successful lung separation in a group of pediatric patients by Wald et al. [24]; however, half the patient population was older than

Fig. 4 **a** X-ray chest PA view (pre-operative) showing large sized cystic lesion in left lobe—hydatid cyst. CT scan thorax, **b** coronal view, **c** axial view showing large cystic lesion and **d** X-ray chest PA view (post-operative) showing expanded left lung with ICD tube in situ

5 years of age. In our study, Fogarty catheter was used for one lung ventilation in 27 patients successfully including 7 patients less than 24 months of age whereas 20 patients of paediatric age group.

Camci et al. [35] reported Techniques and complications of one-lung ventilation in fifteen children undergoing thoracotomy with suppurative lung disease. Right lung isolation was successfully obtained by Fogarty catheters in ten children undergoing right thoracotomy and left in five patients. Our study included 22 patients with empyema thoracis (Fig. 3a–d), out of which 21 cases of late

organizing phase required thoracotomy with decortication, while one case of fibrinopurulent phase was treated effectively with VATS.

Baraka et al. [36] utilized one-lung ventilation in 13 children, undergoing surgical excision of pulmonary hydatid cysts. Five had right-sided pulmonary cysts and eight had left cysts. An ordinary cuffed tracheal tube was introduced to the main bronchus of the healthy side. After operation there was a high frequency of right upper lobe collapse in cases of selective right bronchial intubation, but this cleared completely within 3–4 days. We experienced

Fig. 5 a X-ray chest PA view showing variable sized cystic lesions in left lower lobe? adenomatoid malformation. CT scan thorax, **b** coronal view, **c** axial view showing air filled cysts of various sizes in bilateral

lower lobe suggestive of congenital cystic adenomatoid malformation type 1 (CCAM)

successful one lung ventilation in three patients with pulmonary hydatid cysts (Fig. 4a–d) with Fogarty catheter as bronchial blocker placed by rigid bronchoscopy, with no post operative collapse.

Guruswamy et al. [37] reported the anaesthetic management of a male neonate with congenital cyst adenoid malformation (CCAM) of the lung who underwent thoracotomy for resection of CCAM 24 h after birth and again at 24 days. The use of one-lung ventilation (OLV) with a size 3 Fr Fogarty catheter as a bronchial blocker placed parallel to the ETT allowed for better surgical access and enabled complete resection of the lesion. We provided one lung ventilation in a 3 months infant with bilateral CCAM

(Fig. 5a–d) with a 3fr Fogarty catheter placed in left main bronchus using rigid bronchoscope.

Schmidt and colleagues [38] describe the use of a 65-cm double-lumen fiberoptic wire-guided endobronchial blocker (FWEB) in a 3000-g, 40-day-old infant with congenital emphysema requiring left upper pulmonary lobe resection. This technique differs from ours in that both the FWEB and fiberscope were placed through the ETT whereas in our study in a 3 months old infant with left upper lobe congenital lobar emphysema (Fig. 6a, b), the 3fr Fogarty catheter was placed parallel to the ETT in left bronchus under rigid bronchoscopic guidance for one lung ventilation.

Fig. 6 CT scan thorax, **a** coronal view, **b** axial view showing emphysematous changes in left upper lobe suggestive of congenital lobar emphysema

Fujiwara et al. [39] practised one-lung anesthesia using Fogarty catheter as a selective bronchial blocker in two infants. First case underwent partial resection of the right middle lobe for her giant lung cyst while in the second case thoroscopic resection of left mediastinal tumor was done under general anesthesia.

Yamaguchi et al. [40] performed differential lung ventilation using a Fogarty catheter after accidental damage of a bronchial blocker. They inserted a Fogarty catheter (10 Fr) into the right bronchus under fiberoptic bronchoscopy. Its balloon was inflated for differential lung ventilation.

Yasumoto et al. [41] presented two pediatric patients with one-lung anesthesia using a Fogarty catheter coarctation of the aorta scheduled for coarctectomy while the other with metastatic lung tumor scheduled for partial resection of the left upper lobe under thoroscopic surgery.

Pantavaidya et al. [42] described a dual isolation technique adopted to isolate the lungs from one another at the time of right pneumonectomy in a child (age: 5 years, 10 kg weight) with evidence of infective lung disease

associated with copious purulent secretion and compromised respiratory function. They achieved it by placing Fogarty embolectomy catheter in right main bronchus and a plain polyvinylchloride endotracheal tube (which was aseptically preshaped to have a distal 45° angulation towards left) in left main bronchus.

Use and colleagues [43] describe the use of a 4 Fr. Fogarty catheter with a hollow center (Fogarty Thru-Lumen Embolectomy; Baxter) as a bronchial blocker in left mainstem bronchus for OLV in a 6-year-old child with left pulmonary sequestration undergoing video-assisted thoracoscopic left lower lobectomy.

Thallaj [44] described two adjustments to solve technical problems encountered during use of Fogarty embolectomy catheter as endobronchial blocker. First, bending the catheter tip which will help to direct the tip to the target bronchus by twisting the catheter shaft and second, to inflate the balloon using saline mixed with methylene blue. A blue colored balloon can be identified easily by bronchoscope.

Conclusion

- One must be mindful of the respiratory insult caused by OLV under general anaesthesia, and positioning during operation to overcome the challenges of rendering one lung ventilation technique in infants and children.
- The current use of bronchial blockers highlights that in any service that performs lung separation techniques, bronchial blockers should be available.
- Taking into consideration the equipment in the hospital and technique of the anesthesiologist, various methods should be planned when performing OLV in neonates,
- It is important to plan for a method that can succeed quickly and accurately within the time limit taken for oxygen desaturation, as well as to perform the procedure in a state of sufficient preoxygenation before anesthesia.
- The rigid bronchoscopic guided placement of Fogarty catheter as a bronchial blocker is a safe and effective technique in infants and children for OLV. When Fogarty catheter of appropriate size, pediatric bronchoscopes, and expertise with their use are available.
- The use of Fogarty embolectomy catheters for lung isolation in children undergoing thoracotomy is recommended.

Funding This study was not funded by any Source/Firm/agency.

Compliance with Ethical Standards

Conflict of interest All the authors have filled the potential conflict of interest disclosure forms and declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from parents of all individual participants included in the study. Additional informed consent was obtained from parents of all individual participants for whom identifying information is included in this article.

References

1. Sutton CJ, Naguib A, Puri S, Sprenker CJ, Camporesi EM (2012) One-lung ventilation in infants and small children: blood gas values. *J Anesth* 26(5):670–674
2. Ris HB, Krueger T (2004) Video-assisted thoracoscopic surgery and open decortication for pleural empyema. *Multimed Man Cardiothorac Surg* 10:1510
3. Slinger P (2008) Con: the new bronchial blockers are not preferable to double-lumen tubes for lung isolation. *J Cardiothorac Vasc Anesth* 22:925–929
4. Levine M, Slinger P (2002) Single-lung ventilation in pediatrics. *Can J Anesth* 49(3):221–222
5. Campos JH (2008) Progress in lung separation. *Thorac Surg Clin* 15:71–83
6. Hammer GB, Fitzmaurice BG, Brodsky JB (1999) Methods for single lung ventilation in pediatric patients. *Anesth Analg* 89:1426–1429
7. Guyton DC, Besselievre TR, Devidas M et al (1997) A comparison of two different bronchial cuff designs and four different bronchial cuff inflation methods. *J Cardiothorac Vasc Anesth* 11:599–603
8. Campos JH (2003) An update on bronchial blockers during lung separation techniques in adults. *Anesth Analg* 97:1266–1740
9. Vale R (1969) Selective bronchial blocking in a small child. *Br J Anaesth* 41:453–454
10. Lines V (1969) Selective bronchial blocking in a small child. *Br J Anaesth* 41:893
11. Benumof JL, Alfery DD (2005) Anesthesia for thoracic surgery. In: Miller RD (ed) *Anesthesia*. Churchill Livingstone, New York, p 1704
12. Tan GM, Tan-Kendrick APA (2002) Bronchial diameters in children—use of the Fogarty catheter for lung isolation in children. *Anaesth Intensive Care* 30:615–618
13. Ginsberg RJ (1981) New technique for one-lung anesthesia using an endobronchial blocker. *J Thorac Cardiovasc Surg* 82:542–546
14. Rao CC, Krishna GK, Grosfed JL, Weber TR (1981) One lung pediatric anesthesia. *Anesth Analg* 60:450–452
15. Watson CB, Bowe EA, Burk W (1982) One lung anesthesia for pediatric thoracic surgery: a new use of fiberoptic bronchoscopy. *Anesthesiology* 36:314–315
16. Hammer GB, Manos SJ, Smith BM et al (1996) Single lung ventilation in pediatric patients. *Anesthesiology* 84:1503–1506
17. Larson CE, Gasior TA (1990) A device for endobronchial blocker placement during one lung anaesthesia [letter]. *Anesth Analg* 71:311–312
18. Asai T, Ikeda S, Shingu K (2000) Insertion of a Fogarty catheter through an endotracheal tube for one-lung ventilation: a new method. *Anesthesiology* 93:909
19. Harvey SC, Alpert CC, Fishman RL (1996) Independent placement of bronchial blocker for single lung ventilation: an alternative method for the difficult airway. *Anesth Analg* 83:1330–1331
20. Mohan VK, Darlong VM, Kashyap L, Mishra SK, Gupta K (2002) Fiberoptic-guided Fogarty catheter placement using the same diaphragm of an adapter within the single-lumen tube in children. *Anesth Analg* 95:1241–1242
21. Inoue H, Shohtsu A, Ogawa J et al (1982) New device for one-lung anesthesia: endotracheal tube with movable blocker. *J Thorac Cardiovasc Surg* 83:940–941
22. Arndt GA, Kranner PW, Rusy DA, Love R (1999) Single-lung ventilation in a critically ill patient using fiberoptically directed wireguided endobronchial blocker. *Anesthesiology* 90:1484–1486
23. Bird GT, Hall M, Nel L, Davies E, Ross O (2007) Case report: effectiveness of Arndt endobronchial blockers in pediatric scoliosis surgery: a case series. *Pediatr Anesth* 17:289–294
24. Wald SH, Mahajan A, Kaplan MB, Atkinson JB (2005) Experience with the Arndt paediatric bronchial blocker. *Br J Anaesth* 94(1):92–94
25. Cohen E (2005) The Cohen flexitip endobronchial blocker: an alternative to a double lumen tube. *Anesth Analg* 101:1877–1879
26. Venkataraju A, Rozario C, Saravanan P (2010) Accidental fracture of the tip of the Coopdech bronchial blocker during insertion for one lung ventilation. *Can J Anaesth* 57(4):350–354
27. Ozaki M, Murashima K, Koga K, Sata T (2010) Use of the Coopdech Bronchial Blocker as a tracheal tube introducer in a patient with difficult laryngoscopy. *J Anesth* 24(2):319–320

28. Mourisse J, Liesveld J, Verhagen A et al (2013) Efficiency, efficacy, and safety of EZ-blocker compared with left-sided double-lumen tube for one-lung ventilation. *Anesthesiology* 118(3):550–561
29. Hammer GB, Brodsky JB, Redepath JH, Cannon WB (1998) The Univent tube for single-lung ventilation in paediatric patients. *Paediatr Anaesth* 8:55–57
30. Nino M, Body SC, Hartigan PM (2000) The use of a bronchial blocker to rescue an ill-fitting double-lumen endotracheal tube. *Anesth Analg* 91:1370–1371
31. Capdeville M, Hall D, Koch CG (1998) Practical use of a bronchial blocker in combination with a double-lumen endotracheal tube. *Anesth Analg* 87:1239–1241
32. Otruba Z, Oxorn D (1992) Lobar bronchial blockade in bronchopleural fistula. *Can J Anaesth* 39:176–178
33. Amar D, Desiderio DP, Bains MS, Wilson SR (2001) A novel method of one-lung isolation using a double endobronchial blocker technique. *Anesthesiology* 95:1528–1530
34. Stephenson LL, Seefelder C (2011) Routine extraluminal use of the 5F Arndt endobronchial blocker for one-lung ventilation in children up to 24 months of age. *J Cardiothorac Vasc Anesth* 25(4):683–686
35. Çamci E, Tuğrul M, Tuğrul ST, Şentürk M, Akpir K et al (2001) Techniques and complications of one-lung ventilation in children with suppurative lung disease: experience in 15 cases. *J Cardiothorac Vasc Anesth* 15(3):336–340
36. Baraka A, Slim M, Dajani A, Lakkis S (1982) One-lung ventilation of children; during surgical excision of hydatid cysts of the lung. *Br J Anaesth* 54(5):523–528
37. Guruswamy V, Roberts S, Arnold P, Potter F (2005) Anaesthetic management of a neonate with congenital cyst adenoid malformation. *Br J Anaesth* 95:240–242
38. Schmidt C, Rellensmann G, Aken HV, Semik M, Bruessel T, Enk D (2005) Single lung ventilation for pulmonary lobe resection in a newborn. *Anesth Analg* 101:362–364
39. Fujiwara C, Sato Y, Shoji K, Onozawa H, Takinami M, Kamide M, Tanifuji Y (2002) One-lung anesthesia was successfully maintained by means of Fogarty Catheter in infants. *Masui* 51(8):875–879
40. Yamaguchi S, Ikeda T, Watanabe K, Mishio M, Okuda Y, Kitajima T (1999) Differential lung ventilation using Fogarty catheter after accidental damage of bronchial blocker cuff. *Masui* 48(10):1132–1134
41. Yasumoto M, Harasawa I, Mori M, Tanaka K, Dan K (1994) Pediatric one-lung anesthesia with a Fogarty catheter. *Masui* 43(7):1044–1047
42. Pantvaiddya SH, Golam KK, Pai RV, Saksena SG, Kaul SA (1994) Dual isolation technique for paediatric lung surgery. *J Postgrad Med* 40:89–91
43. Use T, Shimamoto H, Fukano T, Sumikawa K (2004) Single lung ventilation in a pediatric patient using a Fogarty catheter with a hollow center. *Masui* 53(1):69–71
44. Thallaj A (2006) Use of modified Fogarty Catheters in thoracic anesthesia. *Internet J Anesth* 11(2)