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ORIGINAL ARTICLE

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Use of embolectomy catheter for lung isolation in pediatric patients undergoing lung decortication surgery: experience of ten cases

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Abstract

Background: Pediatric one lung ventilation is challenging to achieve; smaller the child greater is the challenge. Challenge gets bigger due to unavailability of proper sized lung isolation devices. The aim of this case series was to assess the feasibility of using embolectomy catheter for lung isolation in 10 children who were planned to undergo lung decortication surgery.

Results: Age wise predictions of airway diameters were used to select sizes of endotracheal tube and embolectomy catheter. We used a Fogarty catheter, with its tip bent to 30° and placed parallel to a cuffed endotracheal tube, under fiberoptic bronchoscope guidance to achieve lung isolation. Desired lung was deflated passively after achieving lung isolation. Embolectomy catheter cuff position was reconfirmed with bronchoscopy after patient positioning. Ages of children ranged from 2 to 6 years. Four patients required right lung isolation while six required left lung isolation. Dislodgement of embolectomy catheter while positioning or during surgery did not occur in any case. Surgeons reported good to excellent lung isolation in all the cases. All cases were successfully extubated at the end of surgery.

Conclusions: Embolectomy catheter for one lung ventilation in pediatric cases maybe a useful alternative in absence of customized devices.

Keywords: Bronchoscopy, Child, General anesthesia, Intratracheal intubation, One lung ventilation

Background

Various vascular, esophageal, and thoracic surgeries require one lung ventilation (OLV). Accomplishing OLV in paediatric patients is a complex task; unavailability of customized equipment for lung isolation makes the situation even more complex.

Endobronchial intubation with single lumen endotracheal tube (SLET) is the most common method of lung isolation in children, but has its own limitations; it is difficult to perform left lung surgeries with SLET in the right bronchus due to short distance between carina and the branching of right upper-lobe bronchus (Chengod et al., 2005). Double lumen tubes (DLTs) which are the most popular devices for lung isolation are not available in sizes below 26 Fr, hence cannot be used for children smaller than 6 years (Chow et al., 1998). Similarly, Univent tubes cannot be used in children below 4 to 6 years of age (Hammer et al., 1998). Marrarow-bilumen tubes which seem like a good option and can be used in children up to 2 to 3 years of age, are rarely available (Marraro, 1994). Bronchial blockers (BB) can be used in infants up to 6 months of age but are expensive and not widely available (Narayanaswamy et al., 2009).

Embolectomy catheter (EC) is a commonly available device which can be improvised to achieve lung isolation but is underutilized. Also, there is a lack of consensus regarding the best technique for correct placement of

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EC. We present a series of 10 pediatric cases in which we achieved OLV using Fogarty EC.

Methods

A total of 10 cases were conducted at a tertiary care teaching hospital in India from January 2018 to December 2019. These children were small enough to preclude the use of even the smallest available DLT (26 Fr). We used EC for lung isolation when another appropriate lung isolation device was not available. For size selection, we used the available data from a study by Szelloe et al. (Szelloe et al., 2017). Almost all the available studies show that age is the best predictor of tracheal and bronchial sizes (Tan & Tan-Kendrick, 2002; Dave et al., 2019).

Since our paediatric fiberoptic bronchoscope (FOB) had an external diameter of 2.8 mm and the smallest endotracheal tube (ETT) through which it could pass was 3.5 mm, we excluded cases that required an ETT smaller than 3.5 mm ID. All the patients had a fair general condition; room air oxygen saturation was more than 94%. Preoperative workup included routine lab investigations and chest X-ray (posteroanterior view). Written informed consent was obtained from the parents/legal guardians of all study participants.

Selection of airway devices

An undersized cuffed ETT (0.5 mm smaller than the size predicted by age) was used for endotracheal intubation. Lung isolation was obtained with Fogarty EC. The size of EC was decided based on age based mean airway diameters of the bronchi to be isolated as predicted by Szelloe et al. (Table 1) and inflated balloon diameter of Fogarty EC (Table 2). Pediatric FOB (*Olympus BF-XP190, ED-2.8 millimetre*) with an external display monitor was used in all cases.

Table 2 Dimension of Fogarty EC along with the dimension of its balloon in deflated and inflated state

Catheter size (Fr)	Diameter of catheter body (millimetre) Size in Fr/3 = size in millimetre	Inflated balloon diameter (millimetre)	Deflated balloon diameter (millimetre)
3	1	5	1.4
4	1.33	9	1.67
5	1.66	11	2
6	2	13	2.3
7	2.33	14	2.66

Premedication and induction of GA

Before wheeling the patient into the operation theatre, patients were pre-medicated with intravenous glycopyrrolate (0.01 mg/kg) and intravenous midazolam (0.1 mg/kg). Non-invasive blood pressure, ECG, pulse oximeter, and capnography were applied in all cases. Patients were preoxygenated with 100% oxygen for 3 min; thereafter, general anesthesia (GA) was induced with intravenous fentanyl (2 μg/kg) and intravenous propofol (2–2.5 mg/kg). Once bag mask ventilation was confirmed, intravenous vecuronium (0.1 mg/kg) was given.

Technique of lung isolation

Step 1

Distance between the incisors and the sternal angle was measured with the neck in an extended position. This length was marked on the EC, with the measurement starting from the distal end. To make the EC steerable into the desired bronchus; it was bent to 30 degree at approximately 2.5 cm (1 in.) before the distal end.

Table 1 Age wise dimensions of the airways as by Szelloe et al. (Inoue, 1982), in comparison with calculated size of ETT

Age (years)	Smallest mean anteroposterior tracheal diameter (millimetres)	Mean right bronchial diameter (millimetres)	Mean left bronchial diameter (millimetres)	Predicted size of cuffed endotracheal tube = [3.5 + age (years)/4] (millimetres)
0–1	6.0(2.9–7.7)	3.9(2.4–6.0)	3.4(2.1–5.7)	3.5
1–2	7.0(4.3–9.2)	4.9(3.8–7.5)	4.2(2.7–6.6)	4.0
2–4	7.9(4.1–10.3)	6.1(3.0–7.9)	5.5(2.7–8.5)	4–4.5
4–6	7.5 (5.1–10.9)	6.1(4.4–7.8)	5.3(4.1–6.6)	4.5–5.0
6–8	8.8(5.7–11.0)	6.8(4.3–9.0)	6.0(4.5–10.1)	5.0–5.5
8–10	9.5(7.4–12)	7.0(5.5–9.4)	6.6(4.9–9.1)	5.5–6.0
10–12	10.8(10.2–15.8)	8.2(6.6–10.0)	7.5(5.6–11.1)	6.0–6.5
12–14	11.7(10.3–15.8)	8.5(7.3–10.5)	8.1(6.5–10.0)	6.5–7
14–16	13.0(8.9–16.8)	9.8(6.5–12.7)	9.2(6.2–11.5)	7–7.5

Step 2

Laryngoscopy was done, and an appropriate size EC was passed through the glottis under direct vision and was progressed until the mark made in step 1 was at the level of the incisors (Fig. 1a). An undersized cuffed ETT (0.5 mm smaller than the size predicted for age) was placed into the trachea, anterior to EC, until the black mark was below the glottis; cuff was inflated with air and bilateral air entry in the lungs was ensured (Fig. 1b).

Step 3

ETT was connected to the anesthesia workstation with a swivel angle catheter mount. Patient was ventilated with 100% oxygen along with age-appropriate minimal alveolar concentration of sevoflurane.

Step 4

A lubricated paediatric FOB (*Olympus BF-XP190 ED-2.8 millimetre*) was introduced through the port of catheter mount. With on-going mechanical ventilation, the tip of FOB was advanced beyond the tip of ETT to visualize the trachea, carina, and the tip of EC. The FOB was stationed at this place and was handed to another anesthesiologist (Fig. 1c).

Step 5

Cuff of the ETT was deflated and the main anesthesiologist maneuvered the EC into the desired bronchus by applying torque to the extra-oral part of EC. Once the EC had entered the desired bronchus, it was progressed till the proximal end of the bulb was visible just beyond the carina.

Step 6

After correct placement of EC, its guide wire was removed, and the cuff was inflated under vision with air. A 2 ml syringe along with a three-way connector was used to inflate the cuff and inflation volume was noted; minimum volume of air sufficient to cause blanching of bronchial mucosa or volume of air to achieve cessation of air entry into the lung (whichever was lower) was instilled in the EC bulb. Once adequate lung isolation was achieved, the three-way connector attached to EC was put in blocked position. While EC was being placed, one resident kept a close watch on the vital parameters of the patient (Fig. 1D).

Step 7

ETT cuff was inflated and FOB was removed. ETT cuff pressure was kept between 20 and 25 cm of water with the use of ETT cuff pressure manometer (*Posey Cufflator*). The isolated lung was left to deflate on its own for approximately 15–20 min; in the meantime, patient was positioned for surgery. After positioning the patient, FOB was reinserted, and the position of EC was reconfirmed. Thereafter, FiO2 and ventilation was managed to maintain a pH, PO2 and PCO2 in the clinically acceptable range. To prevent EC cuff volume expansion, nitrous

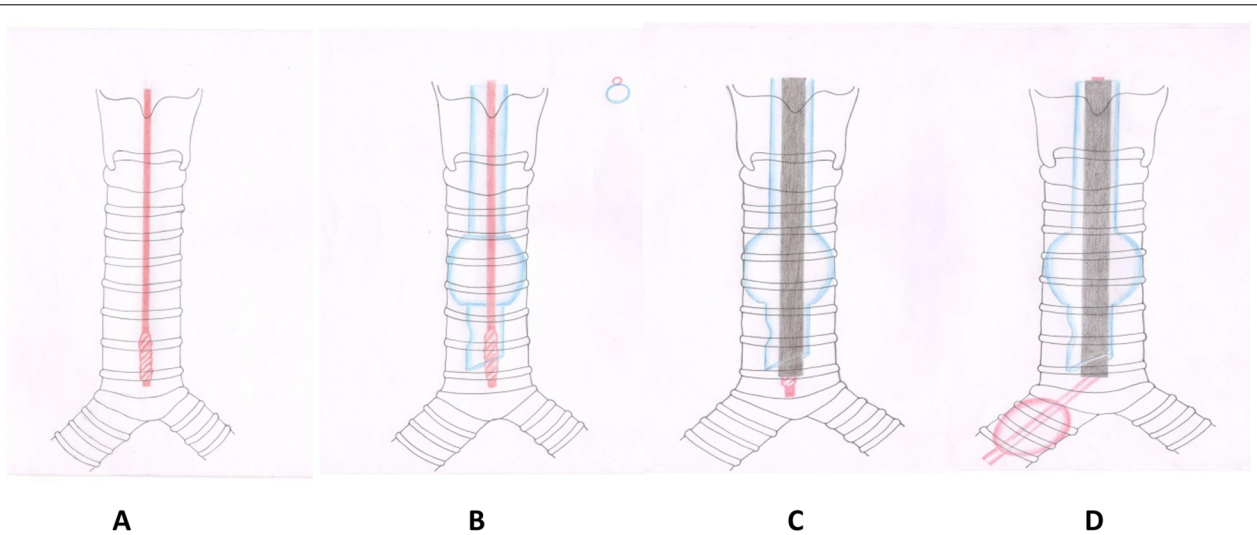

Fig. 1 Schematic diagram portraying use of embolectomy catheter (EC) for achieving lung isolation in pediatric patients. **A** Appropriately sized EC bent 30° at the tip is passed through glottis into trachea under direct vision by laryngoscopy. **B** Undersized cuffed ETT is then placed into the trachea, anterior to EC, until its black mark is below the glottis; its cuff is inflated with air and bilateral air entry confirmed. **C** A lubricated pediatric FOB is advanced through ETT beyond its tip to visualize the trachea, carina, and the tip of EC. **D** The cuff of ETT is deflated and the EC is maneuvered into the desired bronchus by applying torque its extra-oral part. Its guide wire is removed, and the cuff inflated under vision with air. Inflating volume is noted and thereafter ETT cuff is inflated

oxide was not used intraoperatively. In all the ten cases the surgery could proceed uneventfully. After completion of surgery, EC was removed after deflating its cuff while retaining the ETT. Tracheal suction was performed to remove secretions.

All the patients were given ipsilateral ultrasound guided erector spinae block before tracheal extubation. All patients were extubated in the operation theatre and were wheeled out and monitored in post-anesthetic care unit.

Results

We achieved adequate lung isolation with EC in all the 10 patients. Ages of patients ranged from 2.5 years to 7 years. Six children were of male gender while four were female. Four patients required right lung isolation while six required left lung isolation. None of the patients had difficult bag mask ventilation or laryngoscopy. We used size 4 Fr embolectomy catheter in children aged 2 to 3 years; size 4–5 Fr for ages 4 to 5 years and size 5 Fr for ages 5 to 7 years respectively. There was no episode of desaturation (less than 94%) during placement of EC. The average time taken for correct placement of EC was 5 to 7 min. In all the cases, the EC bulb was inflated with less than maximum bulb volume, blanching of bronchial mucosa was not noticed in any case. Dislodgement of EC while positioning or during surgery did not occur in any case. Surgeons reported good to excellent lung isolation in all the cases. Duration of surgery ranged from two to three hours. No major intra or post-operative complications were seen any case.

Discussion

Nowadays, a number of surgical interventions are being done in pediatric population for which lung isolation is a necessity. Lung isolation is especially difficult in children due to size limitations of available lung isolation devices.

Simplest approach to achieve lung isolation would be to intentionally intubate the desired main stem bronchus with a conventional preformed ETT. Even today, this approach is useful for emergencies such as airway hemorrhage or contralateral tension pneumothorax (Kubota et al., 1987).

Double-lumen tubes, the most popular devices for lung isolation, are not available in sizes below 26 Fr (Letal & Theam, 2016), hence are inappropriate for children smaller than 8 years, 30 kg, or 130 cm (Chow et al., 1998). Besides, the smaller sizes of DLT are frequently unavailable.

Bronchial blockers (BB) are another group of lung isolation devices (Fig. 2). The first modern BB was reported by Inoue et al. (Inoue, 1982) in 1982; it was called the UniventTube (Uniblocker, Fuji Systems, Tokyo, Japan). Univent tube was modified in 2001, to the system that is currently in use, i.e., "Torque Control Blocker Univent". The smallest univent tube has Internal diameter (ID) of 6.0 mm, its outer diameter equivalent to a 7.0 mm ETT, hence cannot be used in pediatric patients (Campos, 2003). Arndt wire-guided BB was first reported in 1999. They are available in 5, 7, and 9 Fr sizes and are appropriate for 6 month to 6 years, 6 years to 14 years and 14–18 years age groups respectively (One lung ventilation & bronchial blocker guideline [internet citation], n.d.). Arndt blocker also provides a channel for suctioning. One major disadvantage of this device is the inability to reposition once the nylon loop has been removed. The Cohen Flextip BB was first reported in 2005. Cohen BB have a flexitip which help in guiding it into a desired bronchus but are available only in 9 Fr size and are for coaxial insertion, are appropriate for 7.0 mm ETTs only (Cohen, 2005). Coopdech BB (Smith Medical, Rosmalen, NL) has a preformed angulation at the distal tip to help placement in the desired bronchus (Venkataraju et al., 2010). They have an outer diameter of 3.0 mm (or 9 Fr) and cannot be used in small children. EZ blocker (Teleflex Life Sciences Ltd., Athlone, Ireland) is a Y-shaped BB with two distal extensions to be placed in both main stem bronchi, was introduced in 2013 (Mourisse et al., 2013). It also requires at least a ETT with ID 7.0 mm for insertion and hence inappropriate for children. All these are proprietary devices and besides being costly, are frequently unavailable.

ECs can be a good alternative to BB for lung isolation because of their easy availability and lower cost. The available literature describes two basic techniques of EC insertion, one without guidance of FOB and the other with guidance of FOB. Chengod et al. (Chengod et al., 2005) described a technique in which they inserted a preshaped ETT into the left bronchus and then blindly passed the EC through the lumen of the ETT, till it met with resistance. The authors considered their technique to be safe and effective; they also considered FOB-guided confirmation as non-essential. This technique may come handy in cases where the ET size precludes the passage of FOB through it; but has an innate danger of airway trauma. Besides, since the technique lacks objectivity, it is likely to have a wide-ranging success rate.

Kamara et al. (Kamra et al., 2017) achieved lung isolation by parallel placement of EC alongside a rigid bronchoscope. They utilized forceps to guide the EC into desired bronchus. Although this technique seems appropriate, most anesthesiologists are not well versed with using a rigid bronchoscope.

Another contentious aspect of the technique for EC insertion is whether to place the EC intraluminally (Sharma et al., 2014; Vretzakis et al., 2005; Asai et al.,

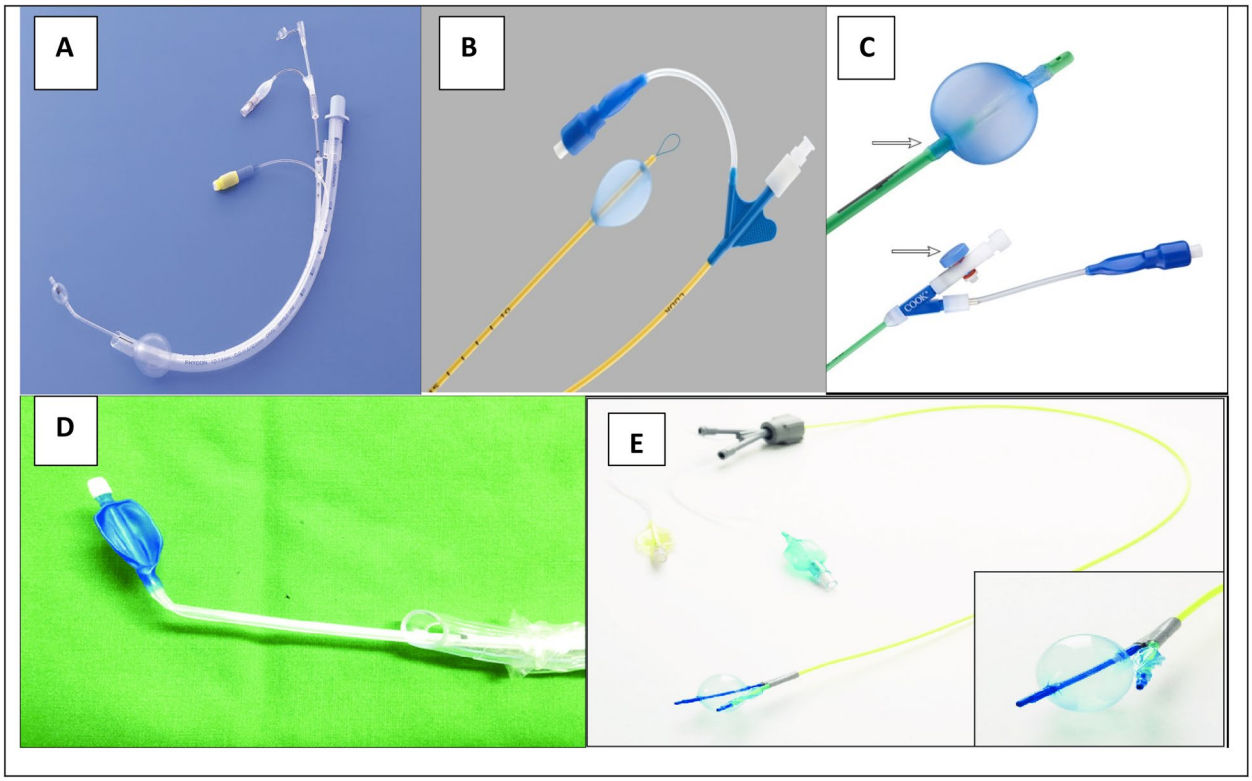

Fig. 2 **A** Torque control blocker uninvent. **B** Arndt bronchial blocker with looped guide wire **C** Cohen flexitip bronchial blocker **D** Coopdech bronchial blocker with preformed angulation at distal tip **E** Y-shaped EZ blocker

2000; Ho et al., 2008) or extraluminally (Chaitanya et al., 2016; Templeton et al., 2016; Sutton et al., 2012; Stephenson & Seefelder, 2011). Passing the EC extraluminally is more common and seems to have a few advantages. Firstly, it abolishes the need for a proprietary three way tube connectors. Secondly, it does not occupy the lumen of ETT; although ECs are narrow, but may occupy significant area of ETT in children. If the diameter of EC is more than 70% of the ETT diameter, then it may predispose the lungs to high airway pressures and also hypoxemia (Letal & Theam, 2016). Thirdly, if cuffed ETT is used, the inflated cuff stabilizes the EC in it place by pressing it against the posterior tracheal wall; hence, chances of misplacement are reduced. However, a few authors trying to insert the EC extraluminally had difficulty in manipulating the EC in to its place and had to resort to intraluminal insertion (Mohan et al., 2002). We used extraluminal approach with tip bent 30° in all the cases and did not have difficulty in manipulating the EC into its final position. Had we faced any problem, then we would have tried using an appropriate size microlaryngeal ETT instead of a conventional ETT. Microlaryngeal tube are narrower but the cuff size is normal, it would have provided extraspace for accommodating the EC, without compromising on the stability.

Although ECs have been inserted intraluminally by many authors (Sharma et al., 2014; Vretzakis et al., 2005; Asai et al., 2000; Ho et al., 2008; Mohan et al., 2002), it poses certain serious concerns. Besides occluding the lumen of the ETT, it precludes FOB guidance for correct placement. The chances of dislodgement will also be higher in intraluminal placement. Certain improvisations (Asai et al., 2000; Ho et al., 2008) have also been successfully used, but in view of the author they are practically cumbersome to implement.

Besides lung isolation, ECs can be used even for selective lobar isolation in conjunction with a DLT. Such selective lobar isolations may be helpful in preventing soillage of healthy lung lobes of an infected lung (Sharma et al., 2014). Besides they may also help manage patients who have poor lung functions and may not be able to tolerate the physiological perturbations of one lung ventilation (Vretzakis et al., 2005).

In children, Arndt BB has also been passed extraluminally to successfully isolate lung in less than 2 years age group (Templeton et al., 2016). Although Arndt BB is a device specifically designed for lung isolation, they

are not easily available; are not available in less than 5Fr size (we used 4-Fr sized Fogarty catheter in six of our patients). Sometimes, even the smallest available FOB may not pass through the very small lumen of the ETT, in such cases the EC may be guided into its place under fluoroscope guidance (Templeton et al., 2016).

Limitations of EC as LI device

ECs appear to be versatile devices for lung isolation. Being available in a variety of sizes they can be used in almost any age group. However, they have some distinct disadvantages. They have low volume and high-pressure cuffs, which may injure the airway mucosa. Borchardt et al. reported a case of bronchial tear in a 4-year-old child posted for right thoracotomy in which lung isolation was achieved using 5 Fr Fogarty catheter (Borchardt et al., 1998). However, in that case, the Fogarty cuff was inadvertently inflated with 4 ml of air, instead of the manufacturer recommended 3 ml, and without noting the balancing of mucosa. We inflated the EC cuff under vision while noting the volume of air causing blanching of bronchial mucosa and thus avoided any injury. ECs that are usually available do not have a hollow core; hence, they cannot be used for active suctioning of the isolated lung. Although hollow core embolectomy catheters (Use et al., 2004) have now become available and may further increase the versatility of EC in lung isolation.

Caution when using EC for LI

When using EC for lung isolation, it is to be kept in mind that lung deflation would be passive and hence take more than usual time (in all our case the lung was deflated by the time thoractomy was done). The size of the EC has to be meticulously selected, inflated bulb of under sized EC may act as a ball-valve and lead to air trapping in the lung; this may result in dangerous rise in intrathoracic pressure. A high degree of clinical suspicion may prevent this complication.

Conclusions

The technique of guiding a extraluminal bent tip (30°) embolectomy catheter under fiberoptic bronchoscopy vision to achieve lung isolation in pediatric patients may be useful in absence customized devices. Large size multicentre studies are required to confirm conclusion of this article.

Abbreviations

BB: Bronchial blockers; DLT: Double lumen tubes; EC: Embolectomy catheter; ECG: Electrocardiaogram; ED: External diameter; ETT: Endotracheal tube; FOB: Fiberoptic bronchoscope; Fr: French Gauge; GA: General anesthesia; ID: Internal diameter; kg: Kilogram; LI: Lung isolation; OLV: One lung ventilation; pco2: Partial pressure of carbon dioxide; pH: Potential of hydrogen; po2 : Partial pressure of oxygen; SLET: Single lumen endotracheal tube.

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None

Authors' contributions

AJ after discussion with BK conceived the idea that Fogarty catheter can be used for lung isolation in children. Subsequently AJ designed the study. AJ, AA, and JP played important role in conduct of cases and data acquisition. BK and SJ helped in analysis and interpretation of data. AA drafted the work and AJ substantively revised it. All authors have approved the submitted version. Also, all authors to have agreed both to be personally accountable for own contributions and ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature. All authors read and approved the final manuscript.

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Availability of data and materials

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

Declarations

Ethics approval and consent to participate

Ethics waiver was obtained from Institutional human ethics committee AIIMS, Bhopal, on 14 October 2019 (IHEC-LOP/2019/ IN0423) before the review of records of cases. Written informed consent was obtained from the parents/ legal guardians of all study participants.

Consent for publication

Written informed consent to publish study information was obtained from parents/legal guardians of all participants.

Competing interests

The authors declare that they have no competing interests.

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