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Technical Note

Techniques of One-Lung Ventilation (Lung Isolation) in Children

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Keywords
Anesthesia technique
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Abbreviations
CPAP - Continuous positive airway pressure
DLT - Double lumen tube
ETT - Endotracheal tube
FOB - Fiberoptic broncho scope
OLV - One-lung ventilation
V/Q - ventilation-perfusion

Abstract

One-lung ventilation (OLV) in pediatric patients, especially those under 8 years of age, poses significant challenges due to anatomical constraints. However, the need for lung isolation is increasing with advancements in surgical techniques such as thracoscopy. The availability of newer bronchial blockers and innovative methods of their placement have made OLV more feasible. This article briefly reviews the recent developments in pediatric OLV. Technique such as double lumen tube, bronchial blockers and endobronchial intubation of single lumen tube are discussed. Technical tips of using Bronchial blockers such as Fogarty catheters, Arndt blocker, uniblocker and univent tube are described.

INTRODUCTION

One-lung ventilation (OLV) (also known as lung isolation technique or single-lung intubation) in children, especially below the age of 8 years, is challenging for anesthesiologists due to anatomical constraints of the pediatric airway.(1) However, the need for lung isolation is increasing due to the popularity of thracoscopic approach. The availability of newer bronchial blockers and innovative approaches to enhance the successful placement of the blockers makes pediatric OLV feasible. This article, briefly reviews the challenges, available options and technical considerations of achieving successful OLV.

CHALLENGES

Anatomical Challenges

OLV in children has several anatomical considerations. Firstly, the smaller size of the pediatric airway necessitates the availability of a wide range of airway devices. Secondly, the diameter of the left main bronchus in children is smaller (roughly 0.66 times of the trachea) than that of the right main bronchus (0.86 times).(2) Also, in infants of age 0-3

months, the left bronchus might be too small even for a 3.0 uncuffed tube. Thirdly, in many children, the distance between the tracheal carina and the right upper lobe bronchus is less than 1 cm, posing a risk of over-insertion of tube past the opening of the right upper lobe bronchus. The distance from the carina to the origin of the left upper lobe bronchus is usually 3 times greater, providing a better margin of safety while intubating the left main bronchus. Fourthly, the right main stem bronchus is angulated less acutely with trachea than its left counterpart. Understanding the tracheo-bronchial anatomy is essential for optimal placement of lung isolation devices and doing successful fibreoptic bronchoscopy. During pre-operative assessment, all the available chest imaging should be assessed for the exact nature of the pathology, the presence of airway narrowing and the diameters of the trachea and bronchi in order to choose an appropriate size tracheal tube.

Physiological Challenges

Pliable cartilaginous rib cage, compression of the dependent lung by the mediastinal structures in lateral positions and upward displacement of the diaphragm by the abdominal viscera will reduce the compliance of the dependent lung. This causes significant ventilation-perfusion (V/Q) mismatch, leading to hypoxia. The smaller size of the lungs leads to less effective shunting of blood from the non-dependent to the dependent lung, worsening the V/Q match that is caused by the hydrostatic gradient between the two lungs in lateral position.

Availability of Equipment

Selecting an appropriate size fiberoptic bronchoscope (FOB) is essential. It should be smaller than the intended endotracheal tube (ETT), allowing easy passage through the ETT. The size of the selected bronchoscope should allow ventilation even when it is inserted through the ETT. With a bronchial blocker and a bronchoscope inside the ETT, ability to manipulate the blocker must be checked before performing the procedure on the patient.

INDICATIONS FOR PEDIATRIC LUNG ISOLATION

Indications of pediatric lung isolation are: [3-5]

1. Facilitation of surgical access to a hemithorax: Lung decortication, Resection of pulmonary, mediastinal or chest wall lesions, and anterior access to thoracic spines or neural structures.
2. Facilitation of ventilation: Repair of bronchial injury and broncho-pleural fistula.
3. Prevention of contaminating spillage of infected secretions from the diseased lung into the healthy side: Lung abscess and hemorrhage

AVAILABLE OPTIONS

1. Double-lumen tubes (DLT)
2. Bronchial blockers
   (a) Low-pressure cuffs (e.g. Arndt blockers and Uniblocker tube)
   (b) High-pressure cuff (off-label use) - Vascular balloon catheters
3. Endobronchial insertion of single lumen ETT
4. Intra-operative usage of lung retractors by surgeons to collapse the ipsilateral lung

The choice of lung isolation technique is often dictated by the availability of suitable size FOB and the type of bronchial blocker.

SINGLE LUMEN ENDOTRACHEAL TUBE

It involves selective insertion of an ETT into the contralateral bronchus (healthy side). It is simple, quick and can be used in any age group. It is the preferred option in children less than 6 months of age. Placement of an ETT on the right side is easier than that of the left side. However, there is a high risk of occlusion of the right upper lobe bronchus because of its low level opening into the trachea. Although the technique can be done blindly, FOB will facilitate correct positioning of the ETT. Disadvantages of using ETT for OLV are inadequate

collapse of the lung and inability to apply suction or continuous positive airway pressure (CPAP) of the operating lung.

BRONCHIAL BLOCKERS

Bronchial blockers can be classified as: (1) low-volume, high-pressure blockers (e.g. off-label use of vascular balloon catheter) and (2) high-volume, low-pressure cuffs (e.g. Arndt blocker and Uni-blocker). (Fig. 1) Blockers can be inserted through the ETT (coaxial technique) or outside it (parallel technique). (Fig. 2) Coaxial technique is preferred in the age group of 6 m to 2 yr. Parallel technique is preferred in 2–8 yr of age. (Table 1)

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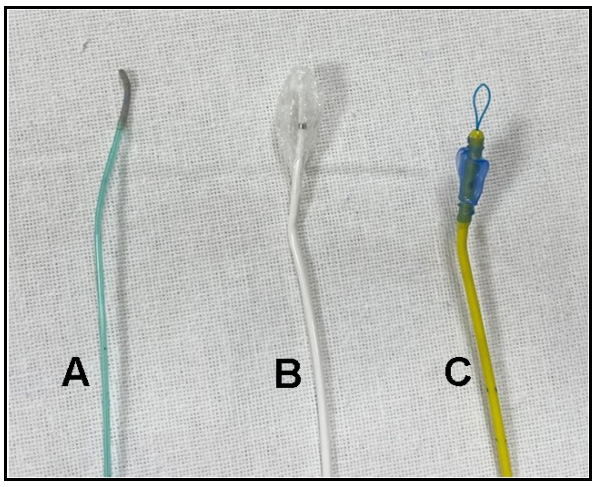

Fig 1. *Bronchial blockers. (A) Fogarty catheter, (B) Atrial embolectomy catheter, (C) Arndt blocker*

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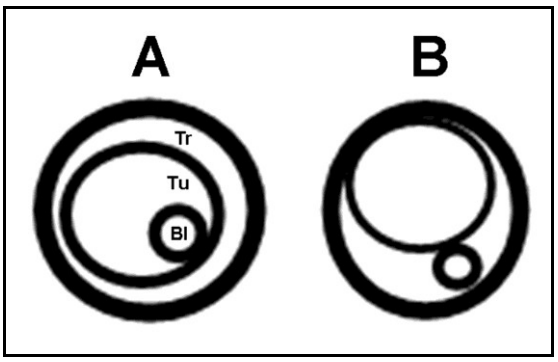

Fig 2. *Coaxial (A) and parallel (B) techniques of inserting bronchial blockers. Tr-Tracheal lumen, Tu- Lumen of endotracheal tube, Bl - Bronchial blocker*

Vascular Balloon Devices

Fogarty and atrial septostomy catheters have been used as bronchial blockers. Fogarty catheters of 3-Fr and 4-Fr size come with a guide wire that can be angulated at the tip to facilitate insertion to the desired bronchus. Positioning it is usually done using FOB. As Fogarty catheters are with high-pressure cuff, it is important to confirm the position of the cuff before inflating it under vision to avoid bronchial rupture or mucosal damage. The atrial septostomy catheter has a predesigned bend at the tip, which aids in directing the blocker to the desired side bronchus. However, it does not have a central channel to apply suction and to maintain CPAP of the operating lung.[6,7]

Arndt Blocker

Frequently a 5-Fr Arndt catheter is used in pediatric patients. It has a flexible long shaft with a central lumen, which houses a looped nylon wire, projects at the tip, and has a cuff at the tip. The looped wire projecting at the tip can be used to position the blocker using a FOB. If the nylon wire is removed, the central lumen can be used to apply suction and CPAP to the operating lung. It should be noted that the wire once removed, it cannot be reinserted, and repositioning will be difficult. A swivel connector with the blocker allows ventilation during placement.[8-9]

Table 1: Choice of lung isolation techniques

Age	EB Intubation	Prefrred bronchial blocker*	Univent	Double lumen tube
0-6 m	Preferable	NA	NA	NA
6m-2yr	Available	Parallel	NA	NA
2-6 yr	Available	Any one	NA	NA
6-8 yr	Available	Available	Available	NA
> 8 yr	Available	Available	Available	Preferred

NA - Not available, EB-Endobronchial

** The two available techniques are parallel or coaxial*

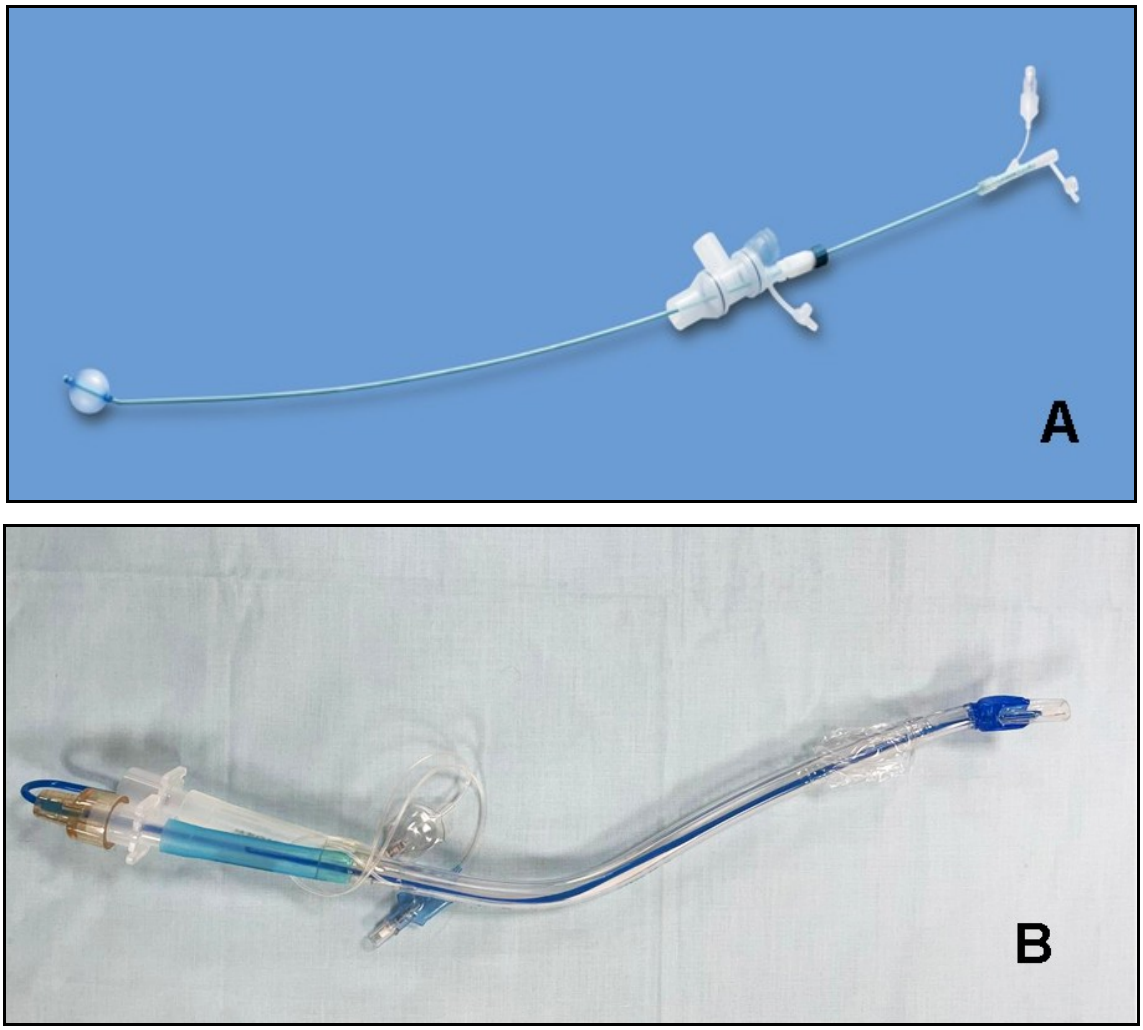

Fig 3. *(A) Fuji Uniblocker™ (Courtesy: Fuji Systems Corporation, Tokyo, Japan), (B) Double lumen tube*

Uniblocker (Fuji Uniblocker)

Fuji uniblocker has a stiff shaft with an angled tip to facilitate correct positioning. It is available with 5-Fr size for pediatric use. A swivel connector with the blocker allows ventilation during placement. (Fig. 3A) There is no central lumen in the shaft to apply suction or CPAP.[10]

Technical Considerations of Blockers

When 2 ml of air is injected, the cuff pressure is 710 cm H_2O for 5-Fr Fogarty, 690 for septostomy catheter, 340 for Arndt bronchial blocker and 330 for Uniblocker. Thus, the cuff inflation pressure of all these devices is always significantly greater than the normal systemic blood pressure (163 cm H_2O). Hence, cuff of bronchial blockers should be inflated with minimum volume required to seal the bronchus, and it should be done only under direct vision of FOB to avoid bronchial injury.[11]

To enable coaxial insertion technique, the combined outer diameter of bronchial blocker and bronchoscope must be less than 90% of the inner diameter of the ETT. No more than 50% of the ETT lumen should be blocked in order to ensure ventilation during bronchoscopy. This is feasible with the currently available devices. However, caution is needed in sick patients due to increased airway

resistance and decreased ventilation. The smallest fibreoptic bronchoscope (outer diameter 2.2 mm) and bronchial blocker (5 Fr, outer diameter 1.67 mm) with a 4.5 ETT (inner diameter 4.5 mm) can be used for patients as young as 2-years old.

For patients under 2-years of age, the bronchial blocker may be placed outside the ETT lumen by parallel insertion technique. The bronchial blocker inserted prior to intubation. Generally, a 3.5 or 4.0 ETT with a 5-Fr bronchial blocker outside the ETT can be used in infants aged 6 mo - 2 yr.

The following precautions should be taken while inserting a bronchial blocker:

1. The cuff of the blocker should be checked by inflating and deflating it prior to use
2. External tracheal manipulation or rotating the head to the contralateral side may be needed to direct the blocker towards the side intended to be blocked.[12-13]
3. The blocker should be inserted a little more inside than the intended length, because it may migrate outside while shifting the patient to lateral position.
4. Minimum volume of air should be used to inflate the cuff avoiding over-inflation in order to prevent pressure damage to the bronchus.
5. Ventilation should be stopped while inflating the cuff of the blocker to avoid the inspiratory volume being trapped in the isolated lung.
6. Micro-cuff tubes are preferabe to avoid leaks.

UNIVENT TUBE

The Univent™ tube is a special form of ETT with a side channel to insert a bronchial blocker. (Fig. 4) If double-lung ventilation is required, the deployed blocker may be deflated and withdrawn into the tracheal lumen. As the blocker balloon is at the distal end of the smaller lumen and is affixed to it, chance of accidental dislodgement is less. Univent tubes are available in two pediatric sizes, 3.5- and 4.5-mm internal diameter. Tubes larger than 4.5 mm internal diameter have an additional channel in the blocker that allows CPAP and suctioning of the operating lung. FOB should be used to position the bronchial blocker.[14]

The main disadvantage of Univent tubes is small cross-sectional diameter of the ventilating lumen. This increases airway resistance and prohibits the usage of FOB to position the blocker. It is important to remember that the size of a Univent tube refers to the internal diameter, and hence its outer diameter will be much larger than the equivalent sized single lumen ETT. The age range (6-8 yr) in which the Univent tube can be used is very narrow.

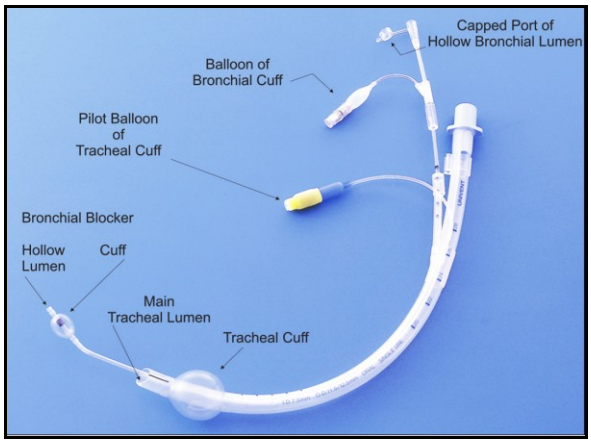

Fig 4. *Univent tube (Reproduced from Atul Prohit et.al, Indian Journal of Anaesthesia 2015 under CC-NC-SA-3.0 license; DOI: 10.4103/00195049.165855)*

Double-Lumen Tube

DLT is considered the gold standard for lung isolation in adults and is suitable for children older than 8 yr of age. (Fig. 3B) The smallest available DLT size is 26-Fr, which is generally suitable for children 8-10 yr of age. DLT has two tubes fused parallelly, of which one is angled and longer to facilitate inser-tion into the desired bronchus, while the shorter tube remains in the trachea. Both the tubes are cuffed so that single-lung and double-lung ventila-tion can be easily done by clamping and releasing the appropriate limb on the adapter piece.[15]

CONCLUSION

The lung isolation techniques in children have evolved over the years with the development of ultra-thin bronchoscopes and newer varieties of bronchial blockers. However, the choice and technique of pediatric OLV are greatly influenced by the availability of resources, provider preferences and skill level.

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