DS (Child) H J 2023; 39(1): 49-55

REVIEW ARTICLE

Flexible Bronchoscopy in Children: An Overview

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Abstract

Bronchoscopy is a dynamic diagnostic tool that has continually advanced alongside the rapid progression of medical technology. It offers a comprehensive evaluation of the upper and lower airways, catering to a wide range of respiratory concerns. Over the course of numerous decades, bronchoscopy has played a pivotal role in the field of pediatric pulmonology, providing invaluable diagnostic and therapeutic options that extend well beyond the boundaries of this specialized medical domain. The purpose of this article is to consolidate the existing knowledge and explore the diverse interdisciplinary facets of pediatric bronchoscopy, with the ultimate goal of establishing a consensus on the safe and effective technical execution of this procedure. The intension is to create a standardized foundation for its practical application.

Introduction

Bronchoscopy offers a comprehensive evaluation of the upper and lower airways, catering to a wide range of respiratory concerns.[1] The clinical application of bronchoscopy dates back to 1897 when Killian removed a pork bone from the right main bronchus in a farmer.[2] Bronchoscopy stands as a versatile tool, providing invaluable insights and therapeutic interventions that enable clinicians to perform a various procedure, significantly enhancing the capacity for precise diagnosis and treatment of respiratory conditions. Thus, bronchoscopy assumes a pivotal role in evaluation of airway anatomy, assessment of airway dynamics, obtaining biological samples and therapeutic interventions.

Types of Bronchoscope

There are two types of bronchoscope - Rigid and flexible (Fig.-1). Both types of bronchoscope exhibit numerous differences offering advantages and disadvantages that vary depending on factors such as the clinical scenario of patient, the intended task and the interventional context (Table I). Frequently, employing both of these instruments in conjunction proves to be most effective in gaining a comprehensive understanding of airway and lung pathology.

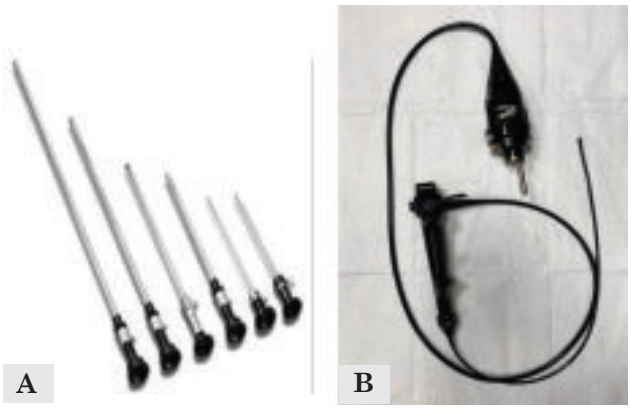

Fig.-1 *Types of bronchoscope. A - Rigid bronchoscope, B - Flexible bronchoscope*

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Received: 6 April 2023; **Accepted**: 30 May 2023

Table I
Comparison of flexible and rigid paediatric bronchoscopy[3]

Rigid bronchoscopy	Flexible bronchoscopy
Advantages	
Airway anatomy • Superior optical quality	**Airway anatomy** • Visualization of more distal airways • Not typically patient position dependent, so can be used in patients with anatomic constraints • Can be performed via nasal passage, LMA or endotracheal/tracheostomy tube
Airway dynamics • Evaluation of the upper and lower airway structures during spontaneous ventilation • With a ventilating bronchoscope, can determine the amount of pressure needed to overcome airway malacia • Visualization and instrumentation of an occult tracheoesophageal fistula can be performed	**Airway dynamics** • Upper airway anatomy is best viewed in an awake patient with a flexible scope • Upper airway endoscopy during simulated sleep can be performed • Less likely to deform or stent the airway during dynamic evaluation
Obtain clinical samples • Easy to obtain tissue biopsies using optical forceps • Direct suctioning of secretions	**Obtain clinical samples** • Better option is to obtain clinical samples from the distal airways • Flexible scope can be "wedged" into the airway to administer and collect BAL fluid
Therapeutic intervention • Diagnosis and treatment of many conditions during the same procedure • Multitude of associated instruments to perform many intra-airway procedures • Innumerable functions including biopsy, foreign body removal, excision of masses/lesions, airway dilation, treatment of airway stenosis, and more	**Therapeutic intervention** • Suctioning and clearance of secretions or mucus plugs from the small/distal airways • Targeted instillation of medications
Drawbacks	
Airway anatomy • Cannot access/visualize smaller airways • Requires collaboration with anesthesiologist for concurrent patient ventilation • Patient anatomy may make access difficult	**Airway anatomy** • Poorer optical quality
Airway dynamics • Rigid scopes may alter airway anatomy	**Airway dynamics** • When using LMA or endotracheal tube, dynamics may be altered • Bronchoscope in ETT contributes to PEEP during the procedure and may alter the airway assessment
Obtain clinical samples • Difficult to "wedge" bronchoscope for BAL collection	**Obtain clinical samples** • More difficult to obtain biopsies in younger patients due to the small size of the scope and instruments
Therapeutic intervention • Difficult to reach right upper lobe or distal bronchi in some patients	**Therapeutic intervention** • Limited use due to small size of scope and instruments

Flexible Bronchoscopy

In the early 1970s, fiber-optic bronchoscopes were introduced, marking a significant advancement in medical technology. In 1978, the first report detailing diagnostic flexible bronchoscopy in children was published.[4] Since then, bronchoscopy has grown into an increasingly vital tool for managing acute and chronic lung conditions in pediatric patients. In 2003, a task force from the European Respiratory Society (ERS) released their findings regarding flexible endoscopy of pediatric airways, ultimately affirming its safety as long as proper preparation is undertaken and the procedure is conducted by proficient and well-trained medical personnel.[1] Concurrently with advancements in adult bronchoscopy, pediatric airway endoscopy has progressed from primarily serving diagnostic purposes to encompassing therapeutic or interventional, bronchoscopy.

Now-a-days, the exception of the 2.2-mm neonatal-size bronchoscope, these instruments are equipped with a suction/working channel, which varies in diameter from 1.2 to 2.8 mm. This working channel facilitates a range of functions, including suctioning of secretions, collection of bronchoalveolar lavage samples, instillation of fluids, oxygen insufflation, and the passage of small instruments like cytology brushes, laser probes, cryoprobes, and biopsy forceps.[5] The different parts of a flexible bronchoscope are: angulation control lever, angulation lock, working channel, suction connector, insertion tube: at the distal end has objective lens, light guides and instrument/working channel and has a bending section at the tip of the bronchoscope and universal cord which connects to the light guide connector section (Fig.-2).

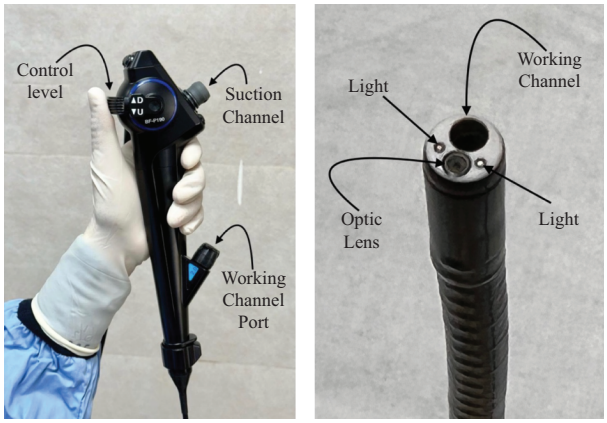

Fig.-2 *Parts of flexible bronchoscope*

Table II
Indications of flexible bronchoscopy[1,3]

Diagnostic	Need for information within the lungs or airways: • Upper airway obstruction • Chronic cough • Lower airway cultures needed • Abnormal imaging • Localization of bleeding • Severe persistent asthma, difficult to treat • Extubation failure • Biopsies-transbronchial, endobronchial
Therapeutic	Need to relieve obstruction in the airways: • Improve atelectasis due to mucus plugging • Removal of foreign body Advanced interventions |: • Cryotherapy • Tracheo-oesophageal fistula repair • Balloon dilation and occlusion • Laser-assisted procedures • Airway stents
Intubation assistance	• Elective, nasotracheal intubation • Difficult view • Spinal issues

Equipment and instrument (Fig.-3)

Minimum equipment for setting a bronchoscopy suit/ operating room (equipment and quantity may vary depending on hospital setting) are as follows-

- Video processor
- Video monitor
- Video recording system
- Bronchoscope
- The light source, video processor, video monitor, and video recording system can be mounted in the operating room or suite or to a portable cart
- For the procedure include
  - 10 ml syringes (filling with normal saline for bronchoalveolar lavage [BAL])
  - Suction tube
  - Suction catheter kit
  - Specimen trap (for BAL specimen collection)
  - Bottle of sodium chloride (for BAL and mucus clearance)
  - Oxygen tubing (for airway insufflation to relieve obstruction)

Fig.-3 *Portable cart having video processor, video monitor & video recording system and bronchoscope*

- Suction valve for scope ventilator bronchoscope elbow (connects to ventilator, for ventilation during procedure)
- Specimen bags (for transport of clinical samples to Pathology and Microbiology)

Advantages of flexible bronchoscopy over rigid bronchoscopy

Flexibility of flexible bronchoscope give the following advantages[4]:

- Access and evaluate more peripheral smaller airways.
- Visualize and evaluate the bronchi of the lung apices, particularly the right upper lobe bronchus, which is challenging to access with rigid bronchoscope.
- Assess the airway using the nasal route, tracheostomy tube, and endotracheal tube.
- Evaluate airways in patients facing challenges with the passage of a rigid bronchoscope, including those with mandibular hypoplasia, cervical or temporomandibular ankyloses, severe kyphoscoliosis, and patients with an unstable cervical spine
- Evaluate airway dynamics without causing distortion of the anatomy which would be affected by the rigid bronchoscope
- If necessary, bronchoscopy can be done under sedation without general anesthesia.

Preparation for a flexible bronchoscopy

The ideal setting for bronchoscopic procedures is either a bronchoscopy suite (Fig.-4) or an operating room equipped with continuous cardiopulmonary monitoring, ensuring readiness to manage any foreseeable emergencies, including pulmonary hemorrhage or cardiac arrest. Alternatively, in emergency situations, bronchoscopic procedures can be performed at the bedside in intensive care units (ICU) with the appropriate support (fig.-5) from ICU staff.[6,7]

Ensuring the safety and comfort of the patient during bronchoscopic procedures is paramount. It is strongly recommended to administer sedation, either conscious sedation or general anesthesia, to minimize the risk of physical or psychological harm. Sedation and monitoring throughout the procedure should be carried out by a trained anesthesiologist and his team.[8]

General Anesthesia

Opting for "anesthesia" rather than "sedation" offers advantages, as it allows for the use of agents such as intravenous (IV) propofol and inhaled sevoflurane, which offer rapid onset and emergence from the sedated state. With an experienced anesthesiologist or anesthetist overseeing the procedure, the depth of anesthesia can be adjusted as needed. Lighter sedation enables spontaneous breathing and assessment of airway dynamics, while deeper sedation can be utilized for procedures in the lower airways, such as bronchoalveolar lavage (BAL) or biopsies.[9]

Sedation and Local Anesthesia

The goals of sedation are to allow the patient to remain comfortable while maintaining adequate ventilation and oxygenation despite the use of bronchoscope in the airway. The medications commonly used for sedation are fentanyl 1-3 mcg/kg/h and midazolam 0.1 mg/kg.[10,11] Reversal agents (naloxone and flumazenil) may be used in the post-operative period. In adult patients who undergo flexible bronchoscopy under local anesthesia and sedation. The commonest indication for use of reversal agents is for patients who develop respiratory depression. Topical lignocaine in doses up to 8 mg/kg can be used safely, Lignocaine jelly (2%) is applied to the nostril and 2% lignocaine is sprayed on the cords, trachea and bronchial tree through the working channel of the bronchoscope as required.[12]

Fig.-4 *Bronchoscopy suit*

Fig.-5 *Bedside bronchoscopy in intensive care units (ICU)*

Steps and technique of performing flexible bronchoscopy[13,14]

A well-coordinated team is indispensable for the effective execution of a bronchoscopic examination, ensuring both its success and the safety of the patient. This team typically comprises a physician bronchoscopist, an assistant, an anesthesiologist, as well as additional personnel responsible for various tasks like scheduling,equipment maintenance, coordination, and housekeeping.

- Flexible bronchoscopy is an invasive procedure and need to take informed written consent from patient or parents before starting the procedure.
- The patient should be kept nothing by mouth (NPO) for a minimum of 6-8 hours prior performing bronchoscopy. This practice is designed to minimize the likelihood of aspiration, though it's important to note that specific institutions might have slightly different guidelines regarding these timeframes.
- The patient is positioned supine on the procedure table and gently secured in place until they reach the desired level of sedation or anesthesia.
- bronchoscopist typically stands at the head of the table or bed and adjust the position as needed for optimal access.
- Continuous monitoring of the patient is essential throughout the entire procedure, encompassing continuous pulse oximetry and comprehensive cardiopulmonary monitoring.

Post-bronchoscopy care of the patient

It is crucial to maintain continuous monitoring and observation for every sedated patient until they fully regain consciousness and return to their normal baseline condition. Patients who experience ongoing issues after the procedure, such as hypoxemia, changes in mental status, heightened respiratory effort, or challenges with airway clearance, may require extended observation either in the post-anesthesia care unit or even admission for overnight monitoring. The decision regarding the appropriate level of care upon admission will be based on the patient's clinical condition, any complications during the procedure, and identified risk factors.

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Post procedure care of the flexible bronchoscope

Cleaning[15]

To maintain cleanliness and functionality, it is important to follow a specific protocolimmediately after completing the procedure:

- Initiate suction with water or saline through the suction channel to clear away any substantial blood or secretions.
- Subsequently, introduce a detergent solution through the channel while maintaining suction to ensure thorough cleaning.
- Use damp gauze or a sponge saturated with detergent solution to wipe away any secretions or blood from the exterior of the bronchoscope.
- Ensure all single-use suction valves and adapters are removed and disposed of appropriately to maintain hygiene.

The bronchoscope is transported to the cleaning station in a suitable container.

Leak test[15]

When the bronchoscope is ready for further processing, it is imperative to conduct a leak test before commencing the sterilizing procedure. This test involves introducing pressurized air through the ethylene oxide valve of the bronchoscope while submerging the instrument underwater.

If a leak is detected, the bronchoscope should undergo a cleaning procedure using enzymatic detergent. Subsequently, it must be subjected to ethylene oxide gas sterilization before sending it for repair. It is crucial to refrain from using a disinfectant solution or an automatic disinfector for cleaning in such cases.

Sterilization[15,16]

Bronchoscopes that are confirmed to be free from any leaks should undergo a thorough cleaning process, both internally and externally, using a specialized brush. Afterward, they should be soaked in enzymatic detergent, followed by a rinsing phase. External rinsing can be accomplished by wiping the scope's exterior and passing a 70% alcohol solution through the channel. To ensure disinfection, the bronchoscope can be either manually immersed in a sterilizing solution like alkaline glutaraldehyde or 0.55% orthophthalaldehyde or processed using an automated cleaning machine. It is of utmost importance to never subject a flexible bronchoscope to an autoclave.

Storage of the bronchoscope

To maintain the cleanliness of the instruments, a recommended practice is to insert the bronchoscope's shaft into a paper sleeve and store it on a shelf, in a drawer, or by hanging it from a bracket (Fig.6). It's important to note that suction adapters should never be affixed to the bronchoscope during storage, as this could lead to bacterial proliferation in any remaining moisture, posing a potential risk.[16]

A **B**

Fig.-6 *A- Flexible bronchoscope hanging self, B- suction adapter is separated from bronchoscope during storage*

What is needed to know before performing a flexible bronchoscopy

Before proceeding with the procedure, it's imperative to take into account the following factors:

- Assess the indications and potential risk factors that may lead to complications during or after the operation.
- Evaluate the urgency of the procedure in conjunction with the patient's overall clinical condition and stability.
- Ensure the availability of essential staff, consultative services, and a suitable facility for both the procedure and subsequent post-operative care.
- Engage in a discussion with the patient and their family to understand their preferences and expectations, aligning them with the planned course of action.

Risk factors for complications

A critical aspect of the preparation process involves recognizing the factors that may increase the likelihood of complications (Table III) and implementing the requisite measures to avert them. While bronchoscopy does not have any absolute contraindications, it is imperative to meticulously evaluate the potential risks associated with both the procedure itself and the administration of anesthesia for each individual patient.

Table III
Possible complications of flexible bronchoscopy[3]

Physiological	Bacteriological	Mechanical	Anesthesia- related	Others
- Hypoxemia - Arrhythmia - Hypercapnia/ hypoventilation	- Iatrogenic infection - Spread of infection to other areas in the lung - Spread of infection to bronchoscopy team	- Pneumothorax - Hemorrhage - Laryngeal trauma/ Nasal trauma, - Mucosal edema - Epistaxis	- Insufficient or excessive anesthesia - Aspiration	Cardiac arrest

Conclusion

A profound comprehension of clinical indications, fundamental principles of pediatric bronchoscopy, and the spectrum of diseases or abnormalities frequently encountered is paramount in the practice of pediatric bronchoscopy. Mastering the art of flexible bronchoscopy is undoubtedly a challenging endeavor, yet it is entirely attainable. Gaining a comprehensive understanding of the potential complications, risk factors, required equipment, techniques, and the indispensable team members is the first step towards acquiring the knowledge necessary for performing the procedure. However, the real key to proficiency, skill refinement, and bolstering confidence lies in diligent practice and hands-on experience under the guidance of experienced mentors.

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