Bronchoscopy in the Intensive Care Unit (ICU)

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Abstract

The diagnostic and therapeutic utility of flexible fibreoptic bronchoscopy (FFB), coupled with its minimal morbidity and mortality, have led to its increasing use in the care of the critically ill patients. FFB allows direct inspection of the upper and lower airway, and facilitates the diagnosis and management of a variety of pulmonary disorders. Patients in the intensive care unit are predisposed to a higher risk of complications as they are usually mechanically ventilated with positive end-expiratory pressure, and have other medical conditions such as coagulopathies, thrombocytopenia, uraemia, cardiac disease, hypoxaemia, pulmonary hypertension, and immunosuppression. An awareness of the higher risks associated with certain clinical conditions, and an understanding of the pathophysiological consequences associated with FFB should alert the bronchoscopists to take the necessary precautions to prevent and deal with these problems.

***Ann Acad Med Singapore* 1998; 27:552-9**

Key words: Complications, Critically ill, Fibreoptic bronchoscopy, Mechanical ventilator, Positive end-expiratory pressure

Introduction

Flexible fibreoptic bronchoscopy (FFB) has become an indispensable tool in the optimal management of intensive care unit (ICU) patients with both diagnostic and therapeutic goals.[1] Its safety and usefulness, in well-trained hands with appropriate precautions, have led to its increasing use even in unstable and mechanically ventilated patients.[1-3] Currently, rigid bronchoscopes are not often used except for the management of massive haemoptysis, removal of tracheobronchial foreign bodies, laser photoresection for obstructing endobronchial tumours, dilatation of tracheobronchial strictures and placement of airway stents.[1,4]

This article reviews the indications, contraindications, pathophysiologic consequences and complications of FFB in adult critical care patients. Based on the literature and the author's personal experience, recommendations for the safe conduct of FFB in the ICU are suggested.

Ancillary Bronchoscopic Procedures

Various ancillary procedures can be performed via the FFB to improve its diagnostic and therapeutic utility.

Brushing

Routine bronchial brushing is used for the exfoliative cytologic diagnosis of malignancy. It is accomplished by passing a brush through the suction channel. Because the usual bronchial brush is not protected from contamination during the passage through the FFB, it is inappropriate for bacterial culture.[5]

Protected Specimen Brushing

A protected specimen brush (PSB) is preferred for the diagnosis of pneumonia as it provides relatively uncontaminated lower airway samples for microbiologic studies.[4,6-8] The external catheter of the PSB surrounds an inner cannula band brush and is protected by a sterile Carbowax plug at the tip. The FFB is advanced to the selected segmental bronchus without using suction or instillation of lignocaine into the working channel. It is advisable to avoid the use of topical anaesthesia such as lignocaine with added preservatives as this may limit the ability to culture bacteria.[4,9] The PSB is advanced until its distal end is visible. The inner catheter is advanced which pushes the polyethylene glycol plug out. When the brush passes into the selected segmental bronchus, it is advanced from the inner catheter, vigorously moved back and forth in the sampling area, and then withdrawn into the inner cannula before removing the catheter from the FFB.[2,6] The brush is aseptically cut off into 1 ml of sterile diluent, most commonly, non-bacteriostatic saline or lactated Ringer's solution.[5] The very small volume of secretions obtained (around 0.001 ml) demands very precise sampling.

Bronchoalveolar Lavage

In bronchoalveolar lavage (BAL), the FFB is wedged into a subsegmental bronchus and multiple aliquots (20

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to 50 ml) of saline are instilled into that lung segment and then withdrawn by suction. The centrifuged BAL fluid is stained for opportunistic pathogens and cultured. Lavaged volumes of 60 ml sample only proximal airways. Volumes of 100 to 120 ml instilled into a single segment appear to perfuse the entire segment (including distal airways and alveoli).[10] Alveolar sampling, estimated at 5 to 20 million alveoli,[1] is important for the diagnosis of infections such as *Pneumocystis carinii* pneumonia. For clinical purposes, a total lavage volume of at least 100 ml should be used, and a total return of at least 40 ml is required for adequate specimens. Although 200 ml was once considered the maximum, recent literature demonstrates that lavage volumes of up to 300 ml are well tolerated.[11]

Biopsy

Endobronchial biopsy is performed under direct vision with a biopsy forceps through the suction channel. Transbronchial lung biopsy (TBLB) is preferably performed under fluoroscopic guidance as this helps to select the most abnormal areas for biopsy and minimise the risk of pneumothorax.[2] TBLB has a more limited role in the diagnosis of pneumonia but invaluable in the diagnosis of non-infectious aetiologies.[5] In the ICU, TBLB is usually done blindly because of lack of fluoroscopy. Optimal biopsy specimens are most frequently obtained at low lung volumes. The presence of the FFB in the trachea impedes pulmonary deflation. Some authors suggested temporary disconnection of the ventilatory circuit and manual compression of the chest to facilitate obtaining adequate TBLB specimens for histologic evaluation.[12]

Transbronchial needle aspiration / biopsy (TNAB) has failed to gain popularity because experience with TBNA in ICU patients is not large and there are no clear advantages of TBNA over other bronchoscopic techniques.[11] Furthermore, it is sometimes difficult to achieve complete insertion of the tracheobronchial wall.[2]

Indications

The common indications for FFB in the ICU are listed in Table I. Between 65% and 79% of the FFB in the ICUs were performed on patients on mechanical ventilation.[9,13,16,18] About 47% to 75% of the FFB performed in the ICU were for therapeutic purposes.[13,16,18] Some of the commoner indications for FFB in the ICU will be discussed below.

TABLE I: INDICATIONS FOR BRONCHOSCOPY IN THE ICU[2,3,7-9,13-17]

Primarily diagnostic
• Pneumonia (immunocompromised host, nosocomial or ventilator associated pneumonia)
• Diffuse or focal lung disease (infiltrates or mass lesions)
• Airway trauma (intubation injury, blunt thoracic injury, postoperative)
• Acute inhalational injury or burns
• Localised wheeze or stridor
• Tracheoesophageal fistula
Primarily therapeutic
• Airway management (difficult intubations, double-lumen ETT placement, extubation)
• Atelectasis (roentgenographic) and excess airway secretions
• Aspiration
• Massive haemoptysis
• Foreign bodies
• Bronchopleural fistula (fibrin glue therapy)
• Obstructing endobronchial neoplasms (laser photoresection or cryotherapy)
• Strictures and stenoses (dilatation and stents)
Many indications require both diagnostic and therapeutic bronchoscopy simultaneously.

Diagnostic Bronchoscopy

Ventilator-associated Pneumonia

Pneumonia is the most common infection in the ICU.[4] The overall incidence of ventilator-associated pneumonia (VAP) ranges from 9% to 25% in a general ICU population, to 70% in patients with acute respiratory distress syndrome (ARDS).[1,4] The risk increases progressively over the first 10 days and reaching as high as 68.8% in patients who have been ventilated for more than 30 days.[8,19] The mortality of VAP ranges from 35% to 90%.[4,20]

Inappropriate initial empiric antibiotic therapy is an independent predictor of increased mortality.[21] A decision analysis by Sterling et al[21] suggested that invasive diagnostic techniques should be used to guide therapy, and thereby potentially improve survival. Fagon et al[22] demonstrated that if patients with VAP were treated for at least 6 days, empiric therapy was more costly than treatment of only patients with positive PSB cultures.

However, Sanchez-Nieto et al[23] reported, in a recent landmark prospective study involving 51 mechanically ventilated patients with nosocomial pneumonia, that diagnostic FFB led to more frequent antibiotic changes with no differences in mortality and morbidity when compared with non-invasive diagnostic management. Despite randomisation, important factors pertinent to mortality of VAP existed in the 2 groups. The incidence of infection with *Pseudomonas* and *Acinetobacter* (with clearly higher crude and possibly higher attributable mortality rates), and inappropriate initial antibiotic therapy were significantly more in the invasive group. A separate prospective randomised study involving a larger sample is warranted to answer whether invasive diagnostic quantitative culture technique lead to better outcome compared to clinical criteria and non-quantitative cultures of tracheal aspirates.

Pulmonary Infection in Immunocompromised Host

The high diagnostic yield of FFB has nearly supplanted open lung biopsies as the initial diagnostic procedure of choice for patients with AIDS (acquired immunodeficiency syndrome) or organ transplants and diffuse pulmonary infiltrates.[5,24]

In AIDS patients, diagnostic yields of BAL for *Pneumocystis carinii* of close to 100%, and other pathogens of 60% to 85% have been reported. In other immunocompromised patients, the yield of BAL for infectious diagnoses was 66% when the results of cultures and rapid diagnostic techniques were included.[11]

The role of PSB in obtaining cultures is complementary to BAL in critically ill patients. BAL and PSB had a diagnostic sensitivity for infection of 90% in immunocompromised patients.[25]

TBLB does not provide any added advantage over BAL alone in diagnosing opportunistic pulmonary infections in immunocompromised hosts except in patients with cytomegalovirus pneumonia, coccidioidomycosis, mycobacterial pneumonia, HIV-related lymphocytic interstitial pneumonitis and non-specific interstitial pneumonitis, where BAL and TBLB combined have a higher yield.[1,4,26] Whether the addition of TBLB to BAL will increase the yield of treatable pulmonary disorders and favourably impact on the course of HIV infection is unknown.[26] In lung transplant recipients, TBLB is invaluable in differentiating between rejection and infection

In bone marrow transplant (BMT) patients, more than 30% of mortality are attributable to pulmonary complications.[27] These include infectious and non-infectious pneumonitis, graft-versus-host disease (GVHD), bronchiolitis obliterans, diffuse alveolar haemorrhage, pulmonary oedema and pulmonary vascular abnormalities. The diagnostic yields of BAL and PSB in BMT patients with pulmonary infiltrates were between 31% to 80%.[24,28,29] However, no impact on survival was demonstrated, and FFB was associated with a significant complication rate of 12% to 27% in BMT patients.[24,28,29] The role of routine diagnostic FFB in BMT patients with pulmonary infiltrates and / or respiratory symptoms need further evaluation.[29]

In neutropenic patients with focal infiltrates, bacterial pneumonia is more common than opportunistic infections, and FFB is often reserved until a trial of broad spectrum antibiotics has failed to achieve resolution.[5]

Upper Airway Obstruction in Non-Intubated Patients

In patients with facial burns or smoke inhalational injury of the airway, heat and large particles damage the pharynx and larynx.[8] FFB can be used to identify early inflammation or swelling of the laryngeal area in such patients suspected of having upper airway obstruction (UAO). These patients, including those with epiglotittis, may need prophylactic intubation prior to development of obstructive symptoms.[6]

Trauma

Tracheobronchial injuries afflict up to 2.8% of severe blunt chest trauma and accidental deaths.[30] The clinical manifestations of tracheobronchial injuries are protean and depend on the site and size of the air leak. Physical and radiological findings include cough, dyspnoea, haemoptysis, pneumothorax, subcutaneous emphysema, mediastinal emphysema, haemothorax, pulmonary contusion, flail chest, atelectasis, "falling lung sign" on chest radiograph (pathognomonic of total rupture of a main bronchus). FFB is the safest and fastest way to diagnose airway disruption after trauma to the chest.[8] Early recognition and repair of such injuries are important in ensuring good outcome.

Therapeutic Bronchoscopy

Endotracheal Intubation

FFB is a very useful tool for difficult intubation, in the presence of anatomic variation in the position of the vocal cords, UAO, reduced mobility of the head and neck, and severe bleeding diathesis which make intubation with a laryngoscope more risky.[8] However, intubation by FFB is only needed in a small number of ICU patients, which represents about 0.07% to 3.4% of all patients.[1,3,13] As 4 minutes or more must be allowed to accomplish intubation, such a procedure is contraindicated in apnoeic or near-apnoeic patients.[6]

The oral route is preferred to nasotracheal intubation as it allows placement of a larger diameter ETT with its potentially lower peak airway pressures and decreased work of breathing.[1,8] Damage to the nasal mucosa and problems with nosocomial sinusitis and otitis media are avoided. A bite block is recommended with oral fibreoptic tracheal intubation to prevent inadvertent biting damage to the FFB.

In an adult, a size 8 ETT can be inserted in most patients. In a smaller adult female, a size 7 ETT may be more appropriate.[6] The external diameter of the currently available FFB ranges from 1.8 mm (ultrathin) to 6.4 mm (most adult FFB average 6.0 mm). Most standard FFB will pass through a size 7.5 ETT, and is the preferred FFB for intubation in an adult.[31] A paediatric FFB should not be used, as it is more flexible and thus more prone to bending into the oesophagus.

Insertion of Double-Lumen ETT

FFB can be used to assist in the placement of a double-lumen ETT that is used for differential ventilation in asymmetric lung disease, management of massive haemoptysis and large bronchopleural fistulae.[4,6] Slinger recommended the use of 39- to 41-F double-lumen tubes

in men and 35- to 37-F tubes in women. A 4-mm, 60-cm FFB will pass through a 35 Fr double-lumen ETT, the smallest size used in adults.[32]

ETT Change

Occasionally, an ETT may need to be changed because of cuff leakage, or a smaller ETT needs to be substituted with a larger one to allow passage of a bigger bronchoscope. Where endotracheal intubation is expected to be difficult, FFB may be used for ETT changes. The stomach content is aspirated via a nasogastric tube. The new ETT is inserted over the FFB, the posterior pharynx is vigorously suctioned, the cuff of the existing ETT is deflated, and the FFB is passed into the tracheal by going outside the old ETT. The old ETT is then withdrawn and the new ETT inserted using the FFB as an obturator.[4,6]

Extubation Over FFB

Patients with suspected UAO, such as after traumatic or multiple intubation attempts, as well as after prolonged intubation or tracheostomy, are ideal candidates for bronchoscopic extubation. The FFB is inserted via the ETT and advanced to a position just outside the distal tip of the ETT. The ETT and the FFB are withdrawn in one piece. During the withdrawal, if there is evidence of significant subglottic or glottic obstruction, the FFB is immediately reinserted and the patient is safely reintubated.[6]

Atelectasis And Excess Airway Secretions

The role of bronchoscopic suction to treat atelectasis secondary to excess airway secretions or decreased cough efficiency (postoperative, mechanical ventilation, neuromuscular disease, sedation and/or neuromuscular blockade) with the belief that bronchoscopic suction of secretions was more efficient is controversial.[1,3,6,8] A prospective study by Marini et al[33] demonstrated no advantage of FFB suction over aggressive respiratory therapy in intubated or non-intubated patients with acute lobar atelectasis. Some of the indications for bronchoscopy in atelectasis and excess secretions are summarised in Table II.[1,3,4,6,8,16]

An innovative method of re-expanding atelectatic lung segments was recently described.[34] It consists of room air insufflation by an Ambu bag connected to the working channel of a bronchoscope, the tip of which is wedged in the selected collapsed segment.

Haemoptysis

Massive haemoptysis, defined as greater than 600 ml in 48 hours, 400 ml in 24 hours or 200 ml in any one event, is considered a thoracic surgical emergency.[6] FFB is the preferred initial procedure after intubation to localise the bleeding accurately to a specific bronchopulmonary segment and for endobronchial therapy to stabilise the patient for subsequent definitive therapy.[1,3,4,6,8] The Fogarty, inserted through the FFB, cannot occlude less than a lobe or even sometimes an entire lung because of its size. The Swan-Ganz, inserted beside the FFB, is smaller in diameter and can be manoeuvred into subsegmental bronchi.[1] This may be useful in preserving gas exchange as much as possible. Placement of a double-lumen ETT to isolate the bleeding lung from the healthy lung in unilateral haemoptysis may be lifesaving. Other methods of management for less extensive haemoptysis include iced-saline lavage, topical saline/epinephrine solution, and fibrin precursors.[1,3,4,6,8] Most measures directed at stopping bleeding require further definitive measures which depends on the underlying aetiology.

TABLE II: INDICATIONS FOR BRONCHOSCOPY IN ATELECTASIS AND EXCESS AIRWAY SECRETIONS

1. Life-threatening acute whole lung or near whole lung atelectasis.[6,16]
2. Lobar or greater atelectasis and a radiologic finding of a bronchogram extending to the segmental bronchi.[4,6]
3. Mucous plugs and resultant atelectasis (failed suctioning and chest physiotherapy).[8]
4. Neuromuscular disease with proximal (lobar) atelectasis secondary to ineffective clearance and mucous plugging.[1,4,16]
5. Thoracic trauma or burns, spinal fractures and severe head injury (chest physiotherapy not feasible and repetitive upper airway suction ineffective).[3,16]
6. Cystic fibrosis or bronchiectasis (copious inspissated secretions)[4]
7. Status asthmaticus and difficulty to wean from mechanical ventilation (removal of endobronchial mucous plugs may improve gas exchange and pulmonary physiology).[8]
8. Lung transplant recipients with thick necrotic mucous plug firmly attached to shredded mucosa (Nd:YAG laser may be necessary to assist in the detachment of necrotic mucosa and partially occluding granulation tissue).[4]

Removal of Foreign Body

Foreign body such as dislodged teeth and aspirated food may lead to pneumonia or respiratory embarrassment. Specialised instruments such as multipronged wire retrieval snare, wire retrieval (Dormia) basket, and biopsy forceps can be passed through the working channel of the bronchoscope to remove the foreign bodies under direct vision.[6,8]

Other Therapeutic Indications

Bronchopleural fistula can be localised by FFB with a catheter balloon occlusion,[8] or installation of xenon into multiple segmental bronchi while monitoring for increased radioactivity in intercostal tube drainage.[6] The bronchopulmonary segment that is the major source of air leakage can be obliterated using tissue glue or lead shots.[8]

FFB can be used to administer therapeutic solutions to selected regions of the tracheobronchial tree. Such management strategies include surfactant in ARDS, and

N-acetyl cysteine in mucous plug.[8]

Weaning of patients with respiratory failure from proximal obstructing tumours can be facilitated by bronchoscopic laser photoresection.[1,6]

The pulmonary artery catheter inserted through a 2.6-mm FFB suction channel was also reported to reinflate persistently collapsed lobes after surgical repair of a tear in the tracheobronchial tree.[6] The balloon was inflated to occlude the bronchus and air was delivered through the distal port of the pulmonary artery catheter.

Pathophysiological Effects

Knowledge of the pathophysiologic consequences of FFB in a mechanically ventilated patient on the respiratory mechanics, gas exchange and haemodynamics is essential to keep complication rate low.

Respiratory Mechanics

In a non-intubated patient, a 5.7-mm outside diameter FFB occupies only 10% of the total cross-sectional area of the trachea.[1,3,35] Therefore, in spontaneously breathing patients, endotracheal pressures generated are similar to those in patients without FFB (-5 cm H_2O during inspiration and +3.5 cm H_2O during expiration).[4] On the other hand, FFB through an ETT or tracheostomy tube generates pressures of -10 to +9 cm H_2O. High airway pressures during FFB are related to the internal diameter of the trachea and FFB. If a standard FFB (5-mm outside diameter) is used and 40 mm^2 is the minimum acceptable cross-sectional airway area that should remain free,[3] most authors recommended that the ETT should be at least size 8 to reduce the risk of barotrauma.[1,3,35]

Positive end-expiratory pressure (PEEP) effect may occur during FFB due to impedance to expiratory flow and insufficient time for complete expiration (hyperinflation).[1,3,35] Usually PEEP remains below 20 cm H_2O in an 8-mm ETT. A PEEP of up to 35 cm H_2O has been recorded with a 7-mm ETT.[1,35] Insertion of a FFB in intubated patients induces a 30% increase in the functional residual capacity (FRC) as well as a 40% decrease in the one-second forced expiratory volume.[1]

Increased intracranial pressure (ICP) can be expected with any manoeuvre, such as coughing or agitation, that increases airway pressure. Bronchoscopy in patients with elevated ICP must be performed cautiously because of the induction of PEEP by the presence of a FFB within the airway.[14] Brief periods of pharmacologic sedation and paralysis may be useful in minimising this complication. A retrospective review of 29 patients with computerised tomogram evidence of raised ICP and underwent FFB concluded that FFB carries a low risk in such patients.[36]

Gas Exchange

The presence of a FFB in the airways causes a slight increase in the $PaCO_2$ (averaging 1.1 kPa), and a moderate decrease in PaO_2 (averaging 1.1 to 2.5 kPa).[35] $PaCO_2$ rises by about 30%, while PaO_2 decreases by about 40% during suctioning.[35] When suction is applied through the FFB, PEEP and the delivered tidal volume decrease.[3,35] As much as 200 to 300 cm^3 of the patient's tidal volume can be removed during each suction period.[14] Reductions in lung volumes and FRC may produce alveolar closure and largely account for the abnormal gas exchange during FFB. In addition, some of the delivered volume can be lost through the swivel adaptor of the ETT. Another mechanism is reflex bronchospasm induced by stimulation of subepithelial vagal receptors in the upper airway.[3,14] Utilisation of short suction periods of no more than 3 seconds and adequate topical anaesthesia should minimise the hypoxic response to these two stimuli.[14]

Arterial O_2 desaturation associated with BAL has been attributed to the decrease in exchange surface produced by fluid lavage and the release of inflammatory mediators.[37] Post procedure, these gas exchange abnormalities slowly return to baseline, from about 15 minutes for normal lungs to several hours for severe parenchymal disease.[35] Such observations have led to the practice of continuous SpO_2 monitoring during and up to 1 to 2 hours after FFB. In unstable or hypercapnoeic patients, monitoring of the end-tidal PCO_2 ($PetCO_2$) at the ETT opening permits breath-by-breath analysis of variation in the ventilatory status.[1,4]

In some patients, improvements in oxygenation may be observed. This may be due to improvement in ventilation / perfusion matching secondary to clearance of tracheobronchial secretions. Another mechanism is the recruitment of atelectatic alveoli by bronchoscopic auto-PEEP, averaging 7 ± 2 cm H_2O, during the procedure.[3,37]

Haemodynamics

There are only a few studies on the haemodynamic consequences of bronchoscopy in mechanically ventilated patients. Lindholm et al[35] reported an increase in cardiac output reaching 50% during the procedure, and returning to baseline in 15 minutes after its completion. Elevation of arterial pressure, heart rate and pulmonary artery pressure and increased cardiac index during FFB are attributed to reflex sympathetic discharge caused by mechanical irritation of the airways.[4,6,35] Other contributory factors may be related to hypoxaemia, elevation of $PaCO_2$, patient apprehension or other factors.[35]

Complications

The reported complications of FFB performed in the ICU (Table III) are less than 10%.[1,2,8,9,13] The risk of major complications with standard FFB in the ICU is 0.08% to 2%.[3,8] The mortality risk is extremely low (0.01% to 0.05%).[6,8] In fact, a review by Olopade and Prakash of 6

TABLE III: COMPLICATIONS ASSOCIATED WITH BRONCHOSCOPY[1-3,8,9,13,17]

Premedication
• Respiratory depression
• Transient hypotension or syncope
Topical anaesthesia
• Respiratory arrest
• Cardiovascular collapse
• Convulsions
Bronchoscopy
• Laryngospasm
• Bronchospasm
• Hypoxaemia
• Cardiac arrthymias
• Hypotension
• Vasovagal reaction
• Pneumonia
• Fever
Biopsy or brushing
• Haemorrhage
• Pneumothorax

papers[7,14-16,18,38] and their own series[13] did not show any deaths among the 804 patients who had 1150 FFB performed in the ICU setting.

Mortality from bleeding during FFB ranges from 0.03% to 0.05%, and is confined to patients undergoing biopsy or brushing procedures.[6] The risk of bleeding is highest in TBLB, followed by endobronchial biopsy and brushings. Most bleeding resolves spontaneously or responds to prompt bronchoscopic segmental tamponade and direct instillation of epinephrine. The risk of bleeding is increased in immunocompromised patients, and in patients who have renal or hepatic disease, malabsorption, malnutrition, platelet dysfunction or acquired coagulopathies.[2] It has been recommended that platelet counts be above 50 000 / mm^3 for routine FFB and above 75 000 / mm^3 for TBLB. The prothrombin and partial thromboplastin times should also be within 1 to 2 seconds of the control values. When the international normalised ratio is prolonged beyond 1.5, fresh frozen plasma should be administered before brushings or biopsies.[9] Cryoprecipitate or 1-deamino-8-D-arginine vasopressin (DDAVP) may be beneficial in patients with dysfunctional platelets as determined by bleeding time.[2,6] In immunocompromised patients who are thrombocytopenic, BAL may be performed as an alternative to biopsy or brushing. An 8% incidence of mild bleeding was reported with BAL in thrombocytopenic patients.[39] A significant bleed is defined as blood loss of more than 50 ml.[2]

The reported risk of pneumothorax with TBLB under fluoroscopic guidance on patients requiring mechanical ventilation for progressive pulmonary infiltrate is between 7% and 15%.[12,27]

Trouillet et al[40] in their study of FFB in 107 ventilated patients reported 5% incidence of major arrthymias, 13% incidence of hypoxaemia ($PaO_2 \leq 60$ mm Hg on FiO_2 of 0.8) but no deaths or cardiac arrest during or within 2 hours of the procedure. Barret[33] reported a 3% incidence of malignant arrthymias, cardiopulmonary arrest, or both directly related to FFB. Patients with cardiovascular disease, unstable angina or severe hypoxaemia are at highest risk of developing acute cardiovascular complications.[5,11]

Oxygen desaturation, especially in the presence of ARDS or those that were insufficiently sedated,[40] is one of the most common complications associated with FFB. The average change in PaO_2 during FFB is 20 mm Hg in healthy patients. In critically ill patients, the drop in PaO_2 may be greater than 30 to 60 mm Hg, and the hypoxaemia may persist for several hours after the procedure.[11] Mechanisms contributing to hypoxaemia are altered ventilation / perfusion and diminished alveolar ventilation.[6]

Laryngospasm and bronchospasm are the most common airway complications.[17] The insertion of a FFB in non-intubated patients is associated with a 0.1% to 0.4% incidence of laryngospasm or bronchospasm, especially in patients with underlying bronchospastic disease.[6] Premedication with atropine and nebulised beta-agonists is indicated in an asthmatic patient. As a precautionary measure, an ETT may be inserted onto the proximal FFB for introduction into trachea if laryngospasm develops. Intravenous lignocaine may be used to prevent and treat laryngospasm.

Lignocaine is most commonly used as a topical anaesthesia for FFB. Lignocaine toxicity can result in tremulousness, shivering, dizziness, sedation, unconsciousness, convulsions, respiratory arrest or cardiovascular collapse.[6] The recommended maximal dose of lidocaine that can be applied to the respiratory tract is 300 mg,[6,17] or 4 mg / kg lean body weight.[2] The blood concentration after topical applications may be 30% to 50% of that obtained by rapid intravenous administration.[17] Aerosolised lignocaine may reduce the amount of topical lignocaine required for tissue anaesthesia by half.[8]

Post-bronchoscopy fever occurs in approximately 5% to 16% of the patients,[4,8] with pulmonary infiltrate occurring in 0.6% of all cases.[4] The self-limiting fever is usually not indicative of pneumonia and may be due to transient bacteraemia, translocation of endotoxins or release of inflammatory mediators.[1,3,8]

Contraindications

Contraindications for FFB include inexperienced bronchoscopist and personnel, inadequate facilities or equipment, inability to oxygenate or ventilate the pa-

TABLE IV: RECOMMENDATIONS FOR BRONCHOSCOPY IN MECHANICALLY VENTILATED PATIENTS[1,2,4,6,7,9,13-15,35]

1. The polyvinyl-chloride ETT should be of at least size 8 to allow the passage of the adult FFB. If the tube diameter does not allow the standard FFB to negotiate, the patient may need to be intubated with a larger ETT. If this is not possible, a paediatric FFB is used.
2. Next, the ETT is shortened as much as possible by cutting at the end to allow access of the tip of the FFB to the periphery of the tracheobronchial tree.
3. A Portex swivel adapter with a fitted rubber cap is attached, allowing FFB with minimal loss of tidal volume.
4. A mouth guard must be used to prevent patient from biting the scope.
5. The FiO_2 is increased to 1.0 starting 5 to 15 minutes before,[1,14] during, and up to an hour after the procedure[9] with the aim of maintaining the SpO_2 as close to 100% as possible.
6. Check arterial blood gases before, and 10 minutes after procedure.[14] Postpone FFB if $SaO_2 < 90\%$ on FiO_2 1.0,[9] except in patients with gross haemoptysis when bronchoscopic suction of the blood clots obstructing the airways may be life-saving.
7. PEEP (or pressure support) is taken off during FFB,[1,2,14,35] where possible, because the peak airway pressures can increased by as much as 25 mm Hg.[2] If discontinuation of PEEP is not feasible, reduce PEEP by 50%, or monitor bronchoscope tip pressure.[1]
8. Volume ventilators were utilised so that the increasing airway resistance secondary to the FFB would not result in a reduced tidal volume.[14] If pressure-controlled ventilation is used, the peak pressure setting is increased to compensate for the loss of tidal volume consequent to the increased resistance.[2]
9. Sedation with intravenous midazolam (1 to 2 mg, or more) may be given depending on patient's ability to cooperate and tolerate the procedure,[13] with supplemental doses as needed. IV atropine 0.6 mg prior to bronchoscopy.[7]
10. The FFB is lubricated with KY jelly.
11. Use short suction periods of 3 seconds or less.[4,14]
12. Instil small amounts of topical lignocaine (aliquots of 2 ml of 2% lignocaine) through the FFB to the trachea, carina, and both main bronchi.[15]
13 Monitor SpO_2 by continuous pulse oximetry.[4,14]
14 Monitor exhaled tidal volume because of the potential for loss of tidal volume around swivel and through suctioning.[7]
15. Monitor pulse and blood pressure.
16. Monitor $PetCO_2$ in selected unstable and/or hypercapnic patients.[1,4]
17. During bronchoscopy, if there is tachycardia, a rise in blood pressure or desaturation occurs, the procedure may be temporarily stopped and reinstituted after return of stable vital signs.
18. Assess bronchospasm by ascultation and airway pressure/compliance measurement.[14]
19. Check position of ETT (via FFB) at the end of procedure.
20. Chest X-ray after procedure to document intrathoracic complications.[4,14]

tient adequately.[8,13] Relative contraindications would include acute myocardial infarction or unstable angina, worsening asthma or status asthmaticus, severe pulmonary hypertension, coagulopathy and bleeding diatheses, thrombocytopenia ($< 50\,000 / mm^3$), severe uraemia, lung abscess and severe debilitation.[2,13]

The Bronchoscopic Technique

To minimise the risk of FFB, precautionary measures during FFB in ICU need to be observed. Some practical recommendations to facilitate FFB in mechanically ventilated patients are suggested in Table IV.

In spontaneously breathing patients who are on Ventimask, or 100% oxygen delivered via tight fitting non-rebreather face mask, a small hole is fashioned opposite the nostril for the passage of the FFB. The nostrils and pharynx are sprayed with lignocaine aerosol. The FFB is lubricated with lignocaine jelly and introduced via the nostril.[14,15] The transnasal approach is associated bleeding and is contraindicated in patients with coagulopathy.[6] The transoral approach, which produces more gagging and retching, requires a mouthguard to prevent biting of the FFB.

Conclusion

FFB in ICU provides valuable diagnostic information and has therapeutic utility. It can be performed in almost all critically ill patients with clinical indications. However, FFB should be performed by experienced bronchoscopists who are skilled in the use of this versatile instrument and can deal with potential complications. It is recommended that guidelines which regulate the utilisation of FFB in ICU be developed to derive maximal benefits and minimise the risk to the patients.

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