Anesthesia for adult rigid bronchoscopy

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Abstract: Rigid bronchoscopy under general anesthesia enables performing diagnostic and/or therapeutic procedures in the tracheobronchial tree. This technique is characterized by specific technical problems, insofar as the anesthesiologist and the operators share the same space, namely the airway. Several potential complications (hemorrhage inside the airway, threat to ventilation ...) may arise. These challenges render the ability to use the variable available techniques essential, as well as knowledge of the complications they could entail, and the ability to rapidly solve them. General anesthesia is usually total intravenous anesthesia, using short acting agents. Ventilation can be spontaneous, but more often insured using high-frequency jet ventilation. The hospital infrastructure and staff must have the expertise to perform this particular procedure, in order to limit the complication rate.

Key words: Anesthesia; bronchoscopy; adult.

INTRODUCTION

Rigid bronchoscopy (RB), initially performed under local anesthesia, was first described in 1898 by Killian (1). Today, general anesthesia and appropriate ventilation method are recommended. RB offers a wide range of diagnostic and therapeutic options for the upper airway. Some procedures even allow avoiding conventional surgery such as thoracoscopy. The anesthetic management during rigid bronchoscopy is challenging. It necessitates the management of the airway of fragile patients, often presenting with an American Society of Anesthesiologists (ASA) physical status III or IV, and an already critically compromised airway. Here we propose to review the specific RB perioperative management. Given the possible occurrence of acute complications such as obstruction of the airway, bleeding, or pneumothorax, and the need for manipulating specific devices and techniques, such as High Frequency Jet Ventilation (HFJV) or extracorporeal circulation, this specialized activity must be performed in hospital environments that gather the needed equipment and expertise. This is the only way to ensure patient safety.

SPECIFIC EQUIPMENT

A rigid bronchoscope, such as the Efer-Dumon bronchoscope (Fig. 1), consists of a metal tube fitted on a base. The base includes first a wide axial entrance to introduce the optic device or introduce specific instruments such as clips, dilation balloons, or stents. The optic device can be a rigid one, which can be used to view the operative field directly or through an integrated video system, or can be a flexible bronchoscope. The flexible bronchoscope allows reaching more distal lesions. Second, the base contains an oblique lateral entrance, through which a laser fiber, an argon plasma coagulation probe, or a suction cannula can be passed. The third orifice of the base is a lateral entrance that is specifically devoted to ventilation.

INDICATIONS OF RIGID BRONCHOSCOPY

The main indication for rigid bronchoscopy is the diagnostic and treatment of intra- and/or extraluminal obstruction of the airway. The stenosis can be located in the trachea, the carina, or the primary or intermediate bronchial tubes. Lesions that provoke the obstruction can be malignant or benign tumors, or foreign bodies. In the event of an acute tracheal obstruction by a malignant pathology, such as primary bronchogenic carcinoma or bronchial metastases, rigid bronchoscopy enables palliative obstruction relief of the main airway, and can be temporarily life-saving (2, 3). In some patients, it
Contraindications

Contraindications are rare when the procedure is managed by experienced anesthesiologists and competent operating room staff (6). Relative contraindications include uncontrolled coagulopathy, extreme ventilation and oxygenation demands, and tracheal obstruction (7).

Treatment techniques

Most of diagnostic procedures are performed using a flexible bronchoscope under local anesthesia or deep sedation and laryngeal mask control of the airway. The rigid bronchoscope allows performing therapeutic acts with immediate or delayed effects. Those therapeutic acts include, for example, cryo-therapy, bronchial brachytherapy, or dynamic phototherapy (8). Here, we will consider the techniques that produce immediate therapeutic results.

Rigid bronchoscope

Owing to its beveled end, and using rotary progression, the rigid bronchoscope can be used for mechanical resection. In that case, its tip can be
used to “drill” through large tumors. In case of life-threatening airway obstruction, it allows restoring efficient ventilation rapidly. Large suction catheters can aspirate blood or remove tissue debris easier than during flexible bronchoscopy.

Balloon dilation

Balloon dilation is performed using a balloon catheter that is attached to a stylet and pushed through the stenosis. Sterile saline filling of the balloon during 30 to 120 seconds and applying a 1-5 mmHg pressure can be monitored using flexible bronchoscope or X-ray. The maneuver can be repeated in case of persistent stenosis. The results are immediate, but often transient. This technique is very stimulating for the patient, mainly causing coughing. It may also prevent the below dilation zone from being ventilated. The sequential introduction of progressively enlarging dilators can be combined with balloon dilation.

Laser

Lasers are of various types. Their wavelength (λ) conditions the vaporization and coagulation effects. The neodymium, or yttrium aluminum garnet (Nd:YAG) laser (λ = 1064 nm) reaches tissues at a 3-5 mm depth, and provides adequate photocoagulation, as compared to the carbon dioxide (CO₂) laser (λ = 10600 nm). This last laser can be used to achieve superficial tissue penetration (0.1-0.5 mm), but has low hemostasis power. It is mainly used mainly during ear, nose and throat surgery. Recently, the thallium laser (λ = 1.9 nm) has become available. Its energy is totally absorbed by the tissue surface, making it more precise than the Nd:YAG laser (9). In 83-93% of cases, the Nd:YAG laser has proved being efficient at relieving endo-bronchial obstructions of pulmonary cancer origin (10).

High-frequency thermo-coagulation

The energy produced by an electrical current can be used for coagulation, similarly to the coagulation obtained with the Nd:YAG laser. This technique is less expensive, but requires frequent cleaning of the probe.

Argon plasma coagulation

Argon plasma coagulation is a monopolar electrosurgical technique that delivers energy, without coming into contact with tissues. It uses a jet of ionised argon, and has shallow penetration (1-3 mm). It ensures superficial coagulation without affecting the underlying tissues.

Stents

Stents can be used to restore and maintain the proximal airway permeability when compromised by various types of intrinsic or extrinsic obstructions. They also help sealing the airway walls in case of eso-tracheal fistulae, dehiscence of bronchial suture after lung transplant, or tracheobronchomalacia. Type of stents may vary according to their physical properties, shape, size, and material composition. They can be made of silicone, or metal, they can be uncovered, partially or totally covered. Others are hybrid, or even biodegradable (11). Silicone stents are chosen for benign pathologies as they are intended to be removed with ease. Uncovered or partially covered metallic stents are primarily used for palliative indications, given the difficulty of removing them. When subsequent tracheal intubation is needed, it must be performed under fiberscope monitoring. Otherwise, supra-glottic devices, such as laryngeal masks, are an alternative.
of dyspnea or respiratory distress. When patients present repeatedly, it is important to consult previous medical reports describing the anesthetic strategy (ventilation, intubation), and the encountered difficulties. However, and noteworthy, the incidence of difficult laryngoscopy is not higher than the incidence of the normal population (12).

Several tests can be performed to precise the nature and location of the airway obstruction, and guide therapeutic management. A conventional X-ray of the thorax cannot determine with precision the size, location and extent of the pathology (12). If an oro-tracheal intubation is planned, a thoracic scanner, possibly with biplanar or even three-dimensional reconstruction, or nuclear magnetic resonance may be considered (17, 18) to provide information on the diameter of the tube to be inserted, the distance of introduction into the trachea, or eventual unfeasibility of the procedure (15). A fiberscope can be used to describe the lesion, its localization, or macroscopic aspect. Functional respiratory testing estimates the impact of the pathology on the respiratory dynamics, and the reversibility of this impact. Flow curve or flow rate volume analysis allows differentiating between intra or extra-thoracic, and fixed or variable obstruction of the airway. Blood gases analysis performed when the patient is breathing ambient air is useful for evaluating the primary state of the patient in terms of hypoxemia and hypercarbia. These are factors that can predict complications during and after the procedure (16).

Premedication

Sedative premedication must be used with caution, as it can cause hypoventilation and aggravate airway obstruction. Medications reducing saliva and bronchial tree secretions are useful. Scopolamine is the most potent in that respect. Anticholinergic agents also reduce the vagotonic effects of remifentanil. Oral clonidine, at a dose of 4 to 4.5 µg/Kg, with a maximum of 300 µg, and given an hour and a half before the procedure is encouraged, particularly for patients at coronary risk (19). Bronchodilators are still given in the perioperative period in order to condition and improve lung function. Except for emergencies, fasting is in line with any procedure requiring general anesthesia.

Intraoperative care

Standard equipment and monitoring, in line with the Helsinki Declaration on patient safety (20), should include electrocardiography, pulse oximetry, non-invasive blood pressure monitoring, and muscle relaxation monitoring. Expired fraction of CO₂ monitoring is often compromised, owing to ventilation methods. The alternatives are transcutaneous CO₂ measurement, intermittent blood sample drawing and analysis through an eventual arterial line, aspiration of CO₂ through the injector of HFJV after having provoked apnea (21), capnography after a few low-frequency respiratory cycles (10-12/min) during HFJV (22), or direct measurement using a new-generation HFJV device. Monitoring depth of anesthesia is useful, to the extent that as interventional RB is considered to be at risk of explicit intraoperative awareness (23, 24).

Total intravenous anesthesia (TIVA) is usually the first choice, to the extent that as closing breathing circuit leaks around the bronchoscope is generally impossible. In addition, periods of apnea are needed to perform specific parts of the procedure. Short acting intravenous agents are recommended. The best approach to administer propofol is a Target Control Infusion (TCI) mode. Remifentanil, which as has demonstrated superiority to alfentanil in terms of blood pressure stability (25), can be given through a continuous intravenous infusion, at a dose of 0.1-0.3 µg/Kg/min (13), or as a 1 µg/Kg bolus in one minute, followed by a 0.5 µg/Kg/min infusion for maintenance (26). Infusion rates should be adjusted according to heart rate and blood pressure. As soon as the patient lose consciousness and manual ventilation is possible, neuromuscular transmission monitoring should be calibrated and started. A bolus of rocuronium at a dose of 0.3-0.5 mg/Kg can be administered to facilitate the insertion of the rigid bronchoscope. Local anesthesia of the glottis, using, for example, 4 ml of 4% lidocaine, can be performed before rigid bronchoscope insertion. Maintaining a deep muscle relaxation, corresponding to a post-tetanic count of 1-5, ensures strict immobilization, vocal cord adduction, and prevention of patient coughing during the procedure.

During induction, the operator should be at the patient’s head, so that an emergency rigid bronchoscopy can be performed to control the airway, if needed (27). A risky situation is the presence of an anterior mediastinal mass (28), which could result in a major cardiovascular collapse at the moment of induction or simply when the patient is placed in the supine position, because of tracheal obstruction.

Deep sedation with spontaneous breathing can be used as an alternative to general anesthesia. However, hypoventilation may occur, as well as laryngospasm, or slight relaxation of laryngeal
Admixture of oxygen-air within the system is proximal. The HFJV advantages include the delivery of small respiratory volumes, often smaller than the dead space, limited movements of the diaphragm, the creation of a positive end expiratory pressure, which improves oxygenation by reducing the alveoli shunt, and the expulsion of laser-generated smoke. However, the airflow can send fragments of neoplastic tissue, and/or viral particles into the tracheobronchial tree. The main risk of HFJV is pulmonary barotrauma, which occurs when expiration of the injected gas is impaired by upper airway obstruction. To reduce this risk, it is important to use a device dedicated to measure end-expiratory pressure (Fig. 2) (31).

Expiration is a priori not compromised because it occurs through the lumen of the bronchoscope and its surroundings (30). However, if the lumen is full of instruments or occupied by a piece of tissue, or if the tip of the bronchoscope is against the tumor, expiration can be compromised. A difficulty in case of bronchial tumors is the lateralization of the bronchoscope. In that case, only one lung is ventilated. If adequate ventilation cannot be achieved, the bronchoscope must be drawn back above the carina, to ensure bilateral lung ventilation. Another option consists in inserting a small catheter along the tumor to permit intermittent deflating of the pulmonary portion under the obstruction. Manual ventilation or mechanical ventilation can be achieved using the lateral arm of the bronchoscope after occlusion of the other entrances. In extreme situations, veno-venous extracorporeal membrane oxygenation can be envisaged. This must be planned...
before the procedure. It prevents the consequences of airway collapse when there is a serious risk of complete obstruction of the airway, such as in case of anterior mediastinal mass, or before withdrawing certain types of metallic stents (32, 33).

Postoperative care

Recovery is often more challenging than induction of anesthesia. Five to ten% of patients requiring active interventions at this stage (15). Deep muscle relaxation, which ensures excellent operating conditions during the entire procedure, must be completely reversed before recovery. Sugammadex, at a dose of 4 mg/Kg, reverses deep rocuronium-induced muscle relaxation within a few minutes. It provides the opportunity to maintain deep blockade of the neuromuscular junction until the end of the procedure, while ensuring fast, predictable, and safe reversal at the time of bronchoscope removal (34, 35). At that time, manual ventilation is restarted. The permeability of the airways can be temporarily reduced by the manipulation-induced edema. If the airway has been traumatized during the withdrawal of the bronchoscope, or if manual ventilation proves precarious, there should be no hesitation to temporarily intubate the patient under fibroscope control.

The post-intervention monitoring of rigid bronchoscopies must occur in the recovery room. In case of complications or special procedures, such as those involving extracorporeal oxygenation, monitoring should be undertaken in an intensive care unit. The most serious potential complication is an acute occlusion of the airway. This may occur, for example, after movement of a stent. Such an event provokes acute respiratory distress. The possibility of an immediate re-intervention must always be considered. There should be no hesitation to perform immediate flexible bronchoscopy to diagnose the obstruction origin (36). An chest X-ray can assess the re-inflation of a lung or segment that had initially collapsed, to confirm the location of a stent, or detect a pneumomediastinum or a pneumothorax (16, 36).

Pain is essentially laryngeal, and is due to repeated repositioning of the bronchoscope. It usually responds to World Health Organisation Analgesic Ladder level I analgesics, that is paracetamol and non-steroidal anti-inflammatory medications. Corticotherapy for anti-inflammatory purposes can be considered in the event of a local inflammatory state, repeated intubations, or long procedure. However, their efficacy after laser use has not been proven after laser resection (37). The procedures are followed by a period of hospitalization, lasting 24 to 48 hours.

Complications

Complication rate ranges between 0.4 and 1%. The ageing population and the learning curve of new technologies increase the occurrence of complications. Patient selection, comorbidities, and the expertise and resources of the center are decisive factors that influence the final outcome. In that respect, the American College of Chest Physicians recommends performing at least 20 supervised procedures before performing the procedure alone (7). It is also essential that the entire team have in-depth knowledge of these complications to ensure optimal patient safety.

General complications

Hypoxia due to ventilation inefficiency, intrabronchial hemorrhage, congestion resulting from bronchial secretions or tissue fragments, and even barotrauma can be remedied by increasing the FiO2, ventilation optimization, repositioning of the bronchoscope, cessation of HFJV and temporary manual ventilation, secretion aspiration, removal of tumor fragments, control of hemorrhages, or pneumothorax drainage. Hypercarbia is frequent, but has generally few repercussions. Hemodynamic instability may be managed using vasoactive medications. Laryngospasm and bronchospasm are fairly rare complications (0.64%) (38).

Technical complications

Some complications are specifically related to the use of the bronchoscope. Repeated manipulations can cause dental or gingival lesions, as well as lesions to the vocal cords, the piriform sinus, the trachea, and, more frequently, the pars membrane, which is the thinnest. Any maneuvers within the bronchial tubes must be careful, particularly when close to the left primary bronchus, owing to its natural curve (39).

Other complications are related to dilatation balloons. Bleeding, tearing of the tracheal wall, and hypoxemia, at the moment of balloon inflation, are the most frequent (40).

Laser-induced complications have a low incidence. The complication rate of Nd :YAG laser is lower than 5% (41, 42), and the mortality rate is evaluated to range between 0.3% and 0.5% (40).
This complication rate is influenced by the condition of the patient, the location of the tumor lesion, the type of endoscopy, failure to observe the rules on the use of the laser [monitoring of Nd:YAG laser energy, exposures of 0.5 to 1 second at a maximum power of 45 W, poor functioning of the fiber cooling system], the experience of the surgeon, and the cooperation among the team members (43). These complications include the following: hemorrhage can be controlled by laser cauterization, local compression using the tip of the bronchoscope or a Fogarty catheter, and adrenaline plugging or instillation. Continuous aspiration can be applied through the lateral arm of the rigid bronchoscope, to clean the work field. Should a serious hemorrhage occur, that is of more than 250 ml (43), an emergency thoracotomy may be necessary (16). Selective intubation to protect the healthy lung should occur before such a risky procedure, that may prove to be fatal to the patient (44). Endo-bronchial fire incidence is approximately 0.1% (45). This incidence is reduced by removing endotracheal tubes, unsheathed flexible fiberscopes, and all inflammable objects from the laser field, as well as by working with a lower than 40% inspired oxygen fraction to prevent the acceleration of combustion (31). Should a fire occur, the following attitude is recommended. The rigid bronchoscope and/or probe should be first withdrawn directly, and the surgical field watered. Ventilation should then be stopped, and the source of oxygen disconnected. Novel intubation should occur to control the airway and allow manual ventilation. The rigid bronchoscope should be reinserted to assess the damage, and steroids, bronchodilators, and antibiotics administered. The patient should be admitted to the intensive care unit for assessment and evaluation of the need for a gastrostomy.

Air embolism may result from a communication between the airway and a vein. Early signs are low arterial blood pressure and arrhythmia. In case of direct communication between the airway and an artery, arrhythmia and convulsions occur, followed by coma. In case of any suspicion of air embolism, the patient must be placed in the Trendelenburg position, inspired oxygen fraction should be set at 100%, vasopressor support should be considered, as well as hyperbaric oxygen therapy (46).

Smoke and tissue particles might be inhaled by the staff and the patient, causing human papilloma-virus contamination and neoplastic dissemination. Smoke can also cause pulmonary edema. Therefore, continuous aspiration is essential.

Various other complications have been described, including pneumothorax after bronchial perforation, non-cardiogenic pulmonary edema, bronchospasm, pneumonia, and broncho-pleural fistula.

Complications linked to high-frequency thermo-coagulation, which is a thermal method similarly to laser, are endo-bronchial fire, hemorrhage (2.5%), perforations of the airway, and, in theory, air embolism (47). Argon plasma coagulation has lower risk of hemorrhage, and tissue perforation. Ignition of the airway, or argon gaseous embolisms are possible (48, 49).

The immediate complications of stents (50) include partial or total obstruction of the airway. This can occur in case of wrong position of the device at the time of release. Migration is the main issue of silicone stents, although the risk can be lowered by the presence of lugs on the external wall. The retention of secretions necessitates the use of mucolytic agents or aspiration with a fiberscope. Delayed complications include halitosis. With uncovered or partially covered metallic stents, the tumor invades the mesh (13). This complication has recently led operators using fully covered metallic stents, which are also easier to remove. Obstruction of the tips by granulomas affects all types of stents, the incidence of that event being 16% for silicone stents (51) and 30% for metallic stents (52). Fractures are occasionally reported with metallic stents (53). Cases of fatal or non-fatal hemoptysis (54) have been reported following vessel erosion. The complications are more frequent when the indication is a benign pathology, given the longer survival time.

Conclusions

The number of therapeutic techniques performed by means of rigid bronchoscopy is multiplying rapidly, presenting to anesthesiologists new challenges for managing those patients with serious comorbidities. In this context, our literature review highlights anesthetic specificities. An in-depth knowledge of the various endoscopic techniques is essential to be able to promptly address occasionally serious complications, ranging from hypoxia to cardiovascular collapse. Interventional rigid bronchoscopies should be performed in institutions with adequate infrastructure and trained dedicated staff.

References

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