Anaesthesia management for bronchoscopic and surgical lung volume reduction

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Abstract: Optimizing the patient's condition before the lung volume reduction (LVR) according to recommendations by American College of Cardiology/American Heart Association (ACC/AHA) guideline on perioperative cardiovascular evaluation is mandatory. Implementation of a multimodal analgesia concept and the use short-acting anaesthetics enhances recovery and avoids postoperative pulmonary complications. Normovolemia, normothermia, lung protective ventilation and an evidence-based concept of airway management (i.e., double-lumen tube, bronchus blocker) are suggested for intraoperative management of surgical lung volume reduction (SLVR). General anaesthesia (using remifentanil, propofol and mivacurium) with an i-gel® supraglottic airway device should be used for bronchoscopic lung volume reduction (BLVR). Jet ventilation through rigid bronchoscopy or with a jet catheter may be an alternative concept. Experienced consultants should perform anaesthesia for LVR.

Keywords: Lung volume reduction surgery (LVRS); bronchoscopic lung volume reduction (BLVR); anaesthesia management

Introduction

Reducing hyperinflated diseased lung in patients suffering from inhomogeneous emphysema was introduced more than 50 years ago (1). Lung volume reduction (LVR) includes surgical methods, so-called lung volume reduction surgery (LVRS) and bronchoscopic lung volume reduction (BLVR).

Anaesthesia management for LVR procedures is challenging. Besides severe airway obstruction and impaired gas exchange, patients undergoing LVR often suffer from pre-existing comorbidity and their physical status of the American Society of Anaesthesiology classification is higher than three (2). The operation site and the mechanical ventilation are interdependent and lung protective mechanical ventilation of the previously diseased lung is crucial for the postoperative success of the procedure. Recovery of spontaneous breathing at the end of surgery and extubation are mandatory to reduce airway pressure (3). Implementation of a multimodal analgesia concept and the use short-acting anaesthetics enhanced recovery. In addition, optimal fluid therapy and active warming could achieve normovolemia and normothermia.

Anaesthesia for LVR is a challenge in these patients and should be performed by experienced consultants, since airway management for BLVR and LVRS is different and may be difficult: BLVR needs the sharing of the airway between interventionist and anaesthesiologist—LVRS needs one-lung-ventilation with lung separation. An algorithm for securing airway management should be established. Beyond the difference from established airway algorithms, training in difficult LVR airway management has been shown very

effective (4).

Preoperative management

Optimizing the patient's condition before the LVR reduces postoperative complications and may be mandatory for successful treatment. First, assessment of individual patient risk factors before the planned intervention allows pre-treatment optimization. Due to the risk factors and pre-existing conditions of patients prior to the LVR, it is sometimes necessary to coordinate further interventions like coronary interventions prior to the LVR (5) recommended by American College of Cardiology/American Heart Association (ACC/AHA) guideline on perioperative cardiovascular evaluation and management of patients undergoing non-cardiac surgery (5). A recent transthoracic echocardiography should have been performed on each patient, especially to evaluate the right ventricular function. A systolic pulmonary arterial pressure (SPAP) >35 mmHg and with a homogeneous emphysema is considered as a contraindication for LVR (6). SPAP up to 45 mmHg in patients with heterogeneous emphysema and severe hyperinflation could be tolerable for LVR, although robust evidence is missing (6).

Alcohol and smoking should be reduced and ceased preoperatively (7,8) to reduce the risk of infections, respiratory, and neurological complications and the intensive care unit (ICU) stay (9). Whether preoperative spirometry training is beneficial in patients undergoing thoracotomy and lung resection (10) and despite lacking data it should be recommended in patients for LVR. As preoperative medication for anxiolysis, benzodiazepines seem to have advantages over alpha-2-agonists (11). However, anxiolysis must be carefully weighed towards sedative and respiratory depressive effects especially in the LVR patient collective.

Anaesthesia management in LVRS

Strategy

The main strategy in anaesthesia management for LVR should be an effective analgesic concept with combined methods, lung protective ventilation and an evidence based concept of airway separation. Better pain control with thoracic epidural anesthesia (TEA) is established in a wide range of surgical procedures (12). A recent meta-analysis of the pulmonary effects of TEA showed a reduced rate of pneumonia after TEA, probably due to earlier mobilization, reduced opioid consumption, and improved cough (13).

In the past, general anaesthesia and separated ventilation of the lungs were always necessary in thoracic surgery (1). The only way to perform lung-separation with one-lung ventilation has been a double-lumen tube or bronchus blockade. The bronchus blockade seemed to have disadvantages due to the over-inflated lungs of the patients undergoing LVR and has been rarely used (14). With the introduction of video-assisted thoracoscopic surgery other strategies such as non-intubated video-assisted thoracic surgery (NIVATS) may be an alternative concept, which has to been further proved to produce robust evidence by future well-designed studies (15). Without intubation, the spontaneously breathing patient develops a pneumothorax after surgical opening of the pleura, which may create sufficient operating conditions. However, the cough reflex must be prevented by surgical vagus blockade (16). The disadvantages are movements, conversion to open procedure, insufficient analgesia, panic attacks and respiratory complications (15,16). The conversion rate is described as less than 5% (15).

Anaesthetics

The selection of short-acting anaesthetics in combination with thoracic epidural analgesia is important to reduce postoperative complications. On one hand, postoperative complications such as nausea and vomiting can be reduced, on the other hand, the avoidance of anaesthesia overhang is essential (17). Remifentanil as a short-acting opioid with a very short context-sensitive half-life seems to be a valid choice for anaesthesia maintenance, but no data on opioid choice in LVR patient exist. Due to the short half-life time of remifentanil and therefore a lack of postoperative effect, it should only be used as part of a multimodal pain concept.

The necessity of muscle relaxation, especially for the suppression of intraoperative coughing, should be performed with reversible muscle relaxants. Clear data on the save use of cisatracurium exists, but after the introduction of a selective binding agent for reversal of neuromuscular blockade—sugammadex-rocuronium bromide may be an alternative. Since postoperative recurarization is a morbidity factor in anaesthesia, antagonization is mandatory. Rocuronium shows slight advantages through the introduction of sugammadex, especially when neostigmine related side effects count. There were no significant differences in a recent single

Table 1 Parameters of lung protective ventilation in LVRS

Procedure	Application	Avoidance
Recruitment maneuver	After induction/positioning and re-ventilation: PEEP 10–20 cmH$_2$O, 30–40 cmH$_2$O, during 10–40 sec	Atelectasis, acute cor pulmonale
PEEP level	During one-lung ventilation: 2 cmH$_2$O PEEP	High shunt volume
Tidal volume	4–6 mL/kg body weight; I:E =1:2.5 or longer expiration time	Hyperinflation of bullae
Peak pressure	<25 (maximum 30) cmH$_2$O	Barotrauma (pneumothorax)
FiO$_2$	Normoxia: paO$_2$ >14 kPa or like paO$_2$ under FiO$_2$ 0.21	Free O$_2$ radicals

I:E means inspiratory time : expiratory time. LVRS, lung volume reduction surgery; PEEP, positive end-expiratory pressure.

blind trial of 120 patients if both are antagonized with neostigmine (18). The use of neuromuscular monitoring for muscle relaxation is strictly recommended, to especially avoid respiratory complications in LVR patients.

The use of intravenous or inhaled anaesthesia has long been the subject of numerous studies. In a randomized controlled multicentre trial of Beck-Schimmer *et al.* with 460 patients addressing the effect of volatile versus intravenous anaesthetics on major complications after lung surgery no difference between the two anaesthesia regimens was evident (19,20). Importantly inhalational anaesthetics dose-dependently influence local inflammatory processes, partially reverse hypoxic pulmonary vasoconstriction and reduce alveolar clearance (19,21). Due to the short half-life time and faster recovery anaesthesia with desflurane seems to be a preferable option.

Lung protective ventilation

Lung injury is the leading cause of death after thoracic surgery. Protective ventilation may prevent postoperative lung injury and reduces postoperative pulmonary complications. Elements of lung protective ventilation are short duration of ventilation (i.e., one-lung ventilation), low FiO$_2$, low tidal volume [4–5 mL/kg body weight (BW)], recruitment after induction and after one-lung ventilation and moderate positive end-expiratory pressure (PEEP) levels (5–10 cmH$_2$O) (see *Table 1*) (22).

Furthermore, permissive hypercapnia may be used to accelerate oxygen delivery during one-lung ventilation and in chronic obstructive pulmonary disease (COPD) patients with residual hyperinflation (3).

Lung protective ventilation has become an integral part of protocols to prevent pulmonary complications like pneumonia or accelerate the recovery time [e.g., enhanced recovery after surgery (ERAS)], which is both also, wanted in LVR (23-25).

One-lung-ventilation allows both open and video-assisted thoracic surgery. However, it also represents an independent risk factor for complications such as pneumonia, atelectasis and acute lung damage.

The two key steps during LVRS are re-expansion and ventilation of the suspended lung and early extubation. Re-expansion and ventilation of the operated lung should be carried out during lung separation because of the different compliance of both lungs. The concept 'open the lung and keep it open' could be a guide in re-ventilation although clear data for patients undergoing LVRS is missing (26). The extubation of patients with a double-lumen tube often leads to coughing, which may affect the outcome of the operation and lead to relevant pneumopleural fistula. For this reason, extubation of the patient in deep anaesthesia and relaxation, intubation with laryngeal mask (LM) second generation, transfer to spontaneous respiration and removal of the LM from the awake and spontaneously breathing patients should be recommended.

Perioperative fluid management

The amount and quality of perioperative fluids applicated treads the tight line between hypovolemic complications, especially acute kidney injury and fluid overload of the lungs (27). The situation increases by the scarce pulmonary functional reserves of the LVR patients. Strong evidence exists for a normovolemic fluid regimen in thoracic surgery (*Table 2*). Balanced crystalloids are recommended, saline solutions should be avoided and colloids should only be used as a substitute for blood loss (23,25).

The integration of volume management into a "Patient Blood Management" tool shows many advantages

Table 2 Perioperative fluid management

Pre-interventional	Intraoperative	Post-operative
❖ Goal:	❖ Goal directed therapy (GDT)	❖ No intravenous (IV)-fluid
◆ Normovolemia	❖ No sodium or fluid overload	❖ Fluid?
◆ Normal weight	❖ Substitution maintenance:	◆ Maintenance?
◆ Avoid hypothermia	◆ 2 mL/kg/h	◆ Substitution?
❖ Period of rest:	◆ Balanced infusion	◆ Resuscitation?
◆ 2-h fluid	❖ Normothermia	
◆ 6-h solid	❖ Avoid hypovolemia, hypoperfusion and fluid overload	
❖ Prophylaxis of thrombosis	❖ Hb >7 g/dL	
❖ Incentive spirometry	❖ Careful use of vasopressors	
❖ Coaching		

in the outcome of anaemic patients. It should start preoperatively with the substitution of ferritin, vitamin B12 or erythropoietin in patients with low haemoglobin levels <120 g/L in women and <130 g/L in men to avoid the intraoperative use of blood products (28). A blood coagulation management with bedside measurements should take place intraoperative and the administration of any blood products should be avoided (28).

Anaesthesia management for bronchoscopy, Chartis measurement and BLVR

The procedure of this combined intervention usually requires general anaesthesia with a possible mélange of different techniques in airway management and ventilation. Rigid bronchoscopy, endotracheal intubation, supraglottic airway (SGA) device, and jet ventilation catheters have been used for BLVR. In contrast to standard bronchoscopy, in which the bronchoscope remains in the airway during retrieval of the biopsy specimen, Chartis measurement and valve implementation requires multiple *en bloc* retrievals of the bronchoscope, the catheter and/or the device. This requires multiple re-navigations through the nose or mouth, may cause epistaxis, and recommends the use of airway protection.

The Chartis measurement, which is an endobronchial pulmonary assessment system, is the preferred and recommended method to measure collateral ventilation in spontaneous breathing or controlled mechanical ventilation with long expiration time and low frequency (29).

Since SGA allows spontaneous breathing or controlled mechanical ventilation and SGA-related complications like mucosal trauma, hematoma, and arytenoid dislocation are rare compared to endotracheal intubation or rigid bronchoscopy (where additional equipment like jet ventilators are needed), SGA devices have numerous well-known advantages (30). The use of the i-gel SGA (Intersurgical Inc., Wokingham, UK) shows fewer complications (i.e., blood staining, sore throat, and dysphagia) compared to other SGA and commonly is used for therapeutic fiberoptic bronchoscopy (31-33). The airway channel cross-section of a size-5 i-gel SGA is elliptical and shows a major axis of 13.4 mm and a minor axis of 12.9 mm (33). This results in a cross-section area of 137 mm^2 compared to 57 mm^2 in a 8.5-I.D. orotracheal tube. The design of the i-gel®, a second-generation SGA with a wide airway channel, facilitates easy passage of the fiberoptic bronchoscope, providing a precise glottic view, easy Chartis measurement, and valve application (34).

To improve bronchoscopist's conditions, general anaesthesia (using remifentanil, propofol and mivacurium) with an i-gel SGA device should be used for BLVR. Jet ventilation through rigid bronchoscopy or with a jet catheter alone may be an alternative concept (respiratory frequency 15–100 breaths/min, inspiratory pressure 150–250 kPa) (35).

Postanaesthesia management

Postinterventional monitoring should detect adverse events like cardiovascular complications (i.e., arrhythmia), pulmonary events (i.e., exacerbation, infection, respiratory failure, and pneumothorax) or valve-related events (i.e., expectoration, migration, aspiration). A 24-h hospitalization on an intermediate care unit may be suggested.

Conclusions

Anaesthesia plays a key role in the perioperative treatment of patients undergoing LVR. Due to lack of evidence common strategies of anaesthesia in thoracic surgery combined with new procedures can successfully be applied. Deep general anaesthesia and one-lung ventilation through a double-lumen tube are the gold standard in the LVRS, SGA device in the BLVR. New methods like NIVATS are gaining more importance but needs evidence (36).

In the perioperative treatment, the anaesthesiologist can contribute to the result through accurate patient preparation and effective multimodal pain therapy.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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