Editorial

What is the best strategy for one-lung ventilation during thoracic surgery?

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Today, one-lung ventilation (OLV) is a highly established and accepted technique to facilitate thoracic surgical procedures, for example a lung lobectomy. In the perioperative period, lung function may critically worsen and impair patient's outcome. On the one hand, the mechanical trauma of the operated lung poses a challenge for the postoperative recovery; on the other hand, a ventilator-induced lung injury can have deleterious consequences (1,2). Atelectases, inflammation, edematous change of the lung and partial over-inflation present a risk for postoperative hypoxemia and hypercapnia. Careful and evidence-based perioperative ventilation strategies are the starting point for a successful, low-complication perioperative pulmonary outcome.

In its "*clinical practice guidelines for mechanical ventilation management for patients undergoing lobectomy*", the "Society for Translational Medicine" places the current evidence for mechanical lung ventilation during surgical lobectomy in the broader context.

An ideal lung ventilation oriented on the present guideline is based on the target parameters arterial oxygen and carbon dioxide partial pressure (paO_2 and $paCO_2$), tidal volumes (Vt), airway pressure including positive end-expiratory pressure (PEEP), and inspiratory oxygen fraction (fiO_2). To minimize atelectases, patients can be treated with continuous positive airway pressure (CPAP) before anesthesia induction, latest with a PEEP during the preoxygenation (3). Successful recruitment of the lung after induction and after the start of the OLV should be mandatory. The ventilation has to be adjusted with small tidal volume of ≤6 mL/kg ideal body weight (IBW). The ventilation ratio is well set at 1:1, an APRV ventilation of 2:1 or higher could be advantageous, but it is essential to avoid over-inflation of the lungs. Ventilation should be set with a pressure-controlled mode (PCV), which is preferable to volume-controlled ventilation (whether conventional PVC or volume-guaranteed PCV-VG). The reduction of fiO_2 is crucial to prevent the damaging and toxic effects of oxygen including subsequent inflammation. Keep paO_2 as low as possible, but in a safe range. The use of adjuvants, for example nebulized budenoside or intravenous sivelestat, are appropriate in selected patients. Postoperatively, the recruitment of atelectases using CPAP may be continued, preferably for at least 6 hours. Definition of patient collectives, qualifying for novel therapeutic concepts, such as non-intubated video-assisted thoracoscopic surgery (NIVATS) have to be defined yet (4). Some of the measures in the guideline are also undisputed in other areas where mechanical ventilation takes place, others are new and innovative, and some have been subject to controversy.

Many areas of acute care medicine successfully apply permissive hypercapnia. In the concept of protective lung ventilation, a permissively increased CO_2 value is for example an accepted standard in critical care medicine and neonatology. Nevertheless, especially in thoracic surgery a cautious application of the concept may be advisable due to the risk of increased pulmonary arterial pressure (5). However, in order to achieve de desired reduction of peak airway pressures, a permissive hypercapnia is urgently required.

The question regarding the correct Vt has been raised by experts since the ground-breaking studies of critical care patients by Vincent *et al.* (6). Initially, a low Vt of 6–8 mL/kg IBW seemed advisable, contrary to the prevailing practice (Vt of 10–12 mL/kg IBW). This practice also found its way into ventilation of patients with healthy lungs during anesthesia. Nevertheless, low Vt ventilation was repeatedly challenged and questioned, but it remains current standard of care since ventilation with larger Vt has a potential to harm and has never been proven to improve patient's outcome (7,8). In addition, there is the meaningful but theoretical consideration to even lower Vt ≤6 mL/kg IBW during OLV because only part of the lungs is ventilated during OLV—2 of 5 lobes while ventilating left and 3 of 5 lobes while ventilating right.

The relatively higher fiO_2 during OLV together with low Vt can lead to the formation of resorption-atelectasis. Therefore, the second part of the concept described by Lachmann *et al.* (open the lung and keep it open) is elementary (9). Keeping the lung open with PEEP seems to be clearly superior to a zero PEEP (ZEEP) strategy. However, PEEP applied solely to the ventilated lung, can lead to an increased shunt fraction of the pulmonary arterial blood flow, especially before the onset of hypoxic vasoconstriction. A reduction of the PEEP in case of reduced oxygen partial pressure could be considered (10). In addition to keeping the lungs open, repetitive alveolar recruitment maneuvers are advisable—manually or mechanically by the ventilator (11).

In the context of atelectasis prevention in thoracic anesthesia, there is evidence for pre- and postoperative CPAP therapy. In many places, however, there are logistical barriers. Efforts like human resources and equipment to implement and keep such a concept running are quite high. In addition, trained personnel and a functioning pre- and a post-anesthesia care unit are mandatory. CPAP ventilation within the scope of regular preoxygenation and immediately after extubation is feasible in any case without further technical effort, but might not be this effective (12). Especially for high-risk patients (FEV1 <70%) and for patients requiring postoperative intensive care, continued CPAP ventilation is highly recommended.

The ventilation mode, volume-controlled versus pressure-controlled, appears to be disproportionately represented in the discussion about ideal ventilation. Meanwhile, all ventilation modes are equipped with a pressure limitation, the discussion about flow curves could not favour either of the two modes. Pressure-controlled ventilation has the advantage of a better right ventricular function, but here the side of ventilation is decisive. With left lung ventilation, this advantage is irrelevant (13). Although the evidence favouring the PCV is low, there are few reasons to prefer a volume-controlled mode. In the context of increasingly accurate and patient-adaptive ventilators, the ventilation mode can be treated dispassionately.

It is undisputed that a balanced breathing time ratio leads to a reduction of the inflation pressure and should therefore be favoured. However, there is an overwhelming prevalence of obstructive pulmonary disease in the lobectomy patient group. In severe obstruction, an over-inflation of the lung due to an insufficiently short chosen expirium should absolutely be avoided due to auto-PEEP.

Equally undisputed is an oxygen fraction with the lowest possible fiO_2. However, there is little evidence about the true target value. The arterial partial pressure of oxygen gives a good clinical idea, although values such as 14 kPa and 20% of the initial value are purely arbitrary. Following current guidelines for acute respiratory distress syndrome, maintaining PaO_2 ≥55 mmHg (7.5 kPa) or SpO_2 ≥88% seems reasonable and safe (14). There is still evidence needed to find a targeted value that will improve outcome. The principle "avoid too much of a good thing" of Martin *et al.* and MacIntyre seems to be especially true for the discussion on optimal fiO_2 (15,16). Adjuvants may lead to a reduction of inflammatory adverse effects, but more solid studies with larger case numbers are warranted. Not all currently used adjuvant drugs seem to be outcome relevant.

An interesting recommendation of the guideline refers to the use of NIVATS for lobectomy. The patient is in deep analgo-sedation (RAAS at least-2), breathing spontaneously, the procedure is performed with local anesthesia of the intercostal nerves or epidural catheter anesthesia. An intraoperative blockade of the vagus nerve seems to be mandatory. The procedure appears to be an alternative according to first controlled trials (4,17). It is clinically astonishingly well feasible, however, comparative studies of different methods of NIVATS analgo-sedation are lacking. Furthermore, careful patient selection will be the key to success. It remains to be waited out whether spontaneous breathing after insertion of an LMA or without airway protection is the better method. The management of complications in this procedure is above any standard, the intubation with a double lumen tube in lateral position or the placement of a bronchial blocker via LMA is reserved for centres with a high number of cases. In the future, NIVATS may become established at some high-volume centres, further studies are highly warranted (18,19).

Overall, the "clinical practice guidelines for mechanical ventilation management for patients undergoing lobectomy" represents the existing clinical practice with current evidence. In addition, new and noteworthy procedures, such as adjuvant drugs or NIVATS are described. The ventilation strategy during thoracic surgery for lobectomy is straightforward; there are clear evidence-based treatment algorithms. Understanding hemodynamic aspects and distribution of blood flow during OLV with subsequent ventilation-perfusion mismatch is another key point in thoracic anesthesia. Ventilation and blood flow are not only two sides of the same coin when it comes to OLV (20). It is desirable and expected that these two aspects will increasingly find their way into the guideline.

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Footnote

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

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