Nonintubated anesthesia in thoracic surgery: general issues

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Abstract: Anesthetic management for awake thoracic surgery (ATS) is more difficult than under general anesthesia (GA), being technically extremely challenging for the anesthesiologist. Therefore, thorough preparation and vigilance are paramount for successful patient management. In this review, important considerations of nonintubated anesthesia for thoracic surgery are discussed in view of careful patient selection, anesthetic preparation, potential perioperative difficulties and the management of its complications.

Keywords: Awake thoracic surgery (ATS); conversion; general anesthesia (GA)

Submitted Apr 06, 2015. Accepted for publication Apr 22, 2015.
doi: 10.3978/j.issn.2305-5839.2015.04.21
View this article at: http://dx.doi.org/10.3978/j.issn.2305-5839.2015.04.21

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Figure 1 Dr. Gabor Kiss.

Introduction

Regional anesthesia for thoracic surgery has been used extensively in the past. In 1950, Buckingham from Kansas City described his experience of 617 thoracic surgery procedures performed under thoracic epidural anesthesia (TEA). He reported no cases of depressed respiration or permanent nerve damage (1). Four years later, Vischnevski from Russia reported a series of more than 600 thoracic surgery procedures under local anesthetic techniques (2). In the last decade, more papers have stressed the advantages of awake thoracic surgery (ATS) compared to thoracic surgery under general anesthesia (GA).

Anesthetic management for ATS is more difficult than under GA, being technically extremely challenging for the anesthesiologist and requiring careful patient selection. The patient must be extensively informed before consenting. Thorough preparation and vigilance are paramount for successful patient management.

Figure 2 Dr. Maria Castillo.

Surgical indications and type of procedures done under ATS

(I) Surgery on the pleural space:
- (i) Drainage of pleural effusion (3);
- (ii) Pleurodesis under TEA, thoracic paravertebral and local anesthesia (LA) (4-6);
- (iii) Pleurostomy under TEA (7);
- (iv) Decortication under TEA or paravertebral block (4,5);
- (v) Treatment of pneumothorax under TEA, including pleurectomy (7,8);
- (vi) Empyema drainage under epidural or paravertebral block (9);
- (vii) Bleb resection (10).

(II) Biopsies:
- (i) Anterior mediastinal mass biopsy (11);
- (ii) Pleural/ lung biopsy under TEA (4-7).

(III) Surgery on the lung:
- (i) Pneumonectomy under TEA (12);
- (ii) Lobectomy via thoracotomy and thoracoscopy under TEA (5,12,13);
- (iii) Bilobectomy under TEA (12);
- (iv) Wedge resection under TEA or LA (5,12);
- (v) Thoracoscopic lobectomy and segmentectomy under TEA (14-16);
- (vi) Lung metastasis resection under TEA (4,17);
- (vii) Lung volume reduction surgery and bullectomy under TEA (4,5,7,18).

(IV) Surgery on the mediastinum:
- (i) Pericardial window (5);
- (ii) Tracheal resection with cervical epidural C7 to T1 (with local anesthetics to blunt the cough response) (19);
- (iii) Thymectomy under TEA (12).

(V) It is important that the surgeons, anesthesiologists and intensivists involved should discuss as a team the strategy for indications and management of ATS.

Pros and cons of ATS compared to thoracic surgery under GA

ATS offers many advantages to the patient. GA may increase the risk of impaired cardiac function with a decrease in myocardial blood flow and left ventricular function (20,21), as well as introduce the possibility of damage induced by mechanical ventilation, such as alveolar barotrauma, volutrauma, and atelectrauma, increasing the risk of pneumonia (22). Neuromuscular blockade during GA increases atelectasis in the dependent lung leading to a right-to-left shunt and increased risk of intraoperative hypoxia (22). GA places the patient at risk for residual neuromuscular blockade (23) and postoperative ventilator dependency (21) with the possibility of multiorgan failure, sepsis, and ICU-induced neuromyopathy or polyneuropathy (7,24). In addition, intubation-related airway trauma to teeth or vocal cords can also occur during intubation (25).

On the other hand, if TEA for ATS is chosen, potential complications are epidural hematoma, spinal cord injury, phrenic nerve palsy and inadvertent high anesthetic level. Predicted risk for neurological complications due to TEA is quoted at 0.07% (26). In contrast, for elective general surgery, the incidence rate of postoperative pulmonary complications was 33.9% and lung-related mortality rate 3.4% in patients with mild-to-moderate COPD (27). The later study only concerns general surgery, but given the fact that higher respiratory complication rates with GA are quoted (27), the risk benefit ratio to reduce pulmonary complications remains in favour of ATS under TEA.

Noda and coworkers in 2012 retrospectively compared the efficacy, morbidity, and mortality of video-assisted thoracoscopic surgery (VATS) awake (ATS) *vs.* GA in the treatment of secondary spontaneous pneumothorax and concluded that ATS patients had a significantly reduced incidence of postoperative respiratory complications, including pneumonia and ARDS. The author hypothesized that avoidance of intraoperative pulmonary barotrauma from mechanical ventilation and preserved deglutition function in ATS patients could be associated with lower prevalence of latent aspiration that could potentially cause pneumonia (28,29). ATS may also reduce stress hormone response (9), attenuate the impact on the immune system, and lower the impact on postoperative lymphocyte response (30) compared with the conventional anesthetic option (28,31-33). Because modern anaesthetic drugs are rapidly metabolized, it can be argued that ATS is unethical because stable dyspnoeic patients should be intubated and would be safer under GA. However, despite short half-lives and the reversibility of modern anesthetics, positive pressure ventilation can significantly increase respiratory complications and cause ventilation-induced lung injury (27,34) compared to spontaneous respiration. Therefore and paradoxically, to offer better chances for recovery, ATS should be the preferred choice in patients with a high risk for ventilator dependency. In case of perioperative panic attacks or cardiorespiratory instability conversion of ATS to GA always remains as the last resort.

Regional anaesthesia techniques may not only provide better haemodynamic stability but also superior postoperative analgesia, reduced thrombotic complications, decreased surgical stress response and fewer side effects, such as nausea and vomiting, when compared to general anaesthesia (6).

Compared with thoracoscopic surgery under GA, ATS also resulted in faster postoperative recovery and lower complication rates (35), and patients can display effective cough minutes after surgery (36).

Patients have no intubation-associated discomfort such as a sore throat and can return more quickly to daily activities, including drinking, eating and walking (7,22).

Several papers conclude that the ATS approach was superior to thoracoscopy under GA in terms of significantly shorter anesthesia and global in-operating room time, less need for nursing care and overall shorter hospital stays with comparable clinical outcomes (4,8,28,37).

There are also cost-cutting arguments in favour of ATS under TEA. For VATS lobectomy awake with TEA, blood loss and surgical duration was comparable with procedures under GA (13,15). In a study on lung volume reduction surgery, ATS under TEA not only resulted in better perioperative outcome and shorter hospital stay (12) but also lower costs since there is no weaning from the ventilator and anesthesia time is reduced (17,38). Given that ATS under TEA patients were spontaneously breathing and ventilator free, nursing labour could be invested for other tasks. Furthermore, in a paper by Klijian and coworkers, a lower mortality rate and less complication for awake VATS were reported (5). Consequently, the use of non-intubated VATS may allow a fast-track protocol avoiding the intensive care unit.

ATS also resulted in high patient satisfaction, especially in patients with severe chronic pulmonary disease who had already experienced long postoperative ICU stays and weaning problems in the past. High patient satisfaction was also due to a better sense of control by patients (7,19).

Patients selection for awake thoracic anesthesia

The literature states no absolute contraindications to GA, which always remains the last resort in case regional anesthesia techniques fail. However, as ATS techniques require more experience, preparation, and vigilance than GA for thoracic surgery, patients must be carefully selected for ATS.

At first, ATS was performed mostly for selected patients classified as ASA I-II and Mallampati grade I-II, with no obesity (body mass index <30), a tumour size of less than 6 cm, and with few comorbidities and good cardiopulmonary function (39). However, indications have been extended to very ill patients. Thoracoscopic surgery for pneumothorax under local and TEA in high-risk patients contraindicated for GA was first described in 1998 by Mukaida *et al.* (40) followed by other papers (7,41).

In one retrospective observational study, high risks patients successfully undergoing ATS had the following severe cardiac and respiratory comorbidities (7): advanced diffuse interstitial lung fibrosis on home oxygen treatment, restrictive chronic respiratory failure on continuous nasal NIV, severe chronic obstructive pulmonary disease with FEV_1 27% and a history of difficult weaning from the ventilator, inflammatory alveolitis, pneumomediastinum, recurrent unilateral or bilateral pneumothorax, pyothorax, multiple bilateral lung metastases, a background of bilateral lung metastasectomy, pleurectomy, undernourishment, atrial fibrillation, severe emphysema with high risk for volu/barotrauma, and two cases of advanced limb girdle myopathy contraindicating muscle relaxants and volatile anaesthetics.

GA can present an ethical dilemma if surgery is the only treatment option for high risk patients with advanced terminal chronic respiratory disease. Under GA, patients with severe respiratory disease carry high risks of ventilator dependency with increased morbidity and mortality (7). In these cases, if the total risk-benefit balance is in favour of surgery to reverse an acute pathology, and in the absence of any contraindications to regional anesthetic techniques, ATS could help avoid early death and could contribute to a reasonable quality of life with comfort and well-being after surgery, even among terminally-ill patients.

ATS can be an option for fragile high-risk patients with dyspnoea at rest to avoid ventilator dependency and to speed up recovery after surgical correction of a reversible pathology. In a retrospective observational study, eight hemodynamically stable patients with acute severe but stable dyspnoea, classified as a maximum grade four of the modified Medical Research Council dyspnoea scale, successfully underwent ATS to reverse the cause for acute dyspnoea (7).

Piccioni and coworkers described two oncology patients with severe dyspnoea (SpO_2 of 85% and 93%, respectively, on room air) undergoing VATS. One patient who had multiple organ and bilateral pulmonary metastases, a large left pleural effusion, and right pulmonary atelectasis underwent VATS on the left thorax. The other patient who was operated on the right thorax presented with right inferior lobe carcinoma, multiorgan metastases, and a large right pleural effusion. According to the authors, thoracic paravertebral block (TPB) provided excellent surgical conditions and postoperative pain control (6).

Whether there is an absolute limit of PaO_2 in arterial blood gas analysis for ATS is unclear. Piccioni and coworkers successfully performed ATS on a 61-year-old man with hypoxaemia, presenting with SaO_2 =93%, pH =7.46, PaO_2 =8.26 kPa (61.9 mmHg), and $PaCO_2$ =4.93 kPa (36.9 mmHg) on room air, and a predicted FEV_1 46% (6).

In another case by the same authors, arterial blood gas analysis on room air showed hypoxaemia and respiratory alkalosis: SaO_2 =88%; PaO_2 =6.39 kPa (47.9 mmHg), $PaCO_2$ =4.39 kPa (32.9 mmHg), and pH =7.51 (6). Pulmonary function tests of the patient revealed a forced vital capacity (FVC) 26% of the predicted value (6).

In order to remain within a margin of safety, it is paramount that patients with severe breathlessness (MMRS 4) have stable cardiovascular and respiratory parameters before ATS (7).

Phrenic nerve paralysis on the non-operated side should be viewed as a contraindication to ATS (7). Patients with suspected difficult intubation in general should not be considered for ATS (6), in case the need for intubation arises emergently during surgery. However, in one paper, a patient with severe breathlessness undergoing ATS had limited cervical mobility with no head extension. In the past, intubation was difficult but successful for cystoprostatectomy and ureterostomy (7). He had bilateral pulmonary metastases and was severely breathless before his planned ATS. Because his risk for ventilator dependency was high and the patient expressed fear of GA, and given that many terminally ill patients at that institution successfully underwent ATS under LA, the patient decided to avoid GA. Thoracoscopy for biopsy by keyhole surgery is a rapid procedure and can easily be done on an awake patient avoiding difficult weaning, ventilator dependency with postoperative complications, and a long hospital stay. In this case of a simple procedure where the benefit of ATS outweighs the risk of a difficult intubation, and considering the patient's wishes, ATS remained an option.

Difficulties in intubation can also be encountered in pregnant patients, yet many clinicians prefer the option of performing cesarean sections under epidural or spinal anesthesia. In a case described by Onodera *et al.*, a 31-year-old female patient in the 9th week of pregnancy underwent chest tube placement for spontaneous pneumothorax with thoracoscopy with local and epidural anaesthesia (33).

Not all patients are willing to tolerate being awake or having surgery with slight sedation. Patients with severe chronic respiratory disease and terminal illness might not want to undergo surgery or accept medical treatment at all. After thorough informed consent about anesthetic risks and options for thoracic surgery, patient refusal for GA also needs to be part of anesthetic decision making (7).

Nakanishi and coworkers raise the issue that surgical difficulties might contraindicate ATS or at least increase the risk of possible conversion to GA. For lobectomy and other major lung surgery, stripping of interlobular vessels and handling of incomplete fissures could be difficult despite inflation of the affected lung. Keeping in mind that bleeding from the pulmonary artery is extremely difficult to control in a limited working space, Nakanishi and coworkers advise that conversion to intubated GA should be performed without hesitation (35). In general, feasibility of ATS may not only depend on the comfort level of the anesthesiologist but also on the experience of the surgeon. This could be a reason for the relatively low number of patients recruited for ATS compared to thoracic surgery under GA, with reports from the literature varying from 8.6 patients per year (17) to 19.7 patients per year (38) at various institutions.

Spontaneous respiration and lung recruitment during ATS

During spontaneous respiration alveoli are opened by negative pleural pressure created by inspiratory muscle contraction (22). This is in contrast to GA with neuromuscular blockade of diaphragm and auxiliary inspiratory muscles, where alveoli are expanded by inflation of a tidal volume with positive pressure ventilation. In addition, during GA intra-abdominal organs push on the paralysed diaphragm, increasing atelectasis thereby reducing lung compliance, increasing pulmonary shunt and pulmonary vascular resistance, and leading to hypoxaemia with an increased possibility of lung injury (42) and delay in patient recovery (22). Therefore, maintaining diaphragmatic motion and creating a negative pleural pressure can decrease detrimental effects of abdominal pressure on the dependent lung.

The open pneumothorax created for the procedure results in a mediastinal shift and compression of the dependent lung and can make spontaneous breathing difficult. However, compensatory maintenance of diaphragmatic tone will tend to reduce the respiratory compromise (6). If necessary, treatment of atelectasis due to mediastinal shift includes application of non-invasive ventilation (NIV). NIV also reduces left ventricular after-load and thereby increases cardiac output.

Given the advantage of gas exchange by physiological expansion of alveoli by negative pleural pressure, even patients dependent on a home treatment with bilevel positive airway pressure (BiPAP) can successfully undergo ATS (7).

As long as patients are breathing spontaneously, they can receive light sedation with short-acting drugs such as propofol, remifentanil, or both with respect to their level of anxiety (7). Dexmedetomidine is another option for sedation.

During ATS, there is never complete lung collapse compared with conditions under GA. Given that patients are awake and breathing spontaneously, the classical lung re-expansion recruitment manoeuvre by manual balloon inflation cannot easily be applied because it is not well accepted by patients. However, at the end of surgery, lung re-expansion can be performed by progressive application of PEEP via NIV. In the absence of air leaks, NIV should also be continued in the recovery room in the immediate postoperative period to prevent atelectasis.

Application of NIV consequently reduces atelectasis, and post-operatively patients will show lower rates of nosocomial infections, decreased ICU and hospital lengths of stay, and decreased morbidity and mortality (43). Lung re-expansion should be monitored with physical examination of the lungs, chest X-rays, or lung ultrasound (44).

Concern is still warranted regarding ATS for patients with severe COPD and its impact on accessory muscles to maintain spontaneous ventilation, because respiratory muscle paralysis and changes in bronchial tone could be induced by regional anesthetic techniques. In a paper by Gruber and coworkers, thoracic epidurals were placed with 0.25% bupivacaine in patients with end-stage COPD undergoing lung volume reduction. The authors concluded that TEA with 0.25% bupivacaine did not adversely affect ventilatory mechanics, gas exchange and inspiratory muscle force (45).

Patient consent

The patient must be thoroughly informed about all possible outcomes of ATS, including the advantages and drawbacks of GA. The patient must be informed that in case of underlying severe chronic respiratory disease, general anaesthesia could lead to difficult or even impossible ventilator weaning.

The patient must understand that the decision to choose ATS is the first option but that conversion to general anaesthesia is always a possibility (6,7).

Premedication

Premedication can be handled in various ways, but it should not be done without the agreement and understanding of the patient, and only given when requested by the patient. Some patients refuse premedication because of underlying chronic respiratory disease and others request it to ease the stress and anxiety of the procedure. In one paper by Kiss and coworkers, three of nine patients did not want premedication (7).

Perioperative monitoring for ATS

Application of standard monitors includes electrocardiogram, pulse oximetry, non-invasive blood pressure measurement, measurement of respiratory rate, and capnography. End-tidal expiratory CO_2 ($EtCO_2$) can be measured with a detector attached to the oxygen mask or nasal cannula, or placed next to or inside one nostril. At least two IV lines should be secured, one for perioperative administration of fluids and another one for intraoperative medications.

It is important that the patient is able to talk throughout the surgery thereby allowing assessment of the patient's breathing, consciousness and comfort level.

Preparation for conversion to GA and emergency intubation

Given the possible pitfalls, caution must be taken with regard to performing ATS without sufficient experience. The critical issue to consider is how to convert ATS to GA if the thorax is still open.

In case of an emergency, quick conversion to GA has to be performed by an experienced and well-prepared team. Planning and coordination between surgeons, anesthesiologists and nursing staff are the keys to success.

Preoperatively, before positioning the patient on the operating table, an additional bed sheet must be positioned under the back of the patient to allow rapid change of positioning during emergency.

Operating room nurses should be reminded before the procedure to keep on stand-by a large surgical drape (example: IOBAN 56 cm × 45 cm incise drape, or a similar product like OPSITE). These drapes are transparent and can be used to cover the incised thorax rapidly in order to keep the wound sterile. Concerning VATS procedures, in a discussion with Professor E. Pompeo from Rome (Italy) one thick silk stitch can close a small VATS incision within a few seconds.

After rapid emergency wound covering with transparent drape by the surgeon, the anesthesiologist keeps the patient's head and neck stable while directing the team to turn the patient back to supine by pulling on the additional bed sheet which is positioned under the back of the patient. This maneuver allows a quick change from the lateral to the supine position while keeping the wound sterile, so that the anesthesiologist can intubate the patient's trachea.

The key to avoiding severe hypoxia is to foresee the problem in advance. The operating room team should practice disciplined coordination when turning the patient supine in order to facilitate immediate intubation and not waste time on surgical manoeuvres.

Quick induction of anesthesia should be performed using a fast acting neuromuscular relaxant such as succinylcholine or rocuronium which can be reversed with sugammadex. The later antagonist is not yet available in the US but is in use in many other countries.

Gonzalez-Rivas *et al.* recommend that in case intubation is necessary, the plan would be to insert a single-lumen endotracheal tube under the guidance of a bronchoscope, followed by insertion of a bronchial blocker without changing the patient's position. Gonzalez-Rivas and coworkers write, depending on the oxygenation status of the patient, that an expert and skilled anaesthesiologist could also achieve a double-lumen intubation in the lateral decubitus position (36). Macchiarini and coworkers even suggest nasotracheal tube intubation but this is debatable because nose bleeding may render further airway management difficult (19).

ATS can be performed in the lateral decubitus position; however, some centers alter the standard thoracotomy technique by performing procedures in a modified supine position. In case emergent intubation would be required, this position would more easily facilitate control of the airway (5).

Surgical and anesthetic reasons for conversion, and ways to avoid it

The risk for conversion depends on the patient's comorbidities as well as the difficulty of the surgery.

Patients must be intubated early when complications begin to emerge in order to reduce the risk of emergency intubation (36).

Reasons for conversions to GA can be due to the anesthesia or to the surgery. Anesthetic causes can include persistent hypoxemia, tachypnoea, poor pain control, and panic attacks (46).

The following lists of surgical difficulties might also trigger the decision to convert to GA: unsatisfactory lung collapse, extensive fibrous pleural adhesions, diffuse pleural adhesions, and bleeding (15,21,46). In an editorial, Nakanishi and coworkers stress that, especially in major lung surgeries, including lobectomy, it can be difficult to strip interlobal vessels and treat incomplete fissures despite lung inflation. The authors warned that bleeding from the pulmonary artery can be extremely difficult to control in a limited working space during ATS. Therefore, a prompt conversion to intubated GA should be performed without hesitation if such bleeding develops (35).

Swift conversion to intubated GA is also recommended in case of significant mediastinal movement and complex hilar dissection, as in cases of silicotic or tuberculous patients (36).

In the literature, conversion rates of an entire patient population undergoing ATS varied in general from 0% (7,47), up to 10% in a paper by Chen and coworkers, who also reported conversion for the subgroup of lobectomies as 13% (15,46).

In the light of elevated conversion rates for lobectomies, Nakanishi and coworkers conclude in an editorial that the safety of major surgery such as lobectomy performed under ATS still remains unclear (35).

Anesthetic complications during ATS

Complications can be classified as problems due to the regional and local anesthetic technique itself as well as respiratory, hemodynamic and neurological events.

During ATS with open pneumothorax, ventilation of the collapsed lung is impaired leading to some measure of hypoxemia, hypercapnia and acidosis, which can cause anxiety and panic attacks.

Except for patients with severe terminal chronic obstructive pulmonary disease tolerating only a low oxygen flow of up to 2 L/min, desaturation can be delayed or even prevented by application of a high-flow oxygen mask (O_2 15 L/min) (7). If O_2 Sat drops below 90%, NIV should immediately be applied to the spontaneously breathing patient to recruit the lungs. In addition, assisted mask ventilation can also correct hypercapnia (7). Patients at risk for perioperative hypercapnic coma may have a history of severe COPD with low FEV_1. Hypercapnic coma can also cause laryngeal oedema which can be treated with supplemental oxygen by facemask (19).

Sore throat leading to panic attack during surgery was once reported by Kiss *et al.* in 2014 in a patient who started to feel the surgeon manipulating inside the thorax. It turned out that xylocaine 1% instead of 2% was given in the TEA. To obtain a dense epidural block, not less than 2% of xylocaine must be administered through the thoracic epidural catheter (7).

Panic attacks can be reduced by reassurance and explanations in a calm surgical environment (5). In the case of VATS, the patient can be allowed to watch the operating video (48). If these steps are unsuccessful, moderate sedation can be given while maintaining spontaneous breathing (7,48).

Mean arterial blood pressure and systolic blood pressure should be kept above 65 and 90 mmHg, respectively. This can be achieved with fluids or vasopressors to compensate for the blood pressure decreases due to the vasodilatory effect of the local anaesthetic administered via epidural. In an observational study no patient required more vasopressors than usually given for the same type of surgery under GA combined with a thoracic epidural (7).

Arterial oxygenation during ATS

Sedation carries the risk of desaturation and atelectasis due to decreased muscle tone of the diaphragm and the intercostal and auxiliary inspiratory muscles. Use of noninvasive BiPAP ventilation via a facemask can help this situation (41). Given that efficient lung reexpansion is difficult or impossible during ATS; postoperative NIV should be performed in the absence of surgical contraindications to decrease postoperative atelectasis.

In one paper, no intraoperative deterioration in arterial oxygenation was observed under ATS with TEA (9). In 2011, Pompeo and coworkers described that perioperative $PaO_2/FiAO_2$ decreased significantly during ATS but remained satisfactory (>300 mmHg), with the intraoperative $PaCO_2$ increase returning to the baseline value 1 h postoperatively (P=0.20). They reported no increase in mortality (18).

Transient permissive hypercapnia during ATS

Transient perioperative permissive hypercapnia (<55 mmHg) has been described in several papers (7,9,18, 22) with no need of conversion to GA.

Dong and coworkers in 2010 studied 22 patients for VATS resection of pulmonary nodules using thoracic epidural and sedation and also local anesthetic block of the vagus nerve block placed intrathoracically to blunt the cough response. PCO_2 increased gradually after incision but returned to normal one hour after wound closure. They reported no hypoxemia (39).

Patients with a background of severe COPD or neuromuscular disease have higher risks for developing perioperative hypercapnia which in most cases can be successfully reversed with assisted ventilation (7). During longer lasting procedures, it is recommended to periodically re-expand the lungs with intermittent NIV in order to limit the risk of hypercapnia.

Coughing during ATS

During ATS, lung manipulation can trigger a cough reflex, which some surgeons want suppressed to improve surgical conditions.

Cough reflex can be minimized by the inhalation of aerosolized lidocaine (41) or application of a spray of lidocaine on the lung surface (16). Other alternatives include a stellate ganglion block (12) or a vagus nerve block placed intrathoracically (15,39). Administration of remifentanil can also help blunt the cough reflex. In order to prevent increased bronchial tone and airway hyper-reactivity, Gonzalez-Rivas and colleagues (36) advise avoidance of epidural anaesthesia-associated sympathetic blockade.

However, with the surgical advantage of suppressing the cough response comes the risk of aspiration and resultant respiratory tract infection. In one paper, surgeons described operating conditions of ATS as good as surgery with GA despite occasional short bouts of coughing (7).

Operative time

In a case series of nine patients, the average duration of ATS surgery under TEA was 76.3 min (SD 23.6 min, range: 46-128 min) (7) proving that epidural ATS can be sustained for surgery lasting for more than 2 hours in patients with severe but stable dyspnoea. In other papers, operating time is quoted as an average of 25.5 min (range: 23-33 min) to 50 min (range: 40-70 min) (9,17).

Postoperative complications of ATS

Patients who underwent ATS with thoracic epidural had faster recoveries and shorter hospital stays (4).

In a study by Liu and colleagues, the ATS group showed shorter hospital stays after bullae resection and lobectomy compared to the GA control group. Liu and colleagues also demonstrated that the rates of postoperative complications, including respiratory complications, were significantly lower in the ATS group than in the control group. In addition, there were no mortalities in either group (46).

Mortality and morbidity of ATS

Several papers conclude that mortality and morbidity up to 6 months for ATS were comparable with thoracic surgery under GA (38) or even lower with fewer postoperative respiratory complications, including pneumonia and acute respiratory distress syndrome (5,12,28).

Surgical results

Several studies conclude that compared to GA, there was no difference in the technical feasibility of ATS for thoracoscopic lobectomies (15), pleural biopsies, decortications (5,9) and wedge resections of lung nodules (4).

Acknowledgements

Disclosure: The authors declare no conflict of interest.

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Cite this article as: Kiss G, Castillo M. Nonintubated anesthesia in thoracic surgery: general issues. Ann Transl Med 2015;3(8):110. doi: 10.3978/j.issn.2305-5839.2015.04.21