Non-intubated anesthetic techniques for thoracic surgery

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Abstract: Non-intubated thoracic surgery is not a new concept, though its use was discontinued with the invention of the double lumen endotracheal tube, and the traditional technique of general anesthesia, muscle relaxation and one-lung positive pressure ventilation became standard. Recent developments in surgical techniques encompassing multi and uniportal video-assisted thoracic surgery in a drive to reduce the operative invasiveness, however, have now allowed us to re-examine our anesthetic technique. This along with advances in anesthetic and monitoring techniques make non-intubated thoracic surgery safer to use by experienced anesthetists. The concept is to maintain spontaneous ventilation and create a surgical pneumothorax providing the operator with a reliable surgical field and reducing the risks associated with intubation and positive pressure ventilation. The technique is gaining popularity and a number of small randomized trials and meta-analyses provide data to suggest that non-intubated surgery is safe and can offer several potential advantages as an alternative to intubation and one-lung positive pressure ventilation. Anesthetic and analgesic techniques vary widely in the published data encompassing a spectrum of consciousness from awake to general anesthesia and utilizing a number of different loco-regional anesthetic techniques and adjuncts. We describe these techniques and expose the common complications and pitfalls in detail in this article. Although experience is still relatively limited, non-intubated techniques are now being used in increasingly complicated patients and surgeries and larger, well-designed studies are now required to establish the preferred techniques, selected patient benefits and the impact on long term outcomes.

Keywords: Anaesthetic; awake; nonintubated; video assisted thoracic surgery (VATS)

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Introduction

Historically, prior to the development of double lumen tubes in the 1950s and routine use of positive pressure ventilation, inhalational anesthetics and muscle relaxants, thoracic procedures were performed awake under local or regional anesthesia (1,2). This, however, carried a high mortality and morbidity rate (3). With the introduction of positive pressure ventilation, it became a standard approach to isolate the operative lung using a double lumen endotracheal tube or single lumen endotracheal tube and endobronchial blocker combined with a general anesthetic (GA) (4). This provided a protected airway, lung isolation and optimal surgical conditions.

With the recent advances in surgical techniques and the development of multi and uniportal procedures, our anesthetic techniques have also been re-evaluated (5-7). The non-intubated concept is to maintain spontaneous ventilation, with a negative intrapleural pressure to create a spontaneous iatrogenic pneumothorax once the pleura is breached by the surgeon. This can provide excellent lung isolation, without the need for positive pressure ventilation of the dependent lung (8).

The term non-intubated video assisted thoracic surgery

(NIVATS) has several connotations, frequently associated with the avoidance of a GA and the patient awake or under minimal sedation using the addition of regional anesthetic techniques or local anesthetic infiltration. A survey from the European Society of Thoracic Surgeons (ESTS) in 2015 reported that 62 out of 96 included responders had experience with non-intubated anesthetic techniques, many prior to 2010, suggesting it was already being widely adopted to perform simple thoracoscopic procedures (9).

Two recent meta-analyses by Deng *et al.* and Tacconi *et al.* in 2016 suggested that NIVATS procedures can reduce operative morbidity and hospital stay when compared to equivalent procedures performed under GA with intubation and one-lung positive pressure ventilation (10,11). The NIVATS procedures in these articles utilize sedation or regional anesthesia to perform these procedures with the avoidance of GA. Tacconi *et al.* included a total of 1,441 patients with the overall conversion rate to GA recorded as 2.4% (10).

Although we are lacking long-term follow up for NIVATS, and robust, large multi-centre trials, this is an exciting new area of increased interest and research potential (10-12).

Potential advantages

An NIVATS technique aims to reduce complications such as intubation related injuries (13,14), ventilation associated lung injury (15) and residual neuromuscular blockade (16). Awake and sedation techniques also have the benefit of avoiding a GA, reducing risks such as nausea and vomiting (17) and pharmacology related changes in cardiorespiratory and cerebral physiology.

A small number of randomized controlled trials (18-22) and two recent meta-analyses (10,11) have shown that a NIVATS can be associated with some advantages over an intubated technique and may be a beneficial alternative. In particular, these meta-analyses show a reduction in operating room time, a reduction in hospital length of stay and a decrease in perioperative complications (10,11). In the largest RCT to date by Liu *et al.* in 2015 including 354 patients, post-operative morbidity was lower in the non-intubated group at 6.7% *vs.* 16.7% in the intubated group (P=0.004). In particular, respiratory complications were reduced from 10% to 4.2% (P=0.039) (22).

Other benefits have been shown including shortened recovery (19) and faster return to oral intake (22), attenuation of stress hormones and immunologic responses (22-24) and better pain scores (25). Moreover, studies have also reported improved patient satisfaction with a NIVATS approach (18,19).

This data not only supports important clinical advantages to the patient but also improved theatre and hospital efficiency with associated cost reductions (10,19-21).

Anesthetic and sedation techniques

The successful conduct of minimally invasive thoracic surgery demands optimal surgical visualisation. Traditionally, the approach to achieving one-lung isolation involved placement of a double lumen endotracheal tube (DLT) or bronchial blocker. Most clinicians prefer to use a DLT, but there are a proportion of patients with complex airway anatomy and other conditions in which bronchial blockers through a single lumen tube may be a better technique (26). Video laryngoscopy and fiber-optic technology has improved the placement of DLTs in difficult anatomical cases, but still do not escape the risk of airway trauma from intubation (27-30).

Non-intubated techniques vary throughout the literature with the majority of the current reports looking at small case series and single institution studies. It is important to understand that there are a range of techniques used from awake procedures to those under sedation and GA. We will consider each of these techniques in more detail below.

General anaesthesia

The bulk of experience in our centre is of non-intubated spontaneously breathing patients under a GA with a supraglottic airway device (8,25). This technique avoids complications of awake and sedation based procedures by alleviating issues with patient anxiety and distress, and reducing coughing and movement during the procedure. GA can be maintained using volatile anesthesia or total intravenous target controlled anesthesia usually with propofol and remifentanil. This can be augmented with local and regional anesthetic techniques including intercostal nerve blocks (ICNB), serratus anterior plane blocks (SAB) or paravertebral blocks (PVB), which can be placed once the patient is asleep in the lateral position.

A recent case control study has shown that this technique is safe and feasible with reduced anesthetic times and improved post-operative pain relief with no increase in morbidity compared with an intubated GA (25). This technique also allows for improved preoxygenation via the supraglottic airway device and a likely smoother conversion should intubation be required without the requirement for induction of GA (8).

Awake procedures

The majority of initial reports of NIVATS describe the use of an awake technique. In fact, all of Pompeo's RCTs to date are single centre studies comparing awake patients with an epidural to GA and intubation with or without epidural (18-21). Patients received a premedication of midazolam prior to arriving in the theatre and thoracic epidurals as the mainstay of their anesthetic technique. These studies indicate that awake NIVATS is safe, feasible and may be of benefit to the patient as an alternative to an intubated GA procedure (18-21).

Sedation

The majority of the literature relating to NIVATS, however, is with single centre case series and studies describing the use of sedation techniques (22,31-41). This includes the largest RCT to date by Liu (22). Sedation may allow the patient to better tolerate the thoracic procedure and allows the use of less invasive regional techniques (2,31,35,36,41).

These studies most often institute the use of a target-controlled infusion of short acting drugs such as propofol with or without the addition of remifentanil. These drugs are easily titratable by experienced anesthetists to achieve optimal sedation and anxiolysis without losing consciousness but care must be taken to avoid loss of spontaneous ventilation and airway reflexes (8). Other agents described in the literature include midazolam, diazepam and dexmedetomidine which can be used for milder sedation and are less titratable.

Studies show that a sedation technique is safe and feasible in NIVATS (22,32-39,41), however, "sedation" comes with its own challenges and complications. It encompasses a spectrum of consciousness from 'conscious sedation' with the patient still able to maintain purposeful responses and airway control that can easily drift into deeper sedation and even general anesthesia. Principle causes of sedation related morbidity and mortality include drug induced airway obstruction, aspiration and respiratory depression with hypoventilation, apnoea and hypoxia (42). It is clear that the line can be blurred between descriptions of deep sedation and GA in the literature. This reinforces the importance of pre-operative selection, technical experience, patient fasting and advanced monitoring to reduce these risks.

Monitoring

Assessment and monitoring of sedation are essential to providing a safe procedure. Each country or region has its own organizational standards and guidelines. In the UK, we follow guidance from The Association of Anaesthetists of Great Britain and Ireland (AAGBI) (43). This report was last reviewed in 2015 and states minimum monitoring should be standard in all patients whether administering general anesthesia or regional anesthesia with or without sedation. This includes pulse oximetry, non-invasive blood pressure, electrocardiogram and end-tidal carbon dioxide monitoring by capnography (43). Capnography is essential in all NIVATS patients and should be used to determine adequacy of airway patency, maintenance of spontaneous ventilation and respiratory patterns (8).

The advancement in depth of anesthesia monitoring systems allows a safer titration of sedation and general anesthesia to determined monitored end points (8). These can be machine based including BIS™ and other forms of processed EEG or subjective scoring systems such as the Ramsey sedation scale. Their uses allow the experienced anesthetist to closely monitor the patient's consciousness and titrate sedation appropriately and are being used more commonly in NIVATS (33,36,38,44,45). It is important, however, to understand the relative target levels with a BIS™ of 100 relating to awake patients, 60–80 to sedation and 40–60 to GA (46). "Sedation" cases employing a BIS™ level of less than 60 are described in the literature without the use of formal airway adjuncts but it is arguably essential to ensure airway support and control via a supraglottic airway device or fitted facemask with adjuncts in these GA patients (8).

Regional analgesia and epidural use

Intraoperative pain control with local anesthesia and regional techniques is central to the success of NIVATS procedures.

Early reports and studies describe the use of thoracic epidurals in conjunction with sedation or GA (12,22,25,32, 38,45,47) but also as a stand-alone analgesia technique in awake patients (18-21). Thoracic epidurals provide arguably the best analgesia for the procedure and have long been considered the gold standard for post thoracotomy pain (48) but are associated with serious complications and unwanted side effects such nerve injury, paralysis, block failure, urinary retention and hypotension (49) which can lead to the need for further interventions such as central line access and urinary catheters, and delayed mobilization.

Many centres are now moving away from the routine use of epidural catheters for thoracic procedures, in particular VATS procedures (50) with studies showing a better side effect profile and no significant difference in post-operative pain with PVB analgesia compared to thoracic epidurals (51,52). With the advent of enhanced recovery programs for thoracic surgery, the use of alternative regional blockades such as PVB, ICNB, SAB or other local infiltrative techniques as a preferred mode of analgesia have become increasingly popular. These help advance patient pathways, reduce morbidity and length of stay (53).

In a drive to reduce the invasiveness of the NIVATS technique, some centres have adopted the use of these alternative regional techniques (31,36,39,44). In fact a recent retrospective review of 238 NIVATS lobectomies performed under thoracic epidural or ICNB by Hung *et al.* in 2015 showed that the patients undergoing NIVATS with ICNB had a reduction in theatre time, less hypotension and fluid administration, lower conversion to intubation, shorter chest drain time and shorter hospital length of stay compared with the epidural patients with no difference in other morbidity or mortality (45). Between 1998 and 2000, Migliore describes a technique using a four-step intercostal nerve block combined with sedation in 125 patients gaining good results in uniportal procedures (41) and the largest case series to date by Katlic *et al.* in 2010 also describes 384 undergoing NIVATS under sedation and local anesthesia without the use of epidural or nerve block (31).

Regardless of technique it is important to use a multimodal approach to analgesia (8). Opiate analgesia, in particular fentanyl or morphine, is often used in combination with a regional technique to supplement the block. These can be titrated in small boluses to the patient's physiological responses during surgery and can be used in a patient controlled analgesic pump post-operatively. Simple analgesics such as paracetamol should also be administered during the procedure and used regularly post op unless contraindicated. Non-steroidal pain relief can be very effective, but use must be balanced against renal impairment and those with gastrointestinal side effects.

Patient selection

When implementing a NIVATS program, it is essential to initially select low risk patients with normal body mass index (BMI), good airway assessment and no significant cardiorespiratory disease for minor VATS procedures. It is also important to have an experienced surgical and anesthetic team approach with individual tailored patient briefings. Patient understanding of the procedure is vital and if a thoracic epidural or other local anesthetic block is planned, consent must be gained and alternative options discussed. As with all new techniques, there is a learning curve for training and it is important to gain exposure in an operating unit in which these cases are performed regularly.

Early studies supported the use of NIVATS in fit, healthy patients undergoing minor diagnostic thoracic procedures (18,19). There is now, however, a growing experience in more major surgical procedures including pulmonary nodule resection, pleural and pericardial effusions, decortication for empyema, pneumothorax surgery, lung and pleural biopsy, thymectomy, lung volume reduction surgery (LVRS) and anatomical lung cancer resections including segmentectomy and lobectomy (10,11).

With this growing experience, higher risk patients are also undergoing NIVATS procedures and contraindications to NIVATS are becoming less defined, depending on procedural factors and clinician experience. There are now reports of NIVATS experience in elderly patients (32), patients with cardiorespiratory disease, interstitial lung disease (54,55), severe emphysema (20,56) and patients with muscular diseases (57,58). Management of complications in post pneumonectomy patients has also been described (59).

This is a technique which aims to potentially benefit the higher risk patients, by avoiding intubation, positive pressure ventilation and, in the case of an awake or sedation technique, a GA. In particular, this may be an advantage in those with pulmonary co-morbidities who are at risk of post-operative ventilator dependency, and this is an important area in which we should be directing our data collection and research studies in future.

Complications and pitfalls

As with an intubated anesthetic approach, the respiratory management of the NIVATS patient is crucial and there are intraoperative complications which the anesthetic and surgical team should monitor and prepare for including the development of hypoxia, hypercapnia, coughing and movement.

On entering the chest and development of an iatrogenic surgical pneumothorax, hypoxia can occur. Historically, there was a fear that spontaneously breathing patients would poorly tolerate this surgical pneumothorax, but it appears to be well endured and the resulting hypoxia is minimal (8,30).

It can usually be managed with supplemental oxygen either via nasal cannula or facemask in awake and sedated patients or by increasing the oxygen delivery through a supraglottic airway device.

In fact, in patient groups studied, concerns about oxygenation have been dispelled finding NIVATS procedures actually have equivalent or improved oxygenation intraoperatively when observing the PaO_2/FiO_2 ratio compared to intubated patients (18,19,21,32,56). It also appears that awake thoracic epidural anesthesia may be protective against the risk of hypoxic intrapulmonary shunt in surgical pneumothorax under spontaneously ventilating conditions (60), and the negative intrathoracic pressure may allow patients to better withstand some of the pathophysiological alterations while positioned laterally with a surgical pneumothorax (61).

A small rise in intraoperative carbon dioxide levels (19,25) has been reported intraoperatively during NIVATS. Hypoventilation exacerbated by the surgical pneumothorax and sedation or GA can result in this hypercapnia. In most cases this has no detrimental effect, a permissive approach is taken and it improves on recommencing two-lung ventilation (33). In fact, hypercarbia was only found to be responsible for conversion in one patient out of 1,441 analysed in a recent review (2).

It is important, however, to recognize the patients where hypercapnia may be contra-indicated including those with elevated pulmonary pressures, raised intracranial pressures and arrhythmias. In these situations, it may be more appropriate to use a DLT and positive pressure ventilation to allow tighter control of carbon dioxide levels.

Coughing and reduced access due to diaphragmatic and/or lung movement can be a concern to some surgeons. This and, more uncommonly, patient movement were identified as the main disadvantages to NIVATS in the ESTS survey (9). Several techniques to attempt to reduce these complications have been published and include local anaesthetic spray to the surface of the lung, vagal and phrenic nerve blocks and the use of a remifentanil infusion (8,22,30,33,34,36,47,62).

Conversion to general anaesthesia and intubation

In the meta-analysis including a total of 1,441 patients the mean rate of conversion was found to be 2.4%. This was highest in major procedures such as VATS lobectomy at 10% (10). Conversion and endotracheal intubation may be required for patient factors such as persistent hypoxia, tachypnoea, agitation (in awake patients) and poor pain control, however, surgical factors were found to be the most common reason for conversion including unexpected complexity, often due to adhesions and conversion to open thoracotomy (30).

Management may require rapid delivery of a GA in those who are awake or under sedation, or administration of a muscle relaxant in those with a supraglottic airway device in place prior to intubation. In either case it is preferable to preoxygenate the patient, if possible, by reinflating the collapsed lung under positive pressure via a fitted facemask or supraglottic airway. Usually, intubation can take place in the lateral position, ideally with a double lumen endotracheal tube to ensure lung isolation to continue surgery, but otherwise a single lumen tube should be placed to secure the airway before placement of a bronchial blocker to gain lung isolation if required (8,30). Video laryngoscopy or a fiberoptic scope can be used to assist intubation, however, in some circumstances the patient may require to be positioned supine to allow intubation (63).

Early elective conversion is always preferable and the indications and protocol for conversion should be discussed with the operating team prior to undertaking NIVATS (8).

Conclusions

With careful patient selection and appropriately experienced anesthetic and surgical teams NIVATS can be successfully performed with current data showing at least equivalent short term outcomes and the advantage of reduced operative morbidity and hospital stay compared with intubated thoracic surgery.

Although experience is still relatively limited, NIVATS techniques are now being used in increasingly complicated patients and surgeries. Currently there is a wide range of anesthetic techniques adopted by different centres for NIVATS and the evidence is limited to small single centre trials and case series.

Having now established the safety and feasibility of the technique, our aim should be to establish the advantages of the different techniques and which patients and surgeries benefit most with larger, well-designed multi-centre research studies.

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Footnote

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