State of the art and perspectives in non-intubated thoracic surgery

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Abstract: Non-intubated thoracic surgery (NITS) entails procedures performed through regional anesthesia methods in awake or mildly sedated, spontaneously ventilating patients. The rationale is the avoidance of side-effects of intubated general anesthesia and maintenance of more physiologic muscular, neurologic, and cardiopulmonary status in order to reduce the procedure-related traumas, fasten recovery and optimize outcomes. Preliminary reports including some randomized studies have suggested optimal feasibility of several surgical procedures including management of pleural effusion, of spontaneous pneumothorax, wedge resection of undetermined pulmonary nodules, lung volume reduction surgery (LVRS) for severe emphysema and anatomical lung resection for lung cancer treatment. So far more widely accepted indications for NITS include easy-to-perform procedures as well as surgical management of patients with significant risks for intubated general anesthesia. On the other hand, the adoption of NITS for major procedures such as anatomic lung resections and LVRS is still controversial. Further detailed investigation including further randomized trials is expected to help define indications, advantages and limitations of NITS, which might represent excellent ultra-minimally invasive strategies of treatment to be reliably offered in the near future to an increasing number of patients.

Keywords: Non-intubated thoracic surgery (NITS); awake video-assisted thoracoscopic surgery (VATS); lung cancer; lung volume reduction surgery (LVRS); thoracic epidural anesthesia (TEA); spontaneous ventilation

Submitted Sep 30, 2014. Accepted for publication Oct 09, 2014.

doi: 10.3978/j.issn.2305-5839.2014.10.01

View this article at: http://dx.doi.org/10.3978/j.issn.2305-5839.2014.10.01

Presentation text (*Figure 1*)

Non-intubated thoracic surgery (NITS) entails procedures performed through thoracic epidural or local anesthesia in fully awake or mildly sedated, spontaneously ventilating patients.

The rationale of NITS is the avoidance of side-effects of intubated general anesthesia with single-lung mechanical ventilation (2) and maintenance of a more physiologic muscular, neurologic, and cardiopulmonary status, in order to minimize the overall surgery- and anesthesia-related trauma, fasten recovery, optimize outcome and possibly reduce costs (3-8).

There are several theoretical advantages that have been hypothesized for NITS including an easier acceptance of surgery; a reduced need of high-dependency stay postoperatively; a better respiratory function in the early postoperative period; a reduced operative mortality; a reduced morbidity; a shorter hospital stay; lower procedure-related costs; an attenuated stress hormone response; an attenuated impairment of immune response; and possibly a better survival in oncological surgery.

The birth of modern thoracic surgery coincided with the development in 1959 of double-lumen endobronchial tubes permitting single-lung ventilation. In fact, general anesthesia with one-lung ventilation assures optimal conditions for safe and easy surgical manipulation of the lung and so far, this type of anesthesia is considered mandatory for most thoracic surgery procedures.

Despite several indisputable advantages, use of general anesthesia with single-lung ventilation can be associated with several potential adverse effects including an increased

Figure 1 State of the art and perspective in non-intubated thoracic surgery (1). Dr. Pompeo's live presention on "Non-intubated thoracic surgery" in the Minimally Invasive Thoracic Surgery Symposium held in Haerbin, China. Available online: http://www.asvide.com/articles/368

risk of pneumonia; an impaired cardiac performance; neuromuscular problems; a risk of major airways injury; a composite ventilator-induced injury with barotraumas, volutrauma, atelectrauma and biotrauma; and the development of atelectasis in both the dependent and the nondependent lung (2).

Following general anesthesia, early postoperative lung function is influenced by residual muscular relaxation, time of extubation, pain therapy, and vigilance. In particular, immediately after a surgical procedure, the ability to cough seems to be one of the most important factors affecting lung function and is depending in great part to the efficacy of diaphragmatic contraction and pain relief.

The main physiologic difference between NITS strategies and intubated general anesthesia, is that with the latter the diaphragm is pharmacologically paralized and ventilation is mechanically driven whereas with the formers, spontaneous ventilation and an efficient contraction of the diaphragm are maintained leading in lateral decubitus to optimal ventilation/perfusion matching in the dependent lung.

Thoracic epidural anesthesia (TEA) has been preferred by the majority of the teams performing NITS even though intercostal and paravertebral blocks by local anesthesia, and use of laryngeal mask with sedation, have been also reliably employed and have shown pros and cons.

Chen and coworkers (3), first reported on thoracoscopic lobectomy and segmentectomy carried out by an innovative NITS protocol which included the use of TEA/intercostals blocks, with target-control sedation and bispectral index monitoring. They also employed the block of the vagus nerve achieved by intrathoracic local injection of lidocaine, which permitted to abolish the coughing reflex for up to 2-3 hours.

In our program we have preferred to employ TEA in fully awake and cooperative patients to assure neurologic vigilance that we consider an ideal way of physiologic monitoring and which allows a constant verbal interaction with the surgical staff (5,6,8).

More recently for simpler procedures such as management of pleural effusion and biopsies, we now prefer intercostal blocks that are easier and faster to be performed and also assure satisfactory thoracic analgesia (9).

It has been suggested that following TEA limited sensory block from dermatom T1 to T5, vital capacity and forced expiratory volume in one second can decrease by 5-6%, an effect which can be explained by a direct motor blockade of intercostal muscles. It has also been hypothesized a potential detrimental effect of sympathicolysis, which could result in an unopposed vagal tone leading to increased bronchial tone and reactivity (2).

However, it is worth noting that in a study published by Gruber and coworkers (10) in 2001 the effect of TEA on maximal inspiratory pressure, pattern of breathing, ventilatory mechanics and gas exchange were not impaired by TEA in awake subjects with severe emphysema. Instead, TEA induced an increase in minute ventilation by means of increased tidal volume, an increase in peak inspiratory flow rate and a decrease in pulmonary resistance.

Overall these findings suggest that TEA has no significant detrimental effects on bronchial tone whereas it improves diaphragmatic contractility and breathing pattern, and provides better postoperative analgesia than patient-controlled intravenous administration of opioids.

It is reasonable to assume that one of the main effects that contribute to keep respiratory function satisfactory throughout NITS, is the maintained diaphragmatic motion, which decreases the detrimental effect of the abdominal pressure leading the paralyzed diaphragm to compress the dependent lung during general anesthesia (8).

Cardiovascular effects of epidural anesthesia include decreased determinants of myocardial oxygen demand, improved myocardial blood flow and left ventricular function, and reduced thrombotic-related complications. Furthermore, it has been shown that epidural anesthesia can reduce heart rate and occurrence of arrhythmias (2).

During NITS, the degree of lung collapse achieved by creation of the surgical pneumothorax is usually comparable to that achievable by intubated single-lung ventilation.

The surgically-induced pneumothorax, represents the

first physiologic change that allows NITS procedurers to be actually feasible. In fact, in most instances, the newly developed intrapleural, atmospheric pressure environment, leads to a drop of lung volume down to the functional residual capacity that assures an adequate space for easy surgical manoeuvring.

The effect of an open pneumothorax on oxygenation is mainly based on clinical evidence due to the paucity of experimental studies in this setting. Some human and animal investigations suggested that changes in ventilation/perfusion ratio are more relevant than the impairment in ventilation. However, it seems that the decrease in arterial oxygenation that occurs following the surgical pneumothorax, is usually of limited extent and can be easily corrected by simple oxygen administration through a Venturi mask.

A frequent finding during NITS is the development of a certain permissive hypercapnia. Both hypoxemia and hypercapnia may be due to a reduced tidal ventilation induced by a rebreathing effect that has been also called *pendular ventilation* and is generated by the development of pressure gradients amongst the lungs following creation of an iatrogenic pneumothorax. Nonetheless, the level of permissive hypercapnia is usually well tolerated even in patients with impaired respiratory function and in most of instances resolves immediately after surgery (8).

The use of TEA to perform NITS was first proposed by the American surgeon Buckingham who reported in 1950 on a series of 607 patients who underwent major thoracic surgery procedures by this method.

In the same period, Vischnevski in Russia developed a multi-step analgesia protocol, which consisted in the block of both phrenic and vagus nerves at the neck, followed by extensive intercostals and lung hilum blocks by novocaine. The rationale of phrenic nerve block was to avoid diaphragmatic motion during the operation, while the parasympathetic block was aimed at limiting the possibility of dangerous vagal reflexes, which could be triggered by surgical manipulation, iatrogenic pneumothorax, or both. Using this technique, Vischnevski performed more than 600 major thoracic surgery procedures, including major lung resections and even esophagectomies (11).

So far several preliminary reports have suggested optimal feasibility of several minor and major NITS procedures including, amongst minor procedures, management of pleural effusion with or without talc pleurodesis (7,9); management of spontaneous pneumothorax including bullectomy with partial pleurectomy (12); management of pleural empyema, bullectomy or bullaplasty for giant bullous emphysema; mediastinal biopsy in bulky undetermined masses; lung biopsy in interstitial lung disease (13); wedge resection of undetermined pulmonary nodules/isolated lung metastases (5,6).

Amongst major procedures, lung volume reduction surgery (LVRS) for severe emphysema (8); thymectomy (14); anatomical lung resection for lung cancer including segmentectomy (15), lobectomy (3,16) and pneumonectomy (4); and even tracheal resection.

Rates of conversion to intubated general anesthesia were reported to be between 2.3% and 10.0%, depending on the type of procedure and the experience matured by the surgical teams (3).

Nonetheless, since conversion to intubated general anesthesia can be rapidly required in emergency instances, a consolidated multidisciplinary team experience including dedicated thoracic surgeons and anesthesiologists must be pursued to optimize the outcomes of NITS.

Indications for NITS are far to be definitively delineated. Nonetheless, some of them are relatively uniformly accepted whereas others are still widely debated.

Amongst the more widely accepted I would include simple and easy-to-perform procedures and surgical management of patients with significant risks for intubated general anesthesia.

Conversely, debated indications include use of NITS for major procedures such as anatomic lung resections, LVRS and thymectomy.

The main contraindications for NITS include, hemodynamic instability; morbid obesity with body mass index >25-30; the presence of expected dense and extended pleural adhesions; non-compliant patients; non-experienced surgical teams and the presence of large and centrally located tumors greater than 6 cm in maximal size. Specific contraindications for use of TEA include thoracic spinal deformity or coagulopathy.

Although NITS entails procedures performed by open approaches or video-assisted thoracoscopic surgery (VATS), in most of instances NITS strategies are employed in association with VATS according to the rationale of a globally minimally-invasive surgical management.

In a survey amongst European Society of Thoracic Surgeons (ESTS) members, I have investigated the currents trends, rates of adoption as well as potential for future expansion of NITS. Out of 105 responders, 68 admitted to have already performed NITS procedures. The preferred types of anesthesia were intercostal blocks with or without

sedation, followed by TEA with sedation.

The most frequently performed procedures included VATS management of recurrent pleural effusion, pleural decortication for empyema thoracis and lung biopsy for interstitial lung disease. More complex procedures such as lobectomy, LVRS and thymectomy have been performed by a minority of responders.

Poor-risk patients due to co-morbidities and elderly patients were considered the ideal candidates for NITS by the majority of responders whereas a faster, recovery, reduced morbidity and shorter hospital stay with decreased costs were indicated as the main potential advantages.

The main technical disadvantages, which were reported included coughing and poor maneuverability due to diaphragmatic and lung movements.

Overall, 68% of responders indicated that NITS procedures will be likely to increase in the near future.

So far there have been few randomized studies dealing with NITS procedures.

In a first randomized study performed by our team (5), 60 patients with undetermined solitary pulmonary nodules underwent wedge resection through either NITS with TEA (30 patients, awake group) or general anesthesia with double-lumen intubation plus TEA (30 patients, control group). There was no difference in technical feasibility although two patients in each group required conversion due to unexpected lung cancer requiring lobectomy.

Comparative results amongst study groups showed that anesthesia satisfaction score, changes in arterial oxygenation, need of nursing care and median hospital stay were significantly better in the awake group. In particular, 47% of the patients in the awake group could be discharged within the second postoperative day whereas this was possible only in 17% of patients in the control group.

In 2007, in a small randomized trial we (12) have compared VATS bullectomy and pleural abrasion performed in patients with spontaneous pneumothorax by either sole TEA or general anesthesia with one-lung ventilation. Results of this study have suggested that awake VATS bullectomy with pleural abrasion was easily feasible and resulted in shorter hospital stay and reduced procedure-related costs than equivalent procedures carried out through general anestesia while providing equivalent recurrence rate.

As far as surgical management of patients with severe emphysema is concerned, it has been clearly shown by several randomized and nonrandomized studies that LVRS can offer superior benefits than optimized medical therapy including respiratory rehabilitation in patients with upper-lobe predominant emphysema and compromised exercise capacity. However, the findings of high morbidity rates and of not negligible operative mortality rates with LVRS have led to raise question about the cost-effectiveness of this clinically highly effective procedure.

In order to reduce the significant morbidity associated with resectional LVRS that can be mainly attributed to deep resection of lung tissue in fragile emphysematous lungs as well as to the use of intubated general anesthesia that also represents a significant risk factor in patients with emphysema, we have developed a novel nonresectional LVRS technique, which entails an introflexive plication of the most emphysematous lung regions and can be ideally performed in spontaneously ventilating awake subjects through TEA only. This original method respects the basic concepts of resectional LVRS including a reduction of about 30% of the overall lung volume, suturing performed along a single ideal line and use of stapling devices. Yet, it adds some potential advantages including peripheral suturing, a linear but interrupted suture line which is more flexible, avoidance of any pleural discontinuation, and a 4-fold inlay buttress created by the plicated bullous tissue itself, which are aimed at facilitating postoperative lung reexpansion and at reducing the occurrence of air leaks.

Following several encouraging non-controlled studies, in 2012, our team (8) published results of a randomized study entailing 63 patients receiving awake nonresectional LVRS under TEA or standard resectional LVRS with general anesthesia.

Results of this study have shown that the proportion of patients who could be discharged within 6 days was significantly greater in the awake group (21 *vs.* 10 patients, P=0.01). In addition, nonfatal adverse events including air leaks were significantly less in the awake group (7 *vs.* 16, P=0.01).

At 6 months, forced expiratory volume in one second improved significantly in both study groups as did forced vital capacity, residual volume, six-minute walking test and the physical functioning short-form-36 health-related quality of life domain, which remained significantly better than baseline values for up to 24 months. At 36 months, freedom from contralateral treatment and survival were also comparable between the study groups.

Patients with malignant pleural effusion are frequently associated with medical comorbidities and carry additional risks for intubated general anesthesia.

It is worth noting that chronic lung collapse due to the existing pleural effusion enables these patients to favorably

tolerate surgical pneumothorax during spontaneous ventilation leading them to represent optimal candidates for NITS management.

In a small controlled study (9), 40 patients with malignant pleural effusion were randomized to undergo VATS talc pleurodesis by NITS with TEA or general anesthesia and single-lung ventilation.

No patient in the NITS group required sedation or conversion to general anesthesia. Thirty-day mortality regarded one patient in the control goup who died due to cancer progression.

The proportion of early discharges and overall costs were significantly better in the NITS group than in the control group whereas oxygenation and postoperative pain at 24 h as well as rates of effusion recurrence and survival were comparable.

More recently, results of the largest unicenter randomized trial completed so far have been published by Liu and coworkers (17).

The trial enrolled 354 patients undergoing bullectomy, pulmonary wedge resections and lobectomy who were randomized either to NITS by VATS with TEA and sedation (174 patients) or to standard intubated VATS management (180 patients).

Seven patients in the NITS group were withdrawn due to by necessity changes in type of anesthesia. Reasons for conversion included pleural adhesions contraindicating the procedure, carbon dioxide retention and hypoxemia, unsatisfactory lung collapse, intraoperative bleeding and need to switch from wedge to lobectomy.

The reported outcomes have been highly satisfactory. In particular, independent by the type of surgical procedure, NITS resulted in shorter fasting time and shorter duration of postoperative antibiotics.

A shorter hospital stay occurred in the groups undergoing NITS bullectomy or lobectomy whereas a decreased volume of postoperative pleural drainage occurred in the NITS lobectomy group only.

Finally, in patients undergoing bullectomy, NITS was associated with a decreased difference between pre-to-postoperative concentration of tumor necrosis factor-α level in the bronchoalveolar lavage fluid.

I believe that there exist three main paths towards which the next future clinical research on NITS might be driven (18).

The first is a standardization of the indications for simple and fast procedures including management of recurrent pleural effusion and of spontaneous pneumothorax for which feasibility of NITS has been shown to be excellent.

The second path entails surgical procedures such as awake LVRS and lung biopsy for interstitial lung disease, which are performed in patients with impaired respiratory function and in whom general anesthesia and one-lung ventilation per se represents a not negligible risk factor.

The third path entails NITS procedures performed for treatment of lung cancer and including metastasectomy and anatomical lung resections. Indications for these procedures are still controversial. In fact it is likely that most of thoracic surgeons would still prefer general anesthesia with single-lung ventilation that assures deeper sedation and an immobile collapsed lung, to perform surgical procedures requiring fine vascular dissection.

Nonetheless, it is worth noting that reduced postoperative stress hormone response and a lesser impairment in lymphocytes activity (19) have been both reported by NITS in preliminary clinical studies performed at our institution. These features led us to hypothesize novel oncologic perspectives including reduced risks of early cancer spread and possibly, even better survival rates.

Critical general issues that merit a careful consideration when trying to foresee the future of NITS include the challenge of newly available nonsurgical alternatives, which promise to offer equivalent benefits with minor or no need of in-hospital stay; the worldwide ageing of populations that will increase the overall burden of health care due to an increasing need of specialistic surgical care to be provided to subjects in an advanced age and with frequently associated multiple comorbidities; and the finding that minimal invasiveness and cost-effectiveness are likely to become the main driving forces in thoracic surgery.

As a result, NITS, which is aimed at minimising both surgery- and anesthesia-related traumas might represent a strong answer to these future challenges by providing excellent ultra-minimally invasive strategies of treatment to be reliably offered to an increasing number of patients.

Acknowledgements

Disclosure: The author declares no conflict of interest.

References

1. Pompeo E. State of the art and perspective in non-intubated thoracic surgery. Asvide 2014;1:350. Available online: http://www.asvide.com/articles/368
2. Groeben H. Epidural anesthesia and pulmonary function. J Anesth. 2006;20:290-9.

3. Chen KC, Cheng YJ, Hung MH, et al. Nonintubated thoracoscopic surgery using regional anesthesia and vagal block and targeted sedation. J Thorac Dis 2014;6:31-6.
4. Al-Abdullatief M, Wahood A, Al-Shirawi N, et al. Awake anaesthesia for major thoracic surgical procedures: an observational study. Eur J Cardiothorac Surg 2007;32:346-50.
5. Pompeo E, Mineo D, Rogliani P, et al. Feasibility and results of awake thoracoscopic resection of solitary pulmonary nodules. Ann Thorac Surg 2004;78:1761-8.
6. Pompeo E, Mineo TC. Awake pulmonary metastasectomy. J Thorac Cardiovasc Surg 2007;133:960-6.
7. Katlic MR, Facktor MA. Video-assisted thoracic surgery utilizing local anesthesia and sedation: 384 consecutive cases. Ann Thorac Surg 2010;90:240-5.
8. Pompeo E, Rogliani P, Tacconi F, et al. Randomized comparison of awake nonresectional versus nonawake resectional lung volume reduction surgery. J Thorac Cardiovasc Surg 2012;143:47-54, 54.e1.
9. Pompeo E, Dauri M, Awake Thoracic Surgery Research Group. Is there any benefit in using awake anesthesia with thoracic epidural in thoracoscopic talc pleurodesis? J Thorac Cardiovasc Surg 2013;146:495-7.e1.
10. Gruber EM, Tschernko EM, Kritzinger M, et al. The effects of thoracic epidural analgesia with bupivacaine 0.25% on ventilatory mechanics in patients with severe chronic obstructive pulmonary disease. Anesth Analg 2001;92:1015-9.
11. Pompeo E, Mineo TC. Awake thoracic surgery: a historical perspective. In: Pompeo E. eds. Awake thoracic surgery (Ebook). Sharja: U.A.E., Bentham Science Publishers, 2012:3-8.
12. Pompeo E, Tacconi F, Mineo D, et al. The role of awake video-assisted thoracoscopic surgery in spontaneous pneumothorax. J Thorac Cardiovasc Surg 2007;133:786-90.
13. Pompeo E, Rogliani P, Cristino B, et al. Awake thoracoscopic biopsy of interstitial lung disease. Ann Thorac Surg 2013;95:445-52.
14. Matsumoto I, Oda M, Watanabe G. Awake endoscopic thymectomy via an infrasternal approach using sternal lifting. Thorac Cardiovasc Surg 2008;56:311-3.
15. Hung MH, Hsu HH, Chen KC, et al. Nonintubated thoracoscopic anatomical segmentectomy for lung tumors. Ann Thorac Surg 2013;96:1209-15.
16. Chen JS, Cheng YJ, Hung MH, et al. Nonintubated thoracoscopic lobectomy for lung cancer. Ann Surg 2011;254:1038-43.
17. Liu J, Cui F, Li S, et al. Nonintubated video-assisted thoracoscopic surgery under epidural anesthesia compared with conventional anesthetic option: a randomized control study. Surg Innov 2014. [Epub ahead of print].
18. Pompeo E. Nonintubated video-assisted thoracic surgery under epidural anesthesia—Encouraging early results encourage randomized trials. Chin J Cancer Res 2014;26:364-7.
19. Vanni G, Tacconi F, Sellitri F, et al. Impact of awake videothoracoscopic surgery on postoperative lymphocyte responses. Ann Thorac Surg 2010;90:973-8.

Cite this article as: Pompeo E. State of the art and perspectives in non-intubated thoracic surgery. Ann Transl Med 2014;2(11):106. doi: 10.3978/j.issn.2305-5839.2014.10.01

