Editorial

The anesthesiologist perspective

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Introduction

We are facing an era of great challenges and opportunities. Since new requests arise, new answers should be offered to our patients, especially to the more fragile ones.

Cooperation between anesthesiologists and thoracic surgeons plays a pivotal role in successfully managing difficult procedures in vulnerable patients. Non-Intubated Thoracic Surgery (NITS) is among the techniques found effective to handle this population, offering a number of surgical opportunities for patients who are too risky for general anesthesia (GA): one-lung ventilation under spontaneous breathing allows maintaining a better match of ventilation and perfusion; respiratory efficiency can be guaranteed by a preserved diaphragmatic function, intubation-related trauma and mechanical ventilation are avoided, and no residual neuromuscular blockage problems occur.

Nevertheless, the intraoperative management, as well as management in critical situations, is quite different during NITS compared to the standard procedures performed under GA.

We will briefly discuss some key topics, starting from the *Anesthesiologist's Perspective*, while keeping in mind that a multidisciplinary approach is essential for safe and effective management.

Preoperative phase

In the preoperative phase patient counseling and engagement are crucial. A proper selection for patients scheduled for NITS, e.g., avoiding the most anxious or the least cooperative patients, is essential. After a careful and multidisciplinary selection, patients must be informed and motivated by providing them a complete description of the procedure, which may be useful to be repeated more than once.

There are no anesthesiologic limits to the surgical procedures that can be performed with this approach. There is evidence of management of pleural effusion, bullectomy for spontaneous pneumothorax and giant bullous disease, resection of pulmonary nodules, lung metastases and lung cancer surgery, pleural decortication, lung volume reduction surgery, thymectomy, thoracotomy, pneumonectomy, and even tracheal surgery (*Table 1*).

Although there is no consensus regarding exclusion criteria (*Table 1*), expert opinions suggest comorbidities such as obesity and smoking as relative contraindications. A consensus of experts in 2019 outlined possible inclusion and exclusion criteria specifically to shed light on the execution of NITS procedures (8).

It is therefore clear that there is considerable confusion about the eligibility criteria of the patient candidate for NITS. However, it is shared that poor performance status (e.g., ASA, NYHA, MET), as well as the presence of impaired preoperative lung function or significant arterial blood gases alterations contraindicate both GA and NITS.

NITS—Physiological considerations

Performing thoracic surgery in non-mechanically ventilated patients requires extremely careful anesthetic management basically due to two physiological phenomena: Pendelluft and mediastinal shift (9). During the surgery, the non-operated hemithorax receives a flow of inspiratory gas not

Table 1 Summary of exclusion criteria applied in patients divided by type of surgery (1-8)

Surgical Procedure	Exclusion criteria	Type of study	Study
Thymectomy	• Age 18–65 years	Case series	3
	• ASA grade ≥ III		
	• Masaoka stage ≥3		
	• Bleeding disorders		
	• Sleep apnoea		
	• Potential pleural adhesions, overweight		
	• BMI)>28		
	• Deranged preoperative blood gases $PaCO_2$ or PaO_2		
	• Poor preoperative FEV1 and FVC		
	• Potential difficult airway for intubation		
	• Bleeding disorder	Case report	4
	• Sleep apnea		
	• Evidence of potential pleural adhesions		
Thoracotomy	• Hemodynamically unstable patients	Retrospective study	8
	• INR >1.5		
	• Sleep apnea		
	• Anticipated difficult airway		
	• BMI ≥30		
	• Persistent cough or high airway secretion		
	• Elevated risk of regurgitation		
	• Raised intracranial pressure		
	• Patient unable to cooperate		
	• Procedures requiring long isolation to protect contralateral lung		
	• Full anticoagulation before surgery		
Lobectomy	• BMI >30	Retrospective study	5
	• Bleeding diathesis		
	• Difficult airway		
	• Previous pulmonary resection or cardiac dysfunction		
	• ASA > III	Retrospective study	6
	• Bleeding disorders		
	• Sleep apnea		
	• Unfavorable airway or spinal anatomy		
Pneumonectomy	• Not specified	Case report	2
Tracheal surgery	• Low cardiac output due to aortic stenosis, hypertrophic cardiomyopathy, severe arrhythmia, mitral stenosis, or complete atrioventricular block	Case report	1

Table 1 (*continued*)

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Surgical Procedure	Exclusion criteria	Type of study	Study
	• ASA score >3 • BMI >25 kg/m^2 • Pulmonary insufficiency (FEV1<60% expected value) and/or poorly controlled asthma • severe pleural adhesions • heart failure, abnormal anatomical structures, or spinal cord and peripheral nerve diseases • Low blood volume, hemodynamic instability, or dysfunction of blood coagulation • Estimated operation time of up >3 hours • ASA ≥3 • BMI ≥25 • compromised cardiopulmonary function	Retrospective study	7

ASA, American Society of Anesthesiologists; BMI, Body mass index; FEV1, forced expiratory volume in 1 second, INR, international normalized ratio.

only from the trachea, but also from the operated lung, which collapses due to surgical pneumothorax. This implies that during inspiration the non-operated lung, called dependent lung (DL), expands and, conversely, the operated lung, known as non-dependent lung (NDL), collapses. The resulting movement is called the 'pendular' movement of the lung, which occurs in both the inspiratory and expiratory phases. Similar behavior has the mediastinum with consequent dislocation of the structures contained in it (10). Minimally invasive procedures such as Video-Assisted Thoracic Surgery (VATS) allow a minimization of these effects, thus making NITS a safer technique especially in high-risk patients (11).

It should also be considered that thoracic surgery is performed in lateral decubitus, this means that the DL receives most of the ventilation in the lower portions and the NDL in the upper ones. Lateral decubitus also distributes the perfusion of the lung parenchyma in a similar way by the direct gravity's effect. As a result, the DL gets about 10% more cardiac output (12).

Summarizing, the lateral decubitus promotes both ventilation and perfusion of the DL, with a with a ventilation/perfusion (V/Q) ratio similar to that found in standing position. Hence some simple practical considerations: first of all, the fact that oxygenation in these patients is usually quite manageable with modest increase in the inspired fraction of oxygen (FiO_2). Secondly, the crucial moment for the onset of dyspnea and discomfort is when the surgical pneumothorax is realized. As a result, in this particular phase, it may be useful to achieve a deeper sedation level in order to prevent subjective symptoms onset. In conclusion, lateral decubitus is the best position for the patient's respiratory performance during surgery, despite the fact that this may reserve technical difficulties in case of advanced airway management.

Intraoperative phase

There is currently no consensus on intraoperative management, probably because of the wide variability within different centers' strategies (13).

Benzodiazepines, propofol, ketamine, dexmedetomidine with or without opioids sedation could be used to have a cooperative and calm patient. The combined use of these drugs often allows the achievement of a better effect while reducing overdose risks.

Given that a stationary operating field is necessary in order to guarantee the success of the NITS procedures while reducing the risk of postoperative air leaks, it may be useful to manage the cough reflex with the use of lignocaine aerosol, with the administration of opioids or with vague nerve block. The use of local anesthetic spray of the pleura

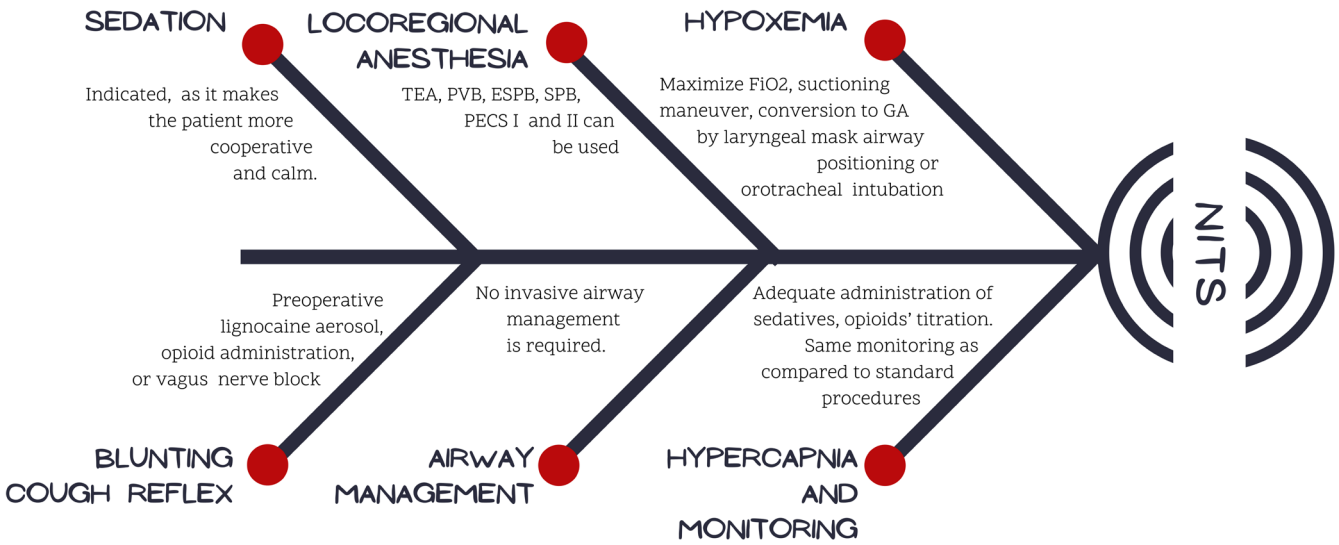

Figure 1 Essential steps to consider in the intra-operative management of the patient undergoing non-intubated thoracic surgery (NITS).

has also been described in the literature (14).

Although the efficacy of these techniques has not yet been confirmed in the context of NITS by randomized clinical trials, locoregional anesthesia techniques can be used to achieve an appropriate analgesic effect.

In a meta-analysis conducted by Deng *et al.* it has been reported that regional anesthesia techniques such as Thoracic Epidural Anesthesia (TEA), intercostal nerve blocks, and Paravertebral Blocks (PVB) can be effective, especially when combined with mild sedation (15). Recently, new techniques have been reported in the context of thoracic surgery such as Erector Spinae Plane Block (ESPB) and Serratus Plane Block (SPB) associated or not with Pectoral Nerves Blocks (PECS I or II) (16).

In addition to new anesthesia techniques, it is noteworthy that even new local anesthetics are beginning to be used in thoracic surgery. Liposomal bupivacaine, which use is still off-label for applications such as TEA and blocks including ESPB, PVB, and intercostal nerve blocks, seems to be effective even in the context of thoracic surgery (17). It is therefore desirable to use it, also in the context of NITS as soon as the indication is confirmed.

If the surgical procedures are not complex, NITS can be accomplished with invasive airway management. An optimal oxygenation level can be in fact easily achieved with simple oxygen masks even in compromised patients. In case of severe hypoxemia, it may be useful to inflate the NDL by a suctioning maneuver from the operative field and/or to reduce the depth of sedation. Only in more complex cases it may be necessary to convert NITS into GA by orotracheal intubation either in lateral decubitus or after supination (18). The possible use of a laryngeal mask, even in conjunction with deep sedation, is not configured as a conversion from NITS to GA.

However, everything should be prepared for a possible conversion of the intervention into GA (19). Regarding the management of difficult airways, a dedicated pathway should be developed possibly in a Crises Resource Management (CRM) context.

Particular attention must be paid to the elimination of carbon dioxide which can be a critical problem even if hypercapnia is normally controlled (*Figure 1*) with an adequate level of sedation and a precise titration of opioids.

NITS is most frequently converted into GA for the following reasons: major bleeding, severe pleural adhesions, severe hypercapnia and acidosis, hypotension, hypoxemia, intractable arrhythmias, right ventricle failure, persistent cough that hinders the performance of the surgery, excessive diaphragm movement, inability to collapse the lung (20). However, it should be noted that the conversion rate, as also reported by Chen *et al.*, is ranging around 4.9% (6).

Postoperative phase

According to the literature, postoperative complications, length of hospital stays, and consequently medical costs are

better with NITS compared to VATS under GA (21). In addition, it has been reported shorter duration of anesthesia, reduced surgical and total time in the operating room, as well as better satisfaction of patients, less need of nurse care, and lower overall intake of postoperative medications. Recent studies measured lower levels of inflammatory cytokines, or lymphocytic response, and reduced blood levels of stress hormones during NITS (22).

The postoperative phase in patients undergoing NITS is therefore faster and qualitatively better than in those receiving GA. This has been confirmed by a study conducted by Liu *et al.* (23) reporting that NITS/VATS biopsies in Interstitial Lung Disease have less postoperative morbidity, less Intensive Care Unit (ICU) admissions, and hospital stays three times lower (13).

Crisis resource management (CRM)

CRM include skills that fall within different clinical fields, including emergency medicine, and include non-technical skills necessary for effective team management in crisis situations. CRM's main elements are awareness of the surrounding environment and available resources, having a plan in advance and an early call for help, exercising leadership and followership, distributing tasks in a prepared manner, mobilizing all available resources, communicating effectively. It is also necessary to prevent any kind of error, always using double-check, re-evaluating the situation and properly evaluating priorities (19).

NITS procedures are a challenge for all OR staff. Complications that occur may or may not be predictable. In these circumstances, prompt treatment is crucial, and this can only be achieved through a team-build approach where preparation, coordination, and strong and consistent leadership are mandatory. Since these are risky procedures, the patient should be the first of the day and it is useful to have a checklist available, similar to the one proposed by Navarro-Martínez *et al.* (19).

Future perspective

The NITS technique is still little known and applied. Further studies are ongoing to evaluate the efficacy of new methods to improve oxygenation in case of hypoxemia, such as high flow nasal cannulas or trans-nasal humidified rapid-insufflation ventilator exchange, possibly improving oxygenation and carbon dioxide clearance or studies evaluating the effect of vagal cervical blockage on cough reflex.

The issue of the effect of muscle relaxants on diaphragmatic function is also of particular relevance given that a reduction in functional residual capacity (FRC), possibly related to the use of anesthesia and muscle relaxants has been reported.

Among the most interesting monitoring systems recently introduced in anesthetic practice there is certainly the ultrasound evaluation of the diaphragm which is the subject of a growing literature especially in the ICU field (24).

But the attention towards diaphragmatic activity is also growing in postoperative care context. Spadaro *et al.* have indeed reported an increased risk of pulmonary complications in patients with impaired diaphragmatic function after thoracic surgery (25). In the same study, the relationship between diaphragmatic dysfunction and postoperative pulmonary complications in thoracic surgery has been evaluated. Comparing data on ultrasound measured diaphragmatic function in patients undergoing thoracotomy or VATS, Spadaro *et al.* found that VATS patients had a lower reduction in the diaphragmatic excursion and therefore fewer pulmonary complications (24).

Based on preliminary data from an ongoing study performed in our center (Registered on Clinicaltrials.gov, NCT04700943), there is less inhibition of diaphragmatic function during NITS compared to GA.

Conclusions

From the Anesthesiologist perspective, NITS is a high-intensity procedure, which according to the most recent scientific literature appear to be cost-effective. Based on our single centers experience it is possible to consider NITS more as an energy and time investment rather than a dangerous and complicated procedure. Future research in this field should be conducted in order to be tailored to the patient, ensuring a personalized approach based on patient characteristics and specific requirements of the surgical procedure.

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