Epidural anesthesia in awake thoracic surgery

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Summary

Despite the indisputable and well-known advantages of general anesthesia in thoracic surgery, this can trigger some adverse effects including an increased risk of pneumonia, impaired cardiac performance, neuromuscular problems, mechanical ventilation-induced injuries, which include barotrauma, volotrauma, atelectrauma, and biotrauma. In order to reduce the adverse effects of general anesthesia, thoracic epidural anesthesia has been recently employed to perform awake thoracic surgery procedures including coronary artery bypass, management of pneumothorax, resection of pulmonary nodules and solitary metastases, lung volume reduction surgery, and even transsternal thymectomy. The results achieved in this early series have been encouraging, although indications and many pathophysiologic aspects remain to be elucidated. In this review we have tried to provide a first-step analysis of the anecdotal reports available in the literature on this topic. We also desired to provide insights into the main physiologic effects of awake thoracic surgery with epidural anesthesia, with particular attention to the several issues raised by its application in patients with chronic obstructive pulmonary disease, which can represent one of the most stimulating challenges in this setting.

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1. Introduction

Much is changed in thoracic surgery since Sauerbruch [1] expressed the conviction that only general anesthesia could avoid the fatal events inevitably triggered by the open pneumothorax deriving from surgical violation of the chest wall integrity.

At the beginning of the 20th century, ingenious but unreliable attempts aimed at avoiding surgical pneumothorax included the Sauerbruch’s negative-pressure operating chamber [2] and the Brauer’s positive-pressure ventilation chamber [3]. Both these methods were directed at maintaining the operated lung expanded during thoracotomy by respectively creating a negative-pressure environment within a closed operating chamber or maintaining a positive pressure within the airway by introducing the head of the patient into a positive-pressure closed box. However, it was only with the clinical application of general anesthesia and endotracheal-tube ventilation that modern thoracic surgery could eventually develop. Subsequently, one-lung ventilation by double-lumen endobronchial intubation introduced by Zavod in 1940 [4] and refined by Bjork and Carlens in 1949 [5] proved a revolutionary advance and is still considered mandatory in both open and video-assisted thoracic surgery (VATS) procedures.

Despite the indisputable and well-known advantages of general anesthesia, this can trigger some adverse effects including an increased risk of pneumonia, impaired cardiac performance, and neuromuscular problems. In addition, during general anesthesia, mechanical ventilation can produce injuries, which include airway pressure-induced injury (barotrauma), lung inflation-induced injury (volotrauma), injury due to cyclic opening and closing of small airways/lung units (atelectrauma), and release of a variety of proinflammatory mediators (biotrauma) [6]. Yet, atelectasis in the dependent lung is a frequent finding during one-lung ventilation with muscle paralysis [7], and prolonged collapse of the nondependent lung can delay its complete re-expansion after weaning, leading to the development of further atelectatic areas.

In order to reduce the adverse effects of general anesthesia, thoracic epidural anesthesia (TEA) has been recently employed to perform awake thoracic surgery procedures including coronary artery bypass [8—12], management of pneumothorax [13—15], resection of pulmonary nodules [16] and solitary metastases [17], lung volume reduction (LVRS) [18], and even transsternal thymectomy [19] (Table 1). The results achieved in these early series have been encouraging, although indications and many pathophysiologic aspects remain to be elucidated.

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2. Physiologic effects of epidural anesthesia

Many surgical procedures can be accomplished with satisfactory anesthesia and analgesia by epidural administration of local anesthetics. In addition, the sympathetic blockade can produce beneficial effects on several organ systems [20] including an increased gastrointestinal motility and perfusion or decreased myocardial ischemia and systemic stress response to surgery [20–23].

2.1. Effect on cardiovascular system

In awake patients under epidural anesthesia we can have the best type of monitoring, namely neurologic vigilance [24]. Instead, general anesthesia can induce a drop of systemic blood pressure to a critically low level during stabilization (usually a blood pressure around 80 mmHg). Yet, some patients experience hemodynamic compromise related to narcotic medication before intubation, which carries the risk of preoperative myocardial ischemia or infarction in patients with severe coronary artery disease [22,25–27]. Conversely, cardiovascular effects of epidural anesthesia include decreased determinants of myocardial oxygen demand [28], improved myocardial blood flow [29,30] and left ventricular function [31], and reduced thrombotic-related complications [32]. Furthermore, it has been shown that epidural anesthesia can reduce heart rate and occurrence of arrhythmias during manipulation of the heart [33,34].

2.2. Effect on lung function

The impact of epidural anesthesia on lung function can be ambiguous. Satisfactory analgesia and the avoidance of mechanical irritation must be balanced against the possible alteration of lung function by epidural motor blockade of respiratory muscles and the potentially detrimental effects of sympathetic block, leaving an unopposed vagal tone with potentially increased bronchial tone and reactivity.

TEA has proven to be particularly beneficial in combination with general anesthesia with volatile anesthetics to reduce the adverse effects of total intravenous anesthesia. In particular, it has shown to reduce impact on physiologic mechanism of hypoxic pulmonary vasoconstriction, and pulmonary and systemic hemodynamics. Yet, complications such as infections and atelectasis can be improved by epidural anesthetic treatment [35]. Furthermore, recent studies have suggested that TEA combined with general anesthesia improved arterial oxygenation during one-lung ventilation, resulted in better cardiac output stability, and reduced time to extubation [36].

Early postoperative lung function is influenced by residual muscular relaxation, the time of extubation, pain therapy, and vigilance. Immediately after an operation, the ability to cough seems to be one of the most important factors affecting lung function and is depending, to a great extent, on the efficacy of diaphragmatic contraction and pain relief. On the other hand, with general anesthesia, reduced vigilance, muscular rest relaxation, and possibly impaired diaphragmatic function can lead to prolonged mechanical ventilation, which is a risk factor for pulmonary infections and morbidity.

The physiological effects of TEA on lung function are determined by the extension of the motor blockade depending on the height of the insertion of the catheter, the choice of local anesthetic, and its concentration.

With a limited sensory block from dermatom T1 to T5, vital capacity is decreased by 5.6% and forced expiratory volume in 1 s (FEV1) by 4.9% [37], an effect that can be explained by a direct motor blockade of intercostal muscles [38]. On the other hand, studies in patients with chronic obstructive pulmonary disease have shown that an epidural block with 0.5% bupivacaine leads to a decrease in vital capacity and FEV1 of only 8%. In this respect, the change in posture has to be also taken into account, since this alone can account for a decrease in vital capacity and FEV1 of up to 23% [39–43]. In fact, there exists evidence that TEA improves postoperative lung function in comparison with general anesthesia alone. At least two effects contribute to this improvement. On the one hand, TEA improves diaphragmatic function and on the other, it provides better postoperative analgesia than patient-controlled intravenous administration of opioids. Yet, there seems to be a direct effect on diaphragmatic contractility and breathing pattern under epidural anesthesia [44].

2.3. Effect in patients with chronic obstructive pulmonary disease

Potential adverse effects of general anesthesia can be particularly dangerous in patients with chronic obstructive...
pulmonary disease. Indeed, in addition to the aforementioned adverse effects related to mechanical and single-lung ventilation, general anesthesia with instrumentation of the airways can elicit bronchospasm and life-threatening complications. Therefore, it is not surprising that surgical procedures performed under epidural anesthesia are associated with fewer respiratory complications [45–47].

However, the use of TEA in respiratory compromised patients raises some concerns. First, the motor blockade that is associated with epidural anesthesia might lead to respiratory failure in patients with an already compromised respiratory function. Secondly, the sympathetic blockade, which is also associated with TEA, would lead to an increased bronchial tone and airway hyperreactivity. Thirdly, use of TEA in awake thoracic procedures can induce hypercapnia, particularly in patients with severe emphysema. On the other hand, neither the arterial—alveolar difference in O2 nor the direct measurement of shunt was negatively affected by TEA [35].

2.4. The problem of permissive hypercapnia

Awake thoracic surgery has shown that simple administration of oxygen through a Venturi mask can prevent hypoxemia while hypercapnia develops frequently, particularly in patients with chronic obstructive pulmonary disease. Yet, there seems to be a direct relationship between operative time and severity of hypercapnia. The pathophysiology of this event is not fully understood, although hypventilation due to partial collapse of the operated lung and a rebreathing effect seem reasonable hypotheses.

Another interesting feature is that even in patients with severe emphysema undergoing LVR, perioperative hypercapnia rarely becomes clinically dangerous. This feature, which has been already extensively investigated in critically ill patients during intensive care unit stay, has led to the development of the concept of ‘permissive hypercapnia’ [48], which is rarely a life-threatening condition and may even exert some potentially beneficial effects including increased parenchymal compliance and improved ventilation/perfusion matching [49,50]. Yet, the hypercapnic-mediated sympathico-adrenergic effects of increased preload, decreased afterload, and increased heart rate lead to a net increase in cardiac output. Hence, it is against this background that one must be judicious with hypercapnia in any patient on β-adrenergic antagonists, or those with heart failure or coronary artery disease. Furthermore, the increase in cerebral blood flow with hypercapnic acidosis must be considered carefully in any patient as a potential risk for raised intracranial pressure [51]. Finally, the marked sympathetic activation of hypercapnic acidosis, particularly when combined with arterial hypoxemia, can reduce glomerular filtration and increase fluid retention [52].

3. Surgical management of spontaneous pneumothorax

Awake VATS represents a particularly attractive approach for treatment of spontaneous pneumothorax, due to the simplicity of the surgical procedure and the peculiar characteristics of this young and healthy patient population. Furthermore, diffuse pleural adhesions, which can contraindicate awake VATS, are exceedingly rare in these patients [53].

In 1997, Nezu et al. [54] have reported satisfactory results with awake VATS bullectomy, with sole intercostal blockade, while use of TEA has been anecdotally investigated in this setting [13,14,55]. Sugimoto et al. [14] employed this approach to treat intractable pneumothoraces following lung transplantation, and suggested that this approach might reveal particularly appealing in patients with posttransplantation bronchial stenosis and living-donor lobar transplantation in whom single-lung ventilation might be difficult to maintain.

We believe that the use of TEA is particularly appealing when VATS bullectomy with pleural abrasion is preferred since an optimal somatosensory block is advisable to minimize perioperative thoracic pain. Furthermore, we have found that since TEA obviates the need of a deep sedation, an interactive cooperation between the surgeon and the conscious patient is allowed.

In a small randomized study, we have recently shown that awake VATS bullectomy with pleural abrasion was feasible and well tolerated by our young cohort, although 12% of recruitable patients refused randomization and preferred a non-awake procedure. Yet, in the awake group, global operating room time and hospital stay were shorter, and hospital charges were lower than those of the control group undergoing the same procedure under general anesthesia with one-lung ventilation [15].

4. Resection of pulmonary nodules

In 2004 [16] we had reported results of a randomized study on awake VATS resection of solitary pulmonary nodules which was easily and safely performed under TEA with no mortality and negligible morbidity. No particular surgical training was necessary and the only two failures were due to the presence of extensive and dense pleural adhesions that, thus, represented the only contraindication for the procedure. In addition, awake pulmonary resection was easily accepted and well tolerated by the patients.

Avoidance of general anesthesia reflected in a faster recovery with immediate return to many daily life activities including drinking, eating, and walking. As a result, the hospital stay was significantly shorter than in the control group.

One of our major concerns related to the risk of operating on a ventilating lung rendered surgical maneuvers more difficult due to the lung movements and the lack of a sufficient ‘operating space’. Instead, we had earlier noticed that the open pneumothorax created after trocars’ insertion produced a satisfactory lung collapse which did not hamper surgical maneuvers.

As expected, arterial oxygenation worsened slightly during the first postoperative day, but this impairment was greater in the general anesthesia group than in the awake group. One concern relates to the patient participation in operating room conversations when unexpected lung cancer is encountered. We believe that in these delicate instances, special care must be devoted by the operating
team in reassuring the patient while explaining the reasons that require conversion to general anesthesia and thoracotomy.

In a more recent study, thoracoscopic metastasectomy under sole TEA for peripheral solitary lung metastases has been performed by the authors of this review [17]. In this study, the awake procedure proved safely feasible while global operating room time and hospital stay were significantly shorter than those of the control group operated under general anesthesia. Finally, oncologic results were comparable between the groups.

5. Lung volume reduction surgery

In a recent pilot study, we have reported that awake nonresectional LVR was safely performed under sole TEA [18]. Avoidance of general anesthesia reflected in an easier patient acceptance of the procedure and allowed a more rapid recovery with immediate return to common daily life activities. In addition, in the awake group nonfatal complications were less frequent and hospital stay was significantly shorter than that of the control group operated under general anesthesia. Finally, at the 6-month follow-up, significant incremental improvements occurred in clinical and respiratory function measures after awake LVR, and these improvements did not differ from those achieved in the control group.

Theoretically, an open pneumothorax could have compressed the dependent lung, eventually resulting in functional compromise. However, in our series, apart from a temporary permissive hypercapnia, respiratory function remained satisfactory throughout the procedure. We hypothesized that maintained diaphragmatic motion could have decreased the detrimental effect of the abdominal pressure, leading the paralyzed diaphragm to compress the dependent lung during general anesthesia [56].

In our study the perioperative rise in CO₂ was well tolerated by the patients and resolved more rapidly than in the control group. We believe that this effect can be addressed to the better synchronization of rib cage—abdominal motion, which we have immediately observed after awake LVR. In fact, after LVR, the greater contribution of abdominal volume changes to tidal volume is consistent with a reduction of inspiratory loading and a greater force-generating capacity of the diaphragm due to resizing of the abdominal volume changes to tidal volume is consistent with a reduction of inspiratory loading and a greater force-generating capacity of the diaphragm due to resizing of the abdominal motion, which we have immediately observed after LVR [57]. Unfortunately, these beneficial effects of LVR are lost in the early postoperative period in patients receiving general anesthesia.

Increasing health care costs have led economic aspects to become more and more prevalent in surgical practice. Fewer financial resources and reduced intensive care unit capacities have led to the development of the fast-track concept, namely early extubation and possibly earlier discharge from the hospital. Actual benefits of fast tracking remain controversial [58,59]. Nonetheless, we have demonstrated that employment of TEA without general anesthesia for awake LVR did not require postoperative intensive care unit stay. Patients were monitored for few hours in the recovery room and were subsequently transferred to the ward where they could immediately start walking, eating, and drinking as desired. As a result, this new surgical approach might eventually improve the cost-effectiveness of the procedure.

6. Thymectomy for myasthenia gravis

Thymectomy for myasthenia gravis (MG) requires special attention as far as type of anesthesia and use of muscle relaxants are concerned [60]. In fact, patients with MG are usually sensitive to the effects of nondepolarizing muscle relaxants [61–63], which can also interact with anticholinesterase drugs administered as therapeutic agents [64]. Although various anesthetic procedures have been reported in patients with MG, almost all of them are intravenous or epidural techniques, and entail use of volatile agents and tracheal intubation [60].

In 2004, Tsunozuka et al. [19] reported on awake extended transternal thymectomy performed in three low-risk patients with moderately generalized MG under sole TEA. The mean operating time was 2 h, and all patients were able to drink and walk within 1 h after the operation. The authors concluded that this procedure was advantageous in that avoidance of muscle relaxants and volatile anesthetic agents prevented the laryngeal injury and potential postoperative respiratory failure.

Despite the fact that this result seems encouraging, there are several issues which can be critically raised. First, paralyzing drugs are not necessarily used for endotracheal intubation in such patients; secondly, management of unexpected life-threatening events requiring urgent endotracheal intubation under less-than-ideal circumstances might result in far greater probability of laryngeal injury than when done electively. Furthermore, extended thymectomy exposes the patient to risk of inadvertent pleural cavity opening on both sides, a situation which can be difficult to manage without endotracheal ventilation [65].

7. Complications of thoracic epidural anesthesia

Potential complications of TEA may reduce acceptance and enthusiasm for this technique. Local anesthetic neurotoxicity is a well-known phenomenon related to the type and concentration of anesthetic and systemic absorption. High doses of intrathecal lidocaine have been associated with neurologic side-effects not related to hemorrhage and infection [66,67]. Systemic absorption of local anesthetics at high doses can produce seizures, loss of airway protective reflexes, respiratory depression, coma cardiac arrhythmias, hemodynamic instability, and motor autonomic blockade (urinary retention, weakness) in 0–45% of patients [68–70]. Hypotension and bradycardia are two important potential hemodynamic consequences induced by sympatheticolysis. A prospective multicenter randomized trial has found the incidence of hypotension after epidural—general anesthesia, defined as a > 30% reduction from baseline blood pressure, to be 41% compared with 23% after general anesthesia alone [71].

The use of TEA in patients undergoing cardiac and thoracic surgery is controversial, because of the risk of vertebral canal hematoma [72]. Yet, neurological complications, including
spinal cord injury [73], may arise during administration of the block, since the needle or catheter may result in direct nerve trauma. The injection of irritant drugs can also cause neurological damage. We must, therefore, be meticulous when injecting drugs into the epidural space. Accidental dural puncture during needle insertion occurred in 0.16—1.3% instances in a series of 51,000 epidural catheters, and subsequent postdural headaches developed in 16—86% of these patients [74—77].

The increasing use of anticoagulant therapy in surgical patients and, in particular, the variety of low-molecular weight heparins available, may make it difficult to safely perform epidural anesthesia. Incidence of hemorrhagic complications has been variable in the literature. In one investigation, Ho et al. [78] have reported a risk of epidural hematoma formation in cardiosurgical patients between 1 in 1,500—150,000 within a 95% confidence interval. Renck [79] calculated an incidence for adverse events of 1:143,000 for an overall population receiving epidural catheters for noncardiac surgery. Recent communications in the medical press have suggested that the rate of vertebral canal complications following epidural catheter placement, in particular, the incidence of epidural abscess is increasing in frequency [80,81]. On the other hand, a very recent wide retrospective analysis [82] indicates that thoracic epidural anesthesia and analgesia are safe in patients receiving cardiac surgery with no epidural hematoma or abscess recorded in 2837 patients. Finally, in a recent meta-analysis [83] the calculated relative risks for spinal hematoma and injury were 0.0002% and 0.0005%, respectively. A further potential risk of high TEA is phrenic nerve palsy caused by inadvertently high anesthetic levels [84]. On the other hand, in awake thoracic surgery, many potential risks of endotracheal intubation, including trauma to teeth or vocal cords and peri-intubational hypoxia, are avoided.

8. Conclusions

Recent reports have suggested that several surgical thoracic procedures can be easily and safely carried out through this novel and globally less invasive approach which is easily accepted by both patients and clinicians. This surgical modality holds promise and might eventually result in cost-effective than equivalent procedures performed under general anesthesia due to reduced hospitalization and overall charges. However, initial encouraging results must be interpreted with caution and enthusiasm mitigated since they are still insufficient to draw any reasonable conclusion on pertinent indications, pathophysiology effects, and potential benefit. Furthermore, use of TEA exposes to risks of potential major complications that one must be aware of particularly in patients undergoing anticoagulant therapy.

Nonetheless, we believe that this represents a new and fully exploratory field, which might evolve unexpectedly in an era in which efficacy, rapidity, and low costs are unceasingly required for modern surgery.

In conclusion, despite the fact that further investigation is needed, we confide that the mystic taboo of primitive men that Sauerbruch thought to be extended to surgeons entering the chest without general anesthesia [1] might wean in the near future as an ancestral nightmare is dispersed by sunrise.

References


