Original Article

Preoperative function evaluation of the major lung resection: muscle-sparing axillary mini-thoracotomy versus video-assisted thoracoscopic surgery

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Background: In surgically fit non-small cell lung cancer (NSCLC) patients, pulmonary lobectomy still represents the standard of care. In recent years, the development of minimally invasive video-assisted techniques has reduced perioperative surgical stress, including patients previously thought to be unfit for surgery.

Methods: We carried out a review of literature in order to evaluate the role of the preoperative parameters in functionally compromised patients and the effectiveness of video-assisted thoracoscopic surgery (VATS) compared to the "muscle sparing" axillary mini-thoracotomy in major lung resections.

Results: Of 99 analyzed papers, we considered the 24 most significant, according to the preoperative functional status evaluation and, especially cardiac and respiratory reserve.

Conclusions: In patients with a reduced cardio-respiratory function undergoing pulmonary resection, VATS guarantees results superimposable to mini-thoracotomy and represents a valid alternative to be taken into consideration.

Keywords: Major lung resections; video-assisted thoracoscopic surgery (VATS); mini-thoracotomy; preoperative evaluation; review

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Introduction

Pulmonary lobectomy represents the standard of care in early stage non-small cell lung cancer (NSCLC) patients (1-4). However, surgeons frequently have to face "high risk" patients who due to the improvement of the quality of life and the increase of the average age, constitute a pulmonary or cardiac reserve and comorbidity indexes would require major pulmonary resections (5-8). According to the 2016 Italian Association of Medical Oncology (AIOM) guidelines about the management of lung cancer (9), the most frequent complications following pulmonary resection are: cardiac arrhythmias, atelectasis, lung infections, prolonged air loss, acute respiratory distress syndrome (ARDS), respiratory insufficiency, heart failure, hemothorax, bronchial fistula, pleural empyema, pulmonary embolism and surgical wound infections. The overall postoperative mortality rate ranges from 2% to 5% in lung lobectomies and 5% to 10% in pneumonectomies (9,10). For these reasons, preoperative assessment, in particular of the respiratory reserve, becomes essential to exclude predicted high-risk patients. Lee *et al.* (11), evaluating data on 4,315 patients aged more than 50 years old undergoing different surgical procedures (orthopedics, vascular, thoracic and abdominal surgery) and analyzing postoperative cardio-circulatory complications (56 patients, approximately 2% of 2,893 patients assigned

Table 1 Risk class according to Brunelli *et al.* (12)

Variable	Class A	Class B	Class C	Class D
Score	0	1–1.5	2–2.5	>2.5
Percentage of risk	1.5%	5.8%	19%	23%
Cardiological examination	Not necessary	Not necessary	Yes	Yes
Echocardiogram	Not necessary	Not necessary	Yes (in case of suspected pathology)	Yes (in case of suspected pathology)

to derivation cohort) identified six independent predictive factors and included them in a Revised Cardiac Risk Index (RCRI): (I) high-risk type of surgery; (II) history of ischemic heart disease; (III) history of congestive heart failure; (IV) history of cerebrovascular disease; (V) preoperative treatment with insulin; (VI) preoperative serum creatinine >2.0 mg/dL. These parameters were then reviewed by Brunelli *et al.* (12) considering only major pulmonary resection interventions. Out of 1,696 patients undergoing surgery (1,426 lung pulmonary lobectomy and 270 pneumonectomy), four parameters were considered by assigning an item score: cerebrovascular disease (1.5 points), cardiac ischemia (1.5 points), renal disease (1 point), and pneumonectomy (1.5 points). The percentage of risk of developing complications varied according to the score, allowing the identification of different risk classes (class A, score 0, risk 1.5%; class B, score 1–1.5, risk 5.8%; class C, score 2–2.5, risk 19%; class D, score >2.5, risk 23%). In particular, in case of a score >2, patients should undergo a cardiological examination and, in case of suspected pathology (valvulopathy, ventricular dysfunction, pulmonary arterial hypertension), an echocardiogram with subsequent prompt treatments should be considered (*Table 1*). The evaluation of respiratory function must be performed through spirometry and the calculation of diffusion lung CO (DLCO) (12-14); based on results, patients could be classified into low (with values >60–75%), moderate (with value between 35% and 60%) or high operative risk (<35%). Another fundamental parameter is the forced expiratory volume in the 1st second (FEV1) (13,15). Licker *et al.* (15), based on the results of a study conducted on 1,222 patients who underwent pulmonary resection by mini-thoracotomy and divided into three groups (728 patients with FEV1 >70%; 397 patients with FEV1 between 50% and 70%; 97 patients with FEV1 <50%), showed that the risk of developing postoperative respiratory complications is greater in patients with reduced FEV1 (risk equal to 10%, 25% and 27% respectively in the three groups) and have calculated the reference cut-off value of FEV1 predictive of respiratory complications equal to 60%, under which value, the risk increases considerably. In the assessment of the respiratory reserve, in addition to FEV1, many authors consider other parameters such as postoperative predictive (ppo) FEV1 (ppo FEV1); DLCO and postoperative predictive DLCO (ppo DLCO) (13,16,17). According to the ACCP guidelines (13), if these values are >60%, patients are considered to be at low risk and, in these cases, pulmonary lobectomy or even pneumonectomy can be safely performed; in case of DLCO ranging from 30% to 60%, further tests such as the "stair climb test", the "shuttle walk test" or the calculation of the maximum volume of oxygen consumed in 1 minute (VO2max) should be considered. The possibility of recruiting patients for pulmonary resection has increased in recent years thanks to the introduction of minimally invasive techniques. The advent of video-assisted thoracoscopic surgery (VATS) has made it possible to consider "functionally compromised" patients for surgery. Compared to the mini-thoracotomy, a minimally invasive technique, reduced the size of accesses and did not significantly compromise respiratory mechanics (18,19).

Methods

A literature review through a PubMed - MEDLINE database was performed according to the following research terms: thoracotomy, video assisted thoracoscopic surgery, preoperative evaluation, lung resection. Ninety-nine papers published in the last fifteen years were found and, of them, thirty were included in our study according to our selection criteria, such as preoperative cardiologic evaluation, preoperative and predicted postoperative FEV1 and DLCO evaluation, outcomes in patients undergoing major lung resection in VATS/mini-thoracotomy (*Figure 1*).

Results

VATS was characterized by longer execution times but

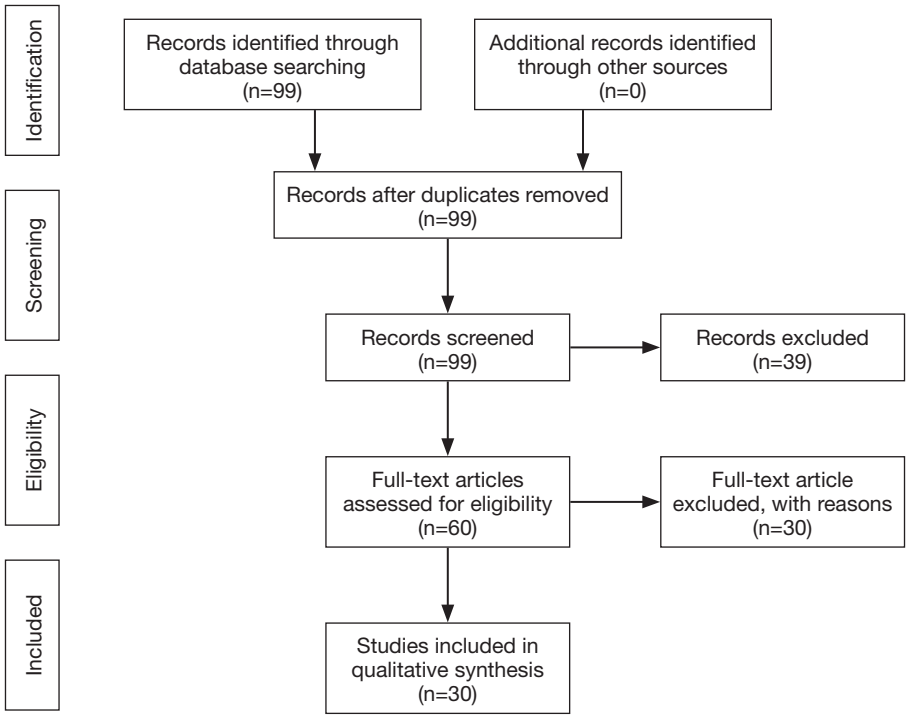

Figure 1 Explaining study design flowchart.

offers shorter hospitalization times (6.1 *vs.* 7.5 days) and a lower complication rate (4.6% *vs.* 8.2%). From the analysis, we found that in the treatment of NSCLC, VATS is superimposable to mini-thoracotomy in terms of effectiveness and oncological radicality and offers indisputable advantages especially in functionally compromised patients. In this category VATS allowed to obtain disease free survival (DFS) and overall survival (OS) values for clinical/pathological stage I not inferior to open surgery (88%/91.5% and 94.1%/94.8% *vs.* 77.1%/93.8% and 81.8%/96.2% respectively), reducing the risk of complications and the mortality rate in case of reduced cardio-pulmonary reserve (10.4–12.8% *vs.* 14.9–21.9% and 0.7–2.0% *vs.* 4.8–5.2%). VATS allowed major pulmonary resection even in patients with FEV1 and DLCO values <60% or affected by COPD who could not undergo the same surgery by mini-thoracotomy, achieving the same radical results of open surgery. In fact, VATS improved the outcome and decreased the surgical stress with a lower complication rate than open surgery (17.8% *vs.* 21.7% and 22% *vs.* 32.9% respectively).

Discussion

Since its introduction, VATS has undergone a continuous evolution and is now considered equivalent to open surgery for the treatment of early-stage lung cancer in terms of safety, efficacy and radical excision. A considerable boost to the development of this technique comes from the possibility that it offers major pulmonary resection even in patients with reduced cardio-pulmonary reserve due to less invasiveness and surgical stress; moreover, in patients with NSCLC it proved to be a feasible and effective technique not only in lobectomies but also in segmentectomies (20). Over the last few years, many studies have been conducted that attest to the superiority of VATS compared to thoracotomy. Zhao *et al.* (21) compared the results of the two methods on a sample of 1,083 patients who underwent pulmonary lobectomy and lymphadenectomy for early stage pulmonary neoplasia (cT1M0N0). In 560 patients a "muscle sparing" open access was used while 523 patients underwent VATS lobectomy. The analysis of the data showed that the video-assisted technique is characterized by longer times (98.8 *vs.* 77.8 min) and a smaller number of resected lymph nodes (12.6 *vs.* 18.2); however, the period of hospitalization was shorter (6.1 *vs.* 7.5 days) thanks also to the shorter drainage time and above all the index of postoperative complications was lower (4.6% *vs.* 8.2%) while maintaining the same long-term survival

outcomes. The effectiveness of VATS in terms of long-term survival has also been demonstrated by Higuchi *et al.* (22). One-hundred and sixty patients with stage I NSCLC underwent pulmonary lobectomy (114 in VATS and 46 in thoracotomy). Patients were divided into two groups according to the staging criteria (clinical stage and pathological stage) and were checked every 2–3 months for the first 12 months after surgery and thereafter every 6 months up to 5 years. In patients undergoing VATS, the DFS was equal to 88% and 91.5% for the clinical stage and pathological stage respectively; while the 5-year OS was 94.1% and 94.8%. In patients undergoing thoracotomy the values were equal to 77.1% and 93.8% for DFS, 81.8% and 96.2% for OS respectively in the two groups. This study demonstrates that in terms of survival, VATS is not inferior to thoracotomy. According to Salati *et al.* (23) VATS does not offer real advantages in terms of functional recovery compared to open. Evaluating 195 patients who underwent lobectomy in VATS (83 patients) or in open (112 patients) 3 months after surgery, noted that the reduction in respiratory function was not significantly different between the two approaches. Preoperative FEV1 mean in VATS patients and "open" patients was 93.2% and 84.8%, respectively, whereas DLCO was 77% and 82.8%. At 3 months from the intervention the reductions calculated in the two parameters were respectively 7.2% and 10.6% in VATS patients and 10% and 11.9% in "open" patients. On the other hand, the effectiveness of the minimally invasive technique in patients with reduced functional reserve is widely reported in literature. Burt *et al.* (24) conducted a study on 13,376 patients who underwent pulmonary lobectomy, 49.1% in VATS and 50.9% in open; all patients showed ppo FEV1 and ppo DLCO <40%. Results revealed that the mortality rate is lower in the VATS group (0.7–2.0%) compared to the "open" group (4.8–5.2%) as well as the complication rate, equal to 10.4–12.8% in the VATS group and 14.9–21.9% in the "open" group. Several authors encourage the use of VATS also in patients with COPD. Jeon *et al.* (25) report the results of 1,502 patients with NSCLC; 446 (29.7%) were diagnosed COPD and 283 were selected among them as having stage I NSCLC. One-hundred and sixty patients underwent VATS lobectomy and 123 patients thoracotomy. The overall incidence of complications was 32.9% in patients undergoing thoracotomy and 22.0% in the VATS group, while pulmonary complications occurred in 12.1% of open patients and only 1.1% in VATS patients. In addition, the period of hospitalization was significantly shorter in patients who underwent VATS lobectomy (6 *vs.* 9 days). The advantages of VATS in patients with limited pulmonary function are also confirmed in a review by Oparka *et al.* (26) who analyzed 280 papers. Data show that VATS is preferable not only in patients with ppo FEV1 <60% because it allows a reduction in the complication rate compared to thoracotomy (17.8% *vs.* 21.7%) (27) but also in patients with FEV1 ppo <40% in which the incidence of pneumonia falls from 21.7% to 4.3% in patients subjected to VATS (28) and the 5-year survival ranges from 18% to 42% (29). Significant data are analyzed in the work of Begum *et al.* (30) about the role of VATS in patients with reduced VO2max. The data come from the ESTS database and concern 1,684 patients undergoing lobectomy (281 in VATS and 1403 in thoracotomy); of these, 471 (28%) had a low VO2max (<15 mL/kg/min) and were subjected to VATS (72 patients) or thoracotomy (399 patients). The overall complication rate was similar in the two groups (with regard to cardio-pulmonary complications in the two groups, they occurred in 18% and 36%, respectively, the mortality rate was five times higher in patients undergoing thoracotomy (1.4% *vs.* 6.7%).

Conclusions

Based on the data collected, VATS is a safe and effective technique and must always be considered in the treatment of surgically treatable pulmonary pathologies or early-stage pulmonary neoplasms even in functionally compromised or COPD-diagnosed patients.

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Footnote

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