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ORIGINAL ARTICLE – THORACIC

A comparative analysis of Pancoast tumour resection performed via video-assisted thoracic surgery versus standard open approaches†

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Abstract

OBJECTIVES: The aim of the present paper was to conduct a comparative analysis of outcomes after thoracoscopic resection versus standard thoracotomy approach in the treatment of Pancoast tumours.

METHODS: All consecutive patients with Pancoast tumours undergoing surgical treatment from March 2000 to November 2012 were enrolled. Patients were divided into 2 groups according to whether a thoracoscopic or standard thoracotomy approach was adopted. In addition to morbidity and mortality, (i) intensity of pain; (ii) respiratory function focusing on the postoperative value and its variation with respect to the predicted value (Delta); (iii) analgesic consumption at different times during the postoperative course; and (iiii) survival rate were recorded in both groups and the inter-group differences were statistically compared.

RESULTS: Of the 45 enrolled patients, 34 (75%) were included in the final analysis (18 in the thoracoscopic group and 16 in the standard group). Eleven (25%) patients were excluded because they (i) were unfit for surgery after induction therapy ($n = 4$); (ii) refused the operation ($n = 1$) or (iii) had unexpected pleural involvement ($n = 6$). Compared with the standard group, in the thoracoscopic group we observed less pain ($P = 0.01$), better recovery of forced vital capacity ($P = 0.01$) and forced expiratory value in 1 s ($P < 0.001$), and a reduction in opioid ($P = 0.01$) and analgesic consumption ($P = 0.02$). The median survival for all patients was 15 months. Patients with N0/N1 disease had better median survival than N2 patients (47 vs 9 months; $P = 0.009$). One local recurrence in the standard group was observed 1 year after operation, whereas 2 local recurrences, 1 in the thoracoscopic group and another in the standard group, were registered 2 years after the operation ($P = 1.0$). Finally, 4 (22%) extrathoracic metastases in the thoracoscopic group and 5 (31%) in the standard group ($P = 0.8$) were found over the 2 years following the procedure.

CONCLUSIONS: In the management of Pancoast tumours, a thoracoscopic approach is safe and may be an effective adjunct to standard surgical resection in selected cases. Such an approach enabled surgeons to explore the pleural cavity and avoid exploratory thoracotomy in cases of unexpected pleural involvement.

Keywords: Pancoast tumour • Superior sulcus tumour • Video-assisted thoracoscopic resection • Surgery • Thoracotomy

INTRODUCTION

The development of video-assisted thoracic surgery (VATS) over the past decade has led to a significant shift in the management of an increasing number of thoracic pathologies, including lung cancer resection. VATS reduced surgical trauma and maintaining oncological principles of traditional open procedures. Recently, in a multicentre study, Bayarri *et al.* [1] reported its use during open *en bloc* chest-wall and pulmonary resection for locally invasive cancer. VATS confirmed chest-wall invasion when suspected on computed tomography (CT) scan, and determined the boundaries and location of the chest-wall involvement. It allowed placing of the incision over the involved area, proceeding with accurate excision of the chest wall without the need for extensive thoracotomies, and to proceed with pulmonary resection *en bloc* only through the space available after the rib excision without the need for rib spreading or extending of the thoracotomy [1]. Similar results were previously obtained by the authors in the management of Pancoast tumours [2]. The goal of this study was to review the experience of different centres to compare VATS and standard approaches in patients who underwent Pancoast tumour resection during the same period, looking at all preoperative, operative and postoperative data and prognosis.

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MATERIALS AND METHODS

Study design

This paper discusses a retrospective multicentre study. All consecutive patients with Pancoast tumours undergoing surgical treatment as part of multimodality treatment between March 2000 and November 2012 were enrolled. Patients were divided into 2 groups according to whether a mini-invasive approach (VATS group) or standard thoracotomy approach (standard group) was adopted. To make the 2 study groups reliable and comparable and to avoid selection bias, all patients were reviewed by the same multidisciplinary thoracic oncological team and deemed by this team to be eligible for VATS resection. However, the decision whether patients received a VATS or standard procedure was based entirely on the individual surgeon's expertise, anatomic consideration as well as patient preference. In addition, we excluded patients with: (i) a previous history of chronic pain; (ii) a previous thoracic procedure; (iii) neurological disease, such as movement limitation or cerebral confusion; and (iiii) other types of chest-wall involvement that did not meet the criteria of the standard definition of Pancoast tumour. The VATS group was compared with the concurrent thoracotomy group in light of the following postoperative results: (i) intensity of pain; (ii) pulmonary function; (iii) narcotic medication; and (iiii) survival rate. The data were prospectively collected in a database and then retrospectively compared to assess statistical inter-group differences. All patients were informed regarding the type of operation and gave written consent before it. Being retrospective, the study was approved by the review board of each centre enrolled.

Patient evaluation

Between 2000 and 2012, 45 patients with Pancoast tumours eligible for surgery were enrolled in the study. The patients were observed in 3 different tertiary units of Italian thoracic surgery, including Second University of Naples ($n = 15$), Hospital Cannizzaro of Catania ($n = 12$) and Istituto Oncologico del Mediterraneo of Catania ($n = 18$). In all centres, the diagnosis of Pancoast tumour was made by the clinical presentation of pain around the shoulder and upper arm, associated with a tumour in the apex of the lung. Standard functional tests were used for assessing pulmonary reserve; forced expiratory volume in 1 s (FEV1) and forced vital capacity (FVC) were computed and calculation of predicted postoperative (ppo) values was performed to assess surgical risk; a ppoFEV1 of >40% was required to schedule the surgical procedure. Lung carbon monoxide diffusion testing (DLCO) and quantitative V/Q scan were only performed in selected cases with limited pulmonary function [3].

In all cases, preoperative staging was performed using chest roentgenogram and CT scan. Magnetic resonance imaging (MRI) was used to determine tumour involvement of the vertebrae, brachial plexus and subclavian vessels in patients who were candidates for surgery. Positron emission tomography (^{18}FDG-PET) has been used since its introduction in 2000, but only became part of the standard staging procedure and of follow-up in 2006. Tumour diagnosis was generally obtained by CT-guided fine-needle biopsy. Invasive staging procedures were performed if pathological lymph nodes in the mediastinum were suspected on CT, unless PET was available and negative for mediastinal nodes. Then, all patients were evaluated by the multidisciplinary thoracic oncological team to assess tumour stage and decide on the treatment strategy. When surgical resection was considered feasible, the same induction therapy proposed by Southwest Oncology Group [4] was adopted by all centres contributing to this study. The induction chemotherapy and radiation began within 24 h of each other. The chemotherapy regimen comprised cisplatin 50 mg/m^2 on Days 1, 8, 29 and 36 and etoposide 50 mg/m^2 on Days 1–5 and 29–33, both administered intravenously. Standard prehydration and antiemetic medications were used. The total dose of radiation was 45 Gy administered at 180 cGy per day, 5 days a week, over a period of 5 weeks. The radiation target was defined by CT scan and included the primary tumour and ipsilateral supraclavicular region, but not the mediastinum or hilum.

Three to four weeks after the completion of radiotherapy, a restaging using CT and MRI was performed while invasive restaging of the mediastinum was done if (persisting) N2 disease was suspected on CT scan. Definitive surgery was scheduled 4–6 weeks after completion of induction treatment. After surgery, at least 2 additional cycles of cisplatin and etoposide were planned. After completing induction therapy, all centres adopted the same exclusion criteria from surgery as follows: (i) progressive disease; (ii) persisting N2/N3 disease; (iii) (extensive) tumour invasion in neural foramina, vertebral bodies, brachial plexus or greater vessels; and (iv) low performance status or insufficient cardiopulmonary reserve.

Surgical resection

All patients received the same regimen of anaesthesia and selective intubation. The VATS procedure was as previously described [2]. Briefly, the patient was placed in the lateral decubitus position with the arm of the operative side prepped and wrapped by sterile waterproof stockinet so that it can be moved within the operative field. According to the VATS findings, either an anterior or a posterior thoracotomy from 8 to 15 cm was performed without the need to change the position of the patient intraoperatively. After having positioned the trocars, thoracoscopic exploration of pleural cavity was attended to evaluate potential pleural dissemination and the relation of the lung with the adjacent structures. In cases of feasibility of surgery, resection was performed using either a combined technique involving small posterior thoracotomy with video-assistance support or VATS lobectomy followed by chest-wall resection. The specimen was then removed *en bloc* from the pleural cavity. Radical dissection of all mediastinal lymph nodes was routinely carried out thoracoscopically, in the standard fashion. At the end of the procedure, 2 inter-costal drainage tubes was generally placed in the pleural cavity and attached to underwater seals, as shown Fig. 1. The patient was usually extubated in the operating theatre and spent their first 24–48 h in a thoracic surgical high-dependency unit before moving to a thoracic surgical ward.

After the operation, all patients received standard medication using intravenous (IV) patient control analgesia (PCA) as follows: 5 mg morphine IV bolus at first, followed by 1.2 mg/h, which could be maximally delivered by any patient with a 5-10-min lockout period for the first 48 postoperative hours (POH). Ketorolac (administered via an intramuscular route at a dose of 15 mg every 6–8 h) was given when the patient noticed strong pain; if the pain was uncontrollable, an additional dose of intramuscular administration of pentazocine (30–60 mg) was used. Early mobilisation and aggressive pulmonary toilet was performed in addition to physical therapy and respiratory therapy. Patients

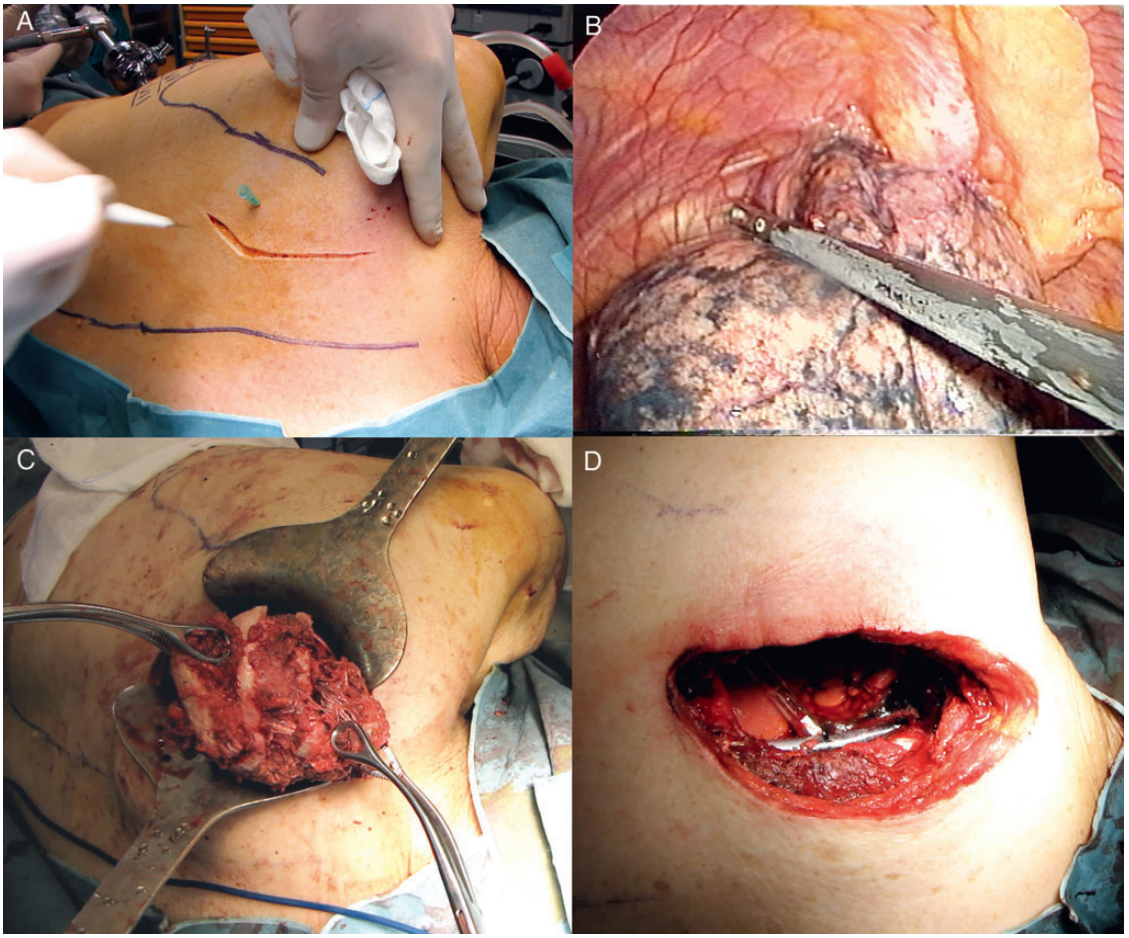

Figure 1: Posterior thoracotomy was performed under thoracoscopic view (**A**). An exploration of the pleural cavity was performed to evaluate pleural dissemination not clinically diagnosed and the relation of the lung with adjacent structures (**B**). The thoracoscopic support allowed an '*en bloc*' chest-wall resection (**C**) through a small posterior thoracotomy (**D**).

were educated regarding incentive spirometry preoperatively and used it frequently postoperatively, including under direct observation. Postoperatively, they received two assisted sessions of chest physiotherapy daily, starting on the first postoperative day, and were asked to repeat the physiotherapy programme 6 times during the day until discharge. Therapeutic bronchoscopy was instituted early, based on clinical findings and correlation with daily chest films. The thoracostomy tubes were usually removed during the first 5 or 6 postoperative days, except in cases with complications.

Postoperative pain

Postoperative pain was measured using a visual analogue scale (VAS) score (from 0 to 10). When asked, patients had to touch a point corresponding to their grade of pain, and this mark indicated the degree of pain on the scale. Participants completed the VAS questionnaire before the operation and 24, 48, 72, 96, 120 h and 1 month after the procedure.

Respiratory function

Pulmonary function tests (FVC and FEV1) were performed using Spirolab, Spirometer (Cosmed®). The best of 3 efforts, completed with the patient sitting on the edge of the bed, was used for the analysis. The ppoFEV1 was calculated by using a Nakahara formula [5]:

$$\text{ppoFEV1} = \left[\frac{1-(n-a)}{(42-a)}\right] \times \text{ppoFEV1},$$

where n relates to the total number of subsegments in the lobe to be removed, whereas a relates to the number of subsegments obstructed by the tumour. The ppoFVC was calculated in a similar way.

The changes in the actual ppo FEV1 compared with the ppoFEV1 (Delta FEV1) was calculated for each patient, according to the formula:

$$\text{FEV1 ratio} = \frac{(\text{actual postoperative FEV1} \times 100)}{\text{ppoFEV1}}.$$

The Delta FVC ratio was calculated similarly. The pulmonary function tests were expressed as a percent of predicted value and performed 72, 96 120 h and 1 month after the operation.

Analgesic requirement

The intake of analgesic medication at different times during postoperative course (up to Day 5 after the operation) was recorded

for both groups. Adverse effects, such as nausea, vomiting, respiratory depression, sedation and pruritus, were recorded and treated with appropriate medication.

Survival

On completion of all treatment, all patients were followed up. Patients were evaluated every 3 months during the first 2 years postoperatively and then every 6 months thereafter by history, physical examination, chest radiography and blood tests. In addition, scans of the brain, chest and upper part of the abdomen were required every 6 months for the first 3 years postoperatively, after which they were done only if clinically indicated. Since 2006, CT/PET has been routinely used in follow-up if requested. Survival was measured from the first day of chemotherapy until death and/or loss to follow-up. Event-free survival was calculated from the first day of chemotherapy until any event occurred, such as tumour progression, incidence of a second cancer, death because of toxicity or secondary conditions, or death because of second malignancy.

Statistical analysis

Data are presented as mean ± standard deviation (SD) or percentage. Differences between the 2 study groups were assessed by χ^2 (qualitative data) and Mann–Whitney test (quantitative data). The inter-group differences (VATS group vs standard group) of the variables measured at the various postoperative time points were achieved by repeated measures analysis of variance (ANOVA). Survival analysis was conducted according to the Kaplan–Meier method, and curves were compared by the log-rank test. A *P*-value of <0.05 was considered statistically significant. MedCalc® statistical software Version 12.4.0 was used for analysis.

RESULTS

Of the 45 enrolled patients, 34 (75%) were included in the final analysis (18 in the VATS group and 16 in the standard group). Eleven (25%) patients were excluded because (i) after completion of induction chemotherapy, they had poor cardiorespiratory and thus unfit for surgery ($n = 4$); (ii) refused operation ($n = 1$); or (iii) had unexpected pleural involvement not clinically detected that contraindicated tumour resection ($n = 6$). Most standard procedures (75%) were performed during 2000–2010, whereas VATS resections were performed during 2010–2012. A flow chart of the study population is depicted in Fig. 2.

Characteristics of patients

The characteristics of two groups are summarised in Table 1. There were no significant differences regarding preoperative data: age, sex, comorbidities, respiratory function, tumour side, clinical stage and histology. At presentation, 31/34 tumours (91%) infiltrated only the bony and soft tissue structures of the upper thoracic inlet and, thus, were classified as cT3 (17 in the VATS group and 14 in the standard group). In the remaining 3 cases (9%), an

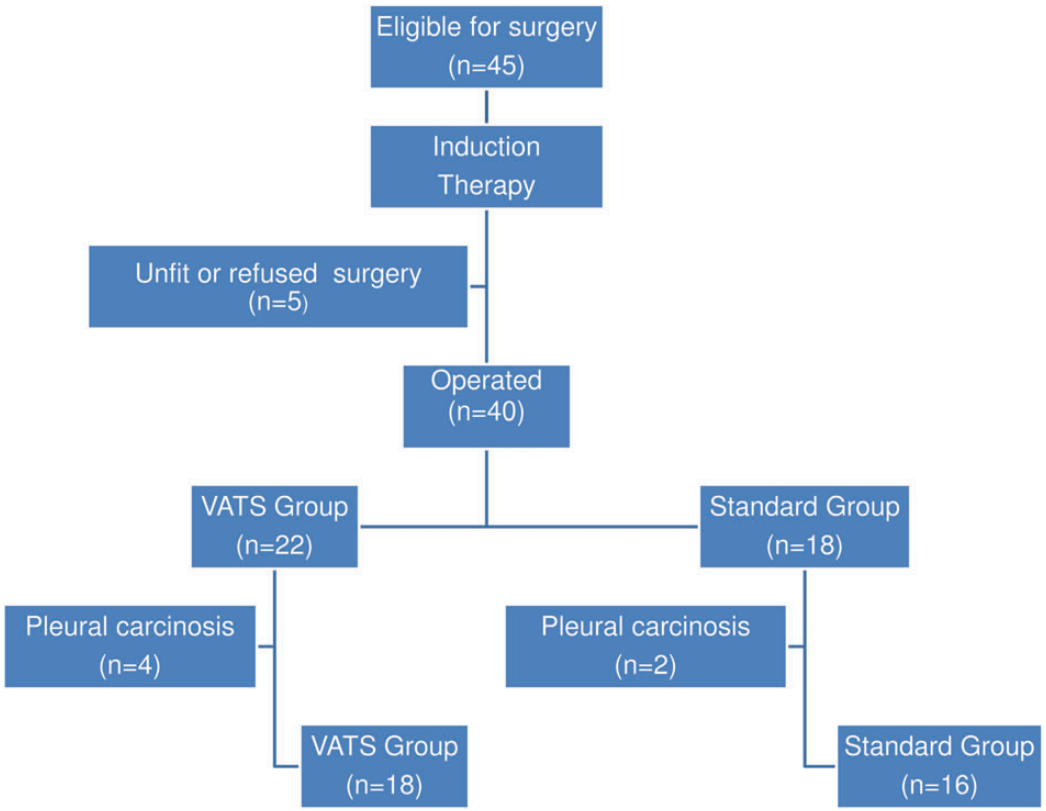

Figure 2: Flow chart of study population.

Table 1: Characteristics of the study population

Variables	VATS group (*n* = 18)	Standard group (*n* = 16)	*P*-value
Age	62.5 (range 39–76)	68 (range 48–78)	0.7
Male	14 (78%)	13 (81%)	0.8
Smoke	15 (83%)	14 (87%)	0.8
Mean body mass index	28 ± 4.5	31 ± 7.5	0.7
COPD	4 (22%)	4 (25%)	0.8
Cardiac	7 (38%)	7 (43%)	0.9
Diabetes	2 (11%)	3 (18%)	0.8
Tumour side			
Right	15 (83%)	11 (69%)	0.5
Left	3 (17%)	5 (31%)	0.5
Diagnosis			
Adenocarcinoma	11 (61%)	10 (62.5%)	0.9
Others	7 (39%)	6 (37.5%)	0.7
Clinical stage			
IIB-T3N0M0	8 (44%)	7 (44%)	1.0
IIIA	9 (50%)	7 (44%)	0.7
T3N1M0	1	0	
T3N2M0	8	7	
IIIB	1 (6%)	2 (12%)	0.9
T4N0M0	0	0	
T4N2M0	1	2	
Induction therapy			
Radiotherapy alone	–	–	
Chemotherapy alone	–	1	0.9
Chemotherapy + radiotherapy	18 (100%)	15 (94%)	0.9
Response to induction therapy			
Partial	16 (89%)	13 (81%)	0.8
None	2 (11%)	3 (19%)	0.8
Approach			
Posterior	16 (89%)	11 (69%)	0.5
Anterior	1 (5.5%)	1 (6%)	0.5
Combined	1 (5.5%)	4 (25%)	0.2
Type of resection			
Lobectomy	15 (83%)	14 (88%)	0.7
Wedge	3 (17%)	2 (12%)	0.7
Operative data			
Operation time	227 ± 25	230 ± 37	0.7
Intraoperative blood loss	291 ± 31	375 ± 75	0.0004
Blood transfusion	1 (5%)	5 (31%)	0.1
Pathological stage			
IIB- T3N0M0	10 (55%)	5 (31%)	0.2
IIIA	7 (39%)	9 (62%)	0.5
T3N1M0	2	1	
T3N2M0	5	8	
IIIB	1 (6%)	2 (12%)	0.9
T4N0M0	0	1	
T4N2M0	1	1	
Postoperative complications			
Respiratory failure	4 (22%)	3 (18%)	0.8
Atelectasis requiring aspiration	2 (11%)	4 (25%)	0.5
Cardiac	–	2 (12%)	0.4
Others	1 (5.5%)	0	0.9
Chest drain duration (days)	4.7 ± 0.7	5.1 ± 1.7	0.2
Length of hospital stay (days)	7.7 ± 1.5	8.5 ± 1.2	0.6

COPD: chronic obstructive pulmonary disease; VATS: video-assisted thoracic surgery.

involvement of the vertebral bodies (cT4) was also detected (1 in the VATS group and 2 in the standard group). All but 1 patient in the standard group completed the planned induction therapy without treatment-related death. At restaging, a partial response was seen in 16 and 13 patients of VATS and standard groups, respectively ($P = 0.8$), whereas no significant change in tumour volume was seen in 2 and 3 patients from the VATS and standard groups, respectively ($P = 0.8$). No case of distant metastases was found.

In the standard group, the surgical approaches were 11 posterolateral thoracotomy, 4 combined posterior thoracotomy and 1 transmanubrial L-shaped incision. Thoracotomy ranged from 30 to 40 cm and latissimus dorsi muscle was always resected. In the VATS group, 16 posterior thoracotomies, 1 combined posterior thoracotomy and 1 transmanubrial L-shaped incision were done. The incision ranged from 8 to 15 cm; no conversion to a wider thoracotomy was attended and latissimus dorsi muscle was always preserved. In only 5 cases (3 of the VATS group and 2 of the

standard group), a nonanatomical resection was performed for a respiratory condition. *En bloc* chest-wall resection and mediastinal lymph adenectomy were always performed. The mean number of resected ribs was 2.9 ± 0.6 in the VATS group vs 3.0 ± 0.7 in the standard group ($P = 0.6$). Among the standard group, in addition to chest-wall resection and lobectomy, a partial vertebrectomy (D2 and D3) with spinal stabilisation was performed in 1 patient and in another a vertebral processes resection of D1–D4 was achieved. Among the VATS group, a vertebral processes resection of D1 and D2, in addition to chest-wall resection of three ribs and lobectomy, was performed. An R0 resection was achieved in all patients except 2 among the standard group (R1). The mean operative time of the VATS group was similar to that of the standard group (227 ± 25 vs 230 ± 37; $P = 0.7$); a significant reduction in intraoperative blood loss was observed in the VATS group compared with the standard group (291 ± 31 vs 375 ± 75; $P = 0.0004$), but no significant difference was found among the two groups regarding blood transfusion, chest drain duration and length of hospital stay. No operative death or reinterventions were registered. Respiratory failure was observed in 4 (22%) and 3 (18%) patients from the VATS and standard groups, respectively, without significant difference ($P = 0.8$). However, patients from the standard group required more bronchoscopic aspiration compared with those from the VATS group. In the standard group, 2 patients presented with postoperative atrial fibrillation, whereas 1 patient from the VATS group had a liquoral fistula treated intraoperatively.

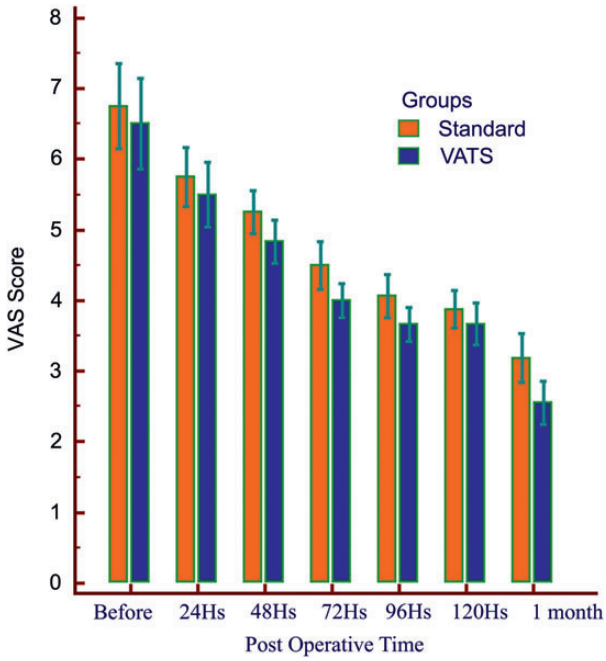

Figure 3: The VAS pain score of the VATS group was significantly lower than that of the standard group during the entire postoperative course ($P = 0.006$; ANOVA test). VAS, visual analogue scale.

Visual analogue scale

The data are summarised in Fig. 3. No significant difference was seen between the VATS and standard groups before operation (6.5 ± 1.2 vs 6.7 ± 1.1). The mean pain score of the VATS group was lower with respect to the standard group at 24 POHs (5.5 ± 0.9 vs 5.7 ± 0.7), 48 POHs (4.8 ± 0.6 vs 5.2 ± 0.5), 72 POHs (4 ± 0.4 vs 4.5 ± 0.6), 96 POHs (3.6 ± 0.4 vs 4 ± 0.5), 120 POHs (3.6 ± 0.5 vs 3.8 ± 0.5) and 1 month after the procedure (2.5 ± 0.8 vs 3.1 ± 0.9). The difference in VAS score between the two study groups was statistically significant ($P = 0.006$).

Respiratory function

The results are summarised in Table 2. Between the VATS and standard groups, similar preoperative values of FVC (85% ± 5.6 vs 89% ± 4.9; $P = 0.7$) and FEV1 (88% ± 3.4 vs 86% ± 6.3; $P = 0.8$) were seen. The ANOVA test showed better values of FVC ($P = 0.01$; Fig. 4A) and FEV1 ($P < 0.001$; Fig. 4B) in the VATS group compared with the standard group. Yet, the comparison of Delta FEV1 and Delta FVC between the groups showed that the loss of FVC ($P = 0.009$; Fig. 4C) and FEV1 ($P = 0.01$; Fig. 4D) was significantly less in the VATS group than in the standard group.

Analgesic requirement

Morphine requirement was lower in the VATS group compared with the standard group on postoperative day 1 (23.3 mg ± 4.8 vs 26.8 mg ± 4.1) and postoperative day 2 (17.7 mg ± 4.7 vs 21.7 mg

Table 2: Functional data of study population

Variable	Group	Baseline value	72 POHs	96 POHs	120 POHs	1 POM	*P*-value
FVC (%)	VATS	85 ± 5.6	61 ± 4.8	64 ± 4.3	69 ± 5.6	72 ± 5.9	0.01
	Standard	89 ± 4.9	58 ± 5.4	63 ± 3.7	65 ± 3.8	67 ± 4.7	
FEV1 (%)	VATS	88 ± 3.4	64 ± 4.5	67 ± 0.9	72 ± 6	72 ± 4.9	<0.001
	Standard	86 ± 6.3	60 ± 5	64 ± 3.6	68 ± 3.9	67 ± 3.5	
		ppoFEV1 (%)					
Delta FVC	VATS	74.5 ± 4.5	−9.6 ± 5.3	−7.1 ± 3.6	−2.5 ± 3.8	−1.4 ± 1.8	0.009
	Standard	72 ± 2.3	−12 ± 4.5	−9 ± 3.4	−5.8 ± 2.8	−4.1 ± 2.7	
Delta FEV1	VATS	74.1 ± 3.7	−8.6 ± 6	−6.2 ± 4	−2.1 ± 3.6	−1.3 ± 0.3	0.01
	Standard	72.5 ± 2.1	−11 ± 3.9	−9 ± 3.3	−5.1 ± 2.8	−3.6 ± 0.4	

FEV1: forced expiratory volume in 1 s; FVC: forced vital capacity; VATS: video-assisted thoracic surgery; POHs: postoperative hours; POM: postoperative month; ppo: predictive postoperative.

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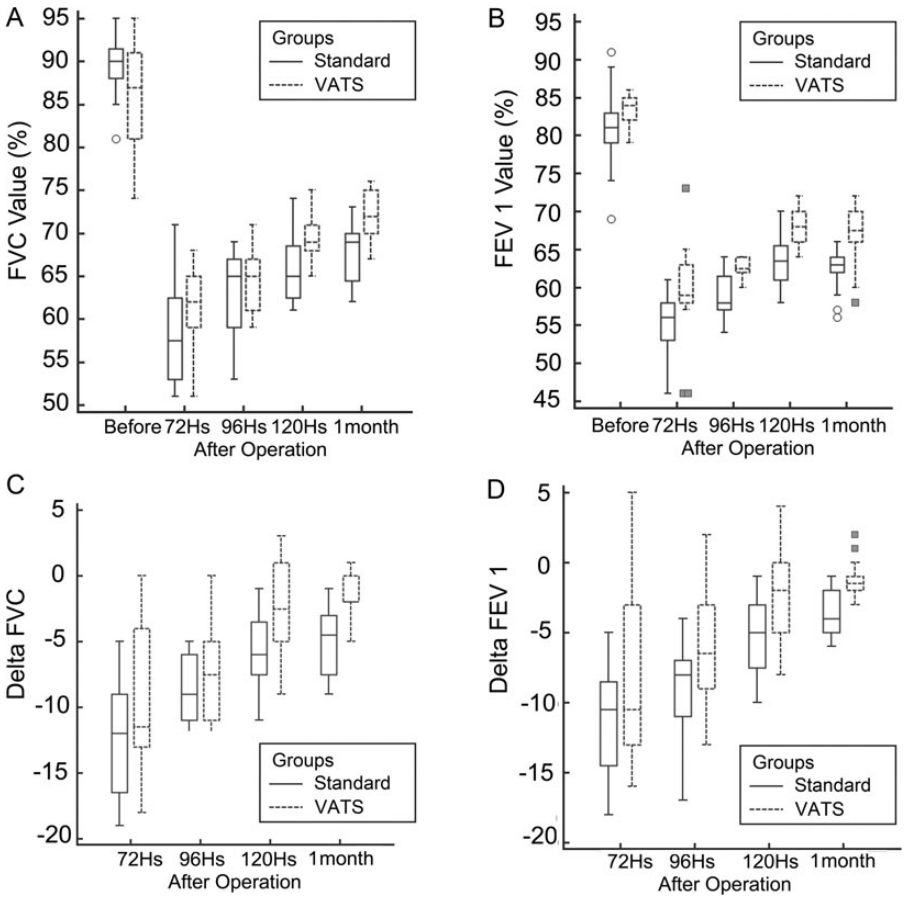

Figure 4: In the VATS group, better values of FVC ($P = 0.01$; **A**) and FEV1 ($P < 0.001$; **B**) were seen compared with the standard group. Yet, the comparison of Delta FEV1 and Delta FVC between the groups showed that the loss of FVC ($P = 0.009$; **C**) and FEV1 ($P = 0.01$; **D**) was significantly less in the VATS group than in the standard group. FEV1: forced expiratory volume in 1 s; FVC: forced vital capacity; VATS: video-assisted thoracic surgery.

± 4.3). The difference between the 2 study groups was statistically significant with a *P*-value of 0.01. After 48 POHs, only 1 patient in the standard group required a supplementary dose of morphine. Compared with the standard group, the VATS group showed a reduction in Ketorolac consumption on postoperative day 1 (10.6 mg ± 7.5 vs 15 mg ± 7.7); 2 (9.3 mg ± 5.7 vs 12.1 mg ± 5.9); 3 (11.2 mg ± 6.1 vs 13.1 mg ± 6.5); 4 (7.7 mg ± 5 vs 13 mg ± 5.1); and 5 (3.3 mg ± 2.3 mg vs 9.6 ± 3.1). The repeated measures ANOVA in the two study groups showed a *P*-value of 0.02.

Survival

The median survival for all patients was 15 months. The 3-year survival rate was 31% ($n = 7$), the 5-year survival rate was 16% ($n = 4$) and the 10-year survival rate was 5% ($n = 1$) (Fig. 5A).

We analysed the effect of the extent of the disease on survival as reflected by the The TNM staging system. Regarding the tumour extension, only 3/34 (9%) patients had a classification of T4, with a median survival of 13 months. Two of these patients had an R1 resection and presented with a local recurrence 5 and 13 months after the procedure, respectively. Another T4 patient with a R0 resection presented with a local recurrence 14 months following the procedure. Of the patients with lymph node involvement, 19/34 (56%) had N0 or N1 disease, and 15/34 (46%) had N2 mediastinal involvement. N0 or N1 were combined as N0 for survival analysis, because of the small number of N1 cases ($n = 2$). The median survival of patients with N0/N1 disease was 47 vs 9 months for N2 patients, with a significant difference [hazard ratio: 2.5; 95% confidence interval (CI): 1.07–6.02; $P = 0.009$] (Fig. 5B). Distant metastasis was observed in 32% of patients (11/34), whereas local recurrence occurred in 12% (4/34). However, considering the shorter follow-up of the VATS group compared with that of the standard group, we evaluated only the 1-year and 2-year recurrence when comparing the two groups (Table 3). Only 1 local recurrence in the standard group was observed 1 year after the operation, whereas 2 local recurrences, 1 in the VATS and another in the standard group, were registered 2 years after the operation ($P = 1.0$). Finally, 9/34 (26%) extrathoracic metastases were found for 2 years following the procedure: 4 (22%) in the VATS group (2 brain, 1 liver and 1 bone metastases) and 5 (31%) in the standard group (3 brain, 1 bone and 1 kidney metastases) with no significant difference ($P = 0.8$).

DISCUSSION

Surgical treatment of Pancoast tumour is a challenging procedure because of the invasion of adjacent structures, such as brachial plexus, subclavian vessels and spine. Over the years, different strategies have been proposed. The surgical standard approach is a radical *en bloc* resection through extended posterolateral

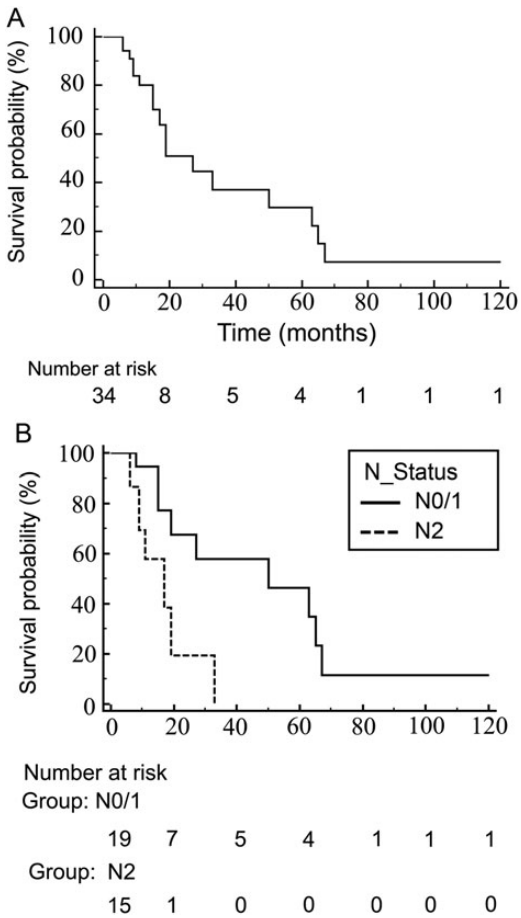

Figure 5: The median survival for all patients was 15 months. The 3-year survival rate was 31%, the 5-year survival rate was 16% and the 10-year survival rate was 5% (**A**); the median survival of patients with N0/N1 disease was 47 months vs 9 months of N2 patients with a significant difference (hazard ratio: 2.5; 95% confidence interval: 1.07–6.02; $P = 0.009$; **B**).

Table 3: Recurrence of study population

Recurrence	VATS group ($n = 18$)	Standard group ($n = 16$)	P-value
1 year			
Local	–	1 (6%)	
Distant	–	–	0.9
2 years			
Local	1	1	1.0
Distant	4 (22%)	5 (31%)	0.8

VATS: video-assisted thoracic surgery.

thoracotomy as described by Shaw *et al.* [6]. With tumours invading the anterior aspects of the first rib or subclavian artery or vein, an anterior approach is helpful. A new anterior approach was proposed by Dartevelle *et al.* [7] using an anterior cervicothoracic approach with an L-shaped incision paralleling the anterior border of the sternocleidomastoid muscle down the midline to the level of the second or third ribs, extending laterally to the deltopectoral groove. The medial clavicle is resected. Grunenwald and Spaggiari [8] then described a clavicle-sparing modification of the anterior approach involving detachment and elevation of the clavicle with an attached portion of sternum to gain access to the first rib and thoracic inlet. The disadvantage of such a technique is the associated morbidity because the operation must be completed with posterolateral thoracotomy to perform the upper lobe lobectomy. The use of VATS in the treatment of Pancoast tumours has been reported in sporadic case reports or small case series. Vallières *et al.* [9] first reported the possible use of thoracoscopy for the staging and assessment of Pancoast tumour candidates for surgery. Other authors [10 11 12 13] reported the resection of Pancoast tumours through the transmanubrial approach of Grunenwald and Spaggiari [8] combined with VATS lobectomy. Recently, we published our positive experience in the treatment of a consecutive series of 10 patients with Pancoast tumours undergoing resection using the VATS approach. It is well known that VATS versus standard lobectomy reduces pain and surgical trauma, and results in less bleeding, earlier functional recovery and a shorter hospital stay with associated cost savings [14]. However, until now, no study has evaluated whether such data can be extrapolated to the treatment of Pancoast tumours.

The results of our study supported the general idea that the VATS approach causes less pain and reduces morbidity in Pancoast surgery. In fact, the VATS group had a lower VAS score compared with the standard group at each time point during the postoperative course and 1 month after the procedure. It is well known that thoracotomy incisions are prone to the development of acute and chronic postoperative pain because of the possibility of direct inter-costal nerve and rib injury from the spreading of the interspace by the thoracic retraction. Given that, in both groups, a chest-wall resection was performed with direct nerve injury and rib fracture, other factors should be taken into account to explain our results.

Whereas the length of skin incision in the VATS group was generally 8–15 cm, that of the standard group was 30–40 cm. Thus, we believe that this comparatively big difference in incision length between the two approaches caused significant differences in chest pain and pulmonary function. Additional crucial factors resulting in a lower level of postoperative pain in the VATS group include the reduced rib spreading and the preservation of latissimus dorsi that was always resected in the standard group. The division of the bulky lateral thoracic musculature following thoracotomy is a well-known factor associated with increasing postoperative pain and significant acute and chronic disability. Nomori *et al.* [15] reported that pain scores between 1 week and 6 months after surgery were significantly lower after anterior limiting thoracotomy than after a standard posterolateral procedure and that VATS resulted in a further lowering of the pain score for 1 week following surgery [16]. In theory, such evidence may be more evident in the management of Pancoast tumours that require larger incisions compared with other types of resection, i.e. lobectomy alone.

The clinical implication of less pain observed in the VATS group helped the earlier recovery of pulmonary function compared with the standard group. The decline in spirometric results was more evident in the standard than in the VATS group. In the VATS group, FVC and FEV1 results decreased from 85 and 88% (preoperative results) to 61 and 64% (at 72 POHs), respectively, whereas in the standard group, FEV1 and FVC results decreased from 88 and 86% (preoperative results) to 58 and 60% (at 72 POHs), respectively. During the subsequent postoperative hours up to the first month after the procedure, FVC and FEV1 increased progressively in both groups but the improvement was more evident in the VATS than

in the standard group. Although the two groups were well matched, the respiratory function percentage after resection may be affected by several factors, including the size of wedge resection, the laterality of upper lobectomy and the size of the tumour that had occupied the upper lobe, rather than because of the surgical approach alone. Thus, we also evaluated the changes in postoperative respiratory functions between the 2 groups with respect to ppo values and found that that the loss of FVC ($P = 0.004$) and of FEV1 ($P = 0.01$) was significantly less in the VATS group than in the standard group. Pulmonary function has been reported to remain unchanged or even improve after lobectomy in patients with chronic obstructive pulmonary disease (COPD). However, the percentage of patients with COPD is similarly low in both groups and, thus, the VATS approach was the principal driver of respiratory benefit observed in the VATS group. The better impact of VATS compared with standard approach on respiratory function especially in patients with poor respiratory function undergoing lung resection has been recently reported in several papers. Berry *et al.* [17] and Kachare *et al.* [18] found that a low preoperative pulmonary function was a significant risk factor for respiratory complications in patients undergoing open lung resection but not in patients who received thoracoscopic resection. Traibi *et al.* [19] found fewer complications in thoracoscopy groups undergoing segmentectomy with poor FEV1, whereas more than half of these patients in the thoracotomy group had a complication. A recent review concluded that patients in whom pulmonary function was poor had perioperative outcomes similar to the outcomes of those with normal pulmonary function when a VATS approach to resection was adopted [20]. In theory, the surgical trauma resulting from traditional thoracotomy prevents the most aggressive physiotherapy and the most cooperation for achieving optimum respiratory care. The depression of respiratory function represents an inability to breathe deeply and cough effectively. This leads to significant alveolar collapse, severe hypoxemia and gross postoperative pulmonary complications [21]. Conversely, the lower trauma resulting from the VATS approach would enable the same patients to tolerate more vigorous physiotherapy and to generate spontaneously more effective cough during the postoperative period, as well as to ambulate in a more liberal manner. In theory, this may explain why patients from the standard group required significantly more frequent bronchoscopic aspiration than the VATS group. The lower pain level of the VATS group also explained the significant difference between the 2 groups in terms of opioid intake over the first 48 POHs and the analgesic intake following surgery.

The median survival of the entire study population was 28 months. The 3-year survival was 45% and 5-year survival was 27%, which is similar to the historical value of 30% reported in the literature [4]. T4 disease ($n = 3$) and incomplete resection ($n = 2$) were adverse prognostic factors with a median survival of 13 months. Although it does not represent a contraindication to surgical resection, Detterbeck *et al.* [22] emphasised that subclavian artery involvement and vertebral body invasion (3 patients from our study groups) were two major negative prognostic factors. Also, the presence of N2 disease was correlated with poor prognosis compared with N0/N1 disease in agreement with other reports. In our series, distant recurrence was the most frequent form of primary relapse with high frequency in the brain; this raises the complex question proposed by other authors of whether patients who have a better prognosis (i.e. major or complete pathological response and complete resection) should be offered prophylactic cranial radiation [4]. However, despite the short follow-up (2 years), no significant difference was found between the VATS and standard procedure groups. Only 1 local recurrence in the standard group was observed 1 year after operation, whereas 2 local recurrences, 1 in the VATS and another in the standard group, were registered 2 years after the operation ($P = 1.0$). In addition, distant metastases were observed in 4 and 5 patients from the VATS and standard groups, respectively ($P = 0.8$). Given that the dimension of the tumor (T status) and the lymph node involvement (N status) were similar between the two groups, this support the impression that VATS presented a similar oncological efficacy compared with the standard technique for resection of Pancoast tumour, as reported previously in other studies that compared VATS versus thoracotomy lobectomy. In the resection of Pancoast tumours, the possibility of having an R0 resection using a VATS approach similar to thoracotomy but with the advantage of lower mortality and morbidity is corroborated by other single-case series. In addition, another merit of the VATS approach is the possibility of evaluating the pleural cavity and avoiding extramorbidity caused by exploratory thoracotomy in cases of unexpected pleural involvement not seen by radiological evaluation [23]. In our study population, 6 patients presented at surgery with a pleural carcinosis not clinically diagnosed and, in 4 cases, exploratory thoracotomy was avoided using VATS.

Finally, proceeding with the VATS approach may reduce postoperative discomfort as reported above, but when inappropriately used, it may result in minimally effective results. Thus, it should be performed by experienced thoracic surgeons who have proper insight into the pathological thoracic process and the expected outcomes from the thoracic surgical intervention.

Study limitations

We are well aware of the limitations of the study: (i) because it was a multicentre study, different surgeons performed surgical resection with inevitable differences; (ii) although no significant differences were seen between the two groups regarding preoperative and postoperative data, the retrospectively nature of the study did not permit random assignment to treatment; (iii) although all patients were eligible for VATS resection, the decision to perform VATS or standard resection may be affected by the surgeon's confidence with the VATS approach; and (iv) the postoperative data were collected by different investigators.

CONCLUSIONS

In the management of Pancoast tumour, our study seemed to confirm the well-known advantages of VATS versus open lobectomy. In fact, in selected cases, the thoracoscopic approach offers a good overview of the superior sulcus, which is helpful in determining the level of thoracic wall resection and avoiding extramorbidity caused by a larger thoracotomy. Another advantage of VATS is the possibility of exploring the pleural cavity and avoiding exploratory thoracotomy in cases of unexpected pleural involvement. However, our data should be corroborated by larger and randomised studies because of the retrospective nature of our study and the small number and the short follow-up of patients enrolled.

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