Sleeve Lobectomy Versus Pneumonectomy for Lung Cancer: A Comparative Analysis of Survival and Sites or Recurrences

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Background. **Sleeve lobectomy (SL) in a lung-saving procedure indicated for central tumors for which the alternative is pneumonectomy (PN). Although it has been suggested that it may provide as good if not better survival results than pneumonectomy in the treatment of lung cancer, there are very few reports of clinical series comparing operative mortality, survival, and sites of recurrences between these procedures.**

Methods. **Survival and sites of recurrences were analyzed and compared in 1,230 consecutive patients who underwent PN (n = 1,046) or SL (n = 184) in a single institution. Sleeve lobectomy was always done when technically possible. Thus PN was reserved for lesions that could not be removed by a bronchoplastic procedure. Pathologic staging was accomplished by nodal sampling except for N2 and selected N1 patients who underwent mediastinal lymphadenectomy. Ultimately, all patients were staged according to the 1997 TNM nomenclature.**

Results. **There were 3 operative deaths of the 184 SL patients (operative mortality of 1.6%) and 55 operative deaths of the 1,046 PN patients (operative mortality of 5.3%, $p = 0.036$). Follow-up was complete for all 1,230 patients. For the entire group, survival at 5 years was 52% after SL and 31% after PN ($p < 0.0001$). These rates for patients with complete resection were 58% for SL and 33% for PN ($p = 0.021$). There was also a significant difference in survival favoring SL for patients with pathologic stage I ($p = 0.018$) and stage II ($p = 0.005$) disease. When recurrences occurred (n = 577), the site of first recurrence was local in 22% of patients with SL and in 35% of patients with PN.**

Conclusions. **Sleeve lobectomy can be done with a much lower risk of operative mortality than PN. Although it is recognized that stage for stage, PN patients likely have more advanced disease, long-term survival and local control are significantly better when complete resection can be achieved by SL.**

(Ann Thorac Surg 2004;77:1152–6)

In April of 1933, Graham and Singer [1] reported the first successful one-stage pneumonectomy for lung cancer (as reviewed in Brewer [2] and Fell [3]). The patient not only survived the operation but he died nearly 30 years after his pneumonectomy of unrelated causes. After this successful operation, pneumonectomy became the standard treatment of lung cancer for the next two decades.

The first reported bronchial sleeve resection was performed in 1947 at the Brompton Hospital in London, England, by Sir Clement Price Thomas [4, 5]. The technique, which involves the resection of a circumferential portion of main bronchus, was designed to conserve as much pulmonary tissue as possible provided that the patient's expectation of prolonged survival was not altered. In the United States, much of the credit has to be given to Paulson and Shaw [6, 7], who promoted throughout the 1950s a philosophy of treatment partly based on conservation of lung function. They were also the first to present credible survival results after bronchoplastic procedures had been done for hilar carcinomas.

Presented at the Thirty-ninth Annual Meeting of The Society of Thoracic Surgeons, San Diego, CA, Jan 31–Feb 2, 2003.

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Currently, sleeve lobectomy has a definite role in the surgical management of lung cancer for patients whose pulmonary reserve is considered inadequate to permit pneumonectomy. Whether sleeve resection is radical enough and indicated for patients who could tolerate pneumonectomy continues to be debated, although many recent reports [8–15] have suggested that sleeve resection can achieve adequate curability rates. Because a literature review only identified a handful of reports [8, 12, 16, 17] that compared the results of sleeve lobectomy to those of pneumonectomy for the treatment of lung cancer, we reviewed 1,230 consecutive patients operated on in our institution and then compared the findings regarding operative mortality, survival, and incidence and patterns of recurrences. The data concerning patients who underwent sleeve resection has been previously reported [13].

Patients and Methods

From January 1972 to December 2000, 1,230 consecutive patients with a clinical diagnosis of non–small-cell lung cancer (NSCLC) underwent sleeve resection (n = 184) [13] or pneumonectomy (n = 1,046) in a single institution. Sleeve lobectomy was considered and performed in any

Published by Elsevier Inc

0003-4975/04/$30.00
doi:10.1016/j.athoracsur.2003.07.040

case that could be completely resected by the technique. These include patients with central tumors located at the origin of a lobar bronchus, patients with positive bronchial margin after standard lobectomy, and patients with N1 disease when both tumor and nodes could be completely resected. Pneumonectomy was only performed for lesions that could not be removed by a lesser bronchoplastic procedure.

Mediastinoscopy was performed in 95% of patients. At operation, pathologic nodal stage was determined by nodal sampling except for N2 and most N1 patients, who underwent mediastinal lymphadenectomy. Ultimately, all patients were staged according to the 1997 revisions in the international system for staging lung cancer [18]. The operative mortality included all deaths related to operation regardless of postoperative interval.

No patient was lost to follow-up, and all are included in the survival analysis. This follow-up information was mainly obtained from hospital charts or direct contact with the patient or his or her relatives. For patients who died, the exact date of death was obtained from the Province of Quebec Health Insurance Plan (RAMQ). Exact causes of late deaths are unknown, although it is safe to assume that most patients who died within 10 years of operation did so because of recurrent disease. Most sites of recurrences were documented through hospital readmission, a locoregional recurrence being defined as any recurrence that occurred within the ipsilateral hemithorax including the mediastinum or neck area. These could be isolated or part of widespread (local and distant) recurrent disease.

Patient survival was analyzed with the date of thoracotomy as the starting point using life-table (actuarial) estimates. Within both groups (sleeve resection and pneumonectomy), survival according to pathologic stage (pTNM), nodal (N) status, side of operation, and completeness of resection was assessed. Incompletely resected patients were defined as those with macroscopic residual tumor, microscopic positive margins, or a positive highest node. Survival rates at 5 years between sleeve lobectomy and pneumonectomy patients were compared using the Wilcoxon test. A p value of less than or equal to 0.05 was considered significant.

Results

Patient Profile

The clinical and pathologic characteristics of the study population are presented in Table 1. No statistical differences were observed between the sleeve lobectomy group and pneumonectomy group regarding age, sex, and completeness of operation. The sleeve lobectomy group consisted of 152 men and 32 women with a mean age of 60 ± 10.0 years (± standard deviation). The pneumonectomy group comprised 827 men and 219 women with a mean age of 60.7 ± 9.4 years.

Among the 184 patients who underwent sleeve resection, 82 (45%) had stage I, and 72 (39%) had stage II disease for a total of 154 patients (84%) with "early stage" carcinomas. This distribution is different from that observed with pneumonectomy in which only 525 patients (51%) had stage I and stage II disease. The same differences can be observed with regards to nodal status for which 165 patients (90%) in the sleeve resection group had N0 or N1 disease as opposed to 696 patients (67%) in the pneumonectomy group. These differences indicate a different pathologic profile with more "early stage" patients undergoing sleeve lobectomy and more "higher or late stage" patients undergoing pneumonectomy.

Table 1. Clinical and Pathologic Characteristics

Variable	Sleeve Lobectomy	Pneumonectomy
Years of study	1972–98	1980–2000
No. cases	184	1,046
Age (y)[a]	60 ± 10.0	60.7 ± 9.4
Men	152 (83%)	827 (79%)
Women	32 (17%)	219 (21%)
Pathologic stage[b]		
I	82 (45%)	164 (16%)
II	72 (39%)	361 (35%)
III	30 (16%)	466 (45%)
p nodal status[b]		
N0	97 (53%)	258 (25%)
N1	68 (37%)	438 (42%)
N2	19 (10%)	311 (30%)
Side of operation		
Right	132 (72%)	482 (46%)
Left	52 (28%)	564 (54%)
Completeness of operation		
Complete	160 (87%)	880 (84%
Incomplete	24 (13%)	155 (15%)

[a] Mean ± standard deviation; [b] Some patients could not be staged or had a completion pneumonectomy for local recurrences.

Operative Risk

The operative mortality for the 184 NSCLC sleeve lobectomies was 1.3% (3 of 184 patients), and all 3 deaths were consecutive to pulmonary complications. Two patients died of pneumonia and the third one died of pulmonary embolism. Of note, there were only 6 complications (2 early, 4 late) related to the bronchial anastomosis.

The operative mortality after pneumonectomy was 5.3% (55 of 1,046 patients) and significantly higher than after sleeve resection ($p = 0.036$). The causes of death were related to respiratory events (pulmonary or bronchial) in 46 of these 55 patients (84%).

Survival Rates

Five-year survival figures and median survival according to patient characteristics are presented in Table 2. The overall 5-year actuarial survival for patients with NSCLC who underwent sleeve lobectomy was 52% whereas the overall survival for those who underwent pneumonectomy was 31%. Statistical comparison shows a significant difference favoring sleeve lobectomy ($p < 0.0001$; Fig 1). This difference in survival remains significant if one only compares patients who had complete resections. In this

Table 2. Survival Results for Patients Included in the Comparative Analysis

Variable	Median Survival (y)	5-year Survival	*p* Value
Overall			
Sleeve	6.0	0.52	<0.0001
Pneumonectomy	2.4	0.31	
Completeness of operation			
Complete resection			
Sleeve	7.5	0.58	0.021
Pneumonectomy	2.63	0.33	
Incomplete resection			
Sleeve	2.2	0.11	NS
Pneumonectomy	1.5	0.18	
Pathologic stage			
Stage I			
Sleeve	10.0	0.66	0.018
Pneumonectomy	5.0	0.50	
Stage II			
Sleeve	5.5	0.50	0.005
Pneumonectomy	3.1	0.34	
Stage III			
Sleeve	3.3	0.19	NS
Pneumonectomy	2.01	0.22	
Pathologic nodal status			
N0			
Sleeve	9.3	0.63	0.001
Pneumonectomy	3.5	0.43	
N1			
Sleeve	5.1	0.48	0.008
Pneumonectomy	2.8	0.30	
N2			
Sleeve	2.4	0.08	NS
Pneumonectomy	1.8	0.21	
Side of operation			
Right			
Sleeve	5.6	0.50	<0.0001
Pneumonectomy	2.3	0.32	
Left			
Sleeve	7.1	0.56	0.001
Pneumonectomy	2.6	0.30	

NS = not significant.

group, actuarial survival after sleeve lobectomy was 58% whereas it was 33% for patients who underwent pneumonectomy ($p = 0.021$; Fig 2).

Survival was compared for each pathologic stage, and there is a significant difference in survival for patients with stage I ($p = 0.018$) and stage II ($p = 0.005$) disease whereas patients with stage III disease had survival after sleeve lobectomy similar to that of the pneumonectomy group.

Among patients with N0 disease, the 5-year survival after sleeve resection and pneumonectomy were 63% and 43%, respectively ($p = 0.001$). By contrast, we could not demonstrate a significant difference in survival for patients with N2 disease, although these results favor sleeve lobectomy.

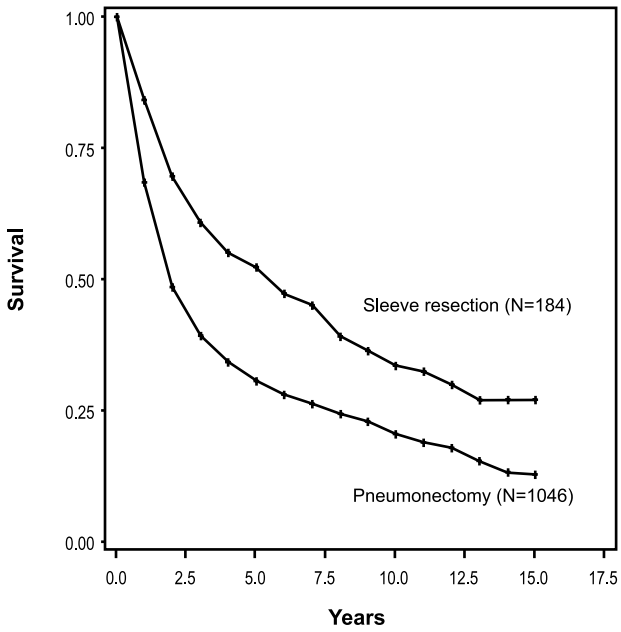

Fig 1. Comparison of survival after sleeve lobectomy and pneumonectomy in all patients whose data were subjected to analysis.

Actuarial survival by side of operation shows that patients who underwent sleeve resection did better whether the operation was performed on the right ($p < 0.0001$) or left ($p = 0.001$) side.

Sites of Recurrences

During follow-up, 577 patients had cancer recurrences. Twenty-two percent of patients with sleeve resection (Table 3) had a locoregional recurrence as the site of first

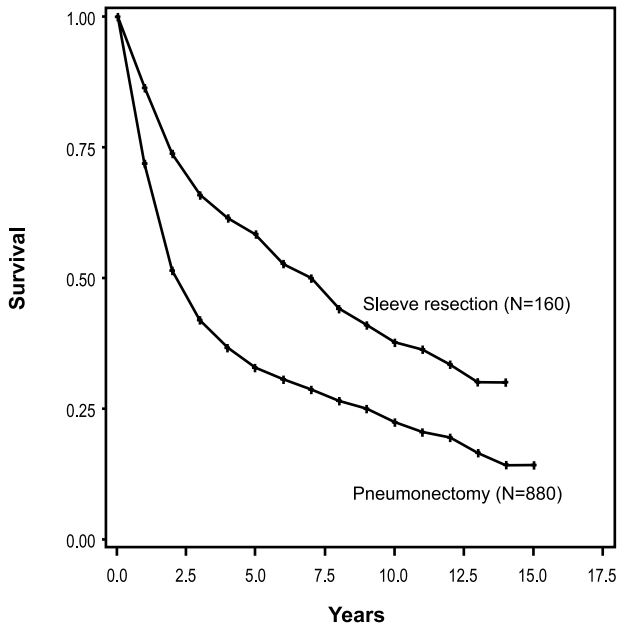

Fig 2. Comparison of survival after sleeve lobectomy and pneumonectomy in patients who had a complete resection.

Table 3. Locoregional Failures

Procedure	Locoregional Recurrences
Sleeve lobectomy	22%
Pneumonectomy	35%

recurrence. This recurrence was either isolated or part of widespread recurrent disease. By contrast, 35% of pneumonectomy patients had locoregional failures.

Comment

Initially, sleeve lobectomy for NSCLC was restricted to patients with compromised lung function who would tolerate a lobectomy, but not pneumonectomy. During the past 20 years, however, there has been an increasing acceptance for the application of sleeve resection as the best elective operation in selected cases of lung cancer patients without compromised lung function and capable of tolerating any extent of resection. In one interesting prospective study, Martin-Ucar and associates [19] showed that the rate of pneumonectomy decreased significantly with increasing experience with parenchymal-sparing surgery. They concluded that pneumonectomy can be avoided in a large proportion of patients with centrally located NSCLC without adversely affecting outcome but with preservation of lung function.

Although many surgeons agree with the statement that sleeve lobectomy should be considered in any case of lung cancer that can be completely resected by this technique, some still are of the opinion that this approach is only applicable to N0 tumors and that pneumonectomy may be a better operation for patients with N1 or N2 disease. The argument in favor of a more extended resection in this setting is that tumor cells may involve peribronchial lymphatics and that in such cases, pneumonectomy may afford better curability rates. There is some evidence, however, that such is not always the case and that N1or N2 disease does not necessarily mandate pneumonectomy when a sleeve lobectomy can achieve complete resection of the neoplasm [20]. In a nonrandomized study, Okada and colleagues [17] paired 60 patients undergoing sleeve lobectomy with 60 patients undergoing pneumonectomy and concluded that sleeve lobectomy should be performed instead of pneumonectomy in patients with NSCLC regardless of the nodal status providing that a complete resection could be achieved. In yet another paper, Okada and coworkers [21] also suggested that extended sleeve lobectomies should even be considered because these lung-saving operations are safer than pneumonectomies and are equally curative.

In this series, the operation-related mortality was significantly lower after sleeve lobectomy (1.6%) than after pneumonectomy (5.3%), indicating that bronchoplasties are safer procedures than pneumonectomies. This is one of the reasons why sleeve resections with or without pulmonary artery angioplasties are considered valid options for patients with locally advanced carcinomas who have had induction therapies [22, 23].

There have been five institutional studies including this one that have compared survival results between sleeve lobectomy and pneumonectomy. All are retrospective because a randomized prospective trial is not possible, not only because of the small number of cases which would be available for study but also because of the definition of eligibility. Although each of these studies has obvious bias related to its retrospective nature, collectively they provide the most reliable information (Table 4). All of them have shown that survival after sleeve resection appears to be no different or is even better than survival after pneumonectomy, provided that a complete resection can be achieved. In all of these series, survival is adversely affected by the nodal status, but this is not considered to be a valid reason to extend the indication for pneumonectomy, again provided that complete resection is possible. In this series, there is no significant difference in survival between sleeve lobectomy and pneumonectomy for patients with N2 or stage III disease, indicating that even in higher stage tumors, a more radical operation such as pneumonectomy is not a more appropriate procedure and does not necessarily lead to better survival figures.

Although the criticism of this study is whether or not the two groups have the same biologic disease and whether we selected for sleeve resection the best cases in terms of local aggressiveness, the results seem to clearly indicate that sleeve lobectomy is preferable to pneumonectomy, both in terms of survival and local control, in patients with stages I and II (N0 and N1 cases) disease.

One of the keys to the use of these operations is the surgeon's ability to determine intraoperatively whether a complete and potentially curative resection is possible with a bronchoplastic procedure. Frozen-section evaluation of resection margins is therefore a critical feature of

Table 4. Comparison of Survival Between Sleeve Lobectomy and Pneumonectomy

Authors	Year of Publication	No Patients	5-year Survival	
			Sleeve Lobectomy	Pneumonectomy
Gaissert, et al. [8]	1996	128	42% (n = 72)	44% (n = 56)
Yoshino, et al. [16]	1997	58	65.7% (n = 29)[a]	58.8% (n = 29)[a]
Suen, et al. [12]	1999	200	37.5% (n = 58)	35.8% (n = 142)
Okada, et al. [17]	2000	120	48% (n = 60)	28% (n = 60)
Current study	2004	1,230	52% (n = 184)	31% (n = 1,046)

[a] These are 3-year survival figures.

the operation. In this series, the difference in survival at 5 years between sleeve resection and pneumonectomy when complete resection was achieved was very significant ($p < 0.0001$).

In summary, our analysis demonstrates that sleeve resection is effective and can be accomplished safely in selected patients with resectable NSCLC. The survival after sleeve resection appears to be better than survival after pneumonectomy provided complete resection can be achieved.

We thank the Régie Assurance-Maladie du Québec (RAMQ) for providing the exact dates of death of patients who died.

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DISCUSSION

DR NASSER ALTORKI (New York, NY): Dr Deslauriers, I want to congratulate you. This is a stellar series, and I think the morbidities and the mortalities that you have shown could become the new benchmark for both of those procedures and specifically as it relates to the technique of doing the bronchial anastomosis. I wish you would elaborate on that a little bit. But my other question is, in stages I and II you have shown that pneumonectomy has a worse outcome than sleeve lobectomy. One presumes that from an oncologic point of view, one encompasses the disease with both operations. So can you elaborate a little bit on the causes of death in the pneumonectomy group—are they cancer-specific or noncancer-related causes? Thank you.

DR DESLAURIERS: I don't know the exact answer to this question. Ever since we began to perform sleeve resections, we have done them whenever it was technically possible. We are always reluctant to do a pneumonectomy and when it is done, it usually is for bigger tumors or more invasive tumors. Ideally, survival should be similar if the cases were evenly matched because tumor clearance is the same for both operations. The majority of patients who die after pneumonectomy (or after sleeve resection) do so because of recurrent disease usually at distant sites. The interesting finding in this study is that several of them also had locoregional failures. This relatively high incidence of local recurrences is likely due to the fact that when a patient presents with recurrent cancer, we always do a complete restaging and our definiton of locoregional failure includes all patients with recurrences within the ipsilateral hemithorax and neck.

DR WICKII VIGNESWARAN (Maywood, IL): Dr Deslauriers, thank you very much for this excellent series. Do you have any vascular sleeve resections included in this series?

DR DESLAURIERS: We don't have many of them. We recently became interested by this operation after becoming familiar with Dr Enrino Rendina's work in Italy. Pulmonary artery sleeve operations are now done whenever possible. In the current series of 184 patients, there are no cases of double sleeve resection although some patients had tangential resection of the main pulmonary artery. These procedures are excellent and for more information, I strongly recommend that everybody reads the papers from Dr Rendina.