Tracheal sleeve pneumonectomy for bronchogenic carcinoma

For a long time, primary tumors arising less than 2 cm distal to the carina have presented a contraindication to surgical excision. Tracheal sleeve pneumonectomy technique allows carinal resection and reconstruction but still carries considerable postoperative complications. From 1983 to 1992 we performed 27 right tracheal sleeve pneumonectomies and one left. Fourteen patients had N0 nodes, nine had N1, and five had N2. No anastomotic complications, either fistula or stenosis, were observed. Successful outcome depends on meticulous attention to surgical details and careful anaesthetic management with a new ventilation tube. One patient died on the twenty-second postoperative day from myocardial infarction. Complications included pneumonia (one), vocal cord paresis (two), and pleural empyema without bronchial fistula (one). Conservative treatment allowed complete recovery from all complications. There are seven patients alive at 4 years after operation and one at 5 years. Six patients have been disease-free for between 1 and 32 months. Two patients died free of disease at 13 and 42 months. Two patients died of mediastinal recurrence and 10 of distant metastases within 6 and 54 months. (*J THORAC CARDIOVASC SURG* 1994;107:13-8)

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Tracheal sleeve pneumonectomy (TSP) was first performed by Gibbon¹ in 1959 to overcome the technical limitations of resection in the case of tumors originating from the carina and tracheobronchial angle. Other sporadic attempts were carried out by various surgeons with different techniques and reported in literature during the following years.²⁻⁵ Only in 1972 did Jensik and associates⁶ publish the first important series: 17 cases were reported, with two operative deaths and 10 patients dying within 1 year. Other famous surgeons have since presented their results, but always with a high mortality rate.⁷⁻¹³ These reports cover approximately 20 years of experience.^{7, 10, 12, 14-17}

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During this relatively long period, important progress in anesthetic techniques, suture materials, drugs, and other areas led to a change in the guidelines for the treatment of stage III lung cancer. For this reason, most available series of TSP procedures are not homogeneous, and their interpretation is therefore often difficult. The high mortality rate, however, is universal (8% to 29%).^{6-13, 17-20} The progress of ventilation techniques in anesthesia has allowed acceptance of TSP, which nevertheless is still only carried out in highly qualified centers for thoracic surgery.

Our experience began in 1983. In this 9-year period, 28 TSPs were performed by our team with a well-standardized technique. A method of ventilation devised by us and a particular care for surgical technique have enabled us to achieve highly satisfactory results. One patient died of myocardial infarction on the twenty-second postoperative day and no anastomotic complications (stenosis or fistula) occurred.

Patients and methods

From 1983 to 1992, we observed 736 patients affected by lung carcinoma. Of 443 patients submitted for resection of bronchial carcinoma, 118 underwent pneumonectomy. During this same period, we observed 56 patients with non-small-cell lung

Table I. *Survival status after TSP*

<i>Patient</i>	<i>Age (yr)</i>	<i>Nodes</i>	<i>Recurrence</i>	<i>Distant metastases</i>	<i>Postoperative death (mo)</i>	<i>Alive at follow-up (mo)</i>
1	70	0	Yes	No	17	—
2	70	0	No	No	—	13
3	61	0	No	No	—	19
4	56	1	No	Yes	27	—
5	63	0	Yes	No	22	—
6	57	0	No	No	—	49
7	34	1	No	Yes	18	—
8	64	0	No	No	—	22
9	59	1	No	Yes	16	—
10	55	0	No	No	—	32
11	62	2	No	No	22 days	—
12	68	0	No	No	—	64
13	69	2	No	No	42	—
14	67	0	No	No	—	1
15	59	1	No	Yes	38	—
16	53	1	No	Yes	8	—
17	53	2	No	Yes	6	—
18	60	1	No	Yes	32	—
19	70	0	No	No	—	2
20	57	1	No	Yes	54	—
21	50	2	No	Yes	18	—
22	57	2	No	No	13	—
23	64	1	No	Yes	42	—
24	61	0	No	No	—	51
25	65	0	No	No	—	49
26	58	0	No	No	—	52
27	67	0	No	No	—	48
28*	42	1	No	No	—	48

*Left TSP. All others were right TSP.

cancer arising less than 2 cm distal to the carina or invading the tracheobronchial angle. Twenty-two patients were declared not to be candidates for operation on the basis of preoperative staging (by computed tomography, bone scintigraphy, bronchoscopy). Of these, eight patients had extracapsular subcarinal lymphadenopathy, eight patients had mediastinal great vessel involvement, and six patients had distant metastases. The remaining 34 patients underwent operation. In six of these, the operation was limited to an explorative thoracotomy because of caval invasion (three patients) or pleural spreading without pleural effusion (three patients). Twenty-seven patients underwent a right TSP and one patient underwent a left TSP. Histologic examination revealed 20 epidermoid carcinomas, six adenocarcinomas, one large cell carcinoma, and one adenoid cystic carcinoma. According to the 1987 American Joint Committee on Cancer Staging TNM classification there were 14 T3 N0, nine T3 N1, and five T3 N2 cases. Fourteen patients received a preoperative radiotherapy protocol consisting of 10 treatments of 30 Gy each. One patient had preoperative chemotherapy. Another patient had preoperative radiotherapy and chemotherapy both. Ten patients did not receive any preoperative treatment.

Technique. To date, operation has always been performed with the same surgical technique. However, we have adopted different techniques of ventilation. Our search for effective ventilation ultimately resulted in a standardized method of our own conception, which we used successfully in the last 21 interven-

tions. In our first three cases, we used the ventilation technique described by Grillo¹⁷ in 1982: the left bronchus was intubated from the operative field with a normal cuffed tube, which was removed during positioning of the stitches and then replaced. High-frequency jet ventilation was used in the next four cases.

Since 1987, we have adopted a ventilation tube, developed by one of the authors (E.S.) and produced by Bivona Inc. (Gary, Ind.) the Sibilla Fome-Cuf tube (Fig. 1). This is a 45 cm silicone reinforced tube, with a thin caliber (ranging from 5 to 6.5 mm) and a small cuff of self-inflating material (polyurethane foam) located 1.5 cm from the tip. This tube greatly facilitates all maneuvers.

General anesthesia is induced and the patient is intubated with a double-lumen Carlens tube and subjected to mechanical ventilation by semiclosed circuit with 60% nitrous oxide, 40% oxygen, and enflurane. The operation begins with a posterolateral incision. Once the chest is open and operability has been ascertained, the distal trachea and carina are mobilized and encircled with a band. Two traction threads are placed, on the trachea and on the left main bronchus, and the anterior aspect of the trachea is delicately isolated for a distance of 4 to 5 cm by gentle, blunt dissection. The left main bronchus is severed at the second bronchial ring, intubated, and transiently ventilated from the operative field with a 6 mm Portex tube (Concord/Portex, Keene, N.H.). Pneumonectomy and resection of the carina are then performed. A stiff lead is inserted from the operative field through the Carlens tube, which is temporarily

Fig. 1. Carlens tube (*top*) and Sibilla tube (*bottom*) are shown.

withdrawn into the trachea. This allows the anaesthetist to remove the Carlens tube and replace it without undue difficulty with the Sibilla tube, which can easily be positioned definitively in the left main bronchus by the surgeon after the normal cuffed tube previously inserted from the operative field has been removed. The small caliber of this tube allows the performance of the anastomosis with great ease (Fig. 2).

Anastomosis is performed by placing interrupted stitches knotted on the outer side of the bronchus. We use 3-0 polyglactin intertwined thread. All the stitches are positioned about 2 mm apart on the bronchus and 3 mm apart on the trachea, commencing first from the deeper ones, which are the most difficult. To avoid tangling the threads, every stitch is held by a Halsted mosquito forceps and kept separated from the others by a gauze sheet; six or eight of the sheets are grouped together with a Kocher forceps. After the traction threads are tied, the stitches are tied, again starting from the deeper end. When the suture is completed, the ventilation tube is withdrawn above the anastomosis so that a hydropneumatic test can be carried out. No further maneuvers for mobilizing the hilum are usually necessary, and the operation is concluded.

Mean operative time is 150 minutes. During the procedure, blood losses have never been more than 350 ml. During anastomosis, single-lung ventilation pressure ranges between 20 and 25 mm Hg with an oxygen tension of 80%. Tidal volume ranges between 550 and 650 ml (according to the weight of the patient), with a mean rate depending on arterial oxygen saturation and carbon dioxide tension. During intervention, 1500 ml of fluids is administered. Halfway through the procedure, 1.5 mg betamethasone and 20 mg furosemide are administered (the latter regardless of blood pressure variations). Both doses can be repeated at the end of the operation. One hour before the end of the procedure, pain-relief therapy is started through intravenous administration of indomethacin; it is continued after the operation with high-dose diclofenac.

The patient is usually extubated in the operating room after bronchoscopic control of anastomoses and vocal chord mobility. During the postoperative course, the patient's cervical spine is kept in normal position without flexion of the neck. No anastomotic tension problem has occurred to date. On the first postoperative day, the patient is given 1500 ml of fluids. Oral feeding is resumed on the second postoperative day.

Results

Fourteen patients are alive and well 1 to 64 months after operation. Two patients died of mediastinal recur-

rence and 10 died of distant metastases within 6 and 54 months after operation. Two patients died free of disease: one of myocardial infarction and the other in a car accident, 42 and 13 months after operation, respectively (Table I).

We recorded few perioperative complications. One patient died of myocardial infarction on the twenty-second postoperative day. Two patients had postoperative dysphonia from unilateral recurrent laryngeal nerve paresis after extensive mediastinal lymphadenectomy, which resolved in 4 months. One patient had a pleural empyema without bronchial fistula 30 days after intervention and received conservative treatment. We saw no anastomotic complications such as fistula or stenosis.

The patient who underwent left TSP showed severe dyspnea on the second postoperative day as a result of the simultaneous double posterolateral thoracotomy; this complication resolved with assisted ventilation. In this specific case, we had opted for a simultaneous double posterolateral thoracotomy, not only because of the inherent difficulty in performing anastomosis through a left thoracotomy but also because a large azygos lobe and firm adhesions to the parietal and diaphragmatic pleura prevented mobilization of the main bronchus and carina. We therefore first carried out pneumonectomy and temporary suture of the bronchial stump on malignant tissue through a left thoracotomy, followed immediately by a right thoracotomy through which we completed the resection of the carina and the anastomosis.^{7, 8, 12, 17, 20} This was done with great difficulty because of the simultaneous ventilation of the right lung.

Discussion

The TSP is the treatment of choice for non-small-cell lung carcinoma invading the main bronchus or arising less than 2 cm distal to the carina, but this intervention has only recently come within the bounds of the thoracic surgeon's capabilities. The differences in surgical techniques, selection of indications, and treatments do not permit

Fig. 2. Pneumonectomy has already been performed. All stitches are passed while left main bronchus is intubated with Sibilla ventilation tube. *BR*, Bronchus.

comparisons among the most important series, which span more than 20 years.^{7-16, 18, 19, 21} It must be added that the generally scanty number of patients does not permit a statistical evaluation. Some aspects of TSP are thus still debatable today. These points of discussion are chiefly concerned with the indications because the peri-operative mortality rates reported in the literature remain high.

We now subject to right TSP all "non-small-cell" lung carcinomas invading the main bronchus or arising at less than 2 cm distal to the carina or at the tracheobronchial angle, and which extend no more than three cartilaginous rings on the distal tracheal wall. We do not consider 70 years as an age limit (one patient in our series was 71 years old).²² The presence of intracapsular mediastinal lymph-

adenopathy does not represent a contraindication, just as it does not for conventional pneumonectomy.^{19, 23-26} On the contrary extracapsular lymph node invasion contraindicates surgical exeresis. Functional criteria for selection of patients are basically the same as for conventional pneumonectomy and also include Arnaud's test of bronchial exclusion, which has always given us excellent results.

In agreement with other authors we adopted preoperative radiotherapy to reduce tumor size, so as to facilitate the anastomotic procedure.¹⁰ We chose the low-dosage protocol introduced by Paulson and colleagues,²⁷ as we have modified it. In our experience, the low-dosage radiotherapy has given good results without complications, such as the postanastomotic fistulas reported by

other authors.^{6, 7, 10, 13} We still use this protocol, reserving it for the larger neoplasms that might be expected to benefit most from this integrated radiotherapeutic and surgical treatment. The confidence acquired with this anastomotic technique has led us to perform carinal resections successfully, even as emergency treatment for an early bronchial fistula that occurred 2 days after pneumonectomy for cancer in a patient who had already undergone a right upper lobectomy 5 years previously.

One of the main technical problems concerning tracheobronchial anastomoses is caused by the ventilation technique used. The one used at the beginning of our series proved to be slow and cumbersome. The need to continuously remove and reposition the tube interrupts the surgeon's action and exposes the remaining lung to the dangers of contamination and blood inhalation. Jet ventilation allows good oxygenation of the patient and gives the advantage of lessened mediastinal movement from reduced ventilatory excursions. Moreover, the slenderness of the tube allows greater ease in maneuvers. If used for too long, however, jet ventilation may cause carbon dioxide accumulation, and the absence of an airtight cuff may permit blood inhalation.^{28, 29}

On the other hand, the Sibilla Fome-Cuf tube has many advantages. Its length allows orotracheobronchial intubation, thus eliminating the need for a tube encumbering the operative field; its slenderness and totally intraluminal position permit great ease in carrying out anastomoses; the armor allows it to be shifted without hindering air flow and the foam cuff will not leak even if accidentally pierced; moreover, the cuff's position close to the tip prevents it from slipping into a lobar bronchus and excluding part of the lung parenchyma from ventilation. Mathisen and Grillo²¹ also recently described the use of a similar extralong tube, positioned in the trachea at the beginning of the operation and later reaching a main bronchus from the patient's mouth.

In all our cases, the anastomosis was done with polyglactin intertwined stitches knotted on the outer side. This technique may appear complex at first because of the numerous threads to control. We believe, however, that it allows an even distribution of the tension along the edge of the anastomosis (Fig. 3).

Indications for left TSP remain exceptional and limited to young patients with low malignancy disease and thus with a good chance of survival. The main difficulties concerning left TSP are caused by presence of the aortic arch, which hinders access to the carina.^{17, 18, 30} Resection of the first intercostal arterial branches does not always permit a sufficient mobilization of the aortic arch to allow good control and maneuverability of the operative field. Right TSP remains a rarely performed intervention and

Fig. 3. Stratigraphy, 1 month after operation, proves excellent caliber of anastomosis.

is always done with a variety of techniques. Because of the limited number of patients our series has not yet been subjected to any statistical evaluation.

Nevertheless, the prognosis of patients who undergo right TSP appears comparable to that of patients at the same stage of disease who undergo pneumonectomy; patients bearing N2 positive lymph nodes die within 42 months. This apparently confirms the prognostic gravity even for patients staged T3. The decision to extend our surgical indications was justified by the few complications observed.

Conclusion

The number of patients who have undergone TSP, as in all other series, does not allow definite evaluation, particularly concerning long-term prognosis. It is possible, however, to discern important considerations regarding the operative techniques. The anastomotic technique we have applied has resulted in no operative deaths and an extremely small number of postoperative complications.

The Sibilla ventilation tube greatly facilitates the procedure, and the interrupted sutures guarantee good anastomotic repair. The confidence acquired with this kind of intervention has allowed us to select for TSP patients with the indications for pneumonectomy and to carry out this operation with little inconvenience even in emergency situations. The great technical difficulties that characterize left TSP narrows its application to patients with long-term survival possibilities.

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