CURRENT ROLE OF BRONCHOPLASTIC PROCEDURE FOR LUNG CANCER

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Abstract

The indication for a sleeve resection is well established: a tumor arising at the origin of a lobar bronchus but not infiltrating as far as to require pneumonectomy. In addition, a sleeve resection may be indicated when N1 nodes infiltrate the bronchus from the outside, as is often the case in the left upper lobe tumors. From a functional point of view, sleeve lobectomy is strictly indicated in patients who cannot withstand pneumonectomy, but recent experiences have shown that the advantages of sparing lung parenchyma are evident also in patients without cardio-pulmonary impairment. Most studies show similar or better survival results for parenchymal sparing resections if compared with pneumonectomy. Moreover, in the analysis of 5-year survival according to stage, sleeve lobectomy results in higher survival rates for stage I, II. The survival advantage in stage III appears to be limited and the benefit is not always confirmed for stage III-N2 patients. Postoperative morbidity and mortality data reveal overall better results for patients undergoing sleeve lobectomy with respect to pneumonectomy. The preservation of lung parenchyma has been indicated by some authors as the possible cause of a theoretical increased risk for locoregional recurrence after sleeve lobectomy. However, although in some experiences a higher local recurrence rate is reported for sleeve resection with advanced nodal status (N2), the few studies analysing risk factors for recurrence, show that the tumor stage and the nodal status are the only negative predictive factors, rather than the type of operation performed.

Key words: Sleeve lobectomy, pneumonectomy, lung cancer

INTRODUCTION

The indication for a sleeve resection for lung cancer is well established: a tumor arising at the origin of a lobar bronchus and/or at the origin of the lobar branches of the pulmonary artery (PA), but not infiltrating as far as to require pneumonectomy (PN). In addition, a sleeve resection may be indicated when N1 nodes infiltrate the bronchus from the outside, as is often the case in the left upper lobe tumors requiring a combined reconstruction of the bronchus and the PA. From a functional point of view, sleeve lobectomy (SL) is strictly indicated in patients who cannot withstand pneumonectomy, but recent experiences have shown that the advantages of sparing lung parenchyma are evident even in patients without cardio-pulmonary impairment (1-7). Oncologically, the primary goal is in every case the complete resection of the tumor with free resection margins. The decision to perform PN or SL is based on both oncologic and physiological considerations. Many authors believe that PN, especially right PN, is a disease itself, with severe impairment of lung function and quality of life after surgery, and therefore the latter intervention should be avoided whenever possible.

The first bronchial sleeve resection was performed in 1947 for a carcinoid tumor (8), while the first SL for lung cancer was reported by Allison in 1954 (9). Since then, significant technical advances and increasing experience over time have allowed achievement of excellent clinical and oncologic results, giving wide diffusion to this procedure.

TECHNIQUE

Bronchial sleeve resections and reconstructions are currently performed through standard posterolateral incisions and lateral muscle-sparing incisions, which are both satisfactory for exposure and dissection.

Hereby we report our standard technique. On both the right and left side we begin our dissection in the anterior hilum and completely dissect out the main pulmonary artery. If there is bulky disease causing increased difficulty during dissection, the pericardium can be opened on either side in order to obtain improved proximal control. Next, the main PA is encircled with an umbilical tape. The remaining steps are specific to the type of sleeve resection performed and each will be described independently in the following paragraphs.

RIGHT-SIDED RESECTIONS

Right Upper Sleeve Lobectomy

After proximal arterial control has been obtained, dissection is performed superiorly at the level of the right upper lobe bronchus. The lung is retracted anteriorly, and dissection is continued in the bifurcation between the right upper lobe bronchus and the bronchus intermedius. A "crotch" lymph node is a frequent finding in this location. This node is elevated away from the bifurcation in order to expose the pulmonary arterial branch to the posterior segment of the right lower lobe. Once this branch is identified, the posterior portion of the fissure is completed with a linear stapler. This approach avoids extensive parenchymal dissection in the fissure. The bronchus intermedius is encircled just distal to the right upper lobe take-off, and an umbilical tape is placed to aid the airway division at the appropriate site.

Once complete resectability is confirmed, ligation and division of the pulmonary arterial branches to the right upper lobe are performed. Similarly, the pulmonary vein branch draining the upper lobe is divided with a vascular stapler taking care to preserve the middle lobe venous drainage. The minor fissure is completed with a linear stapler. The mainstem bronchus is encircled at its origin by an umbilical tape.

The bronchial resection phase is then started. The mainstem bronchus is divided just proximal to the right upper lobe take-off. Once the bronchus has been opened the decision to proceed with a sleeve resection may be made, based on macroscopic or microscopic findings. Subsequently, the bronchus intermedius is divided just distal to the right upper lobe take-off. These cuts must be perpendicular to the long axis of the airway. A frozen-section examination on bronchial resection margins is then performed in order to confirm the radicality of resection. Microscopic tumor found at a bronchial margin requires additional resection of the involved area or possibly pneumonectomy.

Different techniques have been described for bronchial anastomotic reconstruction. The present authors favour the use of interrupted sutures of 4/0 monofilament absorbable material (1, 10). However, the employment of continuous running suture (complete or partial) has been described by others (11, 12).

According to our technique, the first suture is placed in an "outside-to-in" fashion at the junction of the cartilaginous and membranous bronchi. These initial sutures can be immediately tied in order to confer improved stability to this point of the anastomosis. Additional sutures are placed at 2 mm intervals to complete the first half of the cartilaginous anastomosis. Once the midpoint of the cartilaginous bronchus is reached, the anastomosis is then completed on the opposite side of the bronchial circumference in a similar fashion. Sutures are then tied, starting from the either end of the cartilaginous portion and working toward the middle. Placing and tying the sutures in this order allows compensation for even large caliber discrepancies. This technique prevents torsion of the bronchial axis and gently stretches and dilates the circumference of the distal bronchus.

The anastomosis is then tested to 20 cm water inflation pressure, after having filled the pleural cavity with saline solution. Needle hole air leaks are usually ignored; however, air leaks between the cut edges of the bronchus, if small, are reinforced with simple interrupted sutures. A large area of leaking may require the entire anastomosis to be redone.

Protection of the bronchial anastomosis by a viable tissue flap is recommended by most authors (13, 14). The present authors routinely use an intercostal muscle flap (13), which has excellent vascularization provided by the intercostal artery, favouring the preservation of the air tightness even in the case of small anastomotic dehiscence and minimizing the risk of PA erosion, especially when an associated vascular reconstruction is performed. Alternatively, the use of mediastinal fat pad (14), pericardial or pleural flap (12) has been reported.

For the final success of bronchial reconstructive procedures it is essential to avoid tension on the anastomosis. This can be achieved by dividing the pulmonary ligament or, more often on the right side, by opening the pericardium around the pulmonary vein.

Middle Lobe Sleeve Resection

The middle lobe sleeve resection is an infrequently performed resection. The bronchus to the middle lobe lies immediately posterior to the middle lobe vein. The bronchus is followed back to its origin. A right-angled clamp can be placed around the bronchus intermedius, and this is divided proximally to the middle lobe orifice. The division is slightly angled. The distal division is also angled to preserve the orifice to the superior segment of the lower lobe. The PA lies directly posterior and slightly superior to the bronchus. Therefore, care must be taken to avoid injury when dividing the bronchus. The arterial branch to the middle lobe is ligated and divided.

After confirmation of negative margins, the airway anastomosis is performed according to the previously described technique.

Sleeve Bilobectomy

Sleeve Bilobectomy is performed for an endoluminal lesion in the bronchus intermedius that extends up proximal to the upper lobe orifice. At this level the right mainstem bronchus is divided just proximal to the right upper lobe take-off and the right upper lobe bronchus is divided at its origin. The right upper lobe bronchus is then anastomosed to the mainstem bronchus after removal of the middle and lower lobes (the so called "Y" sleeve resection). Due to the reorientation of the upper lobe bronchus after removal of the middle and lower lobes, special care must be taken to avoid torsion of the bronchus at the level of the anastomosis.

LEFT-SIDED RESECTIONS

Left Upper Lobe Sleeve Resection

Proximal arterial control is obtained with care to avoid injury to the short apical-posterior segmental branch of the left pulmonary artery. Dissection is continued along the plane of the artery and the superior segmental branch to the lower lobe is identified. The posterior fissure is then completed with a linear stapler. The arterial segmental branches to the upper lobe are ligated and divided. The upper pulmonary vein is divided with a vascular stapler. The anterior portion of the fissure is completed with a linear stapler. The mainstem bronchus is encircled proximal to the bifurcation, and an umbilical tape is placed. The mainstem bronchus is divided proximal to the bifurcation, and the left lower lobe bronchus is divided at its origin. The origin of the superior segmental bronchus can be quite close to the origin of the lower lobe bronchus, and the lobar division must leave the bronchus intact without separating the superior segmental bronchus. The technique for the anastomotic reconstruction has been previously described for right upper sleeve lobectomy.

Extensive proximal resections can be performed on the left side due to the length of the mainstem bronchus. This anatomical aspect may be responsible of a technically challenging anastomosis, because proximal exposure can be partially obscured by the aortic arch. If required, the arch can be mobilized and carefully retracted to provide additional exposure. Precise suture placement is particularly important to account for size discrepancy between the lobar bronchus and the mainstem bronchus. (Figure 1 A-C)

Left Lower Sleeve Lobectomy ("Y" Sleeve)

For the excision of lesions involving the left lower lobe orifice, with extension into the mainstem bronchus but sparing the upper lobe orifice, a lower lobectomy with sleeve resection of the left main bronchus can be performed. After the bronchial dissection has been completed, an umbilical tape around the left mainstem and left upper lobe bronchus is passed. The left upper lobe bronchus is divided at its origin. Next, the mainstem bronchus is divided proximal to the bifurcation and well beyond the extent of the tumor. Once the margins are confirmed to be microscopically negative by frozen-section analysis, the anastomotic reconstruction is performed according to the previously described technique. The lingular bronchus may

Figure 1. Left upper bronchovascular sleeve lobectomy. Bronchial reconstruction (pulmonary artery stumps are clamped). A) bronchial stumps are visible before anastomotic reconstruction; B) Interrupted sutures have been placed but are still untied; C) Completed bronchial anastomosis

arise proximally to the section line, and care must be taken when dividing the upper lobe bronchus to assure that it remains intact.

PERIOPERATIVE MANAGEMENT

It is important that in candidates for a sleeve resection preoperative bronchoscopy is performed by one of the operating surgeons. This is advantageous at the time of the operation, when the bronchi are incised and divided. It is also useful to have precise knowledge of the preoperative and intraoperative appearance of the airway if any bronchial complication should occur and laser recanalization or stenting should become necessary. Bronchoscopy is performed under local anesthesia to observe bronchial motion during voluntary breathing and coughing, and multiple biopsies are taken. Careful evaluation of bronchial motion is important to infer the state of tissues outside the bronchus: stiffness of the bronchial wall may indicate peribronchial tumor infiltration. This is particularly important in areas where the bronchus is known to be adjacent to the PA, which might consequently be involved.

The use of steroids in the postoperative period in patients undergoing tracheobronchial resection is controversial. We believe that the antiedema effect of steroids is beneficial because it reduces secretion retention and atelectasis, it facilitates parenchymal reexpansion, and it minimizes the risk of dehiscence and granuloma formation. Aerosolized steroids (methylprednisolone 5 mg twice a day) are also part of our preoperative treatment when sleeve lobectomy can be predicted beforehand. It is our experience that patients treated with steroids show reduced need for bronchoscopy or close observation in the postoperative period.

ANALYSIS OF RESULTS

When analyzing survival data reported in the literature in the last 15 years, most studies show similar or better results for parenchymal sparing resections if compared with PN (15-17). Moreover, in the analysis of 5-year survival according to stage and nodal status, SL results in higher survival rates for stages I, II. The survival advantage in stage III patients appears to be limited (17, 25, 31) (Table 1). In a report by Ludwig (6), sleeve lobectomy results in a more favourable prognosis with a survival advantage in patients with N0, N1 and N2 disease. However, this prognostic advantage for stage III-N2 patients is not always confirmed. Therefore, the role of parenchymal sparing operations in patients with N2 disease still remains not completely defined (3, 6).

Postoperative morbidity and mortality data reveal overall better results for patients undergoing SL with respect to PN (15, 18, 31, 32) (Table 2). These results justify the increasing use of parenchymal sparing procedures for lung cancer also in patients with good cardio-pulmonary function, as observed in the last years.

An interesting meta-analysis (19) including 12 papers (5, 6, 15, 17, 18, 20-26) published between 1996 and 2006 has compared the early and long-term outcome of SL with those of PN. A total of 2984 patients have been included in this analysis, of which 21% undergoing SL and 79% undergoing PN. Two-hundred-two patients underwent PA resection and reconstruction in association (164 patients) or not (38

Table 1. Survival rates after sleeve lobectomy and pneumonectomy

Author (yr)	Pts		Stage I 5-y surv.(%)		Stage II 5-y surv. (%)		Stage III 5-y surv. (%)		Overall 5-y surv.(%)	
	SL	PN	SL	PN	SL	PN	SL	PN	SL	PN
Gaissert ('96) (15)	72	56	-	-	53	43	-	-	42	44
Okada ('00) (18)	60	60	-	-	-	-	-	-	48	28
Deslauriers ('04) (17)	184	1046	66	50	50	34	19	22	52	31
Bagan ('05) (24)	66	151	-	-	-	-	-	-	72.5	51.2
Kim ('05) (5)	49	49	88	75	52	36	8	38	53.7	59.5
Lausberg ('05) (25)	171	63	-	-	-	-	-	-	45	30.4
Ludwig ('05) (6)	116	194	57	45	40	42	22	13	39	27
Takeda ('06) (26)	62	110	-	-	-	-	-	-	54.1	32.9
Parissis ('09) (31)	79	129	75	64	53	50	16	18	46.8	37.1
Park ('10) (32)	105	105	-	-	-	-	-	-	58.4	32.1
Gomez-Caro ('11) (11)	55	21	-	-	-	-	-	-	61	31

Table 2. Postoperative morbidity and mortality after sleeve lobectomy and pneumonectomy

Author (yr)	Pts		Complications (%)		Mortality (%)		L-Recurrence (%)		D-Recurrence (%)	
	SL	PN	SL	PN	SL	PN	SL	PN	SL	PN
Gaissert ('96) (15)	72	56	11	16	4	9	14	-	-	-
Okada ('00) (18)	60	60	13	22	0	2	8	10	-	-
Deslauriers ('04) (17)	184	1046	-	-	1.6	5.3	22	35	-	-
Bagan ('05) (24)	66	151	28.8	29.9	4.5	12.6	4.5	7.6	-	-
Kim ('05) (5)	49	49	7.4	44	6.1	4.1	22	6	22	20
Lausberg ('05) (25)	171	63	0.6*	7.9*	1.7	6.3	36.2	21.3	-	-
Ludwig ('05) (6)	116	194	38	26	4.3	4.6	-	-	-	-
Takeda ('06) (26)	62	110	45	40.9	4.8	3.6	9.7	10.9	29	49.7
Parissis ('09) (31)	79	129	16.4	21.6	2.5	8.5	17.7	19.4	-	-
Park ('10) (32)	105	105	29.5	33.4	1	8.6	14.3	16.2	11.4	21.9
Gomez-Caro ('11) (11)	55	21	32	33	3.6	5	3.6	33	38	71

patients) with a bronchial sleeve resection. The evaluation of surgical morbidity including results from 8 studies (5, 6, 15, 18, 20, 22, 24, 26) showed a pooled incidence of 31.3% in the SL group and of 31.6% in the PN group without a statistically significant difference. Similar results were observed limiting the analysis to studies reporting a larger experience (more than 50 patients) of SL (30.8% complication rate in SL group and 33.6% in PN group). The mean postoperative complication rate reported after PA reconstruction was similar (32.4%) to that reported after bronchial SL and PN. Overall postoperative mortality presented a pooled incidence of 3.5% in the SL group and of 5.7% in the PN group, but this difference did not reach statistical significance. However, when considering only studies with a larger number (over 50) of SL (6, 15, 17, 18, 21, 24-26), mortality rate was significantly lower in the SL group than in the PN group.

The overall 5-year survival rate extracted from 10 studies (5, 6, 17, 18, 20-22, 24-26) was 50.3% after SL and 30.6% after PN, showing a statistically significant difference. The median overall survival was 60 months for the SL group and 28 months for the PN group. This result may have been partially influenced by the higher rate of stage III patients included in the PN group in most studies. However, when considering survival according to pathological N status (from the few studies reporting this data (6, 26)), pooled 1-year and 5-year survival rate of patients with N0 or N1 disease are significantly higher after SL. In patients with pN2, a slight statistically significant advantage has been observed in 1-year survival for the SL group, while no significant difference was shown for 5-year survival.

Data regarding loco-regional recurrences have been reported in only 6 (5, 17, 18, 20, 24, 26) of the studies considered in this meta-analysis. The pooled loco-regional recurrence rate resulted 16.1% in the SL group and 27.8% in the PN group, but this difference did not reach statistical significance. Alternatively, if considering only studies with a larger number of sleeve procedures (17, 18, 24, 26) a significantly lower incidence of local recurrence was found in the SL group in comparison with the PN group (14.5% vs 28.7%).

A previous meta-analysis published by Ferguson (27) including 12 studies provided similar survival results reporting a better long term prognosis after SL, although the incidence of local recurrence appeared higher in comparison with PN.

The preservation of lung parenchyma has been indicated therefore by some authors as the possible cause of a theoretical increased risk for loco-regional recurrence after SL. However, although in some experiences (3) a higher local recurrence rate is reported for sleeve resection with advanced nodal status (N2), the few studies (3-5) analyzing risk factors for recurrence show that the tumor stage and the nodal status are the only negative predictive factors, rather than the type of operation performed.

The incidence of microscopic infiltration of the bronchial margins has strong significance when analyzing the anastomotic complication and local recurrence rate. Authors (5) who have observed a significantly higher incidence of anastomotic leak in their SL series, often report an increased rate of positive margins on frozen section.

Looking at the literature data, when morbidity is evaluated according to the type of complication, PN patients appear to experience a higher rate of cardiac complications, while SL patients show increased pulmonary and airway complications incidence (3-6, 15, 18).

Postoperative quality of life has been advocated as one of the strongest indicators that should influence the decision to perform a SL rather than a PN. A number of studies indicate that lung parenchyma sparing improves postoperative quality of life, providing a greater cardio-pulmonary reserve, less pulmonary edema and less right ventricular dysfunction due to a lower pulmonary vascular resistance (4, 23). In the meta-analysis by Ferguson (27) the Quality Adjusted Years Quoted were 4.37 after SL and 2.48 after PN. Melloul (28) has analysed postoperative FEV_1 in a retrospective study reporting significantly higher values for patients undergoing SL. In a prospective study by Martin-Ucar (7) the reported mean FEV_1 loss after parenchymal sparing operations was 170 mL (range 0-500) compared to 600 mL (range 200-1400) after PN, indicating a strongly significant prognostic advantage for patients undergoing SL.

Special concern has been expressed by many thoracic surgeons when considering broncho-vascular reconstructive procedures after induction therapy, due to the significantly higher risk of perioperative complications and mortality. Although only few authors (7, 29) perform sleeve resection routinely after neoadjuvant therapy, it has been proven in our experience (7, 30) that even complex parenchymal sparing operations can be performed safely after oncologic treatment without increased morbidity and mortality rates, observing long-term results comparable to those of the standard procedures (5-year survival: 31%; local recurrence rate:15%).

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