A new classification of bronchial anastomosis after sleeve lobectomy

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Objective: Ischemia and infection of the distal part of the tracheobronchial anastomosis are the leading causes of bronchial anastomotic leakage with a high morbidity and mortality. To improve interpretation of healing of the anastomosis and the consequences, we have developed a classification scheme that allows quality control and defines early and standardized treatment of complications.

Patients and Method: We conducted a retrospective analysis of the records of 202 patients treated in our institution between January 1, 2006 and December 31, 2010 after sleeve lobectomy. All patients received prophylactic inhalation with tobramycin 80 mg twice a day. Neoadjuvant treatment was given in 21% of the patients. Routine bronchoscopy on day 7 was performed with classification of the anastomosis as follows: X, unknown; 1, healing well with no fibrin deposits; 2, focal fibrin deposits and superficial (mucosal) necrosis; 3, circular fibrin deposits, superficial (mucosal) necrosis, and/or ischemia of the distal mucosa; 4, transmural necrosis with instability of the anastomosis; and 5, perforation, necrosis of the anastomosis, and insufficiency.

Results: The anastomosis was graded as satisfactory (1 and 2) in 86% of the patients. In 14%, it was regarded as critical ($\geq$3-5) leading to systemic antibiotic treatment and control bronchoscopy. The overall 30-day mortality was 1%.

Conclusions: Quality control of the tracheobronchial anastomosis comprised bronchoscopy performed before patients were dismissed. Inasmuch As postoperative bronchoscopy is not always performed by the operating surgeon, this classification is an aid to improve the description of endobronchial healing and to commence treatment of critical bronchial healing. (J Thorac Cardiovasc Surg 2012;144:808-12)

Sleeve lobectomy in lung cancer is superior to pneumonectomy in terms of morbidity, early and late mortality, and lung function.[1,2] Therefore, sleeve lobectomy is a standard procedure in the surgical treatment of malignant diseases of the lung.

When sleeve resection is done, complete section of the bronchial wall is necessary. This implies that the bronchial blood supply to the distal bronchus is interrupted, resulting in ischemia in the distal bronchial wall.[3] Successful healing depends on the surrounding tissue covering the anastomosis where neovascularization originates, which will feed the distal bronchus within 7 days.[4] This period of ischemia harbors the risk of infection leading to anastomotic insufficiency and a life-threatening situation. We[5] experienced that additional prophylactic inhalation with tobramycin may avoid infection of the ischemic tissue of the distal bronchus until neovascularization has occurred.

Bronchoscopic control of bronchial healing is performed at our institution before the patient leaves the hospital. Assessment of endobronchial healing by early postoperative bronchoscopy allows timely intervention to avoid severe complications in critical cases.

To our knowledge, systematic bronchoscopic control of the anastomosis is performed routinely. Although we performed a PubMed search, we could find no publication on results and consequences of the observation of endobronchial healing after sleeve resection. In the clinical setting, bronchoscopy is not always performed by the thoracic surgeon. Therefore, the description and communication of the bronchial healing between the thoracic surgeon and the bronchoscopist is important. We[1,5] developed a classification scheme based on our experience in bronchial healing after sleeve lobectomy. This classification was later used by the bronchoscopist to describe the quality of endobronchial healing. With this classification we were able to select those patients with a critical anastomosis who required further observation and treatment. The objective of this study was to determine whether the classification was effective to separate those who could be discharged from those who need further attention.

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PATIENTS AND METHODS

Between January 2006 and December 2010, 288 patients underwent tracheobronchial sleeve resection with curative intent for lung cancer in a single center (Table 1). Of this total, 256 patients required sleeve lobectomy or sleeve bilobectomy, these patients being considered for analysis. Carinal resections, sleeve lobectomy with carinal resection, or isolated bronchial sleeve resection were excluded. The data were collected prospectively by a morbidity documentation sheet and patient records. In

TABLE 1. Distribution of tracheobronchial sleeve resections and standard anatomic resections for lung cancer between 2006 and 2010

Sleeve procedures	No.	%
Lobectomy	221	
Bilobectomy	35	
Pneumonectomy + carina	9	
Lobectomy + carina	14	
Carina	6	
Bronchial sleeve	3	
Total sleeve resections	289	20
Standard anatomic resections		
Pneumonectomy	109	7
Lobectomy/bilobectomy	838	57
Segment resection	232	16
Total anatomic resections	1179	80
Total	1468	100

202 patients, data were complete including documented postoperative bronchoscopy on day 7. Seventy percent were men with a median age of 64 years (range, 26-85 years). Neoadjuvant chemotherapy, chemoradiotherapy, or radiotherapy was administered in 21% (43/202) before surgery owing to N2 (diagnosed through mediastinoscopy or endobronchial ultrasonography).

Operative Procedure

After resection, tension-free bronchial anastomosis was performed with a continuous suture using absorbable 4-0 material (PDS [polydioxanone]; Ethicon Products GmbH, Norderstedt, Germany) over the complete circumference. Radical lymphadenectomy was performed for lymph node staging. After the sleeve resection, routine prophylactic tobramycin inhalation (2 × 80 mg/day) was given for 7 days starting on the evening of the operation. Bronchoscopy was performed on the seventh postoperative day under local anesthesia and prospectively documented according to the classification. The seventh postoperative day was chosen inasmuch as revascularization is effective and complications thereafter are rare. Sleeve resection was performed on the right side in 118 (65%) and on the left side in 85 patients (Table 1). Angioplastic procedures were necessary in 30%. Chest tubes were removed in median after 5 days and the hospital stay was in median 11 days.

How to Interpret the Classification

In about half of the patients, the bronchial anastomosis heals by primary intention without signs of ischemia. In the other half, depending on the grade of ischemia, the bronchial tissue shows different stages of injuries (Table 2). The mucosa is the most sensitive part of the bronchial wall, showing partial or circular fibrin deposits and necrosis, mainly in the proximal part of the distal bronchus. Ischemia of the mucosa with atrophy and submucosal bleeding may extend to the segmental bronchi (see Figure 3). Complete necrosis of the bronchial wall produces softening of the connective tissue and can be detected during bronchoscopy by movements of the distal bronchus in relation to the proximal bronchus when the patient coughs. Unless revascularization occurs from the surrounding tissue, in the early critical phase, this will lead to necrosis with liquefaction of the tissue and insufficiency of the tracheobronchial anastomosis as a sign of aseptic perforation. In all stages of ischemia, infection induced by orobronchial contamination through perioperative intubation or chronic colonization in patients with chronic obstructive pulmonary disease can destroy the ischemic tissue with septic perforation into the mediastinum or pulmonary artery with a high risk of massive bleeding.[6] Our classification scheme was developed to document the grade of ischemia and infection during the critical phase of tracheobronchial healing. Ideally, we can predict anastomotic complications and prevent them.

TABLE 2. Classification of the tracheobronchial anastomosis

Classification	Anastomosis on day 7
X	Unknown
1	Healing well, no fibrin deposits
2	Focal fibrin deposits and superficial (mucosal) necrosis
3	Circular fibrin deposits and superficial (mucosal) necrosis and/or ischemia of the distal mucosa
4	Transmural necrosis with instability of the anastomosis
5	Perforated necrosis of the anastomosis, insufficiency

The anastomosis was regarded as grade 1 when healing was satisfactory along the complete circumference without fibrin deposits (Figure 1). Grade 2 was an anastomosis with focal fibrin deposits and focal superficial necrosis of the mucosa but without signs of transmural bronchial wall necrosis (Figure 2). In grade 3, the anastomosis and bronchial wall had not lost its stability but there were definite signs of ischemia in the distal mucosa and/or circumferential fibrin deposits and superficial necrosis representing a compromised bronchial healing (Figure 3). Grade 4 indicated that the bronchial wall had lost its stability but necrosis had not yet caused dehiscence of the anastomosis (Figure 4). In grade 5, the bronchial wall was destroyed and the anastomosis was dehiscent and had perforated into the mediastinum (Figure 5).

Patients with a satisfactory result were discharged on the following day (grades 1 and 2). In cases of compromised bronchial healing, microbiological assessment was obtained at bronchoscopy, systemic antibiotic treatment was given, and the anastomosis was controlled 4 days later. When necessary, a computed tomographic scan was performed.

Bronchoscopy after sleeve resection is a routine postoperative examination at our institution for which informed consent was obtained from each patient. Only documentation of the bronchoscopic finding and interpretation of the documented results were modified and standardized. Approval by the institutional review board was obtained for this study.

FIGURE 1. Grade 1. Anastomosis healing well without fibrin deposits.

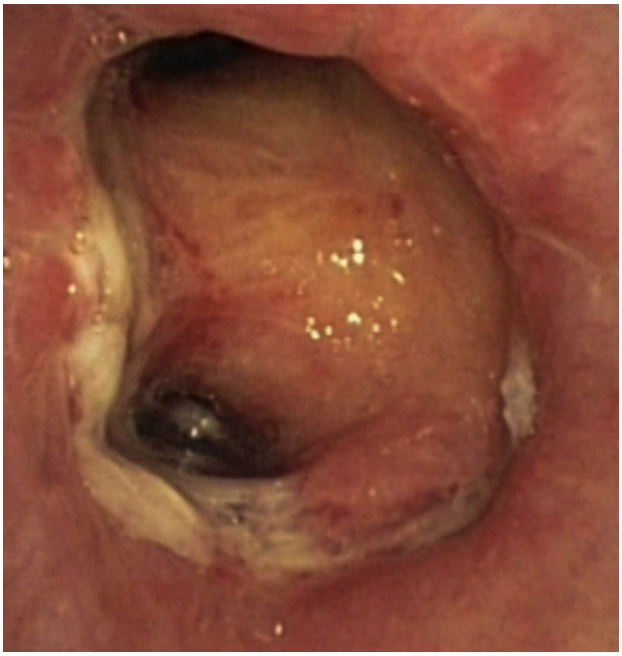

FIGURE 2. Grade 2. Anastomosis healing well with focal fibrin deposits.

Statistical Analysis

All data analyses were performed using MedCalc version 12.2.1.0 for Windows (MedCalc Software, Mariakerke, Belgium). Comparisons were made using paired 2-tailed *t* tests for means of normally distributed continuous variables.

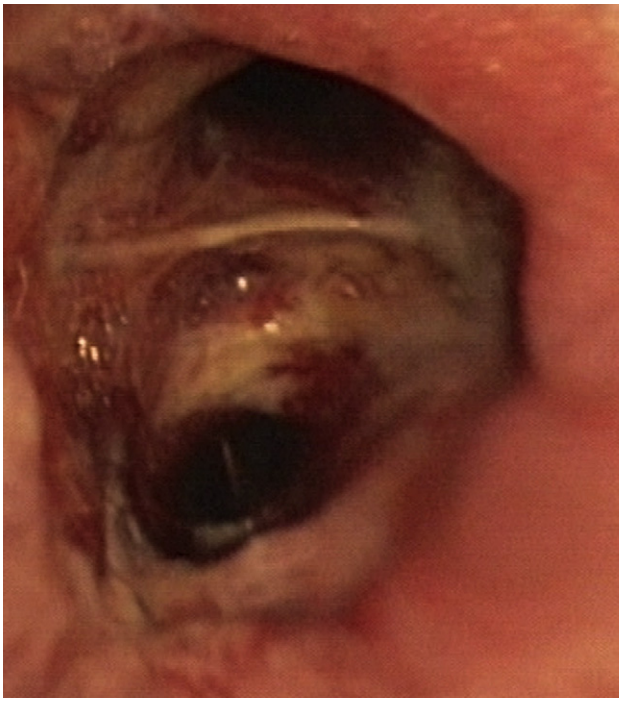

FIGURE 3. Grade 3. Anastomosis with circular fibrin and/or ischemia of the distal mucosa.

FIGURE 4. Grade 4. Anastomosis with transmural necrosis of the bronchial wall and instability.

RESULTS

The distribution of the documented anastomosis healing according to the classification is given in Table 3. Anastomotic healing was grades 1 and 2 in 86% of the patients. Fourteen percent of the patients had a critical anastomosis (grade $\geq$ 3). The rate of grades 4 and 5, an anastomosis with transmural necrosis or insufficiency, was 3.9% (8/202). No secondary pneumonectomy was necessary. The overall 30-day mortality was 1%. Without neoadjuvant therapy, the rate of grades 4 and 5 fell to 3.1%, although 2 patients died within 30 days. In patients who had received neoadjuvant treatment, the rate of grades 4 and 5 rose to 6.9%. Patients who had received

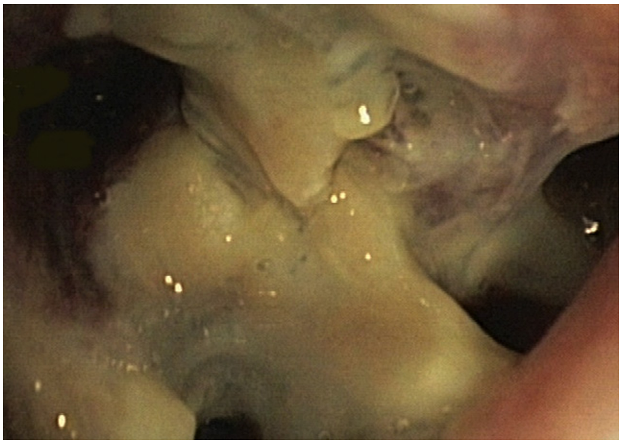

FIGURE 5. Grade 5. Anastomosis with necrosis of the bronchial wall and perforation.

TABLE 3. Distribution of grading in 202 patients

Grade	All (n = 202)	No neoadjuvant therapy (n = 159)	Neoadjuvant therapy (n = 43)	With CT (n = 24)	With RT/CRT (n = 19)
1 and 2	174	137	37	22	15
≥3	28 (13.8%)	22 (13.8%)	6 (14.5%)	2 (8.3%)	4 (21%)
4 and 5	8 (3.9%)	5 (3.1%)	3 (6.9%)	1 (4.2%)	2 (10.5%)
Thirty-day mortality	0.98%	1.25%	0	0	0

CT, Chemotherapy; *RT/RCT,* radiotherapy/chemoradiotherapy.

neoadjuvant chemotherapy had a critical anastomosis in 8% and a rate of grades 4 and 5 of 4.2%. Patients after neoadjuvant radiotherapy or chemoradiotherapy had a critical anastomosis in 21%. The rate of necrotic or insufficient anastomosis, grades 4 and 5, was 10.5%. The difference between patients with or without neoadjuvant therapy was not statistically significant.

DISCUSSION

Increasing experience with sleeve resection has reduced the rate of pneumonectomy below 10%, whereas the rate of sleeve resection has increased up to 20% over the past 5 years.[5] The overall results after sleeve lobectomy in terms of morbidity and mortality depend mainly on the anastomotic healing. In contrast to this finding, there is little scientific evidence about the role of postoperative bronchoscopy after sleeve resection. The incidence of secondary pneumonectomy can be as high as 9%.[7] Previously, a classification was proposed by Couraud and associates[8] to describe tracheobronchial anastomosis after heart–lung transplantation. In this article, bronchoscopy was performed after 15 days.[8] The authors found a correlation between the aspect of the anastomosis on day 15 and late complications such as bronchial stenosis.

A 5-step classification was developed to describe early wound healing of the tracheobronchial anastomosis on day 7. Postoperative bronchoscopy is not always performed by the operating surgeon; therefore, the 5-step classification is also an aid to simplify the description of endobronchial healing. Care was taken to find criteria that best describe which situation may be seen as critical. For example, ischemia of the distal bronchial mucosa should be considered as a sign that anastomotic healing may be compromised. Therefore, together with other signs such as laboratory findings (white blood count and C-reactive protein) and chest radiography, these patients may need systemic antibiotics and close monitoring of the anastomosis.

With increasing experience, this classification has permitted us to conclude that patients with an anastomosis of grade 3 or higher are to be considered as critical and therefore we have changed our postoperative standard. These patients receive systemic antibiotics and a second bronchoscopic examination of the anastomosis 4 days later. When necessary, a computed tomographic scan is performed to identify those requiring drainage or whether the insufficient anastomosis is covered by the mediastinal structures.

Our objective was to identify those patients with early disorders of the anastomosis and to prevent insufficiency of the anastomosis, which has a direct influence on postoperative 30-day mortality. The results show that the use of bronchoscopy on day 7 can detect critical anastomotic healing and prevent severe complications by inducing rapid intervention like antibiotic treatment and endoscopic as well as radiologic control. As one result, we were able to reduce the number of secondary pneumonectomies from 6% to 0%.[1]

Similarly, we could demonstrate that patients with neoadjuvant radiotherapy or chemoradiotherapy will more often have a critical anastomosis on day 7 (21% of grade 3 or higher) in contrast to those with chemotherapy alone (Table 3). This may mean that wound healing of the anastomosis is compromised by neoadjuvant radiotherapy and may require more attention to avoid late complications.[9-14] We therefore introduced the routine procedure of covering the bronchial anastomosis with vital tissue such as pedicled thymus flaps, muscle flap, or pericardial flaps in patients after neoadjuvant treatment including radiotherapy to protect the anastomosis.[15,16] Thirty-day mortality in these patients was not increased compared with the overall 30-day mortality (1%). Comparison of patients with or without neoadjuvant treatment was not statistically significant.

CONCLUSIONS

Postoperative quality control of the tracheobronchial anastomosis by bronchoscopy is performed before patients are dismissed using a classification scheme for documentation and communication. Early bronchoscopy (day 7) permits rapid intervention and prevents further more serious complications with a simple 5-step classification. The classification is more sensitive in detecting systemic adverse factors than mortality and could be used to compare different strategies of surgical techniques and perioperative management like antibiotic treatment.

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