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REVIEW / DERLEME

Pulmonary sleeve resection complications and management

Pulmoner sleeve rezeksiyon komplikasyonları ve yönetimi

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ABSTRACT

In tumors involving the central airway or vascular structures, achieving local control and preserving pulmonary function can be possible with a pulmonary sleeve resection. In this section, complications and management of pulmonary sleeve resections are discussed.

Keywords: Bronchoplasty, complications, pulmonary sleeve resection.

ÖZ

Santral hava yolu veya vasküler yapıları tutan lokal kontrolü sağlamak ve akciğer fonksiyonunu korumak pulmoner sleeve rezeksiyon ile mümkün olabilmektedir. Bu bölümde, pulmoner sleeve rezeksiyon komplikasyonları ve yönetimi tartışıldı.

Anahtar sözcükler: Bronkoplasti, komplikasyon, pulmoner sleeve rezeksiyon.

In centrally located tumors, achieving local control and preserving pulmonary function can be possible with a sleeve resection (SR). If the standard pneumonectomy and lobectomy are unable to ensure complete tumor resection, resection of carina or main bronchus may be necessary (Figures 1 and 2). Historically, considering that patients have poor cardiopulmonary reserve, SRs were an alternative to pneumonectomy. Even in patients who have no cardiopulmonary limitations, lung-sparing procedures have shown to be favorable compared to pneumonectomy, when it is anatomically feasible. However, specific complications associated with SRs are more common than standard lung resections.[1] Since technical information was given in the previous sections, only risk factors and complications are summarized in this section.

Indications

Sleeve resections are procedures characterized by circular resection of the airway and/or vessels followed by end-to-end anastomosis of the remaining airway and/or vessels. Since SRs are parenchyma-sparing surgeries, these resections are most often used in patients with low cardiopulmonary functions. Even in patients who have no cardiopulmonary limitations, SRs have been shown to be favorable compared to pneumonectomy in anatomically feasible cases, as postoperative morbidity and mortality risk of SRs is lower than pneumonectomy. Sleeve resection can be performed for either benign or malignant central tumors such as carcinoid tumors, non-small-cell lung cancer (NSCLC) or adenomas.[2,3]

Risk factors

Since bronchoplastic procedures are more demanding, there is an increased risk of complications compared to standard pneumonectomy or lobectomy. With attention to the technical details, these complications can be minimized. Similar to all other surgical procedures, to avoid complications, patients should be selected accordingly, also surgical tenets and potential pitfalls of this particular operation should be considered. First step to prevention of possible complications is to eliminate systemic and local risk factors. Overall, it is better to prevent complications first. Some of the known risk factors are chronic corticosteroid use, active smoking, active tuberculosis, pneumonia, anticipated need for prolonged

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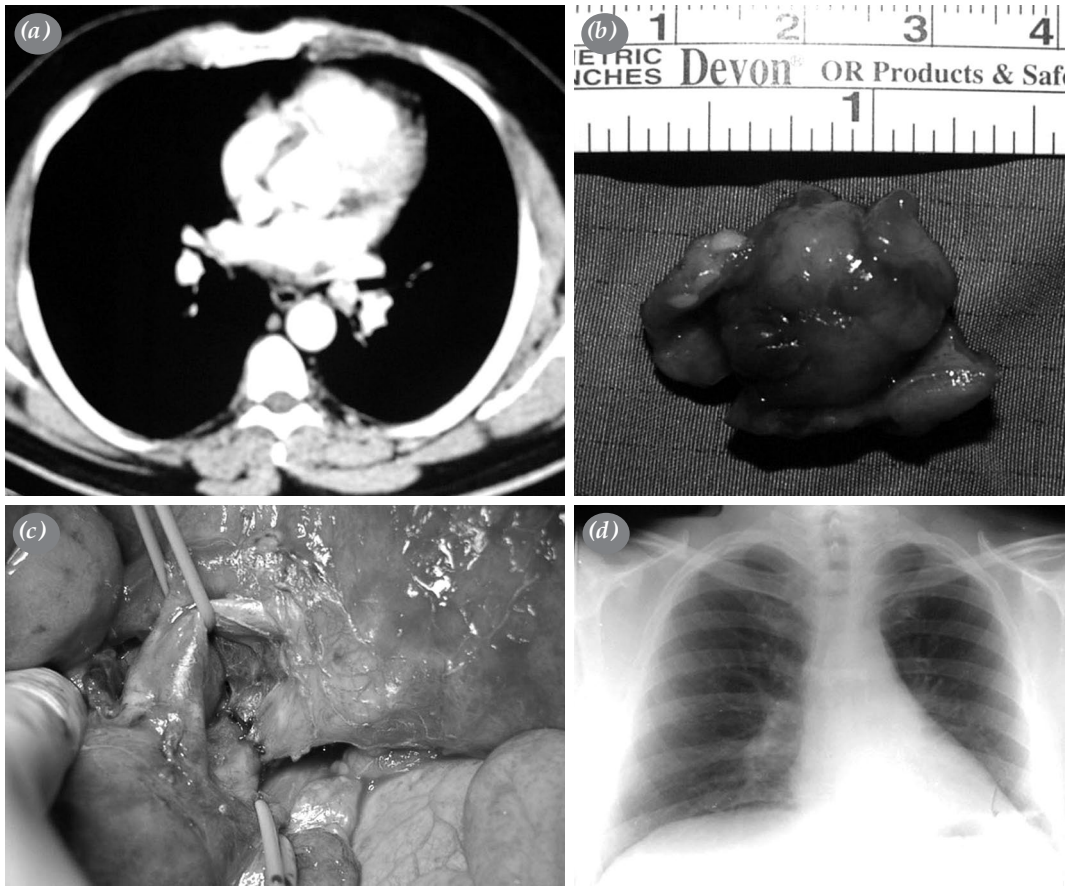

Figure 1. The patient who underwent partial bronchoplasty due to a carcinoid tumor located in the upper lobe-lower lobe separation carina of the left lung; **(a)** Preoperative thoracic computed tomography mediastinal window view, **(b)** specimen image, **(c)** intraoperative view after bronchoplasty was completed, **(d)** postoperative posterior-anterior chest radiography image.

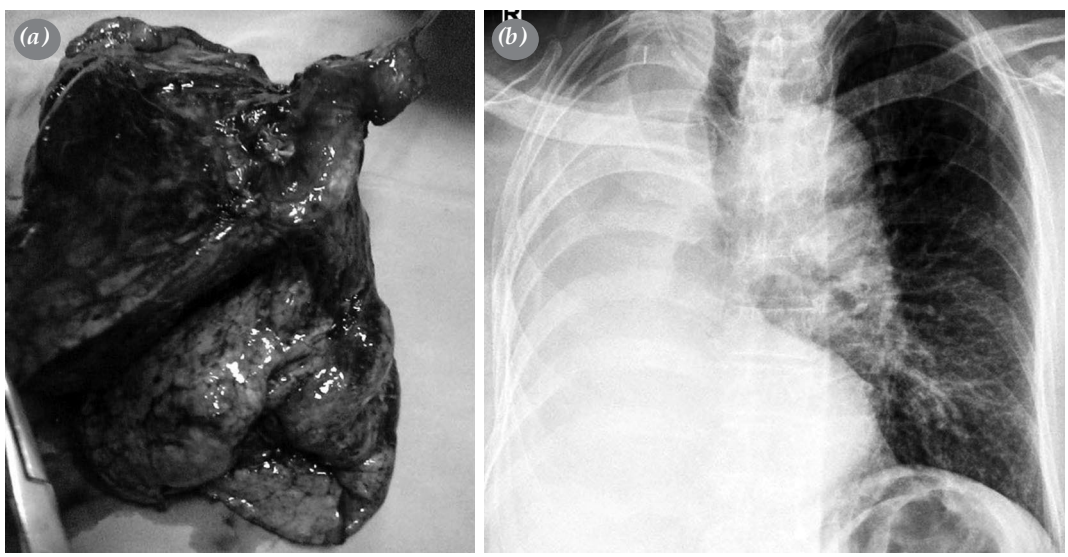

Figure 2. The patient who underwent sleeve right pneumonectomy due to a squamous cell lung carcinoma; **(a)** Surgical specimen and **(b)** posterior-anterior chest radiography at the postoperative eighth year.

postoperative mechanical ventilation, neoadjuvant and adjuvant therapy, diabetes mellitus, malnutrition/hypoalbuminemia, elderly patients (>60 years of age), preoperative anemia, compromised pulmonary function (e.g., chronic obstructive pulmonary disease [COPD], low forced expiratory volume in 1 sec [FEV1], and low diffusing capacity of the lungs for carbon monoxide [DLCO]), postoperative empyema, requirement of blood transfusions, prolonged usage of chest tube drainage, tumor positive bronchial margin, and devascularization of bronchus.[4]

Suture technique of the anastomosis

Since the information about the suture technique was given in the previous sections, only the relationship between the suture technique and complications is summarized in this section. Postoperative airway complications can be significantly reduced by the use of absorbable monofilament materials instead of non-absorbable materials. There is no established standard practice regarding the suture technique of the anastomosis. However, SRs can be performed with end-to-end bronchial anastomosis using the continuous suture technique with a low postoperative complication rate.[5,6]

Complications

Procedure-specific complications after SRs are mostly related to airway anastomosis and include the development of bronchopleural fistulas (BPFs), bronchovascular fistulas (BVFs), benign anastomotic strictures, and local tumor recurrence at the anastomotic line (Table 1).[7-9]

Early mortality is often caused by acute respiratory distress syndrome (ARDS) or pneumonia, whereas late mortality is almost exclusively linked to anastomotic complications. The postoperative mortality and overall morbidity rates of bronchial SRs range from 1.5 to 11% and 11 to 51, respectively (Table 2). These complications will be discussed respectively.

Bronchial stenosis and dehiscence

Atelectasis is one of the most common complications after bronchoplastic procedures. If aeration is supplied, atelectasis can be solved by removal of the secretions through bronchoscopy or physiotherapy. In the majority of cases, it is a minor problem and can be solved by the bronchoscopy and respiratory physiotherapy. The other reason may be an unsuccessful anastomosis. In this case, redo surgery and anatomical resection seem to be the only solution.[10]

Bronchoscopy should be performed to evaluate healing of the anastomosis in the postoperative period. Even if the anastomosis is intact, stenosis may develop in the late period. Benign strictures or stenosis, including suture granuloma formation, are the result of ischemia at the anastomosis site, leading to scar formation with an insidious onset.[11] Anastomotic strictures occur at a rate of 2.5 to 7.5% and 0 to 15.1% of the carinal resections and patients undergoing SR, respectively.[12-41]

Bronchoscopic debridement and recurrent bronchoscopic dilatations are applied in the management of excessive granulation tissue and fibrotic strictures (Figure 3).[10]

Bronchial stents have a limited application for stenosis following SRs. If dehiscence, partial separation, or frank necrosis is revealed through bronchoscope inspection of the anastomosis; a surgical intervention is mandatory. In this case, completion pneumonectomy should be considered. If the patient's pulmonary function capacity is not suitable for pneumonectomy, repair should be attempted. The greatest chance of success without fatal complications can be provided by wrapping the anastomosis with a pedicled omentum flap or a healthy muscle tissue.[21]

Bronchopleural fistula

The development of BPF is one of the most important complications. It develops in 3.8 to 21.6% and 0 to 8.1% of patients undergoing carinal resections and after SR, respectively.[12,16-43] If BPF is suspected, bronchoscopic evaluation is required. If a small fistula is seen on bronchoscopy, conservative treatment should be the first approach. Conservative treatment includes antibiotic therapy, drainage and irrigation. Thus, the

Table 1. Postoperative complications of pulmonary sleeve resections

Some early complications	Some late complications
• Pneumonia	• Local tumor recurrence (for lung cancer)
• Atelectasis requiring bronchoscopy	• Bronchial anastomotic stenosis, strictures
• Bronchial anastomotic dehiscence	• Bronchopleural fistula (BPF)
• Post-pneumonectomy pulmonary edema	• Bronchovascular fistula (BVF)
• Acute respiratory distress syndrome (ARDS)	

Table 2. Summary of complications after carinal and sleeve resections in published surgical series with (n>50)

Author	Year	n	Mortality (%)	Morbidity (%)	Anastomotic complications (%)					5-year Survival (%)
					Bronchopleural fistula/dehiscence/ischemia	Bronchovascular fistula	Stenosis	Local recurrence	Empyema (%)	
Carinal resection										
Tedder et al.,[12]	1992	1915	20.9	-	10.1	2.9	-	4.2	8.6	-
Mitchell et al.,[13]	1999	134	12.7	38.8	17.2b	-	-	-	2.2	-
Mitchell et al.,[14]	2001	60	15.0	45.0	16.7b	-	-	3.3	-	42
Porhanov et al.,[15]	2002	231	16.0	35.5	21.6	-	7.4	5.0	14.7	25
Regnard et al.,[16]	2005	65	7.7	50.8	10.8	-	4.6	-	7.7	27
de Perrot et al.,[17]	2006	119	7.6	47.1	10.1	-	2.5	4.2	5.0	44
Roviaro et al.,[18]	2006	53	7.5	11.3	3.8	-	-	-	1.9	33
Eichhorn et al.,[19]	2013	64	3.1	40.6	10.9	-	-	-	10.9	31
Sezer et al.,[20]	2020	51	10.9	48.8	9.4	-	-	-	31	42.2
Blatter et al.,[21]	2018	73	8.2	10	5	-	-	5	-	42.2
Sleeve lobectomy										
Tedder et al.,[12]	1992	1915	5.5	-	3.0	2.5	4.8	12.5	2.0	40
Kawahara et al.,[22]	1994	112	-	-	5.6	1.8	6.3	7.1	-	-
Gaissert et al.,[23]	1996	72	4.0	11.0	1.4	-	2.8	1.4	1.4	42
Icard et al.,[24]	1999	110	2.7	44.5	3.6	0.9	3.6	-	-	39
Tronc et al.,[25]	2000	184	1.6	15.8	1.1	-	2.2	-	2.2	52
Fadel et al.,[26]	2002	169	2.4	12.4	1.2	1.2	1.2	3.8	2.4	52
Mezzetti et al.,[27]	2002	83	3.6	10.8	3.6	-	-	20.0	-	43
Terzi et al.,[28]	2002	160	11.3	24.4	8.1	1.9	5.6	-	-	39
Hollaus et al.,[29]	2003	108	5.5	26.8	2.8	-	-	-	2.8	-
Burfeind et al.,[30]	2005	73	2.7	37.0	1.4	0.0	9.6	2.7	-	-
Lausberg et al.,[31]	2005	171	1.8	-	0.6	-	0.0	-	0.0	43-46
Ludwig et al.,[32]	2005	116	4.3	-	6.9	-	0.9	-	1.7	39
Takeda et al.,[33]	2006	62	4.8	45.2	3.2	-	-	9.7	9.7	54
Yildizeli et al.,[34]	2007	218	4.1	22.9	3.7	0.9	1.8	5.3	1.8	53
Rea et al.,[35]	2008	199	4.5	17.9	1.0	2.0	15.1	-	1.0	40
Yamamoto et al.,[36]	2008	201	1.5	39.8	2.0	-	1.5	2.5	3.0	58
Merritt et al.,[37]	2009	196	2.0	34.6	2.0	0.0	0.0	4.8	2.0	44
Milman et al.,[38]	2009	64	3.1	45.3	0.0	1.6	1.6	4.7	-	41-48
Gómez-Caro et al.,[39]	2011	58	3.4	34.5	0.0	1.7	0.0	1.7	3.4	62
Storelli et al.,[40]	2012	103	2.9	23.3	0.0	0.0	1.0	7.8	-	63
Gonzalez et al.,[41]	2013	99	3.0	50.5	2.0	-	3.0	-	-	28-45
Bylicki et al.,[42]	2014	108	-	-	9.3	-	12.0	-	-	-
Comacchio et al.,[43]	2019	159	0.006	29	0.02	-	0.09	-	-	50

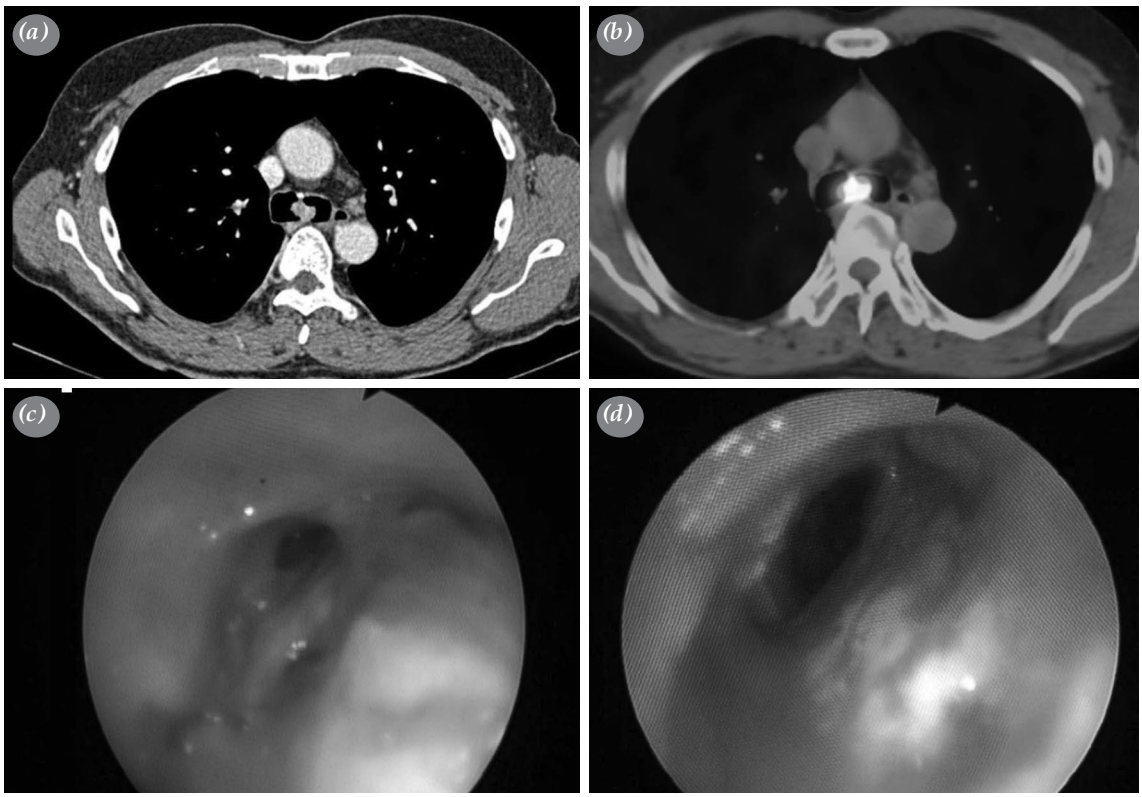

Figure 3. The patient who underwent carina resection due to a squamous cell lung carcinoma; **(a and b)** Image of tumor on thoracic computed tomography mediastinal window and 18F-fluorodeoxyglucose (18F-FDG) positron emission tomography/computed tomography image, **(c)** postoperative first-month bronchoscopy, stricture in the right main bronchus is seen. **(d)** After dilatation view of the right main bronchus.

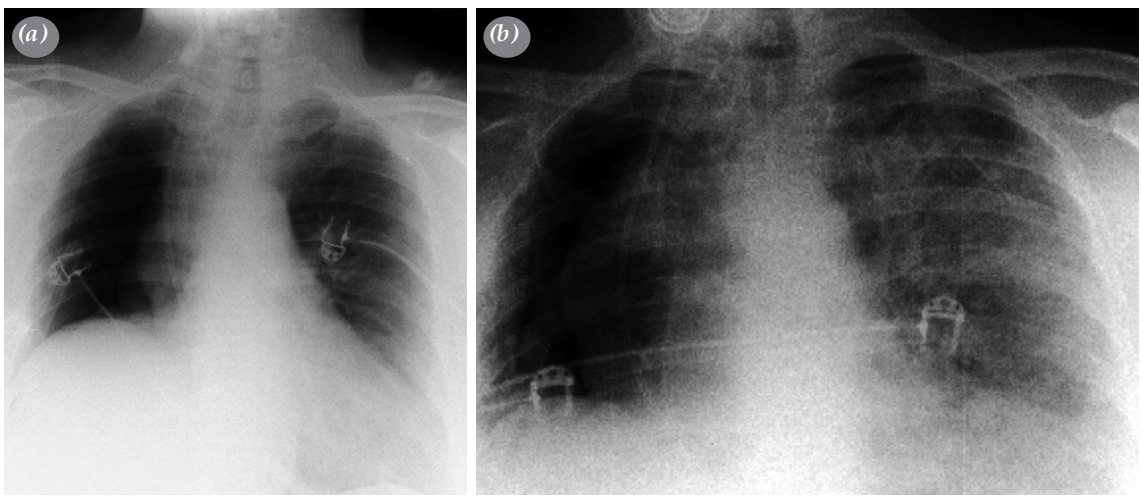

Figure 4. The patient who underwent right pneumonectomy due to a lung adenocarcinoma; **(a)** Chest radiograph taken in the early postoperative period and **(b)** on postoperative Day 3. Due to post-pneumonectomy pulmonary edema, the patient died on postoperative Day 3.

fistula may close spontaneously in the late period. However, if the fistula cannot be controlled with conservative treatment, surgical exploration should be considered. Debridement, closure with absorbable sutures, and pedicled omental or muscle flap buttress should be done. Late bronchial stenosis may develop

after BPF, as well.[4] Completion pneumonectomy becomes necessary, if the repair of the anastomosis is deemed impossible.

Bronchovascular fistula

Bronchovascular fistulas are catastrophic complications. These fistulas have been reported in 2.9% of patients undergoing carinal resections.[12] They occur in 0 to 2.5% of patients after SR. Although BVFs are rare, they have a very poor prognosis invariably.[22-43] Massive hemoptysis can be seen in these patients and they may die suddenly. This massive bleeding is often a successor of a sentinel bleed caused by an anastomotic breakdown and erosion into the adjacent pulmonary artery. Once confirmed, immediate surgical intervention is warranted for BVFs. Mortality is close to 100%, and only very few can be diagnosed early and applied emergent surgical correction. In this case, completion pneumonectomy should be considered. If the patient's pulmonary function capacity is not suitable for pneumonectomy, repair should be attempted.

The incidence of pulmonary embolism and acute thrombosis reported in the literature is 1.9% after bronchoplastic procedures and pulmonary artery reconstructions.[44] A cardiac arrest with pulseless electrical activity following PA thrombosis can be induced by a rapid pressure overload and right ventricular dysfunction, thereby leading to a decrease in the left ventricular preload.[45] Thoracic computed tomography (CT) and transthoracic echocardiography are the most commonly used methods to demonstrate pulmonary artery thrombosis after surgery. The use of intraoperative anticoagulation is recommended for the prevention of postoperative pulmonary artery thrombosis in patients undergoing vascular SR.[46] Unlike past practices, the currently administered anticoagulation regimen is as follows: intravenous injection of 1,500 U sodium heparin during the resection without reversal by protamine sulfate at the end of the procedure and 6,000 U/day low-molecular-weight heparin (LMWH) administered subcutaneously for seven days after surgery.[47,48] If bleeding occurs due to heparin in the postoperative period, protamine sulfate should be used. Furthermore, since pulmonary artery thrombosis may develop in the late postoperative period, patients should be followed closely.[49]

Post-pneumonectomy pulmonary edema

Post-pneumonectomy pulmonary edema is a catastrophic complication that can develop two to three days after surgery. It may present with clinically progressive dyspnea, tachypnea, hypoxia and hypercapnia. Radiological findings are consistent with interstitial pulmonary edema (Figure 4). Histological findings are similar to ARDS. There are many factors in the pathophysiology of post-pneumonectomy pulmonary edema, such as extensive lymph node dissection, pulmonary endothelial damage, increased pulmonary capillary pressure, fluid overload and right ventricular dysfunction. It has been reported in 4 to 14% of cases undergoing a carinal resection. The treatment protocol is similar to ARDS. Fluid restriction, morphine, diuretic, mechanical ventilator support and, in some cases, extracorporeal membrane oxygenation are used in the treatment.[9,13,15,18]

Local tumor recurrence

Considering a local recurrence of tumor as a late complication of sleeve lobectomy, surveillance bronchoscopy is warranted in these patients biannually. An opportunity for re-resection may be offered by early detection in some cases. Radiation therapy can be utilized in poor surgical candidates for re-resection or completion pneumonectomy. Fewer than 5 to 10% of the cases of carinal and SRs have local recurrence.[12,26,27]

In conclusion, SR has been developed as an alternative to pneumonectomy in lung cancer patients with limited respiratory reserve for the preservation of the healthy pulmonary tissue distal to the tumor. In addition, due to its lower mortality and morbidity rates than pneumonectomy, it is also performed in patients with adequate respiratory reserve. To minimize postoperative complications following bronchoplastic procedures, patients should be selected meticulously and technical details should be considered carefully. Complications are often devastating and require early diagnosis and intensive treatment. Unsuccessful management of these complications often leads to death.

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Author Contributions: Idea/concept, design, control/supervision, analysis and/or interpretation, writing the article, critical review, other: Y.K., C.Y.; Data collection and/or processing, literature review, references and fundings, materials: Y.K.

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