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Contralateral Pulmonary Resection after Pneumonectomy

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Background: Contralateral pulmonary resection after pneumonectomy presents considerable challenges, and few reports in the literature have described this procedure.
Methods: We retrospectively reviewed the medical records of all patients who underwent contralateral lung resection following pneumonectomy for any reason at our institution between November 1994 and December 2020.
Results: Thirteen patients (9 men and 4 women) were included in this study. The median age was 57 years (range, 35–77 years), and the median preoperative forced expiratory volume in 1 second was 1.64 L (range, 1.17–2.12 L). Contralateral pulmonary resection was performed at a median interval of 44 months after pneumonectomy (range, 6–564 months). Surgical procedures varied among the patients: 10 underwent single wedge resection, 2 were treated with double wedge resection, and 1 underwent lobectomy. Diagnoses at the time of contralateral lung resection included lung cancer in 7 patients, lung metastasis from other cancers in 3 patients, and tuberculosis in 3 patients. Complications were observed in 4 patients (36%), including acute kidney injury, pneumothorax following chest tube removal, pneumonia, and prolonged air leak. No cases of operative mortality were noted.
Conclusion: In carefully selected patients, contralateral pulmonary resection after pneumonectomy can be accomplished with acceptable operative morbidity and mortality.

Keywords: Contralateral pulmonary resection, Postoperative complication, Pneumonectomy

Introduction

Contralateral pulmonary resection after pneumonectomy presents considerable challenges. To date, fewer than 200 cases of this procedure have been reported in the literature. The largest case series currently available is a 2017 report from the United States conducted by Ayub et al. [1], which included 63 patients. Retrospective analyses suggest that contralateral lung resection following pneumonectomy can be a beneficial operation for carefully selected patients [1-7]. However, detailed patient selection criteria have not been clearly established. The functional status and cardiopulmonary reserve of candidate patients should be thoroughly assessed. The objective of this study was to determine the feasibility of contralateral pulmonary resection after pneumonectomy, based on our experience.

Methods

We retrospectively reviewed the medical records of patients at a single institution who underwent contralateral lung resection after pneumonectomy for any reason between November 1994 and December 2020. The data collected included age, sex, cardiopulmonary function, initial diagnosis and post-surgical stage, type of subsequent resection, morbidity, and mortality. Lung cancer staging was performed in accordance with the eighth edition of the tumor-node-metastasis staging system. For patients with lung cancer, newly developed tumors were categorized as either secondary primary lung cancer (metachronous lung cancer) or metastatic lung cancer, following the criteria set forth by Martini and Melamed [8]. Survival data were verified through medical records and the national insurance database. The Institutional Review Board of the Samsung Medical Center approved the study (IRB approval no., 2023-08-059-001). Due to the retrospective design of the research, the requirement for informed consent was waived.

Survival was analyzed using the date of contralateral pulmonary resection following pneumonectomy as the starting point and the date of death as the endpoint. A p-value of less than 0.05 was considered to indicate statistical significance. Statistical analyses were performed using IBM SPSS ver. 27.0 (IBM Corp., Armonk, NY, USA).

Results

At our center, we performed a total of 1,185 pneumonectomies between November 1994 and December 2020. Of these, 13 patients (9 male and 4 female) underwent contralateral lung resection following initial pneumonectomy. This initial procedure was performed on the left side for 10 patients and on the right side for 3 patients (Table 1). Extended pneumonectomy was performed in 4 patients. Specifically, patient 1 required *en bloc* resection of the pericardium, while patient 6 was treated with *en bloc* resection of both the pericardium and the adventitia of the descending aorta. Patient 8 underwent resection of the main pulmonary artery and the right pulmonary artery, along with pulmonary valve replacement. Patient 9 underwent *en bloc* resection of the left diaphragm. The diagnoses at initial pneumonectomy included squamous cell carcinoma in 6 patients, adenoid cystic carcinoma in 1 patient, pulmonary artery angiosarcoma in 1 patient, lung metastasis from osteosarcoma in 1 patient, and tuberculosis (TB) in 4 patients. Two patients with cN2 primary lung cancer underwent neoadjuvant concurrent chemoradiotherapy prior to pneumonectomy. Following pneumonectomy, 2 patients received adjuvant radiotherapy, 3 patients were given adjuvant chemotherapy, and 1 patient received a combination of chemotherapy and radiotherapy (Table 1).

The patients were monitored following pneumonectomy. Subsequent chest computed tomography (CT) was employed to detect new tumors; however, the nature of these tumors could not be confirmed due to the risks associated with percutaneous needle aspiration biopsy. In 2 patients, bronchoscopy was conducted to rule out the presence of endobronchial lesions. To exclude the possibility of distant

Table 1. Clinical background of patients at the time of pneumonectomy

No.	Sex	Age (yr)	Pneumonectomy site	Diagnosis for pneumonectomy	Adjuvant treatment after pneumonectomy	Interval[a] (mo)	FEV1 (L)	DLCO%	LVEF%
1	M	77	Lt (+pericardium)	Squamous cell carcinoma: pT3N1M0 (IIIA)	RTx	77	1.17	50	60
2	M	59	Lt	Squamous cell carcinoma: pT2bN0M0 (IIA)	CTx (taxol/carboplatin)	33	1.58	62	69
3	M	61	Lt	Squamous cell carcinoma: pT2aN1Mo (IIB)	CTx (cisplatin/vinorelbine)	60	1.49	55	62
4	F	51	Lt	Adenoid cystic carcinoma: pT2aN1M0 (IIB)	RTx (60 Gy/30 Fx)	64	1.78	47	69
5	M	64	Lt	Squamous cell carcinoma: cT4N2M0 (IIIB), ypT0N1	-	12	1.52	61	66
6	M	46	Lt (+pericardium, aorta[b])	Squamous cell carcinoma: cT3N2M0 (IIIB), ypT1bN1	RTx (30 Gy/15 Fx), CTx (paclitaxel/cisplatin)	24	2.12	44	55
7	M	70	Lt	Squamous cell carcinoma: pT2aN0M0 (IB)	CTx (docetaxel/cisplatin)	30	1.98	-	59
8	M	39	Rt (+PA, PVR)	Angiosarcoma	-	6	2.07	-	61
9	F	35	Lt (+diaphragm)	Metastasis from osteosarcoma	-	44	1.68	55	58
10	F	57	Lt	Tuberculosis	-	531	1.59	81	55
11	M	64	Rt	Tuberculosis	-	564	1.66	-	63
12	F	37	Lt	Tuberculosis	-	243	1.55	88	62
13	M	36	Rt	Tuberculosis	-	42	1.64	48	50

FEV1, forced expiratory volume in 1 second; DLCO, diffusion capacity for carbon monoxide; LVEF, left ventricular ejection fraction; Lt, left; RTx, radiotherapy; CTx, chemotherapy; Rt, right; PA, pulmonary artery; PVR, pulmonary valve replacement.
[a]Time interval between pneumonectomy and contralateral lung resection surgery. [b]Patient No. 6 received en bloc resection of the adventitia of the descending aorta.

metastases and enlarged lymph nodes, a metastatic workup was carried out using positron emission tomography/CT (PET/CT), abdominal CT, or brain magnetic resonance imaging. Of the 4 patients who underwent pneumonectomy for TB-related lung damage, 2 were declared TB-free (patients 10 and 11), while the remaining 2 (patients 12 and 13) continued to receive treatment for TB. Patient 10 was found to have a new tumor during a routine health examination. Patient 11 was diagnosed with colon cancer and underwent right hemicolectomy; 22 months following colon surgery, CT examination detected lung metastasis originating from colon cancer. Two patients experienced a recurrence of TB and were diagnosed with multidrug-resistant TB (patients 12 and 13). Despite the introduction of various anti-TB medications, their symptoms persisted without relief.

All patients underwent pulmonary function tests (PFTs) when the resection of the contralateral lung was under consideration. The median value for forced expiratory volume in 1 second (FEV1) was recorded at 1.64 L (range, 1.17–2.12 L). The diffusion capacity for carbon monoxide (DLCO) was assessed in only 10 patients, revealing a median DLCO of 55% (range, 44%–88%). Peak oxygen consumption with exercise was assessed in only 5 patients, with VO_2 max exceeding 14.5 mL/kg/min, (range, 14.5 to 25.6 mL/kg/min). Echocardiography was performed for each patient. One patient was found to have moderate aortic stenosis, while another exhibited mild to moderate tricuspid regurgitation accompanied by moderate pulmonary hypertension (patients 1 and 8, respectively). The median left ventricular ejection fraction was determined to be 61% (range, 50%–69%) (Table 1).

Contralateral lung resection was performed 6–564 months (median, 44 months) after initial pneumonectomy. The median age at contralateral lung resection was 57 years (range, 35–77 years). Two, 6, and 5 patients underwent video-assisted thoracoscopic surgery, mini-thoracotomy, and thoracotomy, respectively. Ten patients underwent single wedge resection, 2 patients were treated with double wedge resection, and 1 patient (patient 12) underwent lobectomy. The last of these patients was diagnosed with a TB-damaged lung and consequently underwent left pneumonectomy. Following the procedure, the patient experienced TB recurrence and was diagnosed with multidrug-resistant TB. This patient presented with hemoptysis and dyspnea. Despite receiving anti-TB medication, the symptoms did not abate, necessitating contralateral lung resection. Due to severe adhesions, the surgical team opted for a posterolateral thoracotomy approach. During the procedure, a cavitary lesion measuring 5×5 cm was discovered in the right upper lobe, and lobectomy was performed.

Complete R0 resections were achieved in 12 patients. Patient 3 was the sole exception, undergoing an incomplete R2 resection because of multiple tiny nodules that were identified during surgery. To preserve postoperative pulmonary reserve, only a single wedge resection was carried out in this patient (Table 2).

Anesthesia for patients undergoing contralateral resection following pneumonectomy presents a unique challenge. These individuals possess only 1 lung; therefore, lung resection must be conducted with ventilation applied to the lung undergoing surgery. Among 11 patients, either intermittent manual ventilation was applied or tidal volumes were minimized using a single-lumen endotracheal tube. Selective bronchial blockade was employed in 2 patients (Table 2).

Prior to undergoing contralateral lung resection, patients were diagnosed with lung cancer, lung metastasis from other primary cancers, and TB in counts of 7, 3, and 3, respectively. Among those diagnosed with lung cancer, histological analysis revealed adenocarcinoma in 3 patients, squamous cell carcinoma in 3, and adenoid cystic carcinoma in 1. For the 3 patients presenting with lung metastases, the primary cancers identified were colon cancer, pulmonary angiosarcoma, and osteosarcoma (Table 2).

The median operative time was 62 minutes (range, 32–170 minutes), and the median volume of blood loss was 50 mL (range, 20–400 mL). Eight patients underwent immediate extubation following surgery. Two patients were extubated approximately 5 hours after surgery, while 3 patients were extubated on the first postoperative day. The median length of hospital stay was 9 days (range, 4–17 days) (Table 2).

Complications arose in 4 patients (36%), including acute kidney injury, pneumothorax following chest tube removal, pneumonia, and prolonged air leak. No cases of operative mortality were observed. All patients were discharged without the need for supplemental oxygen. One patient received radiotherapy for local recurrence of lung cancer, while another received it for distant metastasis. Two patients underwent chemotherapy for subcarinal lymph node metastasis from angiosarcoma and for stage 4 colon cancer, respectively. Concurrent chemoradiotherapy was administered to 1 patient for metastases in the lower paratracheal and subcarinal lymph nodes. Patient 9 required reoperation for lung metastasis from osteosarcoma, which was discovered in the right lower lobe 4 months following initial surgery on the opposite lung. One year later, the tumor

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Table 2. Operative procedure and results of contralateral lung resection

No.	Approach	Resection	Indication for contralateral lung resection	Anesthesia technique	OP time (min)	Blood loss (mL)	Hospital days	Complication	Recurrence (interval after operation) (mo)	Additional treatment	Outcome	Survival (mo)
1	VATS	Wedge (RLL)	Squamous cell carcinoma: pT1a	Lung down	32	50	11	AKI	-	-	Dead	25
2	Mini-thoracotomy	Wedge (RUL)	Adenocarcinoma: pT1a	Lung down	73	100	7	-	-	-	Alive	76
3	Mini-thoracotomy	Wedge (RUL)	Adenocarcinoma: pT3	Lung down	50	20	8	-	Lower paratracheal & subcarinal LN (6)	CCRT	Alive	49
4	Mini-thoracotomy	Wedge ×2 (RML)	Adenoid cystic carcinoma	Blocker	63	100	6	Pneumothorax	RLL (5)	-	Alive	41
5	Thoracotomy	Wedge (RLL)	Squamous cell carcinoma: pT1b	Lung down	29	20	4	-	RLL, liver, bone (14)	RTx	Dead	16
6	Mini-thoracotomy	Wedge (RUL)	Squamous cell carcinoma: pT1a	Blocker	62	50	6	-	RLL (3)	RTx	Dead	13
7	Thoracotomy	Wedge (RLL)	Calcified granuloma	Lung down	159	20	17	Pneumonia; prolonged air leak	RLL (60)	-	Dead	71
8	Mini-thoracotomy	Wedge (LUL)	Angiosarcoma	Lung down	45	20	11	-	Carina LN (3)	CTx	Dead	13
9	Mini-thoracotomy	Wedge (RUL)	Osteosarcoma	Lung down	66	50	8	-	RLL (4)	Re-operation	Alive	112
10	VATS	Wedge (RLL)	Adenocarcinoma: pT1a	Lung down	60	50	9	-	-	-	Alive	60
11	Thoracotomy	Wedge (LUL, LLL)	Adenocarcinoma (colon ca metastasis)	Lung down	51	20	15	-	-	CTx	Dead	76
12	Thoracotomy	Lobectomy (RUL)	Tuberculosis	Lung down	170	20	13	-	MDR-TB	-	Alive	231
13	Thoracotomy	Wedge (LUL)	Tuberculosis	Lung down	147	400	12	Prolonged air leak	MDR-TB	-	Alive	125

OP, operation; VATS, video-assisted thoracoscopic surgery; RLL, right lower lobe; AKI, acute kidney injury; RUL, right upper lobe; LN, lymph node; CCRT, concurrent chemoradiotherapy; RML, right middle lobe; RTx, radiotherapy; LUL, left upper lobe; CTx, chemotherapy; LLL, left lower lobe; MDR-TB, multi drug-resistant-tuberculosis.

recurred in the para-esophageal lymph node and the right lower lobe, necessitating further lung resection that included the removal of the para-esophageal mass and en bloc wedge resection of the right lower lobe (Table 2).

All patients were monitored for a period ranging from 13 to 231 months, with a median duration of 60 months. To date, 7 patients are still alive. Three patients have experienced no cancer recurrence, while 2 patients have had recurrence. One patient with recurrence underwent concurrent chemoradiation therapy for mediastinal lymph node metastasis. The other patient developed recurrent adenoid cystic carcinoma in the right lower lobe, diagnosed 5 months following resection of the lung on the opposite side; this patient has not undergone further treatment. Additionally, 2 patients are receiving treatment for multidrug-resistant TB.

Of the 6 patients who died, 5 deaths were attributed to either local recurrence or distant metastasis, while the cause of death for 1 patient remained unknown. The time from surgery to death for these 6 patients ranged from 13 to 76 months (median, 20.5 months).

Discussion

Limited data are available regarding contralateral lung resection in patients who have previously undergone pneumonectomy. Previous research has focused on pulmonary resection following pneumonectomy due to metastases or metachronous lung cancer. In this study, we included both patients with cancerous and benign conditions. The aim of this study was to ascertain the safety and value of contralateral pulmonary resection in individuals with prior pneumonectomy. The existing literature indicates that long-term survival is attainable and that operative mortality can be extremely low among carefully selected patients.

The selection of candidates for contralateral lung resection after pneumonectomy is challenging. To ensure an acceptable quality of life, only patients who are likely to tolerate the procedure and maintain adequate pulmonary reserves should be selected. We utilized standard PFTs to assess patient eligibility for contralateral lung resection. Those with relatively low PFT results were additionally evaluated using a 6-minute walking test or an oxygen consumption test. The median FEV1 was 1.64 L, a level indicating suitability for wedge or segmental resection. To achieve a meaningful survival benefit, the predicted postoperative (PPO) FEV1 should exceed 0.8–1.0 L/sec [3]. Additionally, a PPO DLCO of greater than 40% is advised [4]. Cardiopulmonary reserve is another crucial factor. Echocardiography was performed on each patient to confirm systolic function and to exclude the presence of right heart dysfunction and pulmonary hypertension, both of which are contraindications for lung resection [4].

Extensive testing is recommended to assess whether patients exhibit advanced disease within the thoracic cavity and in distant organs. Patients with lung cancer underwent routine evaluation using chest CT scans. Most patients showed no symptoms when a new lesion was detected. To exclude the possibility of regional and distant metastases, PET/CT scans were performed. Furthermore, it is critical to differentiate between metachronous lung cancer and metastatic lung cancer due to the unfavorable impact of metastatic lung cancer on long-term survival [3-6]. According to Martini and Melamed [8], a second lung tumor in a patient who previously underwent surgery for lung cancer should be considered a second primary lung cancer (metachronous) rather than a metastasis if the histology of the 2 lesions differs, the tumor-free interval exceeds 2 years, and no other distant metastases are observed. In the present study, 6 patients underwent pulmonary resection for second lung cancer after pneumonectomy. Among these patients, 4 had metachronous lung cancer and 2 had metastatic lung cancer (patients 1–4 and 5–6, respectively). The 5-year survival rate following resection for metachronous cancer was 25%, in contrast to 0% for those with metastatic disease. These results align with prior research, which has shown that patients who undergo surgical resection for metachronous cancer have a more favorable long-term survival rate than those who experience resection for metastatic cancer [5-7]. However, a need exists for comparative studies on survival rates and quality of life between patients undergoing contralateral lung resection and those receiving radiotherapy, chemotherapy, or observation alone after previous pneumonectomy. Surgery should be considered with caution in patients with metastatic lung cancer due to the poor survival outcomes. For patients with metastatic lung cancer, contralateral pulmonary resection may not be the optimal treatment approach.

To ensure the safe performance of contralateral lung resection following pneumonectomy, several factors must be considered. Among our cases, pulmonary nodules were frequently superficial and readily apparent; however, for nodules situated more deeply, manual palpation was employed for detection. Additionally, we prepared for the potential use of extracorporeal membrane oxygenation (ECMO) to manage potential desaturation during lung deflation. In 1 instance, ECMO was on standby; fortunately, however, no adverse events arose during lung deflation,

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and the use of ECMO was not necessary. Having ECMO ready for use during contralateral lung resection surgery is a prudent measure to ensure preparedness for any unforeseen complications.

The successful recovery of patients who have undergone contralateral lung resection following pneumonectomy is contingent upon several factors, including anesthesia, surgical technique, critical care, and rehabilitation. It is critical to manage respiratory function meticulously during surgery [9]. Anesthesia that minimally depresses respiratory and cardiac function is associated with early extubation, which in turn can decrease the frequency of ventilator-associated pneumonia. In the present study, all patients were extubated within the first day following surgery. Additionally, it is imperative to operate without air leaks during contralateral lung resection to facilitate early recovery. A prolonged air leak, defined as one persisting for more than 7 days, was noted in patients 7 and 13. These patients experienced severe adhesions, and their operation times were longer than those observed in other patients (operation times of 159 and 147 minutes versus median operation time of 62 minutes). The chest tube remained in place for 10 and 9 days, respectively, compared to a median duration of 3 days. Postoperative care should include effective pain management, which allows patients to clear secretions more efficiently through enhanced coughing, deeper breathing, and earlier mobilization. We encouraged our patients to participate in respiratory rehabilitation.

The present study had several limitations. First, the retrospective study design and single-center approach may have introduced selection bias. Additionally, the sample size was small. Nonetheless, given the infrequency with which this procedure is performed, our case series is comparable to previously published studies. A second limitation is the absence of a control group. Comparing long-term outcomes between lobectomy and wedge resection is challenging, and our study included only a single case of lobectomy. This particular patient had never smoked, was diagnosed with a benign condition, and exhibited good pulmonary function, as evidenced by an FEV1 of 1.55 L and a DLCO of 88%. At 231 months after surgery, this patient remained alive. Typically, lobectomy is contraindicated for patients who have undergone previous pneumonectomy, due to its detrimental effects on cardiopulmonary reserve [1-7]. Therefore, the survival rate post-lobectomy in our study may appear higher than that reported in earlier research. As more data are gathered, lobectomy and wedge resection will be more easily comparable with regard to long-term survival.

In conclusion, contralateral pulmonary resection after pneumonectomy can be accomplished with acceptable operative morbidity and mortality among carefully selected patients. Patients should be meticulously chosen for contralateral lung resection after pneumonectomy, paying particular attention to their cardiopulmonary reserve and the extent of cancer involvement.

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Conceptualization: YSC. Data curation: GHJ. Formal analysis: YSC, YMS. Visualization: GHJ. Writing–original draft: GHJ, YSC. Writing–review & editing: all authors. Approval of the final version: all authors. Accountability: all authors.

Conflict of interest

Junghee Lee and Seong Yong Park are editorial board members of the journal, and Hong Kwan Kim was an editorial board member during the submission of the manuscript. None of them were involved in the peer reviewer selection, evaluation, or decision process for this article. No other potential conflicts of interest relevant to this article were reported.

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