Prolonged air leak after segmentectomy: incidence and risk factors

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Background: We designed this study to investigate the rate and risk factors of prolonged air leak (PAL) in patients undergoing pulmonary segmentectomy in our unit.

Methods: We performed a retrospective cohort study on 191 patients undergoing pulmonary segmentectomy (January 2017–August 2021). A PAL was defined as an air leak >5 days.

Results: One hundred and sixty-eight segmentectomies were performed using video-assisted thoracoscopic surgery (VATS), 13 were open operations and 10 were robotic. PAL occurred in 36 patients (19%). Their average post-operative stay was 2.4 days longer than those without PAL. Logistic regression analysis showed that a low preoperative carbon monoxide lung diffusion capacity (DLCO) (OR 0.98, P<0.001), low body mass index (BMI) (OR 0.95, P=0.002) and the performance of complex segmentectomies (OR 2.2, P<0.001). were significantly associated with PAL.

Conclusions: Pulmonary segmentectomies are associated with a not negligible risk of PAL when using real world data, especially in patients with compromised pulmonary function and after complex segmentectomies. This finding is useful to inform the decision-making process.

Keywords: Pulmonary segmentectomy; prolonged air leak (PAL); outcome

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Introduction

With lung cancer remaining the leading cause of cancer death worldwide and surgical resection the choice of treatment in early stage disease, there is significant importance in ensuring that surgical technique continues to be examined and refined to maintain optimal patient outcomes. The gold standard of performing pulmonary lobectomy is based on a trial that is now almost three decades old. The Lung Cancer Study Group (LCSG) showed an increased locoregional recurrence rate in patients undergoing sublobar resection (1). This evidence combined with a long standing view that might not be as invasive as lobectomy, and often a more technically challenging operation with associated complications, has meant segmentectomy had often been approached cautiously.

However, as there has been an increased early detection

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of smaller lesions with improvement in computed tomography (CT) combined with the practice of low dose helical CT for screening, the role of segmentectomy was subject to renewed discussion. A series of studies have shown that it could be performed safely without compromising oncological principles (2-4). The recent findings from the JCOG-0802 randomized trial have confirmed that anatomic segmentectomy is associated with at least similar if not superior overall survival compared to lobectomy for solid or partly solid early stage lung cancer (5). The role of segmentectomy is therefore expanding in in thoracic surgical practice. This will warrant specific analyses to explore procedure-specific morbidity. In this context, one of the most common concerns traditionally linked to segmentectomy is the increased rate prolonged air leak (PAL).

PAL represents one of the common complications following lung resection. It is associated with significant complications including pneumonia and empyema and is a major factor impacting on hospital stay and costs (6).

The objective of this study was to assess the rate of PAL following pulmonary segmentectomy when using real world data and identify specific risk factors associated with this complication. We present the following article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-623/rc).

Methods

Ethical statement

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was reviewed by the research and innovation departments of Leeds Teaching Hospitals and classified as service evaluation not requiring formal review by the research ethics committee and individual consent for this retrospective analysis was waived.

Patients

This is a retrospective cohort analysis of patients undergoing segmentectomy at the Department of Thoracic Surgery, St. James's University Hospital, Leeds from August 2017 to August 2021. Our unit is a tertiary referral centre. All consecutive patients submitted to anatomic segmentectomy during the study period were deemed eligible for inclusion.

Indications for segmentectomy

Indications for an anatomic segmentectomy in our unit were according to the Brunelli's classification.

(I) Intentional: a primary NSCLC smaller than 2 cm, located peripherally in a well-defined segment in a patient otherwise fit for lobectomy (72 patients, 38%).
(II) Compromised (functional): in a patient deemed unfit for lobectomy but sufficiently fit for a sublobar resection (51 patients, 26%).
(III) Compromised (multiple): in patients with multiple primary tumours in different lobes or lungs, or who underwent a previous lobectomy (32 patients, 17%).
(IV) Compromised (diagnostic): in patients with undetermined nodules, in whom tissue confirmation from other means (CT guided biopsy, electro-magnetic navigational TBNA) has been deemed unfeasible or resulted non diagnostic, or in patients with suspected metastases from other primary tumours (36 patients, 19%).

All patients received surgery under the care of 6 board certified general thoracic surgeons. Segmentectomies were performed by the individual dissection and division of the segmental arteries, bronchus and veins. A systematic lymph node dissection was performed in all patients including lymph nodes at the foot of the segmental hilum. The intersegmental planes were identified using the inflation-deflation technique and following the anatomic structures of the segment. They were divided using mechanical stapler devices. Air leak was assessed at the end of the operation using submersion technique and estimated through the ventilator. Any significant air leak was addressed by suture whenever possible. Sealants were only occasionally applied and at the discretion of the surgeons. No PGA-sheet, buttressed sutures, pleural tent or pleurodesis was performed in this series. All patients had a single chest tube inserted peri-operatively that was connected to a digital drainage system. The air leak was then assessed objectively using the digital device and absence of air leak was accepted with an air flow of 0–10 mL/min without any spikes for a period of a least 8 hours whilst the drain was set at –8 cmH_2O. In addition, drain removal would be recommended with effluent less than 300–400 mL in the last 24 hours.

PAL was defined as an air leak persisting after 5 days. Generally, patients with air leak after 5 days were

Table 1 Types of segmentectomies performed and included in the analysis

Segmentectomies	n
Right segmentectomies (n=85)	
S6	29
S1	18
S2	11
S1+2	3
S3	9
S7+8	5
S9+10	5
S7-10	4
S6+10	1
Left segmentectomies (n=106)	
Lingula (S4+5)	22
S3+4+5	1
S4+5+6	1
Upper division (S1-3)	17
S3	2
S1+2	25
S1	1
S2	1
S6	19
S7+8	3
S9+10	5
S7-10	9

transferred onto an ambulatory chest drainage system and discharged home if their overall clinical status allowed. Those patients discharged with a chest drain in place were then reviewed on a weekly basis in a dedicated outpatient clinic.

For the purpose of this study, the following segmentectomies were classified as simple segmentectomies: superior segmentectomy of the lower lobes (S6); left upper division segmentectomy (left S1+S2+S3); lingulectomy (left S4+S5) and basilar segmentectomies (S7-S10). *Table 1* lists the types of segmentectomies performed during the study period and included in the analysis. All other segmentectomies or combinations of segmentectomies were classified as complex segmentectomies (6).

Statistical analysis

The following baseline and procedural factors were tested for a possible association with occurrence of postoperative PAL: age, gender, body mass index (BMI), smoking status (never smoker, ex-smoker, current smoker), forced expiratory volume in one second expressed as percentage of predicted values (FEV1%), carbon monoxide lung diffusion capacity expressed as percentage of predicted value (DLCO%), performance status, diabetes, coronary artery disease, cerebrovascular disease, surgical access (minimal invasive *vs.* open), side of resection, site of resection (upper *vs.* lower lobe), presence of pleural adhesions, number of segments removed (single *vs.* multiple), and complexity of segmentectomy (complex *vs.* simple). Numeric variables with normal distribution were compared using the unpaired Student's *t*-test, and those without normal distribution were compared using the Mann-Whitney test. Categorical variables were compared using the χ^2 test or Fisher's exact test (whenever the count in any of the cells was less than 10). Patients were followed for at least 30 days after surgery or over a longer period if still in hospital. There was no missing data in the present series. Variables with a P value <0.2 at univariable analysis were included as independent variables in a logistic regression analysis adjusted for clustering with surgeons to test the independent association of factors with PAL. The statistical analysis was performed on Stata 10.1 statistical software (Stata Corp, College Station, TX, USA).

Results

One hundred and ninety-one patients were analysed. They represent 16% of all anatomic lung resections performed in our unit during the same period. One hundred forty-three (75%) procedures were performed for primary non-small cell lung cancer (NSCLC). A total of 10 cases were performed by robotic assisted thoracoscopic surgery (RATS), 13 by open operation, and 168 by video-assisted thoracoscopic surgery VATS). Patients started on minimally invasively (VATS/RATS) and converted to open (9 of 178, 5.1%) were included in the minimally invasive group as per the intention- to treat analysis.

Table 2 displays the characteristics of the patients included in this study. Fifty four percent were older than 70 years of age, 6% had a FEV1 <60% and 18% a DLCO

Table 2 Characteristics of patients included in the study, with and without PAL

Variables	Total population (n=191)	Without PAL (n=155)	With PAL (n=36)	P value
FEV1%	92.4 (22.2)	94.2 (22.3)	84.9 (20.6)	0.024
DLCO%	76.5 (19.1)	78.5 (18.5)	68.3 (20.0)	0.004
CAD (n, %)	20 (11%)	17 (11%)	3 (8.3%)	0.77
BMI, kg/m^2	27.1 (5.1)	27.5 (5.0)	25.3 (5.3)	0.047
BMI <18.5 (n, %)	10 (5.2%)	6 (3.9%)	4 (11%)	0.096
Age	69.1 (9.5)	69.5 (9.6)	67.7 (8.8)	0.13
Male gender (n, %)	87 (46%)	71 (46%)	16 (44%)	0.88
Diabetes (n, %)	15 (7.8%)	12 (7.7%)	3 (8.3%)	1
Smoking status (current, ex-smoker, never smoker) (n, %)	36 (19%), 122 (64%), 33 (17%)	25 (16%), 99 (64%), 31 (20%)	11 (30.5%), 23 (64%), 2 (5.5%)	0.031
PS >1 (n, %)	11 (5.7%)	9 (5.8%)	2 (5.6%)	1
MIS access (*vs.* open) (n, %)	178 (93%)	143 (92%)	35 (97%)	0.46
Side of operation (right) (n, %)	85 (45%)	70 (45%)	15 (42%)	0.70
Location of tumour (upper lobe) (n, %)	113 (59%)	91 (59%)	22 (61%)	0.79
Pleural adhesions (n, %)	40 (21%)	31 (20%)	9 (25%)	0.50
Complex segmentectomies (n, %)	95 (50%)	73 (47%)	22 (61%)	0.13
Multiple segments removal (n, %)	98 (51%)	82 (53%)	16 (44%)	0.36
Intentional segmentectomies (*vs.* compromised) (n, %)	72 (38%)	58 (37%)	14 (39%)	0.87

Results expressed as means and standard deviation (numeric variables) and count and percentage of total within the group (categorical variables). PAL, prolonged air leak; FEV1, forced expiratory volume in one second; DLCO, carbon monoxide lung diffusion capacity; CAD, coronary artery disease; BMI, body mass index; PS, Performance Status; MIS, minimally invasive surgery.

<60% of predicted. Ninety-five patients (50%) underwent complex segmentectomies and 98 (51%) had more than one segment removed.

Four patients (2.1%) died within 30 days from operation or while in-hospital. Their main cause of death was respiratory failure. Thirty-six patients (19%) developed a postoperative prolonged air leak. *Table 2* shows the characteristics of patients with and without PAL in our unit. Patients who developed postoperative PAL had 10% lower values of preoperative FEV1 (P=0.024) and DLCO (P=0.004), had a lower BMI (P=0.047). Compared to simple segmentectomies, more patients in the complex segmentectomies group developed PAL (23% *vs.* 15%, P=0.13).

Interestingly the surgical access was not associated with PAL. In the patients operated with a minimally invasive approach we had 9 conversion (5%). However, the incidence of PAL did not differ between converted patients and those who had their operations completed with a minimally invasive approach (2.9% vs 5.6%, respectively, Fisher's exact test P=1), *Table 3* shows the results of the multivariable logistic regression analysis adjusted for clustering within surgeons. The following factors with a P<0.2 at univariable analysis were used as co-variates: age, FEV1, DLCO, BMI, smoking status, complex segmentectomies. After logistic regression the following independent factors remained significantly associated with PAL: a low DLCO (OR 0.97, P<0.001), a low BMI (OR 0.95, P=0.002) and complex segmentectomies (OR 2.2, P<0.001).

Table 4 shows that the characteristics of patients

Table 3 Results of the logistic regression analysis adjusted for clusters within surgeons (dependent variable: PAL)

Variables	OR	Robust SE	P value	95% confidence interval
Age	0.97	0.04	0.37	0.89–1.04
FEV1	0.99	0.006	0.12	0.98–1.01
DLCO	0.98	0.004	<0.0001	0.97–0.99
BMI (kg/m^2)	0.95	0.014	0.002	0.92–0.98
Smoking status (reference never smoker)				
Current smoker	3.30	3.13	0.22	0.5–21.4
Past smoker	3.70	3.35	0.15	0.62–21.9
Complex segmentectomy	2.23	0.43	<0.0001	1.52–3.27

PAL, prolonged air leak; OR, odds ratio; SE, standard error; FEV1, forced expiratory volume in one second; DLCO, carbon monoxide lung diffusion capacity; BMI, body mass index.

Table 4 Characteristics of complex vs simple segmentectomies

Variables	Simple segmentectomy (n=96)	Complex segmentectomy (n=95)	P value
Age	68.5 (8.9)	69.8 (10.0)	0.31
BMI (kg/m^2)	27.6 (5.2)	26.5 (4.9)	0.19
Male gender	45 (47%)	42 (44%)	0.71
FEV1%	91.5 (23.1)	93.4 (21.5)	0.56
DLCO%	74.9 (19.2)	78.1 (19.2)	0.26
PAL	14 (15%)	22 (23%)	0.13

Results are expressed as means and standard deviation (numeric variables) and count and percentage of total within the group (categorical variables). BMI, body mass index; FEV1, forced expiratory volume in one second; DLCO, carbon monoxide lung diffusion capacity; PAL, prolonged air leak.

undergoing complex segmentectomies were similar to those undergoing "simple" segmentectomies. We were not able to find any patient-related statistical difference between the two types of segmentectomies. However, the incidence of PAL after complex segmentectomies was 53% higher compared to that after simple segmentectomies (21% *vs.* 15%, P=0.13).

The average postoperative length of stay in patients with PAL was 2.4 days longer than those without PAL (7.5 *vs.* 5.1, P=0.016). Thirty-three percent of patients with PAL stayed in hospital longer than 7 days (*vs.* 12% of those without PAL, P=0.001). Twenty eight of 36 patients with PAL (78%) were sent home with a chest drain in place. The median duration of the chest drains in patients with and without PAL was 13 and 3 days respectively. Of those patients discharged home with a chest drain 7 (25%) patients required hospital re-admission within 30 days (*vs.* 5% of patients discharged without a drain). The reasons for readmission were empyema in three patients, pneumonia in two, worsening pneumothorax and drain displacement in one patient.

In this series two of the surgeons (AB and KP) performed 60% and 18% of the segmentectomies, respectively. The remaining 32% were shared between four surgeons. The incidence of PAL was higher in AB cases than in those performed by other surgeons (25% *vs.* 10%, P=0.005). However, 63% of his cases were complex segmentectomies compared to 30% by the other surgeons (P<0.0001). For this reason, the logistic regression was adjusted for clustering within surgeons.

Discussion

Several recent observational studies and metanalysis (2-4,7,8), the results of the JCOG randomized trial (5) and the recent findings from the CALBG randomized trial reported at the WCLC 2022 have sparked a renewed interest in employing segmentectomy in early-stage lung cancer as an intentional procedure and not only reserved to compromised patients with limited cardiopulmonary function.

The incidence of PAL after segmentectomy has been generally reported to be similar compared to lobectomies (9-11) with the notable exception of the JCOG trial which found an increased incidence of this complication in the segmentectomy arm (12).

A recent study from Gonzalez and coll. (13) found a PAL incidence after segmentectomy of 14.1% which is similar to the one detected in our study. Compared to lobectomy, segmentectomy requires a deeper dissection into the lung parenchyma with often lend to longer stapled lines crossing multiple planes (especially in complex segmentectomies). The specific technical steps of a segmentectomy warrant an in-depth analysis of risk factors for PAL after this procedure.

We found that a low DLCO was associated with PAL. This confirms previous findings (13,14). Lower DLCO can be interpreted as a surrogate of lung frailty and increased susceptibility to tear during lung procedures and slower healing.

Notably, we were not able to show an association between FEV1 and PAL after logistic regression. This may be explained by the concomitant inclusion of DLCO in the model which represents a more comprehensive parameter influenced by several factors, including lung volumes. This finding was consistent with the one reported by Gonzalez and coll. (13) and is at variance with previous studies which found lower FEV1 significantly associated with PAL after lobectomy (15-17). In these studies, DLCO was not tested. Nevertheless, Seder and coll. (18) found both FEV1 and DLCO significantly associated with PAL when included together in a logistic regression model in a large dataset from the STS database.

A low BMI has been previously found associated with increased risk of PAL being a surrogate of malnutrition and hence potentially affecting healing of the lung after resection (14-19).

The novel finding of this study was the association of complex segmentectomies with increased risk of PAL compared to simple segmentectomies. This should be likely attributed to a technical factor as the characteristics of the patients undergoing the two types of procedures were similar in this study. In complex segmentectomies the intersegmental planes are often three-dimensional and multiple staples lines crossing different planes are required. This may in turn generate an increased parenchymal tension on re-expansion of the lung which may lead to parenchymal tearing along the staple lines. This finding is at variance with the ones reported by others who were not able to find any difference in PAL incidence between complex and simple segmentectomies (13,20). However, Suzuki and coll. (12) in their early report of the JCOG randomized trial focussing on perioperative outcomes found that nearly 70% of patients with PAL after segmentectomy had complex segmentectomy. In addition, in that study complex segmentectomy remains a significant risk factor of pulmonary complication after multivariable regression analysis.

As reported in previous studies (21,22), we found a high re-admission rate of those patients discharged home with a chest drain. Most of these re-admissions were caused by drain-related complications. In light of this finding, we have now started a policy of prescribing antibiotics to patients sent home with a tube.

Limitations

This study may have some limitations. First, this is a retrospective single centre study with inherent selection bias. The choice of performing a segmentectomy was based on multidisciplinary team discussion and on the surgical judgement. Surgical experience with this operation may have likely played a role in influencing the decision. This is shown by the fact the majority of the operations are performed by a single surgeon in this team with the others gradually starting to adopt the procedure.

Only a third of patients had their segmentectomy on an intentional basis. This reflects current national standard of care at the time of when the procedures were performed. This is likely to change with the recent results of the randomized trial showing a favourable outcome of sublobar resection in patients with peripheral tumour smaller than 2 cm.

All patients were managed using digital chest drainage system generally applying a low level of negative pressure (−8 cmH_2O or less). As negative pressure applied to chest drains has been shown to potentially influence duration of air leak, the results may not be reproducible in other settings where digital device are not used or different pressure settings are applied.

Finally, in this series, no preventative measures for air leak were used with the exception of the occasional use of sealants. Whether the routine use of such measures would affect the incidence of air leak after segmentectomy should be the object of specific efficacy studies.

Conclusions

Segmentectomy is being recognised as an increasingly important procedure for the thoracic surgeon. Our study has shown that it can be associated with a not negligible risk of PAL. This is particularly true for patients undergoing complex segmentectomies and in those with low DLCO and BMI, marker of more compromised pulmonary parenchyma. These findings should be used to inform the shared decision-making process and set realistic patient's expectations.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was reviewed by the research and innovation departments of Leeds Teaching Hospitals and classified as service evaluation not requiring formal review by the research ethics committee and individual consent for this retrospective analysis was waived.

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