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# Incidence of air leaks in patients undergoing robotic thoracic surgery and video-assisted thoracic surgery

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## ABSTRACT

Postoperative air leakage is the most common complication in surgery for malignant lung tumors, leading to extended hospital stays and substantial medical expenses. This study aimed to identify the incidence and characteristics of intraoperative and postoperative air leaks in both robotic-assisted thoracic surgery (RATS) and video-assisted thoracic surgery (VATS), as well as the causes of persistent air leakage following RATS. We conducted a retrospective analysis of patients who underwent lung resection for malignant lung tumors at our institution from October 2018 to August 2022. We compared the incidence rates of intraoperative air leak, postoperative air leak, and persistent air leak between patients who underwent RATS and those who underwent VATS. Background factors were adjusted using propensity score matching. A subanalysis was performed to compare unexpected air leaks, defined as air leaks not observed intraoperatively but confirmed postoperatively. The study included 295 cases of RATS and 227 cases of VATS. In both the overall population and the matched group (187 cases each for RATS and VATS), RATS demonstrated a significantly higher incidence of persistent air leaks compared to VATS (11% vs 3%, $p < 0.01$; 9% vs 3%, $p = 0.02$, respectively). RATS also had a significantly higher incidence of unexpected air leaks compared with VATS (29% vs 18%, $p = 0.05$). Although there was no statistically significant difference in hospital stays, RATS showed a higher incidence of postoperative persistent air leaks and unexpected postoperative air leaks than VATS.

Keywords: air leak, robotic thoracic surgery, video-assisted thoracic surgery

Abbreviations:
RATS: robot-assisted thoracic surgery
VATS: video-assisted thoracic surgery



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## INTRODUCTION

Postoperative air leaks are one of the most common complications of thoracic surgical procedures, leading to prolonged hospitalization and increased medical expenses. The incidence of persistent postoperative air leaks after robot-assisted thoracic surgery (RATS) or video-assisted thoracic surgery (VATS) for malignant tumors has been reported to be 4%–17%.[1-12] When performing RATS, surgeons must consider limitations in the movement and range of motion of the robot arm, as well as the absence of tactile sensation. In particular, the lack of tactile feedback may lead to damage to delicate lung tissue by the robotic instruments. Hence, RATS requires different technical skills and precautions compared with VATS.[13,14] In two recent meta-analysis papers, it was suggested that there is no significant difference in the incidence of persistent air leaks between RATS and VATS.[15,16] However, RATS is a relatively new surgical technique, and the available literature on persistent air leaks is limited. Certain medical institutions have reported a markedly higher incidence of persistent air leaks with RATS than with VATS.[4,11] To the best of our knowledge, there have been no reports providing a detailed analysis of intraoperative and postoperative air leaks, including unexpected air leaks and air leak repair in the context of RATS and VATS. Therefore, we conducted a retrospective analysis of the incidence and characteristics of intraoperative and postoperative air leaks in RATS and VATS to obtain a deeper understanding of the issue. The current study aimed to evaluate the incidence of intra- and postoperative air leaks and persistent air leaks after RATS and VATS at our institution. Furthermore, the incidence of unexpected air leaks between RATS and VATS was compared to determine the underlying causes of persistent air leaks.

## MATERIALS AND METHODS

A retrospective study was conducted on patients who underwent pulmonary lobectomy or segmentectomy for lung tumors and metastatic pulmonary tumors at Nagoya University Hospital between October 2018 and August 2022. Patients who underwent uni-portal VATS, those who received investigational drugs, those with a history of surgery on the same side of the lung, and those who transitioned to thoracotomy were excluded from the study. RATS was performed using four robot ports and one assistant port. The camera was inserted from the midaxillary line of the 8th intercostal space, and $CO_2$ insufflation at 8 $cmH_2O$ was used via one assistant port during the procedure. The number and position of the VATS ports were based on the discretion of the surgeon. During surgery, a sealing test was performed by inflating the lung with saline solution at a pressure of 15 $cmH_2O$ to check for air leaks. In RATS, the sealing test was performed with the cessation of $CO_2$ insufflation. In total, 9 and 14 surgeons performed RATS and VATS, respectively, during the study period. The repair method in case of air leaks discovered during the sealing test was based on the surgeon's discretion. A persistent air leak was defined as either a prolonged air leak persisting for 7 days or more postoperatively or the performance of pleurodesis with OK-432 within 7 days postoperatively. We compared the incidence of intraoperative, postoperative, and persistent air leaks between RATS and VATS.

A subanalysis was performed, focusing on cases in which no intraoperative air leaks were observed. An unexpected air leak was defined as a confirmed air leak after surgery even though there was no air leak during surgery. We compared the incidence of unexpected air leaks and the proportion of cases leading to persistent air leaks between RATS and VATS.

The descriptive statistics are summarized as median and range for continuous variables and as frequency and percentage for categorical variables. All statistical analyses were performed using

EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan). The Mann–Whitney U test and Fisher exact test were used for analysis. All P values were two-tailed, and significance was set at $P < 0.05$. A propensity score was generated using a logistic regression model to minimize differences among baseline variables between the RATS and VATS groups. Variables included in the propensity score matching process comprised sex, age, body mass index, Brinkman index, percent predicted Forced Expiratory Volume in one second (%FEV1), presence of interstitial pneumonia, underlying disease, tumor maximum diameter, type of surgery (lobectomy or segmentectomy), location within the lung, and lobe fissure. A 1:1 matching without replacement was conducted with a caliper 0.2 standard deviation of the logit of the propensity score and using the nearest neighbor method.

The study protocol received approval from the institutional review board of Nagoya University School of Medicine (2015-0458, March 8, 2016). Informed consent requirements were waived owing to the retrospective study design.

## RESULTS

The current study comprised 295 RATS cases and 227 VATS cases. RATS had a significantly higher %FEV1 and prevalence of lung cancer, a larger tumor maximum diameter, and a greater proportion of lobectomy procedures than VATS. Furthermore, a significant imbalance was observed in the distribution of specific lung lobes targeted for surgery. In total, 137 (46%) and 109 (48%) cases of intraoperative air leaks were observed after RATS and VATS, respectively ($p = 0.72$). Further, there were 116 (39%) and 72 (32%) cases of postoperative air leaks ($p = 0.08$), and 31 (11%) and 7 (3%) cases of persistent air leaks ($p < 0.01$). Hence, RATS had a significantly higher incidence of persistent air leaks than VATS. The median postoperative drainage duration was 2 days in both RATS and VATS ($p = 0.02$). The length of hospital stay was 5 days in both groups ($p = 0.36$; Table 1).

**Table 1** Comparison of clinical characteristics and surgical outcomes between RATS and VATS

| Characteristics | RATS n = 295 | VATS n = 227 | p-value |
|---|---|---|---|
| Sex, Male (%) | 157 (53) | 123 (54) | 0.86 |
| Age, years | 71 [31–85] | 70 [35–88] | 0.62 |
| Body mass index | 22.8 [13.7–37.4] | 22.9 [15.0–34.4] | 0.54 |
| Brinkman index | 200 [0–4000] | 300 [0–3600] | 0.49 |
| %FEV1, % | 100.9 [49.8–151.5] | 95.7 [44.4–156.2] | 0.01 |
| Interstitial pneumonia (%) | 29 (10) | 13 (6) | 0.11 |
| Underlying disease, Lung cancer (%) | 280 (95) | 201 (89) | 0.01 |
| Maximum tumor size, mm | 22 [5–105] | 18 [2–61] | <0.01 |
| Surgical procedure, Lobectomy (%) | 253 (86) | 150 (66) | <0.01 |
| Lobe (%) | | | 0.03 |
| Right Upper | 107 (36) | 59 (26) | |
| Right Middle | 28 (10) | 14 (6) | |
| Right Lower | 63 (21) | 59 (26) | |
| Left Upper | 63 (21) | 55 (24) | |
| Left Lower | 34 (12) | 40 (18) | |
| Lobe fissure, clear (%) | 184 (62) | 147 (65) | 0.58 |

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|---|---|---|---|
| Repair method of the air leak (%) | | | |
| Suture | 74 (25) | 59 (26) | 0.84 |
| PGA sheet | 106 (36) | 78 (34) | 0.78 |
| Fibrin glue | 46 (16) | 35 (15) | 1.00 |
| Intraoperative air leak (%) | 137 (46) | 109 (48) | 0.72 |
| Postoperative air leak (%) | 116 (39) | 72 (32) | 0.08 |
| Persistent air leak (%) | 31 (11) | 7 (3) | <0.01 |
| Postoperative drainage period, day | 2 [1–13] | 2 [1–18] | 0.02 |
| Postoperative hospital stay, day | 5 [3–54] | 5 [3–24] | 0.36 |

The numbers within the square brackets represent the [minimum-maximum] range.
The number within the parentheses represents the (%).
PGA: polyglycolic acid
RATS: robot-assisted thoracic surgery
VATS: video-assisted thoracic surgery
%FEV1: percent predicted Forced Expiratory Volume in one second

After a 1:1 propensity score matching, 187 cases were selected from both RATS and VATS, with no significant differences in the background characteristics of the matched groups.

The results revealed no significant difference in the occurrence of intraoperative air leaks between RATS and VATS, with 96 cases (51%) and 90 cases (48%), respectively (p = 0.60). Similarly, there was no significant difference in postoperative air leaks, with 62 cases (33%) in RATS and 64 cases (34%) in VATS (p = 0.90). However, persistent air leaks were significantly more prevalent in RATS, with 17 cases (9%) compared to 6 cases (3%) in VATS. The duration of postoperative drainage was 2 days in both RATS and VATS (p = 0.18). The length of hospital stay was 5 days for both groups (p = 0.77; Table 2).

**Table 2** Comparison of clinical characteristics and surgical outcomes between RATS and VATS following propensity score matching

| Characteristics | RATS n = 187 | VATS n = 187 | p-value |
|---|---|---|---|
| Sex, Male (%) | 97 (52) | 101 (54) | 0.76 |
| Age, years | 71 [31–84] | 70 [35–87] | 0.76 |
| Body mass index | 22.9 [14.4–35.2] | 22.6 [15.0–34.4] | 0.41 |
| Brinkman index | 300 [0–4000] | 300 [0–3600] | 0.65 |
| %FEV1, % | 100.3 [49.8–146.4] | 95.7 [54.4–156.2] | 0.29 |
| Interstitial pneumonia (%) | 13 (7) | 12 (6) | >0.99 |
| Underlying disease, Lung cancer (%) | 172 (92) | 173 (92) | >0.99 |
| Maximum tumor size, mm | 21 [5–52] | 19 [2–61] | 0.51 |
| Surgical procedure, Lobectomy (%) | 146 (78) | 148 (79) | 0.90 |
| Lobe (%) | | | 0.93 |
| Right Upper | 58 (31) | 59 (32) | |
| Right Middle | 15 (8) | 14 (8) | |
| Right Lower | 48 (26) | 48 (26) | |
| Left Upper | 38 (20) | 43 (23) | |
| Left Lower | 28 (15) | 23 (12) | |
| Lobe fissure, clear (%) | 121 (65) | 119 (64) | 0.91 |

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|---|---|---|---|
| Repair method of the air leak (%) | | | |
| Suture | 55 (29) | 47 (25) | 0.42 |
| PGA sheet | 68 (36) | 65 (35) | 0.83 |
| Fibrin glue | 23 (16) | 31 (17) | 0.30 |
| Intraoperative air leak (%) | 96 (51) | 90 (48) | 0.60 |
| Postoperative air leak (%) | 62 (33) | 64 (34) | 0.90 |
| Persistent air leak (%) | 17 (9) | 6 (3) | 0.02 |
| Postoperative drainage period, day | 2 [1–13] | 2 [1–18] | 0.18 |
| Postoperative hospital stay, day | 5 [3–54] | 5 [3–24] | 0.77 |

The numbers within the square brackets represent the [minimum-maximum] range.
The number within the parentheses represents the (%).
PGA: polyglycolic acid
RATS: robot-assisted thoracic surgery
VATS: video-assisted thoracic surgery
%FEV1: percent predicted Forced Expiratory Volume in one second

The surgical repair options for intraoperative air leaks included suturing and the application of a polyglycolic acid sheet and fibrin glue. There was no difference in the repair methods between the two groups before and after propensity score matching, as shown in Table 1 and Table 2.

In the intraoperative sealing test, 158 and 118 patients who underwent RATS and VATS, respectively, did not present with air leaks. Patients who underwent RATS had a significantly higher %FEV1, larger tumor diameter, and greater frequency of lobectomy than those who underwent VATS. RATS had a higher incidence of unexpected air leak than VATS (45 [29%] vs 21 [18%], p = 0.05; Table 3). The probability of unexpected air leaks progressing to persistent air leaks was 17% for RATS (7/42) and 5% for VATS (1/21), and no significant difference was observed (p = 0.25; Table 4).

**Table 3** Comparison of clinical characteristics and surgical outcomes between RATS and VATS without intraoperative air leaks

| Characteristics | RATS n = 158 | VATS n = 118 | p-value |
|---|---|---|---|
| Sex, Male (%) | 85 (53) | 50 (42) | 0.07 |
| Age, years | 71 [31–84] | 69 [44–88] | 0.56 |
| Body mass index | 23.6 [13.7–37.4] | 22.8 [15.2–34.4] | 0.19 |
| Brinkman index | 50 [0–2200] | 0 [0–3600] | 0.67 |
| %FEV1, % | 103.5 [51.4–151.5] | 95.2 [44.4–156.2] | 0.01 |
| Interstitial pneumonia (%) | 11 (7) | 9 (8) | 0.82 |
| Underlying disease, Lung cancer (%) | 149 (94) | 112 (95) | >0.99 |
| Maximum tumor size, mm | 23 [5–105] | 19 [5–61] | 0.01 |
| Surgical procedure, Lobectomy (%) | 137 (87) | 81 (69) | <0.01 |
| Lobe (%) | | | 0.07 |
| Right Upper | 60 (38) | 35 (30) | |
| Right Middle | 15 (10) | 4 (3) | |
| Right Lower | 29 (18) | 29 (25) | |
| Left Upper | 36 (23) | 28 (24) | |
| Left Lower | 18 (11) | 22 (19) | |

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|---|---|---|---|
| Lobe fissure, clear (%) | 107 (68) | 84 (71) | 0.60 |
| Unexpected air leak (%) | 42 (29) | 21 (18) | 0.05 |
| Persistent air leak (%) | 7 (4) | 1 (1) | 0.14 |
| Postoperative drainage period, day | 2 [1–13] | 2 [1–10] | 0.04 |
| Postoperative hospital stay, day | 5 [3–34] | 5 [3–11] | 0.50 |

The numbers within the square brackets represent the [minimum-maximum] range.
The number within the parentheses represents the (%).
RATS: robot-assisted thoracic surgery
VATS: video-assisted thoracic surgery
%FEV1: percent predicted Forced Expiratory Volume in one second

**Table 4** Based on the comparison between RATS and VATS, there was no statistically significant difference in the likelihood of an unexpected air leak progressing to a persistent air leak

| Characteristics | RATS n = 42 | VATS n = 21 | p-value |
|---|---|---|---|
| Cases leading to persistent air leak (%) | 7 (17) | 1 (5) | 0.25 |

RATS: robot-assisted thoracic surgery
VATS: video-assisted thoracic surgery

In the RATS group, unexpected air leaks occurred in the upper or middle lobe in 31 of 111 (28%) cases and in the lower lobe in 14 of 48 (29%) cases. There was no significant difference between these two lobe groups (p > 0.99; Table 5).

**Table 5** Distribution of resected pulmonary lobes in RATS cases with and without unexpected air leaks

| Characteristics | Upper or Middle lobe n = 111 | Lower lobe n = 48 | p-value |
|---|---|---|---|
| RATS, unexpected air leak | | | >0.99 |
| Yes (%) | 31 (28) | 14 (29) | |
| No (%) | 80 (72) | 34 (71) | |

RATS: robot-assisted thoracic surgery

## DISCUSSION

The findings of this study suggest that when comparing patients who underwent RATS with those who underwent VATS, there was no statistically significant impact on the length of hospital stay. However, RATS exhibited a higher incidence of persistent air leaks than VATS. In our institution, the frequency of persistent air leaks after VATS was 3%, which was lower than that in other reports,[3,8-12,15,16] while the frequency of persistent air leaks after RATS in our institution was similar to that reported in other facilities.[1-7] Notably, RATS is a relatively new surgical technique. In Japan, its initial application was restricted to lung lobe resections owing to insurance coverage constraints, resulting in differences in patient backgrounds between the RATS and VATS groups. To adjust for these differences, we conducted 1:1 matching using propensity scores to adjust for background factors. When comparing the matched groups, there were no significant differences in the incidence of intraoperative and postoperative air leaks between the two surgical approaches. Furthermore, the repair methods for intraoperative air leaks were not significantly different between the RATS and VATS groups. Despite the lack of significant differences in these aspects, RATS demonstrated a higher incidence of persistent air leaks than VATS. During the initial learning phase of RATS, repair techniques may have been less effective, or the repair procedures in RATS may not have met the same standards as VATS.

Our study revealed a significantly higher incidence of unexpected air leaks in RATS. The reasons for the occurrence of unexpected air leaks in RATS can be attributed to two main factors. First, in RATS, the fixed camera position may create blind spots, particularly after upper lobe resections, making it challenging to thoroughly evaluate air leaks around staple lines with our port configuration. Second, the absence of tactile feedback in RATS can lead to unintended contact between surgical instruments and residual lung tissue, potentially causing undetected lung damage. In such cases, surgeons may not anticipate air leaks and are more likely to overlook them during the sealing test.

In the subanalysis, there was no significant difference in the incidence of unexpected air leaks among different pulmonary lobes. This suggests that lung damage may occur in unanticipated areas. Although there was no significant difference in the likelihood of unexpected air leaks progressing to persistent air leaks, the variance in the occurrence rates of unexpected air leaks itself contributes to the elevated prevalence of postoperative air leaks in RATS.

To address these challenges, our institution is currently developing a novel system that utilizes image analysis to detect and identify air leak locations during surgery.[17] This system has the potential to reduce the risk of missing air leak locations, even in areas that are difficult to submerge in sealing tests and in unexpected locations for the operating surgeon.

In this study, concerning the increased occurrence of persistent air leaks in RATS when compared to VATS, it seems that neither the presence of air leaks overlooked during the sealing test nor the sole deficiency in repair methods can fully explain the observed disparity. It is highly likely that a combination of these two factors played a role in shaping this outcome.

This study has several limitations that warrant acknowledgment. First, it is a retrospective study. Given that the occurrence of postoperative air leaks was assessed through medical records, there is a possibility of an overestimation of the air leak incidence. Furthermore, the high turnover rate of surgeons during the study period posed challenges in accounting for individual surgeon learning curves. Second, the surgical techniques employed by the surgeons, including the management of pulmonary air leaks, were not entirely standardized. Third, the evaluation of cases with unexpected air leaks was constrained by the limited number of cases available for analysis, making it challenging to adequately control for background differences between the compared groups. Addressing these limitations and conducting further investigations into the intricate factors contributing to the observed disparities between RATS and VATS in terms of postoperative persistent air leaks will be imperative for future research endeavors in this field.

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