General Thoracic and Cardiovascular Surgery (2019) 67:794–799
https://doi.org/10.1007/s11748-019-01094-7

ORIGINAL ARTICLE

Early chest tube removal after surgery for primary spontaneous pneumothorax

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Received: 7 November 2018 / Accepted: 20 February 2019 / Published online: 23 February 2019

Abstract

Objective The purpose of this study was to analyze the safety and validity of early chest tube removal after bullectomy for primary spontaneous pneumothorax (PSP).

Methods Between January 2005 and July 2018, 123 cases of thoracoscopic surgery for PSP were reviewed. The principle procedure was bullectomy accompanied by mechanical and chemical pleurodesis. Approximately 4 h after surgery, we confirmed patients' sufficient recovery from anesthesia and investigated the presence of air leak in a sitting position. Chest tubes were removed on the same day as the surgery if there was no air leak or bloody drainage observed. Postoperative complications and factors that prevented early chest tube removal were analyzed by comparing the early removal group and the remaining tube group.

Results Chest tubes could be removed on the day of the surgery in 105 cases (85.4%). There were 7 cases (5.7%) in which chest tubes could be removed because air leak was not detected after patients' recovery despite intraoperative detection of minor air leak from the resection stump. No patients required chest tube reinsertion during their hospital stay. The mean length of postoperative hospital stay was 1.1 ± 0.5 days. In a logistic regression analysis, surgical history of ipsilateral PSP was independently and significantly associated with the prevention of early chest tube removal.

Conclusions Chest tube removal on the day of surgery for PSP appears to be safe when air leak examination can be performed after sufficient recovery from anesthesia.

Keywords Chest tube removal · Primary spontaneous pneumothorax · Video-assisted thoracoscopic surgery

Introduction

Primary spontaneous pneumothorax (PSP) frequently occurs in young patients. Young patients tend to experience greater postoperative pain intensity than elderly patients [1], and chest tubes are one of the main causes of postoperative pain. Moreover, most young patients wish to be discharged earlier due to commitments pertaining to work or school. Thus, the early removal of chest tubes is desirable. Often, chest tubes are removed on the first postoperative day after thoracoscopic wedge resection of the lung if there is no air leak [2]; however, there is currently no standardized protocol for the timing of chest tube removal.

In recent years, some studies have reported a no chest tube strategy after wedge resection of the lung if air leak is not detected during an intraoperative air leak test [3–5]. This approach has resulted in reduced postoperative hospital stays. However, we sometimes encounter an air leak at the time of extubation or after waking from anesthesia, even when no air leak was detected during or immediately following surgery. Therefore, a no chest tube strategy entails the potential risks of drainage failure and pneumothorax.

To remove the chest tube early and safely after bullectomy of PSP, we have adopted a standard protocol of removing chest tubes on the day of surgery. Our concept comprises an early chest tube removal strategy following secure confirmation of no air leak, as soon as possible after complete recovery from anesthesia. We routinely confirm the absence of air leak and bloody drainage after patients fully emerge from anesthesia. The purpose of the present study was to analyze the validity of the strategy of removing the chest

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tube on the day of surgery for PSP. The factors preventing early chest tube removal were also investigated.

Methods

This retrospective study was approved by the Institutional Review Board of Otsu City Hospital (No. 362). Because it was a retrospective study, the need for patient consent was waived.

Patients

A retrospective study was conducted including all patients who underwent surgery for PSP between January 2005 and July 2018 at Otsu City Hospital, Japan.

Operative management

Throughout the study period, all PSP operations were performed under general anesthesia with single lung ventilation using a double-lumen endotracheal tube. Operations were performed via video-assisted thoracoscopic surgery (VATS) with one 2-cm incision for manipulation and two 1.5-cm incisions for the trocar ports. The basic policy was to perform bullectomy using mechanical staplers, accompanied by mechanical and chemical pleurodesis.

Mechanical pleurodesis was performed via ablation of the mesothelial layer of the parietal pleura from the cupola of the apex of the thoracic cavity to the fifth intercostal space using a Cherry Dissector (Ethicon Endo-Surgery Co. Ltd., Cincinnati, OH, USA) until slight bleeding occurred diffusely in the abrasion area. Chemical pleurodesis was performed by instilling 200 mg of minocycline and 100 mL of saline into the pleural cavity. Mechanical and chemical pleurodesis were not performed in patients with a surgical history of ipsilateral PSP, because these procedures had already been performed.

A sealing test was performed under bilateral ventilation at 20 cmH_2O of maximum intrabronchial pressure. We graded air leak using the scoring system described by Macchiarini et al. [6], whereby grade 0 = no leak, 1 = countable bubbles, 2 = a stream of bubbles, and 3 = coalesced bubbles. When grade 2 or 3 air leak was identified, it was repaired by suturing or binding, to reduce the grade of the leak. When grade 1 air leak from a pinhole of the staple line was detected, we treated it by covering the site with a polyglycolic acid (PGA) sheet and fibrin glue. We also applied a PGA sheet and fibrin glue to the staple line in patients with a surgical history of ipsilateral PSP in an effort to prevent further recurrence, even when intraoperative air leak was not detected.

We performed direct intercostal nerve block with 0.25% bupivacaine (5 mL per nerve) to relieve postoperative pain. A chest tube with an outer diameter of 6.5 mm (Argyle™ Multi-Channel Drainage Catheter S®, Covidien, Dublin, Ireland) was placed at the top of the pleural cavity. The chest tube was connected to a portable suction drainage system (Compact drain unit®; Sumitomo Bakelite Co. Ltd., Tokyo, Japan), and continuous suction was applied at − 10 cm H_2O in the operating room. A routine chest roentgenogram was taken before the patient emerged from anesthesia in the operating room.

Postoperative air leak examination for removing chest tubes

All patients who underwent surgery for PSP returned to the general ward after they were extubated. The presence or absence of air leak was assessed while the patient breathed deeply, and during vocalization and coughing in a supine position just after returning to the recovery room. We checked if the patient had fully emerged from anesthesia approximately 4 h after surgery and re-assessed the presence or absence of air leak in the aforementioned manner while the patient was in a sitting position. We removed the chest tube on the same day as the surgery if all of the following criteria were met:

1. The lung was completely expanded on a postoperative chest roentgenogram;
2. The patient was lucid and capable of sitting up straight in bed on his/her own;
3. There was no air leak detected while the patient breathed deeply or vocalized or coughed in the sitting position; and
4. There was no bloody drainage.

Outcomes

We divided the cases into two groups: one in which patients underwent chest tube removal on the day of surgery (the early removal group), and one in which patients underwent chest tube removal on postoperative day 1 or later (the remaining tube group). The safety and validity of chest tube removal on the day of surgery for PSP were evaluated by analyzing postoperative clinical courses. The clinical characteristics and postoperative courses of the two groups were compared and the factors that prevented early chest tube removal were identified.

Statistical analysis

All continuous variables are presented as means ± standard deviation. Differences between the two groups were assessed using the Mann–Whitney *U* test. Categorical variables are presented as numbers and percentages and were compared

using Pearson's Chi-square test or Fisher's exact test (when the value of any cell was < 5). A multivariate analysis was performed using a logistic regression model. Variables with p values < 0.05 in the univariate analyses were included in the multivariate logistic regression model. The presence or absence of recurrence of pneumothorax after surgery was determined via medical records. p values < 0.05 were considered statistically significant. Statistical analyses were performed using the JMP® software program (version 14.0; SAS Institute Inc., Cary, NC).

Results

Clinical characteristics of all cases with PSP examined for air leak after bullectomy

We performed surgery in 199 cases of pneumothorax and in 5 case of hemopneumothorax during the study period. There were 128/199 (64.5%) cases in which patients were diagnosed with PSP in the absence of clinically apparent underlying lung disease on computed tomography (CT). In 5 of these 128 cases, the aforementioned examination for air leak was not performed on the day of surgery because the surgery was performed late at night (4 cases), or because the patient requested to retain the chest tube until the following day (1 case). Thus, we analyzed 123 cases (105 men and 18 women) in which the aforementioned examination was performed on the day of surgery. The mean age at the time of surgery was 26.0 ± 10.6 years. The clinical characteristics are shown in Table 1.

In 9/123 (7.3%) cases, the patient had a surgical history of ipsilateral PSP. Partial adhesion requiring sharp dissection was detected in 7 cases, and no adhesion was detected in 2 cases. The mean operative times of cases with and without a surgical history of ipsilateral PSP were 85.4 ± 15.7 and 75.4 ± 23.5 min, respectively ($p = 0.06$).

During the first intraoperative sealing test, air leak was detected in 14 cases. The leak site was the resection stump in all 14 cases. Among the cases with air leak, grade 1 air leak was identified in nine cases and grade 2 air leak in five cases. Grade 2 air leak was successfully stopped in two cases and reduced to grade 1 in two cases but remained in one case. Therefore, air leak remained grade 1 in 11/123 cases (8.9%) and grade 2 in 1/123 cases (0.8%) during the final sealing test. A PGA sheet and fibrin glue were used to cover the leak site in the cases with remaining air leakage.

Postoperative evaluation for chest tube removal

The chest tube could be removed on the day of surgery in 105 cases (85.4%, early removal group). In 7 of these 105 cases, air leak was not detected after the patient returned to the general ward but grade 1 air leak was detected in the final sealing test. Of the remaining 18 cases (14.6%) in which the chest tubes could not be removed on the same day as the surgery (remaining tube group), there were 17 cases with an air leak and one with bloody drainage. Among the 17 cases with an air leak, the timing of the appearance of the air leak differed. Air leak was first identified during surgery in 5 cases (29.4%), immediately after chest closure in 1 case (5.9%), during extubation in 2 cases (11.8%), just after returning to the recovery room in 4 cases (23.5%), and during the air leak examination performed after sufficient recovery in 5 cases (29.4%). All air leaks that were first identified after initial chest closure were still apparent at the time of air leak examination after sufficient recovery.

Table 1 Clinical characteristics of 123 cases of surgery for primary spontaneous pneumothorax

	Mean ± SD or number (%)
Age (years)	26.0 ± 10.6
Male sex	105 (85.4%)
Smoking history	44 (35.8%)
BMI (kg/m^2)	19.2 ± 2.1
Right side	58 (47.2%)
Recurrent pneumothorax	68 (55.3%)
Surgical history of ipsilateral pneumothorax	9 (7.3%)
Operative findings	
Pleural adhesion	25 (20.3%)
Number of specimens	1.2 ± 0.4
Number of stapler cartridges used	2.4 ± 0.9
Intraoperative air leak	
Grade 1	11 (8.9%)
Grade 2	1 (0.8%)
PGA sheet + fibrin glue	20 (16.2%)
Mechanical and chemical pleurodesis	116 (94.3%)
Intraoperative repair of air leak	5 (4.1%)
Operative time (min)	76.1 ± 23.2
Postoperative course	
Postoperative hospital stay (days)	1.3 ± 1.0
Recurrence after surgery	14 (11.4%)

BMI body mass index, *PGA* polyglycolic acid, *SD* standard deviation

Comparison of clinical characteristics in the early removal group and the remaining tube group

A comparison of the clinical characteristics in the early removal group and the remaining tube group is shown in Table 2. In the remaining tube group, there were significantly higher proportions of cases of patients with a surgical history of ipsilateral pneumothorax ($p = 0.003$) and those requiring PGA sheet + fibrin glue ($p = 0.034$) and a long

Table 2 Comparison of clinical characteristics according to the timing of chest tube removal

	Early removal group ($n=105$)	Remaining tube group ($n=18$)	p value
Age (years)	25.7 ± 10.5	27.8 ± 11.8	0.54
Male sex	91 (86.7%)	14 (77.8%)	0.32
Smoking history	37 (35.2%)	7 (38.9%)	0.77
BMI (kg/m^2)	19.4 ± 2.2	18.4 ± 1.9	0.085
Right side	51 (48.6%)	7 (38.9%)	0.45
Recurrent pneumothorax	60 (57.1%)	8 (44.4%)	0.32
Surgical history of ipsilateral PSP	4 (3.8%)	5 (27.8%)	0.003
Pleural adhesion	19 (18.1%)	6 (33.3%)	0.14
Number of specimens	1.2 ± 0.4	1.3 ± 0.6	0.22
Number of cartridges	2.4 ± 0.8	2.7 ± 1.1	0.17
PGA sheet + fibrin glue	14 (13.3%)	6 (33.3%)	0.034
Mechanical and chemical pleurodesis	101 (96.2%)	15 (83.3%)	0.063
Intraoperative repair of air leak	3 (2.9%)	2 (11.1%)	0.15
Intraoperative air leak			
Grade 1	7 (6.7%)	4 (22.2%)	0.055
Grade 2	0 (0%)	1 (5.6%)	0.15
Operative time (min)	74. 1 ± 21.8	87.7 ± 28.0	0.027

BMI body mass index, *PGA* polyglycolic acid, *PSP* primary spontaneous pneumothorax

operative time ($p=0.027$). There were no significant differences between the two groups with regard to age, sex, smoking history, body mass index, pneumothorax side, pneumothorax recurrence, pleural adhesion, number of resected specimens, number of stapler cartridges used, mechanical and chemical pleurodesis, repair of air leak, or intraoperative air leak. In the multivariate logistic regression analysis, surgical history of ipsilateral PSP was a significant predictor of the prevention of early chest tube removal (odds ratio 8.06, 95% confidence interval 1.83–35.40; $p=0.006$) (Table 3).

Postoperative course and complications

The postoperative courses are shown in Table 4. After chest tube removal, there were no cases of postoperative complications during the hospital stay in the early removal group. There was one case of a patient with persistent air leak (> 7 days) in the remaining tube group. After discharge from the hospital, only 1 patient in the early removal group required reinsertion of a chest tube, which occurred on postoperative day 6 due to lung collapse. That patient had been discharged with a slightly collapsed lung on postoperative day 3 after confirming that there was no worsening of the lung collapse. After a chest tube was reinserted on postoperative day 6, the air leak resolved 5 days later without any further treatment.

The length of the postoperative hospital stay was 1.1 ± 0.5 days in the early removal group, which was significantly shorter than that of the remaining tube group (2.1 ± 2.0 days, $p<0.001$). In the early tube removal group, there were 98 cases (93.3%) in which the patient was discharged on postoperative day 1 after chest roentgenogram follow-up. Average hospital costs, excluding surgical costs, were 194,834 ± 68,931 yen in the early chest tube removal group, whereas they were 238,248 ± 104,823 yen in the remaining tube group; however, this difference was not statistically significant ($p=0.15$).

Recurrence of PSP after surgery occurred in 14/123 cases (11.4%). There were no significant differences in recurrence rate, interval from surgery to recurrence, and early recurrence rate (within 1 month) between the two groups.

Table 3 Multivariate logistic regression analysis of factors potentially associated with the prevention of early chest tube removal

	Coefficient	Odds ratio	95% CI	p value
Surgical history of ipsilateral PSP	1.044	8.06	1.83–35.40	0.006
PGA sheet + fibrin glue	0.375	2.12	0.60–7.53	0.25
Operative time	0.019	1.02	0.99–1.04	0.10

CI confidence interval, *PGA* polyglycolic acid, *PSP* primary spontaneous pneumothorax

Table 4 Postoperative courses in the early removal group and remaining tube group

	Early removal group ($n=105$)	Remaining tube group ($n=18$)	p value
Duration of chest tube placement (days)	–	1.7 ± 1.7	–
Postoperative hospital stay (days)	1.1 ± 0.5	2.1 ± 2.0	< 0.001
Persistent air leak (> 7 days)	0 (0%)	1 (5.6%)	0.15
Pneumothorax requiring chest tube	1 (1.0%)	0 (0%)	1.0
Hospital costs excluding surgical costs (Japanese yen)	194,834 ± 68,931	238,248 ± 104,823	0.15
Recurrence of PSP after surgery	12 (11.4%)	2 (11.1%)	1.0
Interval until recurrence after surgery (months)	35.3 ± 44.3	1.0 ± 0.3	0.08
Early recurrence within 1 month	1 (1.0%)	1 (5.6%)	0.27

PSP primary spontaneous pneumothorax

Discussion

This study evaluated the safety and validity of the strategy of chest tube removal on the day of surgery for PSP. With regard to postoperative courses, there were no cases of postoperative complications during the hospital stay although one patient required reinsertion of the chest tube after discharge. Most patients in the early removal group were discharged on postoperative day 1, which is thought to be the shortest stay unless bullectomy is performed as an outpatient surgery. There might be no difference in the length of the hospital stay between the strategy of no chest tube and our strategy of early chest tube removal on the day of surgery. Therefore, our strategy of chest tube removal on the day of surgery was safe and feasible and could offer the shortest possible hospital stay after surgery for PSP.

Some of the studies designed to assess methods of facilitating early hospital discharge have investigated avoiding chest tube placement entirely or removing the chest tube early in the postoperative period. With specific regard to wedge resection (our surgical procedure for PSP is wedge resection of the bulla), some studies suggest that a chest tube need not be placed after wedge resection of the lung if no air leak is detected during an intraoperative air leak test [3–5]. In a trial investigating early chest tube removal after wedge resection of the lung, Russo et al. reported that they could safely remove chest tubes within 90 min of surgery in 31/33 patients after VATS wedge resection when air leak was not detected in the recovery room [7]. However, in the present study, air leak was first observed after chest closure in 12/123 cases (9.8%); in 5 of these 12 cases, air leak was first observed after complete emergence from anesthesia (4 h after surgery). Thus, performing air leak evaluation during the operation, or while patients are still drowsy post-anesthesia, is not always sufficient. Extubation also can entail a risk of air leak because the associated stimulation causes bucking and severe coughing [8, 9]. It is safer to assess the presence or absence of air leak after patients have fully emerged from anesthesia after extubation.

In the present study, there were 7 cases in which grade 1 air leak was detected intraoperatively, but disappeared at the time of evaluation (after complete recovery from anesthesia). Our results suggested that chest tubes could be removed safely when air leak was not detected after sufficient recovery, even if minor air leak was detected intraoperatively. Intraoperatively detected minor air leaks may sometimes resolve early or may be of no clinical importance. However, caution must be exercised in patients with a surgical history of ipsilateral PSP, because the present study demonstrated that a surgical history of ipsilateral PSP was a significant risk factor for postoperative air leak. This could be due to multiple factors, including potential vulnerability of pleura, unequal tension of pleura associated with multiple lung resections, and failure of formation of a staple-line due to stapling the same staple-line utilized in a previous surgery.

The recurrence rate in the present study was similar to that of previous studies, in which it was reported to be approximately 10% [10]. In a recent systematic review, the lowest recurrence rates after treatment for spontaneous pneumothorax were observed in the wedge resection + pleural abrasion + chemical pleurodesis group, compared with other combined treatments [11]. Further, in the wedge resection + pleural abrasion + chemical pleurodesis groups, minocycline, which is used in our surgical technique, was used as a chemical agent in 2 of 4 reports [12, 13]. Our challenging postoperative drain management was carried out based on the conventional and reliable surgical technique supported by these reports. Pleural adhesion by pleural abrasion + chemical pleurodesis causes difficulties regarding re-operation when PSP recurs. In our study, this caused operative time to increase by 10 min in cases that required re-operation for recurrent PSP. The additional time to manage pleural adhesion was minimal in our study, and could thus be regarded as clinically acceptable.

The present study had several limitations. Although the removal of a chest tube is thought to reduce postoperative pain [14] and may improve mental health among patients, we lacked quantitative pain and mental health data with which to evaluate the effects of early chest tube removal. Our assessment of air leak depended on the assessment of air bubbles in analog drainage systems, which includes some degree of subjectivity compared with digital drainage systems [15]. However, we could remove chest tubes safely based on this conventional assessment of air bubbles, which is more practical because it does not require expensive digital drainage systems. The present study could not directly demonstrate that chest tube removal on the same day of surgery contributed to a reduction in the postoperative hospital stay due to the non-randomized study design. However, the present study demonstrated that early chest tube removal strategy performed following secure confirmation of no air leak, as soon as possible after complete recovery from anesthesia, could offer the shortest possible chest tube placement and hospital stay; moreover, it may be safer than a strategy excluding the use of a chest drain. We believe that our present strategy may be less painful and of greater benefit, especially for young patients with PSP. The results of the present study must be confirmed in subsequent prospective randomized studies.

Acknowledgements The authors thank Satoru Okada (Division of Thoracic Surgery, Department of Surgery, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, Kyoto, Japan) for his help with data interpretation and manuscript revision.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest to disclose.

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