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ORIGINAL RESEARCH

Is Saline Sealing of Needle Tract Effective to Prevent Pneumothorax after Computed Tomography-guided Lung Biopsy?

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Abstract:
Purpose: To evaluate the efficacy of needle tract sealing using normal saline instillation for decreasing the risk of pneumothorax after computed tomography-guided lung biopsy.
Material and Methods: This retrospective, single-institution study included 391 computed tomography-guided lung biopsies performed by 12 operators between January 2022 and October 2024. After exclusion, 298 biopsies were analyzed by comparing the saline seal (n = 138) and control (n = 160) groups. A 17/18-gauge or 19/20-gauge coaxial biopsy system was used, and tract sealing was performed by instilling 1-5 mL of normal saline during the withdrawal of the introducer needle in the saline seal group; tract sealing was not performed in the control group. After 1:1 propensity score matching was performed to balance baseline characteristics, the incidences of pneumothorax and chest tube placement were compared between the two groups using Fisher's exact test.
Results: After propensity score matching, 108 pairs (mean lesion size: 17 mm) were well balanced. The incidence of pneumothorax did not differ significantly between the control and saline seal groups (50.0% vs. 60.2%, respectively; p = 0.171). Similarly, the incidence of chest tube placement was not significantly different between the two groups (7.4% vs. 13.0%, respectively; p = 0.260).
Conclusions: According to the propensity score-matched analysis, normal saline instillation for tract sealing did not significantly reduce the incidence of pneumothorax or chest tube placement. In our cohort, which had a high prevalence of small lesions, saline sealing alone may be insufficient to reduce post-biopsy pneumothorax risk. Hence, combined strategies require further investigation.

Keywords:
pneumothorax, lung biopsy, image-guided biopsy, needle tract sealing

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Introduction

CT-guided lung biopsy is widely used and effective for the histological diagnosis of pulmonary lesions, with a high diagnostic yield of 93%-95% [1, 2]. However, pneumothorax remains its most common complication, reported in 4.3%-52.4% of cases, with a pooled overall incidence of 25.9% in a systematic review [3]. Although most pneumothoraces are minor and self-limiting, major or symptomatic cases may require chest tube placement, with a pooled incidence of 6.9% [3], leading to increased patient discomfort, prolonged hospitalization, and higher healthcare costs [4, 5].

Various techniques to prevent post-biopsy pneumothorax have been investigated. Among them, tract sealing methods are recognized as some of the most effective approaches [6]. Normal saline has been reported to be a tract sealing material with several advantages, including easy availability, low cost, ease of handling, and no local or systemic adverse effects [7]. However, this technique has only been described in a small number of reports, and evidence of its effective-

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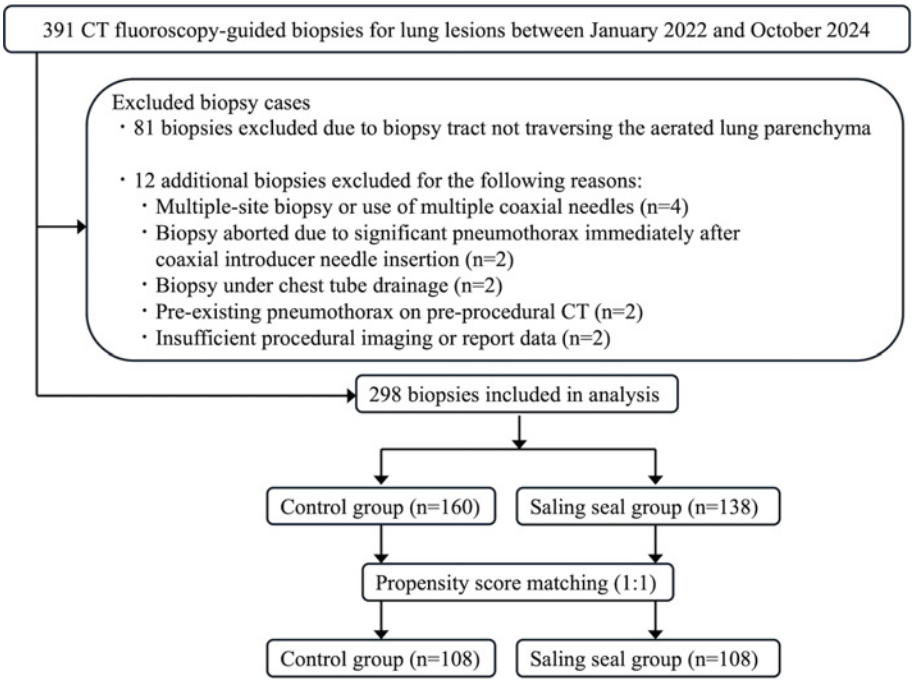

Figure 1. Flow chart of biopsy selection process.

ness remains limited.

Therefore, this study aimed to evaluate the efficacy of saline sealing in reducing the incidence of pneumothorax and chest tube placement after CT-guided lung biopsy using a propensity score (PS)-matched analysis.

Material and Methods

This retrospective study was approved by the institutional review board (approval number: KEN2501-030), which waived the requirement for informed consent for the use of medical data. All patients provided written informed consent before undergoing CT-guided lung biopsy.

Patients

Between January 2022 and October 2024, 391 CT fluoroscopy-guided lung biopsies were performed at our institution. The tract sealing technique was not used in any patient from January to December 2022. From January 2023 to October 2024, the saline sealing technique was introduced and generally applied when the biopsy tract traversed aerated lung parenchyma. However, the final decision to perform the sealing technique was left to the discretion of the operator. The exclusion criteria for this study were: (i) biopsy tract not traversing the aerated lung parenchyma, (ii) multiple-site biopsy or use of multiple coaxial needles, (iii) biopsy aborted due to significant pneumothorax immediately after coaxial introducer needle insertion, (iv) biopsy under chest tube drainage, (v) pre-existing pneumothorax on pre-procedural CT, and (vi) insufficient procedural imaging or report data. In total, 93 biopsy cases were excluded from the study. The selection process of biopsy cases is summarized in **Figure 1**.

Biopsy procedure

All biopsies were performed under CT fluoroscopy guidance using either Aquilion ONE or Aquilion 64 (Canon Medical Systems, Otawara, Japan). Eight experienced interventional radiologists (>5 years of experience) or four supervised radiology trainees (≤5 years of experience) conducted the biopsies. A coaxial needle system consisting of a 17- or 19-gauge introducer needle and an 18- or 20-gauge semi-automatic biopsy needle (Temno Evolution; CareFusion, McGaw Park, IL, USA) was used in all cases. The 20-gauge needle was primarily used, whereas the 18-gauge needle was selected when a larger tissue sample was required for genomic analysis. Depending on the location of the target lesion, patients were placed in the supine, prone, or lateral decubitus positions to allow for an optimal needle trajectory. After local anesthesia, the introducer needle was advanced under CT fluoroscopy guidance, followed by insertion of the biopsy needle to obtain samples. This procedure was repeated until an adequate amount of tissue was collected. Upon completion, the introducer needle was withdrawn either with the instillation of 1-5 mL normal saline using a 5 mL syringe or without any tract sealant. Immediately afterward, chest CT with 5-mm slices was performed to detect complications, such as pneumothorax, pulmonary hemorrhage, hemothorax, or air embolism (**Figure 2**). Patients were not instructed regarding post-procedural positioning, and no other preventative techniques, such as rapid rollover, were applied. Follow-up chest radiographs were obtained 3 hours after the procedure and the next morning. Chest tube placement was performed when pneumothorax was symptomatic or occupied more than one-third of the hemithorax.

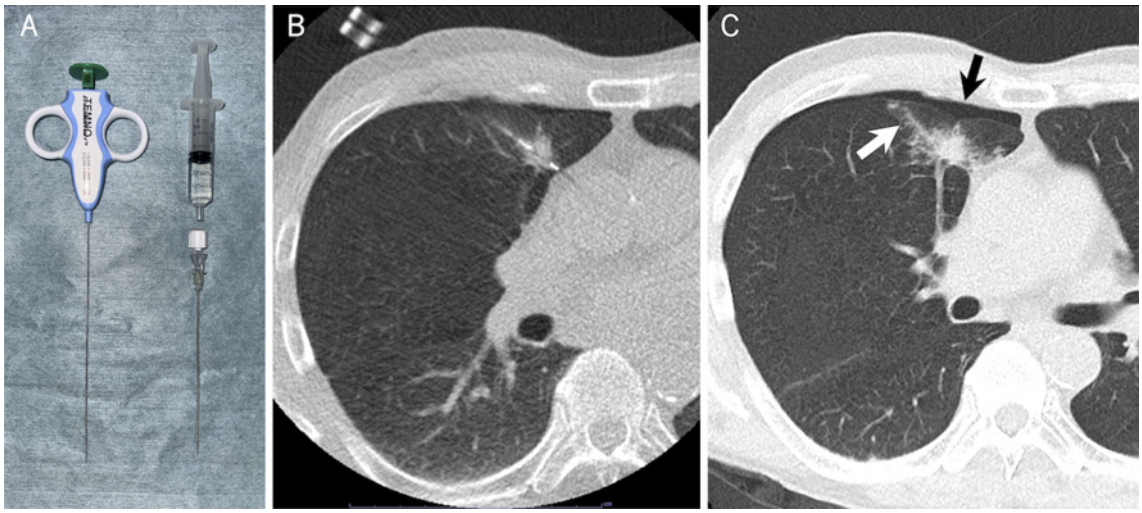

Figure 2. Instruments and representative images for CT-guided lung biopsy using saline tract sealing.
(A) Instruments used for the procedure: a 19-gauge introducer needle, a 20-gauge biopsy needle, and a 5-mL syringe filled with normal saline.
(B) CT image showing coaxial biopsy of a 2-cm lung nodule in the right upper lobe.
(C) Post-procedural CT image demonstrating the saline-sealed needle tract as ground-glass opacity (white arrow) and a small pneumothorax (black arrow).

Data collection

Data included patient characteristics, lesions, and procedural factors. Patient-related variables included age, sex, emphysema on CT images, and history of surgeries on the same side of the lung where the biopsy was performed. Lesion-related variables included size, location (left or right lung, lower or non-lower lobe), pleura-to-lesion distance, and lesion type (solid or ground-glass nodule, including part-solid nodules). Procedural variables included patient position (supine/lateral or prone), biopsy needle diameter (18- or 20-gauge), angle of the introducer needle trajectory (<45° or ≥45°), intrapulmonary tract length, number of fissure crossings, number of tissues obtained, presence of pneumothorax before introducer needle removal, procedure time, and operator experience (experienced vs. trainee). Lesion size was defined as the maximum long-axis diameter on axial or coronal CT images, and the pleura-to-lesion distance was defined as the shortest distance from the lesion margin to the pleural surface. Procedure time was defined as the interval between the preprocedural CT scan used for lesion localization and the post-biopsy CT scan performed after biopsy completion. An experienced interventional radiologist (S.O.) evaluated all images.

Statistical analysis

Patients with missing data on the variables used in the analysis were excluded before inclusion in the study. Categorical variables were compared using Fisher's exact test, whereas continuous variables were analyzed using Welch's *t*-test. To compare the saline seal and control groups, PS-matched analysis was performed to minimize the influence of confounding factors. The PS was calculated using a logistic regression model with sealing or no sealing as the response variable and 18 factors such as age, sex, emphysema, prior surgery, lesion size, lesion location, pleura-to-lesion distance, lesion type, patient position, biopsy needle diameter, angle of the introducer needle trajectory, intrapulmonary tract length, number of fissure crossings, number of tissues obtained, presence of pneumothorax before introducer needle removal, procedure time, and operator experience, as explanatory variables. The variables used in the PS calculation were selected based on the results of previous studies [3, 8]. The study subjects were matched 1:1 using the nearest-neighbor algorithm without replacement. A caliper was set at 0.2 of the standard deviation of the logit of the estimated PS. Standardized mean differences (SMDs) were calculated before and after matching to evaluate covariate balance. Variables with an SMD ≤0.1 were considered balanced. The incidences of pneumothorax and chest tube placement were compared between the saline seal and control groups using Fisher's exact test. Statistical significance was set at $p < 0.05$. Statistical analyses were performed using EZR v.1.68 (Saitama Medical Center, Jichi Medical University, Saitama, Japan) [9] and R version 4.4.1. An a priori sample size calculation was conducted. Previous studies reported that saline sealing reduced the absolute risk of pneumothorax by 14%-25.7% [7, 10-13] Based on these findings, we hypothesized a reduction from a baseline of 40% to 20%. To detect this 20% absolute risk reduction with 80% power at a significance level of 0.05, a minimum of 81 matched pairs was required.

Results

A total of 298 CT-guided lung biopsies were included in the analysis, with no missing data for any of the evaluated variables. The control and saline seal groups comprised 160

Table 1. Patient Demographics, Pulmonary Lesion Characteristics, and Biopsy Parameters before and after Propensity Score Matching.

	Before matching				After matching			
	Control group (n = 160)	Saline seal group (n = 138)	SMD	p	Control group (n = 108)	Saline seal group (n = 108)	SMD	p
Patient characteristics								
Age, years	70.6 ± 11.5 [33-93]	71.7 ± 9.9 [42-93]	0.106	0.365	71.2 ± 11.8	70.8 ± 10.0	0.033	0.808
Male	98 (61.3)	76 (55.1)	0.125	0.291	59 (54.6)	61 (56.5)	0.037	0.891
Emphysema	60 (37.5)	47 (34.1)	0.072	0.547	40 (37.0)	41 (38.0)	0.019	1.000
Prior surgery	14 (8.8)	27 (19.6)	0.314	0.011	13 (12.0)	14 (13.0)	0.028	1.000
Lesion characteristics								
Size, mm	17.4 ± 9.8 [5-56]	15.6 ± 8.2 [4-43]	0.199	0.089	17.4 ± 10.0	17.0 ± 8.4	0.039	0.775
Left lung	72 (45)	52 (37.7)	0.149	0.239	44 (40.7)	45 (41.7)	0.019	1.000
Lower lobe	68 (42.5)	55 (39.9)	0.054	0.723	46 (42.6)	47 (43.5)	0.019	1.000
Pleura-to-lesion distance, mm	6.8 ±7.9 [0-41]	8.5 ± 8.1 [0-38]	0.210	0.072	7.4 ± 8.0	7.6 ± 7.7	0.032	0.816
Solid nodule	114 (71.2)	105 (76.1)	0.110	0.360	75 (69.4)	80 (74.1)	0.123	0.546
Procedure characteristics								
Patient in prone position	80 (50.0)	61 (44.2)	0.116	0.353	53 (49.1)	55 (50.9)	0.037	0.892
20 G needle	154 (96.2)	136 (98.6)	0.145	0.293	105 (97.2)	106 (98.1)	0.062	1.000
Angle of the introducer needle trajectory < 45°	35 (21.9)	24 (17.4)	0.113	0.383	20 (18.5)	22 (20.4)	0.047	0.864
Intrapulmonary tract length, mm	20.2 ± 16.3 [1-80]	22.7 ± 14.1 [1-71]	0.166	0.156	21.1 ± 16.9	21.0 ± 13.0	0.006	0.968
Number of fissure crossings	2 (1.2)	3 (2.2)	0.071	0.666	2 (1.9)	3 (2.8)	0.062	1.000
Number of tissues obtained	3.3 ± 1.1 [1-8]	3.31 ± 1.1 [1-8]	0.011	0.924	3.4 ± 1.1	3.3 ± 1.0	0.112	0.410
Presence of pneumothorax before introducer needle removal	30 (18.8)	19 (13.8)	0.135	0.275	17 (15.7)	17 (15.7)	<0.001	1.000
Procedure time, min	30.7 ± 19.3 [12-169]	31.4 ± 14.6 [15-134]	0.038	0.747	30.9 ± 19.1	31.4 ± 15.7	0.025	0.852
Procedure by trainee	53 (33.1)	63 (45.7)	0.259	0.032	47 (42.6)	43 (39.8)	0.075	0.679
Pneumothorax	85 (53.1)	81 (58.7)		0.351	54 (50.0)	65 (60.2)		0.171
Chest tube placement	16 (10.0)	23 (16.7)		0.120	8 (7.4)	14 (13.0)		0.260

Data are presented as mean ± standard deviation for quantitative variables, with ranges in brackets. Qualitative variables are shown as counts, with percentages in parentheses.

SMD: standardized mean difference

and 138 biopsies, respectively. Before propensity score matching (PSM), significant differences were observed between the two groups in terms of prior surgery (p = 0.011) and operator experience (p = 0.032). The mean ± standard deviation lesion diameter was 17.4 ± 9.8 mm in the control group and 15.6 ± 8.2 mm in the saline seal group. The incidence of pneumothorax did not differ between the saline seal and control groups (58.7% vs. 53.1%, respectively; p = 0.351). Similarly, the incidence of chest tube placement did not differ significantly between the two groups (16.7% vs. 10.0%, respectively; p = 0.120). Regarding other complications, pulmonary hemorrhage was the most frequent, observed in 244 cases (81.9%). Less common complications included hemoptysis in eight cases (2.7%), asymptomatic air embolism in three cases (1.0%), and hemothorax in two cases (0.7%). No cases of needle tract dissemination were observed.

After the PSM, 108 matched pairs were generated. Baseline characteristics between the saline seal and control groups were well balanced, with most SMDs ≤0.1 (**Table 1**). The incidence of pneumothorax was not significantly different between the saline seal and control groups (60.2% vs. 50.0%, respectively; p = 0.171). Similarly, the incidence of chest tube placement did not differ significantly between the two groups (13.0% vs. 7.4%, respectively; p = 0.260). To assess potential selection bias, the characteristics of the unmatched groups (82 biopsies) were also analyzed, and the results are listed in **Table 2**.

Discussion

In our PS-matched cohort, saline sealing of the needle tract did not significantly reduce the incidence of pneumothorax or the need for chest tube placement. These findings contrast with those of previous studies that have reported the protective effect of this technique [7, 10-14]. The reasons for this discrepancy are likely multifactorial, and it is difficult to definitively explain why our results differed. However, we can speculate several contributing patient-related and procedural factors, which are compared with those of previous studies in **Table 3**.

One primary consideration was the difference in the baseline risk of pneumothorax among the study populations. The mean lesion size in our cohort was 17 mm, notably smaller

Table 2. Patient Demographics, Pulmonary Lesion Characteristics, and Biopsy Parameters between Matched and Unmatched Groups.

	Matched group (N = 216)	Unmatched group (N = 82)	SMD	p
Patient characteristics				
Age, years	71.0 ± 10.9 [33.0-93.0]	71.4 ± 10.7 [45.0-93.0]	0.038	0.769
Male	120 (55.6)	54 (65.9)	0.212	0.139
Emphysema	81 (37.5)	26 (31.7)	0.122	0.426
Prior surgery	27 (12.5)	14 (17.1)	0.129	0.404
Lesion characteristics				
Size, mm	17.2 ± 9.2 [5.0-56.0]	15.1 ± 8.6 [4.0-50.0]	0.233	0.079
Left lung	89 (41.2)	35 (42.7)	0.030	0.921
Lower lobe	93 (43.1)	30 (36.6)	0.132	0.378
Pleura-to-lesion distance, mm	7.5 ± 7.8 [0-41]	7.9 ± 8.5 [0-38]	0.053	0.679
Solid nodule	155 (71.8)	64 (78.0)	0.145	0.341
Procedure characteristics				
Patient in prone position	108 (50.0)	33 (40.2)	0.197	0.169
20 G needle	211 (97.7)	79 (96.3)	0.079	0.811
Angle of the introducer needle trajectory <45°	42 (19.4)	17 (20.7)	0.032	0.931
Intrapulmonary tract length, mm	21.1 ± 15.0 [1-80]	22.1 ± 16.2 [1-71]	0.063	0.621
Number of fissure crossings	5 (2.3)	0 (0.0)	0.218	0.376
Number of tissues obtained	3.3 ± 1.1 [1-8]	3.2 ± 1.0 [1-6]	0.148	0.265
Presence of pneumothorax before introducer needle removal	34 (15.7)	15 (18.3)	0.068	0.722
Procedure time, min	31.1 ± 17.4 [12-169]	30.7 ± 16.9 [13-119]	0.027	0.834
Procedure by trainee	90 (41.2)	27 (32.9)	0.208	0.149
Pneumothorax	119 (55.1)	47 (57.3)	0.045	0.830
Chest tube placement	22 (10.2)	17 (20.7)	0.295	0.027

Data are presented as mean ± SD for quantitative variables, with ranges in brackets. Qualitative variables are shown as counts, with percentages in parentheses.

SD: standard deviation; SMD: standardized mean difference

Table 3. Comparison of Patient Demographics, Lesion Characteristics, and Procedural Details with Previous Studies using the Saline Sealing Technique.

Study	Groups	Number of patients	Emphysema, %	Lesion size, mm	Biopsy needle gauge, G	Intrapulmonary tract length, mm	Number of tissues obtained	Number of Operators	Pneumothorax		Chest tube placement	
									Rate, %	p	Rate, %	p
Li et al. [10]	Sealing/ Control	161/161	41/37	32/33	20	-	-	2	6.2/26.1	<0.001	0.6/5.6	0.010
Bourgeais et al. [11]	Sealing/ Control	93/149	55/55	30/25*	18 or 20	21/19*	-	-	19.4/40.9	0.001	4.3/10.7	0.126
Roman et al. [12]	Sealing/ Control	87/111	35.6/27.9	29.2/32.7	18	19.2/17.7	2.1/2.1	1	20.7/35.1	0.020	1.1/5.4	0.100
Babu et al. [13]	Sealing/ Control	100/100	-	39/37	18 or 20	-	3/3	5	32/46	0.042	1/7	0.030
Billich et al. [7]	Sealing/ Control	70/70	4.3/1.4	30.1/29.4	18	-	-	3	8.6/34.3	<0.001	1.4/11.4	0.010
This study (after matching)	Sealing/ Control	108/108	38/37	17.0/17.4	18 or 20	21.0/21.1	3.3/3.4	12	60.2/50.0	0.171	13.0/7.4	0.260

Data are presented as the mean unless otherwise indicated. The "Number of operators" indicates the total number of physicians who performed the procedures during the study period.

*Data are presented as median.

than the 29-39 mm range reported in previous studies that demonstrated a significant reduction in pneumothorax incidence by saline sealing [7, 10-14]. This difference is critical, as smaller lesions are associated with a higher intrinsic risk of pneumothorax; a supporting meta-analysis reported a pooled incidence of 39.9% for lesions ≤2 cm vs. 24.1% for larger lesions (pooled OR: 1.98, 95% CI: 1.55-2.51) [3]. Hence, it is possible that in a high-risk population, such as that of this study, the increased baseline risk may have masked any protective effect associated with saline sealing.

Furthermore, procedural variability might have contributed to the lack of observed efficacy. This study involved 12 different operators, a substantially higher number than the one to five operators used in previous positive studies [7, 10, 12-14]. Although syringe size and saline volume were standardized, other aspects of the injection technique, such as speed, were not controlled, and injection is recognized as an operator-dependent procedure [15]. Although the precise contribution of each factor remains uncertain, their confluence might have created a clinical context in which a protective effect is difficult to achieve.

Our findings suggest that saline sealing alone may be insufficient, especially in high-risk cohorts. This may reflect the potential limitations of saline's physical properties, such as its low viscosity, which provides only a transient seal. Therefore, exploring more robust materials or combined strategies may be warranted. The importance of a more robust mechanical obstruction was demonstrated in a recent randomized trial in which gelatin sponge slurry, a more viscous agent, was significantly more effective than saline in preventing pneumothorax (12.1% vs. 24.6%, respectively; p = 0.008) [16]. In addition to alternative sealing materials, other techniques have also been explored to reduce pneumothorax rates. These include rapid rollover [17, 18], deep expiration and breath-hold [19], and combined protocols such as the PEARL method [20], which incorporates patient positioning with biopsy-side down, needle removal during expiration, autologous blood patch sealing, rapid rollover, and pleural patching. Several studies have reported that combining saline sealing with rapid patient rollover may further reduce the risk of chest tube placement [21, 22]. These studies highlight the potential of combining multiple preventative approaches rather than relying solely on tract sealing to further decrease the incidence of pneumothorax. This synergy warrants further investigation to optimize preventive strategies for CT-guided lung biopsies.

The overall pneumothorax rate in our study (55.7%) was higher than that reported in previous studies, which ranged from 4.3% to 52.4% [3]. We attribute this to two methodological factors. First, our cohort represented a higher-risk population, as we exclusively analyzed biopsies traversing the aerated lung parenchyma—a procedure associated with a significantly greater risk of pneumothorax than biopsies that do not traverse the lung [23]. Second, our protocol employed immediate post-procedural whole-chest CT scans, which enabled the detection of even minimal pneumothoraces.

This study has some limitations. First, it was a single-center retrospective study, which may limit the generalizability of our findings. Second, a key consideration is the statistical power of our analysis. Our final cohort of 108 matched pairs was adequately powered to detect the pre-specified large effect (a 20% absolute risk reduction). The absence of a significant difference suggests that an effect of this magnitude is unlikely. However, the study was underpowered to detect smaller, yet potentially clinically meaningful, reductions in pneumothorax incidence. Third, all imaging data were evaluated by a single radiologist, which could have introduced observer bias. Furthermore, other unmeasured or unstandardized factors may have influenced the outcomes. These include subtle differences in needle manipulation techniques or patient respiratory patterns, as well as the lack of evaluation of emphysema severity, a known risk factor for pneumothorax [14]. Additionally, procedural aspects were not fully standardized; although the injected saline volume was within the 1-5 mL range, the specific volume and injection speed were left to the operator's discretion. Finally, we did not systematically measure pneumothorax size, which prevented us from evaluating whether saline sealing might attenuate its severity, a potential benefit reported in a previous study [21].

In conclusion, this PS-matched analysis did not demonstrate a statistically significant reduction in pneumothorax or chest tube placement with saline sealing. Although the lack of statistical significance in this study does not necessarily negate the potential effectiveness of this technique, in a high-risk cohort such as ours, with a high prevalence of small lesions, the efficacy of saline sealing alone may be insufficient. Therefore, further investigation is warranted to clarify any potential benefits and to explore combined preventive strategies.

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Clinical Registration Number: None

Ethical Approval: This study was approved by the Institutional Review Board (approval number: ken2501-030). All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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