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ORIGINAL RESEARCH

Novel Laser System-Assisted CT-Guided Percutaneous Transthoracic Lung Biopsy in Patients with COPD Combined with Pulmonary Nodules

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Objective: The diagnosis and management of pulmonary nodules in patients with COPD are challenging, as these nodules may represent either lung cancer or other pulmonary diseases. This study aims to evaluate the efficiency of a novel laser systems (LGS)-assisted CT-guided percutaneous lung biopsy in COPD patients with pulmonary nodules.

Methods: A retrospective analysis was conducted on the data of 60 COPD patients with pulmonary nodules. Thirty patients (n=30) underwent CT-guided percutaneous transthoracic lung biopsy assisted by LGS, while the remaining 30 (n=30) underwent conventional manual CT-guided percutaneous transthoracic lung biopsy. The surgical time, number of punctures, CT scan frequency, and complications were compared between the two groups.

Results: No significant differences were found between the two groups in terms of clinical characteristics, lesion size, location, puncture depth, or nodule nature. Compared to the traditional method, LGS-assisted CT-guided percutaneous lung biopsy significantly reduced the number of CT scans (2.3 ± 0.5 vs 3.2 ± 0.6, $P < 0.001$) and the average procedure time (12.6 ± 2.7 min vs 25.1 ± 3.4 min, $P < 0.001$). Additionally, the total intraoperative time per procedure was significantly reduced (25.1 ± 3.4 min vs 45.9 ± 8.8 min, $P < 0.001$). With the use of LGS, 73% (22/30) of the procedures hit the target on the first needle insertion, compared to only 6.7% (2/30) in the conventional group. Furthermore, there was no significant difference in the incidence of complications between the two groups.

Conclusion: Compared to the traditional method, the use of LGS improved puncture efficiency in COPD patients, reduced the need for needle adjustments, and effectively shortened the procedure time.

Keywords: novel laser systems, pulmonary nodules, COPD, PTNB, CT

Introduction

Chronic obstructive pulmonary disease (COPD) and lung cancer have long been major global public health concerns, posing serious threats to public health and economic development worldwide. COPD is a chronic lung disease characterized by airflow limitation and progressive dyspnea, with a global prevalence of 10.3%. Approximately 3 million people die from COPD each year, making it the third leading cause of death.[1,2] Lung cancer, one of the most common cancers globally, is the sixth leading cause of death worldwide. The 2020 global cancer statistics report revealed that lung cancer ranks second in new cases, accounting for 11.4% of all new cancer cases. Nearly 1.8 million people die from lung cancer each year, representing 18.0% of all cancer-related deaths. The prognosis for lung cancer patients is also poor, with a 5-year survival rate of approximately 10% to 20% in most countries.[3,4] However, with advances in molecular targeted therapies, overall survival (OS) has significantly improved in actionable mutation-positive patients. Recent studies report median OS exceeding 3–5 years for advanced NSCLC with targeted agents versus 10–12 months with chemotherapy alone.[5,6] And studies have shown that COPD is an independent risk factor for the development of lung cancer. COPD patients are approximately 3 to 6 times more likely to develop lung cancer compared to those without COPD.[7,8] Moreover, lung cancer patients often have comorbid COPD, with an estimated comorbidity

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rate of 50% to 80%. However, COPD in lung cancer patients is frequently undiagnosed and untreated, with only 7.1% of patients receiving an accurate diagnosis and only 28% to 35% receiving standardized treatment for COPD.[9,10] Although the link between COPD and lung cancer has been established, methods to prevent lung cancer in COPD patients remain limited. Therefore, early screening for lung cancer in COPD patients is of utmost importance in clinical practice.

Pulmonary nodules are a common finding on chest CT scans and are considered potential precursors or early signs of lung cancer. They are defined as round, focal, density-enhanced solid or subsolid lung lesions with a diameter of 3 cm or less.[11,12] International guidelines provide standardized management algorithms based on nodule size, morphology, and patient risk factors, particularly emphasizing timely histological diagnosis for high-risk COPD patients.[13] Early detection is critical given that stage I diagnosis followed by targeted therapy achieves 5-year OS>80% in actionable mutation-positive cases.[14] However, the management of COPD patients with concomitant pulmonary nodules remains challenging, as current diagnostic tools and strategies have limitations in accurately locating and differentiating these lesions.

In current clinical practice, CT-guided percutaneous transthoracic needle biopsy (CT-PTNB) is a commonly used and important method for evaluating pulmonary nodules. CT-PTNB is the gold standard for histological diagnosis but carries increased risks of pneumothorax and bleeding in COPD patients.[15–17] With the continuous advancement of medical technology, various devices ranging from low-cost, simple equipment to highly complex electromechanical systems have been developed to improve the accuracy of CT-PTNB. While auxiliary technologies like 3D-printed templates, robotic systems, and electromagnetic navigation (EMN) improve accuracy, their high cost, complex registration workflows, and need for specialized training limit widespread adoption.[18–20] Laser-assisted systems represent a simpler alternative. However, current platforms such as the laser navigation system (LNS) described by Gruber-Rouh et al[21] require permanent room modifications (eg, ceiling-mounted rails), dedicated calibration (>10 minutes/procedure), and specialized software integration—making them infeasible for most hospitals.

Therefore, to address these limitations, we designed a laser-guided system (LGS) characterized by a portable holder that requires no modifications to the room structure, simple operation without software registration, and low cost while retaining tactile control by the operator. With this retrospective study, we evaluated the safety and efficacy of utilizing this technology to assist CT-PTNB in the diagnosis of lung nodules in patients with COPD. This approach is intended to provide clinicians with a more accurate and safer method of diagnosing lung nodules, thereby increasing diagnostic accuracy and improving clinical outcomes and prognosis for patients.

Study Design and Methods

Study Design

This study is a single-center, retrospective, observational research comparing the safety and efficacy of the laser-guided system (LGS) and the traditional method in CT-PTNB for COPD patients with pulmonary nodules. We included COPD patients with pulmonary nodules who underwent CT-PTNB in the Department of Respiratory Medicine at Hunan Provincial People's Hospital from December 2022 to June 2023, and retrospectively analyzed their clinical and imaging data. Patients were consecutively enrolled and alternately assigned to LGS or control groups biweekly to minimize selection bias. A total of 60 patients underwent lung biopsy under either the LGS (n=30) or traditional manual puncture (n=30). All lesions were evaluated by the interventional team, and biopsies were performed by two pulmonologists with more than two years of experience in CT-guided biopsy, using the same CT scanner. Inclusion criteria were as follows: patients aged 18 years or older, diagnosed with COPD, CT imaging showing pulmonary nodules, and patients who agreed to participate in the study and signed informed consent. Exclusion criteria included: severe coagulation disorders, pulmonary anatomical abnormalities unsuitable for puncture biopsy, refusal to participate in the study or inability to provide complete data, and patients unable to follow verbal instructions or guidance. The study was approved by the Ethics Committee of Hunan Provincial People's Hospital, and all procedures were performed after obtaining informed consent from the patients.

Laser-Guided System (LGS) and Biopsy Procedures

The laser-guided system (LGS) utilizes a custom-made laser locator to determine the puncture angle and provides precise guidance for the puncture through real-time imaging (Figure 1). The main components of the LGS consist of two supports and a laser angle device mounted on each support (Patent No. ZL 20222016072.3). One set of laser angle devices is fixed on the

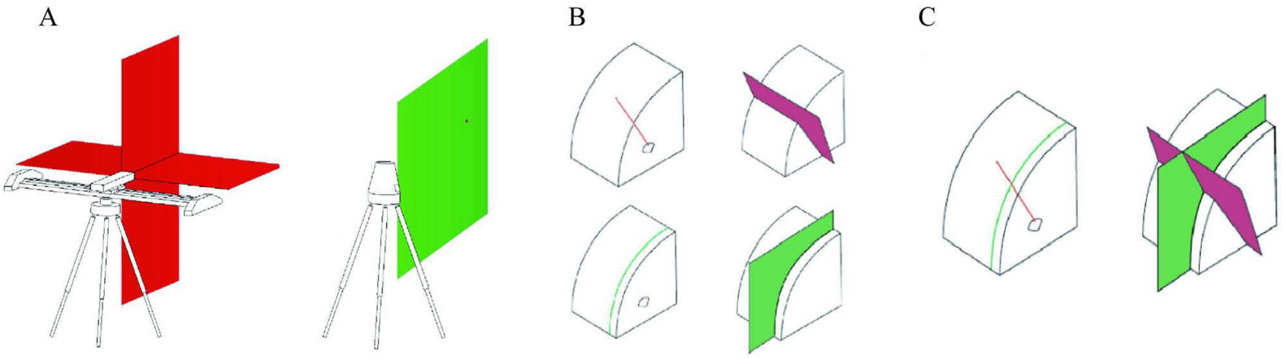

Figure 1 Principle of the Laser-Guided System (LGS). (**A**) The red laser is positioned on the patient's foot or head side to determine the puncture angle; the green laser is placed on the opposite side of the operator to determine the puncture plane. (**B**) The fan-shaped column represents the patient's chest, and the irregular circular shape represents the pulmonary nodule. The red line represents the red laser, which defines the angle, while the green laser determines the puncture plane, guiding the puncture needle. (**C**) The puncture needle is advanced under the guidance of the two sets of lasers.

horizontal rails of the support, emitting a red laser that is perpendicular to both the vertical and horizontal planes. The support is then positioned at the patient's head or tail side. The red laser is used to determine the puncture angle, with specific angle data displayed on the laser device. The vertical laser is adjusted to the pre-determined angle, and the two red laser beams intersect at the puncture point on the patient's surface. Another set of supports is placed on the opposite side of the operator, with the laser angle device emitting a vertical green laser. The green laser is used to determine the puncture plane. Before insertion, the position of the puncture needle is adjusted so that both the vertical red and green lasers intersect at the tip of the needle. The needle is then advanced under the guidance of the two sets of lasers.

During CT-guided percutaneous lung biopsy, we strictly follow standardized operating procedures to ensure the accuracy and safety of the puncture path. All biopsies were performed in an inpatient setting. Patients were admitted 24 hours pre-procedure for baseline assessments (coagulation, lung function) and observed for ≥24 hours post-biopsy to monitor complications (pneumothorax, hemorrhage). The control group underwent conventional manual CT-PTNB: Puncture paths were planned using CT scout images and body surface grids. Needle adjustments were made iteratively based on real-time CT scans without laser guidance. The preparation for the LGS is the same as for conventional puncture methods: disinfection, anesthesia, draping, and selection of the appropriate position based on the location of the pulmonary nodule, with instructions for the patient to maintain a fixed posture. The optimal puncture plane is chosen based on the patient's lung CT images, and the puncture point is marked using a combination of the body surface positioning grid and CT scanner alignment crosshairs. The puncture path is then recalculated, measuring the insertion direction, horizontal angle (avoiding ribs and major blood vessels), and insertion distance. Under the guidance of the LGS, the red and green laser beams are kept aligned with the puncture needle as it is slowly advanced. Once the needle reaches the target site, CT is used again for final positioning confirmation (Figure 2). The imaging parameters of the CT scanner were 120 kV, 100 mA, 0.75-second rotation time, 0.985 pitch, 5 mm slice thickness, 5 mm increment, and a 512 matrix (Philips, Precedence 16, Netherlands). All patients underwent preoperative thin-slice chest CT to confirm nodule characteristics (size, location, density). Inclusion required nodules≥8mm in diameter, accessible via percutaneous transthoracic approach, and visible on standard CT windows (lung/mediastinal). Exclusion criteria included: nodules obscured by severe emphysema/bullae, or inability to define a safe path avoiding major vessels/bronchi. During the procedure, close monitoring of the patient's vital signs is maintained. All patients underwent coaxial biopsy using a 17-gauge coaxial introducer and an 18-gauge internal automatic cutting needle (Leapmed, QZDB 16G, Suzhou, China). After the puncture, the needle is removed, and pressure is applied with gauze until bleeding stops. A CT of the chest was performed immediately after surgery to assess complications, clinical tests (SpO_2, blood pressure), and to observe the patient for symptoms such as chest pain, shortness of breath, or hemoptysis, while a 24-hour CT follow-up was performed for delayed pneumothorax. Procedures followed the 2017 CIRSE Guidelines for Percutaneous Lung Interventions and the Fleischner Society recommendations for thoracic imaging. COPD management adhered to GOLD 2023 criteria.

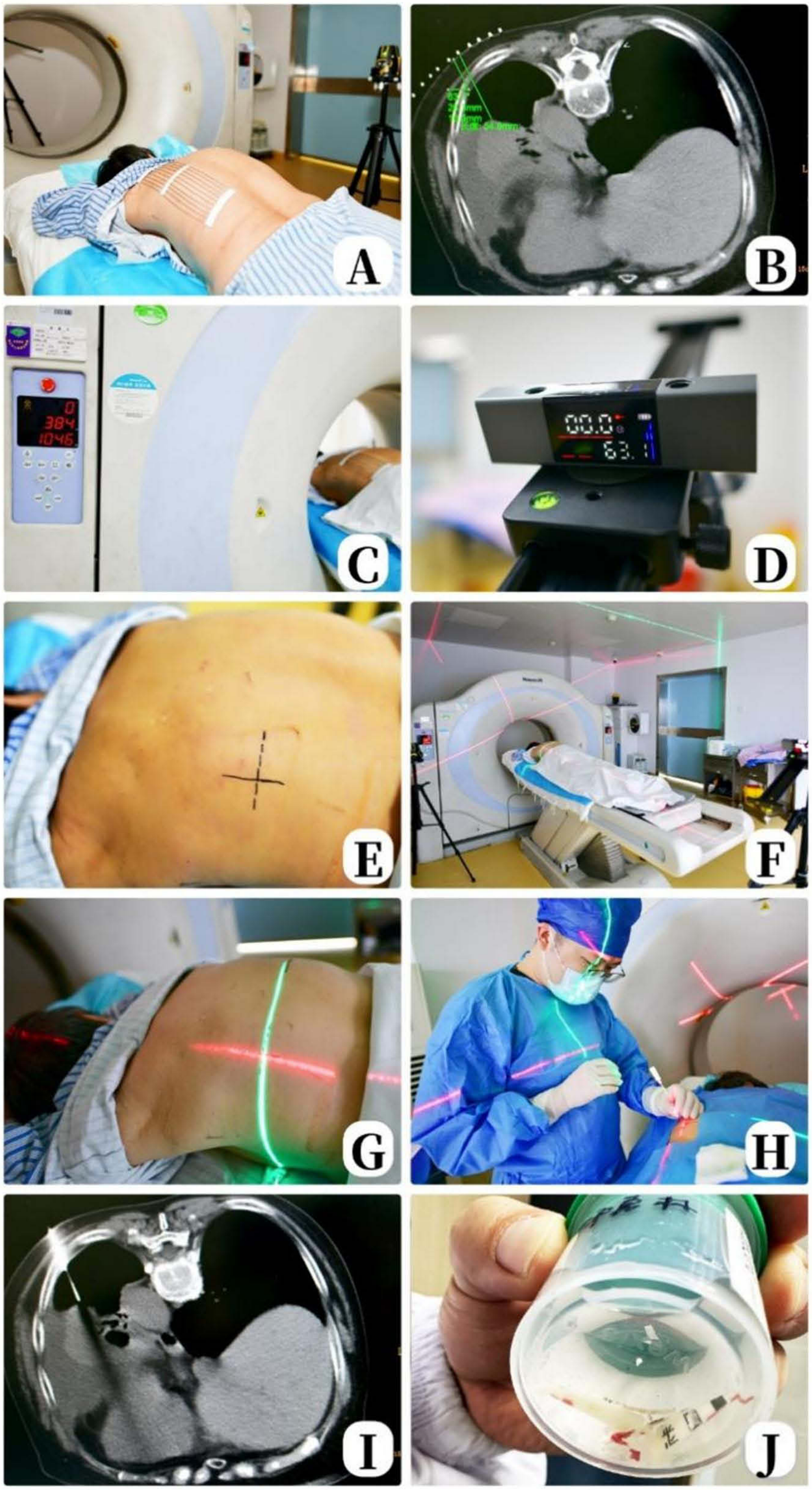

Figure 2 Operation Workflow of the Laser-Guided System (LGS) Assisted CT-PTNB. (**A**) Attach the custom-made grid to the patient's chest. (**B**) Perform preoperative CT scan to plan the puncture path. (**C**) Adjust the CT slice to the puncture cross-section. (**D**) Adjust the angle of the red laser device to the specific value consistent with the planned angle. (**E**) Mark the puncture point on the body surface. (**F**) Attach the device to the appropriate position. (**G**) Ensure that the two laser beams intersect at the puncture point. (**H**) The operator inserts the coaxial needle under the real-time guidance of the two laser beams. (**I**) Perform another CT scan to observe if any complications occur. (**J**) Obtain lung tissue and promptly fix it in formalin.

Data Evaluation

Clinical and imaging data of patients meeting the inclusion criteria were collected. This included demographic data (age, sex, medical history, COPD severity, etc.) for both the LGS group and the control group, lesion characteristics (size, location, nodule nature), as well as puncture complexity (position, distance from the target to the pleura, surgical time, number of punctures, number of CT scans, etc)., and post-biopsy complications. Surgical time was defined as the time interval between the initial localization scan and the control scan showing the needle tip entering the target. Room time was recorded from the patient's entry to the CT room to their departure. Data were retrieved and organized by professional researchers in the hospital's information system.

Statistical Methods

The collected data were analyzed using SPSS 22.0. Continuous variables are expressed as mean ± standard deviation (SD). For group comparisons, analysis of variance (ANOVA) or Mann–Whitney *U*-test was used, with $P < 0.05$ considered statistically significant.

Results

Demographic Data and Lesion Characteristics of COPD Patients

Table 1 summarizes the baseline characteristics and pulmonary nodule features of patients in the LGS group and the control group. There were no statistically significant differences between the two groups in terms of basic information (age, sex, smoking history, lung function, clinical status) and lesion characteristics (lesion size, location, puncture depth, nodule nature).

All biopsy needles were successfully inserted into the target area, sufficient for pathological diagnosis. Table 2 summarizes the puncture results for both groups. Compared to the control group, the number of CT scans required in the LGS group decreased

Table 1 Demographic Data and Lesion Characteristics of COPD Patients

Characteristic	Laser-Guided Group (n=30)	Control Group (n=30)	P value
Age, mean (SD), y	62.6 (9.9)	63.7 (9.5)	0.67
Sex			
Men	23	24	0.75
Women	7	6	
Smoking history, No.			
Yes	24	25	0.74
No	6	5	
BMI, mean (SD)	22.4 (2.7)	22.9 (3.2)	0.28
FEV1 (%predicted), mean (SD)	61.9 (14.2)	65.0 (11.1)	0.36
GOLD, No.			
1	4	1	0.67
2	22	27	
3	4	2	
4	0	0	
6-MWT, mean (SD), m	374.7 (30.6)	386.1 (31.1)	0.16
mMRC, No.			
1	4	5	0.62
2	22	22	
3	4	3	
4	0	0	

(*Continued*)

Table 1 (Continued).

Characteristic	Laser-Guided Group (n=30)	Control Group (n=30)	P value
SP02, mean (SD), mmHg	77.7 (6.4)	77.3 (9.2)	0.85
SPC02, mean (SD), mmHg	41.8 (5.8)	43.8 (6.8)	0.22
Hypertension	27	25	0.71
Diabetes	19	20	0.79
Coronary artery disease	20	18	0.59
Pulmonary heart disease	8	9	0.77
Nodule location, No.			
RUL	9	11	0.53
RML	4	2	
RLL	4	8	
LUL	7	4	
LLL	6	5	
Nodule size, mean (SD), mm	24.0 (4.9)	25.4 (3.9)	0.22
Nodule type, No.			
Pure GGO	3	3	0.81
Mixed GGO	7	8	
Solid GGO	20	19	
Distance from pleura, mean (range), mm	73.8 (15.3)	74.2 (20.1)	0.94

Table 2 Puncture Results and Post-Biopsy Complications in Patients with COPD

Puncture Results and Post-Biopsy Complications	Laser-Guided Group (n=30)	Control Group (n=30)	P value
Operation Time, mean (SD), min	12.6 (2.7)	25.1 (3.4)	<0.001
Room Time, mean (SD), min	28.2(5.5)	45.9(8.8)	<0.001
Operating position, No.			
Supine	21	24	0.37
Prone	9	6	
Number of CT scans, mean (SD)	2.3 (0.5)	3.2 (0.6)	<0.001
Insertion attempts, No.			
1	22	2	<0.001
2	7	20	
≥3	1	8	
Pneumothorax, No.	5	8	0.35
Hemorrhage, No.	4	6	0.37
Hemoptysis, No.	8	11	0.58

from 3.2±0.6 to 2.3±0.5 (P<0.001). In the LGS-assisted procedures, 73% (22/30) of patients reached the target on the first attempt, while only 6.7% (2/30) of procedures in the traditional method group achieved this. For procedures requiring more than one attempt, the LGS group had only 3.3% (1/30), while the control group had 26.6% (8/30), with a significant statistical difference (P<0.001). Additionally, LGS-assisted puncture significantly reduced both the surgical time (12.6±2.7 minutes vs 25.1±3.4 minutes, P<0.001) and the operating room time (28.2±5.5 minutes vs 45.9±8.8 minutes, P <0.001).

After the biopsy, pneumothorax was detected in 13 patients (5 patients in the LGS group [17%], 8 patients in the control group [27%], P=0.35). In the control group, 2 patients underwent closed chest tube drainage, while the remaining patients required no further treatment. Mild pulmonary parenchymal bleeding occurred in 10 patients (4 patients in the LGS group [13%], 6 patients in the control group [20%], P=0.37), and no further treatment was required. Mild hemoptysis occurred in 19 patients (8 patients in the LGS group [13%], 11 patients in the control group [20%], P=0.58), with no further treatment needed. There were no other major complications in either group.

Discussion

In COPD patients, the diagnosis and treatment of pulmonary nodules often pose significant challenges. COPD patients are frequently accompanied by structural changes in the lungs and varying degrees of pulmonary function impairment, which increases the risk of complications during the puncture procedure. Although traditional puncture localization methods are widely used, they have drawbacks such as high radiation exposure, complex operation, and a higher incidence of complications, which makes the procedure inaccessible for some high-risk patients. Traditional puncture methods require doctors to repeatedly adjust the puncture path, manually adjusting the direction and angle to determine the optimal puncture point. This process is not only time-consuming but also highly influenced by the doctor's experience, increasing the complexity and failure rate of the procedure. Our findings align with evolving screening paradigms. Current guidelines (GOLD2024) advocate integrating LDCT surveillance for COPD patients with incidental nodules≥6 mm. The LGS system's efficiency in biopsy acceleration supports timely histological confirmation within these screening frameworks, potentially reducing diagnostic delays.

In recent years, various auxiliary devices have been widely reported to address these issues and have demonstrated significant advantages in pulmonary nodule puncture localization. Compared to other laser-assisted localization technologies currently reported, although they can provide precise puncture guidance, the localization systems they rely on often require more complex operations and considerable space. This can lead to potential errors or localization deviations, especially for doctors with less technical experience.[22,23] In contrast, our device uses only two flexible, movable brackets and associated laser angle instruments. With more accurate path planning, it can easily and precisely guide the localization of the biopsy needle in the X-Y plane, allowing the doctor to perform effective puncture. Additionally, without the need to alter room structure or complex software, operators can complete the installation and setup of the LGS within minutes using a conventional CT room. Achieving the target with the first puncture is crucial for reducing the patient's surgery time and minimizing the number of CT scans, especially in COPD patients, where the advantages are particularly prominent[17]. Recent evidence confirms that smoking-induced inflammation promotes genetic instability in pulmonary nodules, accelerating malignant transformation in COPD patients.[24] This is because some COPD patients have cachexia, and their lung structures are destroyed, leading to insufficient support for the puncture from the chest wall and lung tissue. Frequent punctures increase the surgery time, radiation dose, and the risk of related complications in such patients.[25] Preliminary results from this study show that 73% of the procedures with LGS achieved the target with the first puncture, while only 6.7% of procedures using traditional methods did. Furthermore, by improving localization accuracy, the overall and surgery time was shortened, and the number of CT scans was reduced. This is consistent with other auxiliary devices reported,[22,26,27] indicating that LGS not only offers the advantages of flexibility, convenience, and simplicity but also significantly enhances the efficiency of puncture biopsy. Unlike EMN or robotic systems requiring substantial capital investment and recurring per-procedure costs, the LGS operates without software, disposable components, or room modifications, reducing financial barriers for widespread adoption.

Furthermore, the LGS has effectively reduced the incidence of complications during the puncture process through its precise localization technology. In COPD patients, as lung function is already impaired and lung tissue is more fragile, the risk of complications during the puncture procedure, such as pneumothorax and pulmonary hemorrhage, is higher.[14] However, with the high-precision localization provided by the laser-assisted device, the puncture path can avoid direct injury to vital tissues and blood vessels, thereby significantly reducing the occurrence of complications. Our study shows that the incidence of pulmonary hemorrhage and hemoptysis in the LGS group was 13%, which was lower than the 20% observed in the manual group, but the difference was not statistically significant. Larger-scale studies are needed to confirm this advantage. Additionally, due to the limited number of patients included, the difference in the incidence of pneumothorax between the two groups was not significant. Some patients in the manual group required treatment, which may be related to the common presence of emphysema in COPD patients. Although overall pneumothorax rates did not differ significantly, 6.7% (2/30) of control-group patients required chest tube drainage versus 0% in the LGS group, suggesting reduced severity. The significant reduction in needle adjustments and CT scans with LGS inherently lowers complication risk, as repeated pleural punctures are a known predictor of pneumothorax. The lower number of puncture attempts in the LGS group, along with the stepwise puncture technique, may have helped avoid damage to the lung tissue, potentially benefiting the patients.

Although the LGS-assisted puncture has advantages, there are some limitations in this study. First, for certain complex cases, especially those involving nodules in unusual locations or with significant anatomical variations, the LGS-assisted system may still face some challenges, which may require experienced physicians to make appropriate adjustments and supplementary judgments. Second, the sample size of this study is relatively small. Although our sample size (n=30/group) provided sufficient power to detect differences in procedural efficiency (eg, operation time, CT scans), it was underpowered for complication analysis. As a single-center retrospective study, potential selection bias remains despite consecutive enrollment and baseline equivalence between groups. Future multi-center studies with larger cohorts are warranted to validate the safety profile of LGS-assisted biopsy in high-risk COPD patients. Additionally, this study did not explore the long-term economic benefits and clinical outcomes of this device. Future research with long-term follow-up is needed to further assess the comprehensive benefits of this device, particularly its advantages in reducing hospital stays and lowering healthcare costs.

Conclusion

In conclusion, this study suggests that LGS-assisted CT-guided percutaneous transthoracic lung biopsy can improve puncture efficiency and shorten surgery time in COPD patients, while LGS reduced procedure time and CT scans, its impact on complications requires further investigation in larger cohorts.

Abbreviations

LGS, Laser-guided system; COPD, Chronic obstructive pulmonary disease; PTNB, percutaneous transthoracic needle biopsy; SD, standard deviation.

Ethics Approval and Consent to Participate

This study was approved by the Hunan Provincial People's Hospital ethics committee and obtained informed consent from all participants involved in the research. All procedures involving human participants in this study were conducted in accordance with the ethical standards of the institutional and/or national research committees, as well as the 1964 Declaration of Helsinki and its later amendments or similar ethical standards.

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Disclosure

The authors declare no conflicts of interest in this work.

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