

The surgeon's needle and the assurance of diagnosis: New players in CT-guided tru-cut biopsy

Cerrahin iğnesi, tanının güvencesi: BT eşliğinde tru-cut biyopsinin yeni oyuncuları

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ABSTRACT

Background: This study aims to encourage the use of percutaneous transthoracic biopsies by thoracic surgeons as a diagnostic method.

Methods: This retrospective study was conducted between January 1, 2015, and January 31, 2024, with 793 patients (632 males, 160 females; mean age: 65±12 years; range, 11 to 93 years) who underwent lung tru-cut biopsy under computed tomography guidance. Patients whose radiologic and pathology records were accessible via the Hospital Information System and the Picture Archiving and Communication System were included.

Results: A total of 973 tru-cut biopsy procedures were performed. There was no statistically significant difference in age distribution between sexes (p=0.15). Most biopsies were performed on the upper lobes, predominantly the right upper lobe (33.2%). The supine position was the most commonly used during the procedure (49.4%). The mean lesion diameter and distance from the chest wall were 49±17 mm and 51±16 mm, respectively. A definitive diagnosis was obtained on the first attempt in 78.6% of patients, while repeat biopsies were required in 21.4%. Primary lung malignancy was diagnosed in 63% of cases. Postprocedural complications included pneumothorax in 16.1%, intraparenchymal hemorrhage in 0.1%, hemoptysis in 0.1%, and hemothorax in 0.1% of patients. Complications were most frequently observed following biopsies of the left lower lobe (32.4%). Lesions located in the upper lobes were significantly more likely to be malignant (p=0.01). A significant increase in complication rates was observed with greater parenchymal tissue penetration during the procedure (p=0.001).

Conclusion: Computed tomography-guided percutaneous lung biopsies can be performed more safely by thoracic surgeons due to their procedural experience. Additionally, in the event of complications, thoracic surgeons are more capable of providing prompt and effective intervention, thereby enhancing patient safety. Thoracic surgeons should be actively involved in all diagnostic stages of pulmonary or mediastinal nodules or masses, including procedures such as tru-cut lung biopsy and endobronchial ultrasonography.

Keywords: Lung biopsy, lung cancer, pulmonary nodule, thoracic surgery, tru-cut biopsy.

ÖZ

Amaç: Bu çalışmada tanıda kullanılan yöntemlerden biri olan perkütan transtorasik biyopsinin göğüs cerrahları tarafından uygulanmasını teşvik etmek amaçlandı.

Çalışma planı: Bu retrospektif çalışma 01.01.2015 - 31.01.2024 tarihleri arasında bilgisayarlı tomografi eşliğinde akciğer tru-cut biyopsi uygulanan 793 hasta (632 erkek, 160 kadın; ort. yaş: 65±12 yıl; dağılım, 11-93 yıl) ile yürütüldü. Hastane Bilgi Sistemi ve Görüntü Saklama ve İletişim Sistemleri kullanılarak radyoloji ve patoloji sonuçlarına ulaşılan hastalar çalışmaya dahil edildi.

Bulgular: Toplamda 973 tru-cut biyopsi işlemi yapıldı. Her iki cinsiyette yaş dağılımı açısından anlamlı bir farklılık yoktu (p=0.15). Biyopsi en çok üst loblara, ağırlıklı olarak da sağ üst loba yapıldı (%33.2). İşlem sırasında en sık supin pozisyon kullanıldı (%49.4). Lezyonların ortalama çapı ve göğüs duvarına uzaklığı sırasıyla 49±17 ve 51±16 mm idi. Hastaların %78.6'sına ilk girişimde kesin tanı konulurken, %21.4'ünde tekrarlayan biyopsiler gerekti. Hastaların %63'üne primer akciğer malignitesi tanısı kondu. İşlem sonrası komplikasyonlar hastaların %16.1'inde pnömotoraks, %0.1'inde intraparanhimal hemoraji, %0.1'inde hemoptizi ve %0.1'inde hemotoraks olarak görüldü. Komplikasyonlar en çok sol alt lob biyopsilerinden sonra (%32.4) gözlemlendi. Üst loblarda yer alan lezyonların malignite olasılığı önemli ölçüde daha yüksekti (p=0.01). Biyopsi almak için geçilen parankim dokusu arttıkça komplikasyon oranının anlamlı olarak arttığı görüldü (p=0.001).

Sonuç: Bilgisayarlı tomografi eşliğinde perkütan biyopsi uygulamaları göğüs cerrahisi uzmanlarının deneyimi sayesinde daha güvenli şekilde uygulanabilir. Ayrıca göğüs cerrahisi uzmanları olası bir komplikasyon durumunda hızlı ve etkin bir müdahalede bulunma konusunda daha yetkin olduğundan hasta güvenliğine olumlu katkıda bulunurlar. Göğüs cerrahisi uzmanları akciğer veya mediastendeki nodül veya kitlenin tru-cut akciğer biyopsisi ve endobronşial ultrasonografisi dahil her türlü tanı aşamasında aktif olarak yer almalıdır.

Anahtar sözcükler: Akciğer biyopsisi, akciğer kanseri, pulmoner nodül, göğüs cerrahisi, tru-cut biyopsi.

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Lung cancer is the most common malignancy worldwide and is the leading cause of cancer-related death.^[1,2] Primary lung tumors, once rare lesions in the last century, have now become the leading cause of cancer mortality.^[3,4] In cases of pulmonary and mediastinal masses, histopathological diagnosis in addition to clinical and radiological findings is required to formulate a treatment plan. Depending on the lesion's localization, tissue diagnosis is obtained via fiberoptic bronchoscopy, endobronchial ultrasound-guided biopsy, surgical approaches (mediastinoscopy, mediastinotomy, video-assisted thoracoscopic surgery, and thoracotomy), and percutaneous biopsies. Percutaneous transthoracic lung biopsy (PTLB) was first employed by Leyden in 1883 for bacteriological sampling in the diagnosis of pneumonias and subsequently by Menetrier in 1886 for the diagnosis of lung cancer.^[5]

Today, endobronchial and image-guided (computed tomography [CT], ultrasonography) percutaneous methods, which are less invasive than surgery, have become the preferred diagnostic techniques. In patients whose lesion localization is unsuitable for endoscopic interventions, PTLB under CT guidance is generally preferred. Image-guided biopsies include fine-needle aspiration and core needle (tru-cut) biopsy. While fine-needle biopsy allows for cytological examination of aspirated material, tru-cut biopsy enables multiple immunohistochemical staining and certain molecular biology analyses to investigate tumor architecture.

Indications for PTLB are as follows: peripheral or hilar masses or pulmonary nodules not accessible by bronchoscopy; suspicion of mediastinal invasion in the presence of lung cancer or enlarged hilar/mediastinal lymph nodes; undiagnosed mediastinal masses; pleural thickening suspicious for malignancy; and focal or multifocal parenchymal consolidations or abscesses with no infectious agent detected.^[5] Contraindications for PTLB include vascular lesions such as arteriovenous malformations and pulmonary varices, thrombocytopenia, respiratory failure (FEV1 [forced expiratory volume in 1 sec] <35%), patients with myocardial infarction, uncooperative patient, uncontrollable cough, and bullous lung. Biopsy must be strictly avoided in cases of suspected hydatid cyst. Relative contraindications for PTLB include severe obstructive lung disease, coagulopathy, moderate to severe pulmonary hypertension, ventilator dependence, and patients with prior pneumonectomy.

The aim of this study was to analyze patients who underwent tru-cut biopsy under CT guidance in our thoracic surgery clinic with respect to age, sex, lesion location, size, distance from the thoracic wall, patient position during biopsy, and the relationship of accompanying lesions with diagnosis and complications and to contribute to the existing literature through comparative evaluation. Additionally, we sought to encourage thoracic surgeons to perform this procedure by outlining the management of complications arising after PTLB.

PATIENTS AND METHODS

This retrospective study was conducted at the Thoracic Surgery Clinic of the Kayseri City Hospital and included 793 patients (632 males, 160 females; mean age: 65±12 years; range, 11 to 93 years) who underwent CT-guided core needle lung biopsy between January 1, 2015, and January 31, 2024. The study included patients whose PACS and pathology results were retrieved via the Hospital Information System. Written informed consent was obtained from all participants. Ethical approval for this study was obtained from the Kayseri City Hospital Non-Interventional Clinical Research Ethics Committee (Date: 25.02.2025, No: 351). The study was conducted in accordance with the Declaration of Helsinki.

Before the procedure, bleeding diathesis and the use of antiplatelet or anticoagulant medications were assessed, and these medications were discontinued for an appropriate duration. Complete blood count and bleeding parameters (activated prothrombin time, INR [international normalized ratio]) were evaluated; the procedure was performed in patients with platelet counts >50,000 and INR <1.5.^[6] Fasting was not recommended prior to the procedure, and no antibiotics were administered before or after the procedure.

Biopsies were performed under sterile conditions using a 256-slice Siemens Somatom Definition AS CT scanner (Siemens AG, Munich, Germany). Lesions were evaluated with 1-mm CT images. An 18-gauge semiautomatic biopsy needle was used in all procedures. After determining the optimal patient position and shortest path to the lesion, radiopaque metal markers were placed on the chest wall closest to the lesion. Using 1-mm CT images, the distance to the lesion was measured. If the location was suitable, the entry site was marked and cleaned with povidone-iodine, and local anesthesia with 2% lidocaine was administered. The needle was

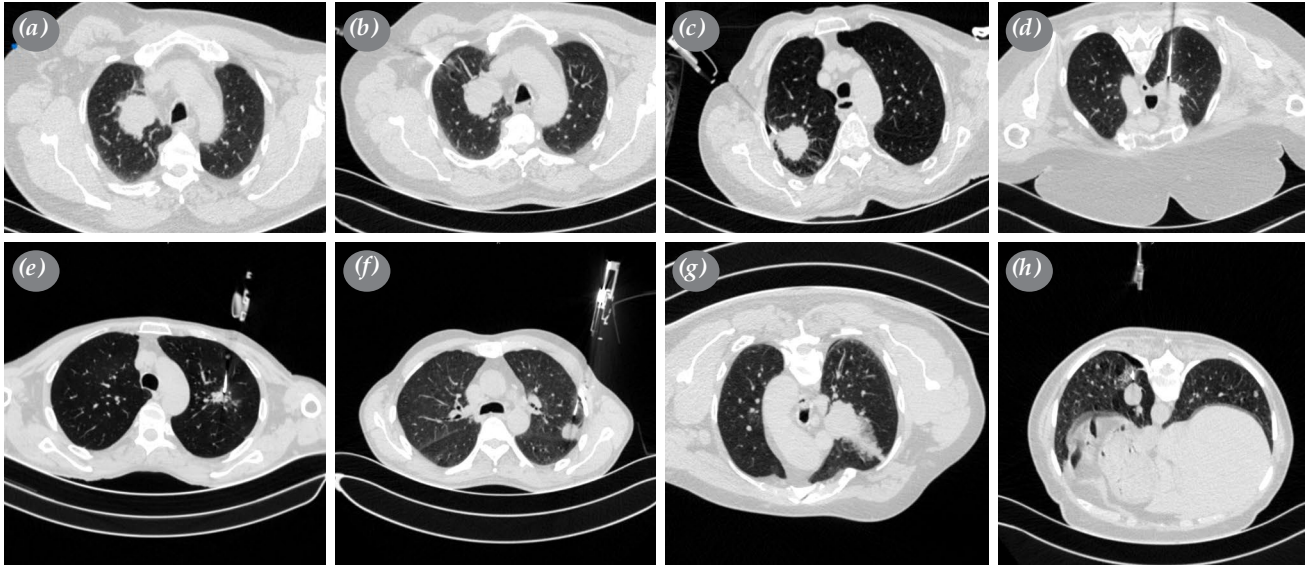


Figure 1. Prebiopsy marking and examples of various biopsies and complications. (a) Markers placed. (b) The needle advance through the pleura. (c-f) Biopsy samples from lesions at different locations. (g) Intraparenchymal hemorrhage. (h) Intraparenchymal hemorrhage and pneumothorax.

advanced through the pleura toward the lesion, and 1-mm control images were obtained (Figure 1). The biopsy specimen was placed in a sterile 10% formalin solution. After the procedure, control CT images were acquired and complications were evaluated. A chest radiograph was obtained 3-4 h after the procedure to evaluate delayed complications. Patients without complications were discharged the same day.

Postprocedure CT images were compared with preprocedure images to evaluate the following complications: pneumothorax (air in the pleural space), hemothorax (fluid), and intraparenchymal hemorrhage (ground-glass opacities in the parenchyma). Preprocedure CT images were analyzed to assess cavitation (low-density areas within the lesion) and emphysematous changes in the parenchyma.

Statistical analysis

Data were analyzed using IBM SPSS version 27.0 software (IBM Corp., Armonk, NY, USA). Normality of data distribution was assessed with the Kolmogorov-Smirnov test. Continuous variables were analyzed with Student's t-test, and categorical data were analyzed with the chi-square test. One-way analysis of variance was used for group comparisons. A p-value of <0.05 was considered statistically significant in all analyses.

RESULTS

Over the study period, 973 core needle biopsy procedures were performed on 793 patients. No significant difference in age distribution was observed between male and female patients ($p=0.15$). Of the tru-cut biopsies, 758 (95.7%) were performed for intraparenchymal lesions and 35 (4.3%) for mediastinal and pleural lesions. Evaluation of intraparenchymal lesion locations revealed a predominance in the upper lobes, with the right upper lobe being the most frequent biopsy site ($n=263$, 33.2%). The supine position ($n=392$, 49.4%) was most commonly used for biopsies, followed by prone and lateral positions. Most lesions showed no cavitation ($n=588$, 74.8%). The smallest lesion biopsied was 5 mm, the largest was 140 mm, and the mean diameter was 49 ± 17 mm. The distance of lesions from the chest wall ranged from 3 mm to 99 mm (mean: 51 ± 16 mm). Thirty percent of the lesions were smaller than 3 cm, 30% were between 3 cm and 5 cm, 22.7% were between 5 cm and 7 cm, and 18.8% were larger than 7 cm. Patient data are presented in Table 1.

Diagnoses were confirmed in 623 (78.6%) patients during the initial biopsy, while 21.4% required repeat biopsies (160 patients underwent two biopsies, 10 patients underwent three). Final pathology results included benign or necrotic findings in 28.9%, primary lung malignancy in

63%, and lymphoma, thymoma, or metastasis in 8.1% of the cases. Among primary lung cancers, 28.1% (n=223) of cases were adenocarcinoma, 10.3% were squamous cell carcinoma, 4.9% were small cell lung cancer, and 19.7% were non-small cell lung cancers of unspecified subtype. Other diagnoses included normal lung parenchyma (12.7%), pneumonia or chronic infection (10.2%), necrosis (3.2%), granulomatous disease (1.5%), and atypical adenomatous hyperplasia (1%). Postprocedural complications included pneumothorax (16.1%), intraparenchymal hemorrhage (0.1%), hemoptysis (0.1%), and hemothorax (0.1%). Over half of patients

with complications received only oxygen therapy, while 44.7% (7.29% of all procedures) required tube thoracostomy. Repeat biopsy rates were significantly higher in patients requiring tube thoracostomy (35% vs. 22%, $p=0.04$; Table 2). No patient required surgical intervention for complications, and there were no procedure-related in-hospital mortalities.

Complications were most frequent following left lower lobe biopsies (32.4%), whereas no complications occurred in mediastinal tumor biopsies; this difference was statistically significant ($p=0.011$). One-way analysis of variance revealed no

Table 1. Clinical characteristics of patients

	n	%	Mean±SD	Min-Max
Age (year)			65±12	11-93
Sex				
Male	632	79.7		
Female	161	20.3		
Lesion size (mm)			49±17	5-140
Distance to chest wall (mm)			51±16	3-99
Lesion localization				
Right upper lobe	263	33.2		
Left upper lobe	205	25.9		
Right lower lobe	158	19.9		
Left lower lobe	111	14.0		
Mediastinum	23	2.9		
Right middle lobe	22	2.8		
Pleura	11	1.4		
Accompanying lesion				
No	395	49.8		
Satellite lesion	359	45.3		
Emphysema	39	4.9		
Biopsy position				
Supine	392	49.4		
Prone	302	38.1		
Lateral	99	12.5		
Cavitation				
No	588	74.8		
Yes	198	25.2		
Lesion sizes (cm)				
<3	232	29.3		
3-5	232	29.3		
5-7	180	22.7		
>7	149	18.8		
Parietal pleura relationship				
Subpleural	444	56.0		
Intraparenchymal	349	44.0		

SD: Standard deviation.

Table 2. Biopsy results

	n	%
Malignancy subgroup		
Squamous cell cancer	82	10.3
Adenocancer	223	28.1
Non-small cell cancer	156	19.7
Small cell cancer	39	4.9
Thymoma	2	0.2
Lymphoma	16	2.1
Other malignancy	46	5.8
Benign subgroup		
Lung tissue & non-diagnostic	102	12.7
Pneumonia & chronic inflammation	82	10.2
Atypical adenomatous hyperplasia	8	1.0
Granulomatous disease	12	1.5
Necrosis	25	3.2
Rebiopsy		
No	623	78.6
Yes 2 times	160	20.1
Yes 3 times	10	1.3
Complications (included rebiopsy n=973)		
No	803	83.6
Pneumothorax	157	16.1
Hemoptysis	4	0.1
Hemothorax	1	0.1
Intraparenchymal hemorrhage	8	0.1
Complication treatment		
Oxygen therapy	88	55.3
Tube thoracostomy	71	44.7

significant differences in chest-wall distance among lobar biopsy sites ($p=0.08$). Cavitation rate was lowest in right lower lobe lesions (16%) and highest in left upper lobe lesions (30%). This difference was statistically significant ($p=0.025$). When repeat biopsies were evaluated, it was found that 35.1% of the left lower lobe lesions and none of the right middle lobe lesions required repeat biopsy, which was statistically significant ($p<0.001$). Lesion location showed no significant association with tumor size ($p=0.074$; Table 3).

Factors influencing benign versus malignant outcomes were assessed. Male sex and advanced age were identified as significant risk factors for malignancy ($p=0.01$). Lesion diameter and chest-wall distance did not significantly affect benign versus malignant outcomes ($p=0.20$ and $p=0.70$, respectively). Cavitation and laterality (right vs. left) did not have a significant effect on benign versus malignant outcomes ($p=0.90$ and $p=0.74$, respectively). However, upper lobe lesions

were significantly more likely to be malignant ($p=0.01$; Table 4).

Age and sex had no effect on the development of complications ($p=0.11$ and $p=0.45$, respectively). Complication rates were significantly higher in benign lesions compared to malignant ones ($p=0.023$). Although left lower lobe biopsies had a higher complication rate, neither laterality (right vs. left) nor lobar group (upper vs. lower) significantly affected complication risk ($p=0.41$ and $p=0.25$, respectively). Lesions adjacent to the chest wall were associated with fewer complications ($p=0.01$). An increased volume of traversed parenchyma during biopsy was significantly associated with higher complication rates ($p=0.01$). Tumor diameter had no significant effect on the development of complications ($p=0.127$). Complications were most frequent in the lateral biopsy position ($p=0.009$). No significant difference was found between supine and prone positions. Emphysema did not increase complication risk ($p=0.17$). However, the distance of the lesion to the chest wall was significantly shorter in patients with emphysema ($p=0.01$; Table 4). Lesion diameter, distance of the lesion from the chest wall, and cavitation had no significant effect on the need for repeat biopsy ($p=0.89$, $p=0.94$, and $p=0.89$, respectively).

DISCUSSION

Imaging modalities play a critical role in the diagnosis of pulmonary and mediastinal pathologies. Despite the advanced imaging technologies available today, histopathological examination remains the gold standard for diagnosis and treatment planning.^[7,8] Computed tomography-guided PTLB using a tru-cut needle has been reported as a safe and accurate method for obtaining a specific histological diagnosis with low complication rates.^[9]

In the literature, the diagnostic rate of PTLB for benign and malignant lesions has been reported as 85 to 95%.^[7,8,10-12] In the present study, the diagnostic rate on the first attempt was 78.6%. Percutaneous transthoracic lung biopsy is a user-dependent technique that requires experience and manual dexterity. Our results may have been influenced by the fact that procedures were performed by multiple thoracic surgeons with varying levels of experience and technical skill.

Prior studies have reported that biopsies are most frequently performed in the right upper lobe.^[13] Similarly, in our cohort, the right upper lobe was the most common biopsy site, and 33.3% of

Table 3. Results according to lesion localization

	L1		L2		R1		R2		R3		M		PI		p
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	
Rebiopsy															
No	72	64.9	161	78.5	123	77.8	22	100.0	216	82.1	22	95.7	7	63.6	<0.001
Yes	39	35.1	44	21.5	35	22.2	0	0.0	47	17.9	1	4.3	4	36.4	
Complication															
No	75	67.6	166	81.0	128	81.0	17	77.3	204	77.6	23	100.0	10	90.9	0.011
Yes	36	32.4	39	19.0	30	19.0	5	22.7	59	22.4	0	0.0	1	9.1	
Complication treatment															
Oxygen therapy	21	60.0	25	69.4	16	66.7	4	80.0	22	37.9	0	0.0	0	0.0	0.001
Tube thoracostomy	14	40.0	11	30.6	8	33.3	1	20.0	36	62.1	0	0.0	1	100.0	
Lesion sizes (cm)															
<3	37	33.3	61	29.8	55	34.8	5	22.7	69	26.2	3	13.0	2	18.2	0.074
3-5	38	34.2	49	23.9	51	32.3	7	31.8	79	30.0	3	13.0	5	45.5	
5-7	17	15.3	46	22.4	34	21.5	5	22.7	67	25.5	8	34.8	3	27.3	
>7	19	17.1	49	23.9	18	11.4	5	22.7	48	18.3	9	39.1	1	9.1	
Pathology results															
Benign	43	38.7	51	24.9	64	40.5	4	18.2	59	22.4	4	17.4	4	36.4	0.001
Malignancy	68	61.3	154	75.1	94	59.5	18	81.8	204	77.6	19	82.6	7	63.6	
Lesion localization															
Subpleural	62	55.9	120	58.5	80	50.6	14	63.6	141	53.6	17	73.9	10	100.0	0.08
Intraparenchymal	49	44.1	85	41.5	78	49.4	8	36.4	122	46.4	6	26.1	0	0.0	

L1: Left lower; L2: Left middle; R1: Right lower; R2: Right middle; R3: Right upper; M: Mediastinum; PI: Pleura.

Table 4. Distribution of benign and malign cases and complication status according to clinical features

	Pathology				<i>p</i>	Complication				<i>p</i>
	Benign		Malign			No		Yes		
	n	%	n	%		n	%	n	%	
Age (year)										
<50	34	48.6	36	51.4	0.01	59	84.3	11	15.7	0.11
50-70	132	29.7	313	70.3		352	79.1	93	20.9	
>70	63	22.7	215	77.3		212	76.3	66	23.7	
Sex										
Male	164	25.9	468	74.1	0.01	493	78.0	139	22.0	0.45
Female	65	40.4	96	59.6		130	80.7	31	19.3	
Lesion size (cm)										
<3	71	30.6	161	69.4	0.2	176	75.9	56	24.1	0.12
3-5	74	31.9	158	68.1		177	76.3	55	23.7	
5-7	44	24.4	136	75.6		144	80.0	36	20.0	
>7	40	26.8	109	73.2		126	84.6	23	15.4	
Skin-to-lesion distance (cm)										
<2	7	22.6	24	77.4	0.66	30	96.8	1	3.2	0.01
2-4	61	30.3	140	69.7		178	88.6	23	11.4	
>4	161	28.7	400	71.3		415	74.0	146	26.0	
Complication										
No	168	27.0	455	73.0	0.02	-	-	-	-	
Yes	61	35.9	109	64.1		-	-	-	-	
Cavitation										
No	172	29.3	416	70.7	0.90	459	78.1	129	21.9	0.71
Yes	57	28.8	141	71.2		157	79.3	41	20.7	
Lung										
Right	127	28.7	316	71.3	0.70	349	78.8	94	21.2	0.25
Left	94	29.7	222	70.3		241	76.3	75	23.7	
Lobe										
Lower	107	39.8	162	60.2	0.01	203	75.5	66	24.5	0.41
Upper	110	23.5	358	76.5		370	79.1	98	20.9	
Biopsy position										
Supine	123	31.4	269	68.6	0.10	314	80.1	78	19.9	0.01
Prone	74	24.5	228	75.5		243	80.5	59	19.5	
Lateral	32	32.3	67	67.7		66	66.7	33	33.3	
Emphysema										
No	222	29.4	532	70.6	0.12	589	78.1	165	21.9	0.17
Yes	7	17.9	32	82.1		34	87.2	5	12.8	
Pathology										
Benign	-	-	-	-		168	73.4	61	26.6	0.02
Malign	-	-	-	-		455	80.7	109	19.3	

these patients had lesions smaller than 3 cm. There was no association between laterality (right vs. left) and malignancy ($p=0.74$). However, malignancy was significantly more frequent in upper lobe lesions ($p=0.01$). There was no association between lesion location and tumor diameter ($p=0.74$).

Male sex and advanced age were significantly associated with malignancy ($p=0.01$). Patient positioning during biopsy is crucial for selecting the shortest trajectory to the lesion, ensuring patient comfort, and avoiding intercostal obstruction. The literature reports that the prone position is optimal for biopsy due to reduced respiratory motion, wider intercostal spaces, and decreased patient anxiety.^[14] However, in the present study, supine position was preferred most frequently (49.4%). In the present study, the highest complication rate occurred in the lateral position ($p=0.009$), which we attribute to patient discomfort and suboptimal intercostal space widening. The lack of significant differences in complication rates among other positions supports this interpretation.

In our series, complications were most common following left lower lobe biopsies (32.4%, $p=0.001$), with no significant differences among the other lobes ($p=0.074$). Approximately one-third of the lesions in the left lower lobe (33%) and the right lower lobe (34%) were smaller than 3 cm. We believe that the higher complication rate in left lower lobe biopsies is due to greater diaphragmatic movement on the left side compared to the limited movement on the right hemidiaphragm stabilized by the liver.

Studies have reported that most biopsied lesions are solid.^[13] Similarly, 74.8% of lesions in our cohort were solid. Cavitory lesions were most common in the upper lobes (30%) and least frequent in the right lower lobe (16%). There was no association between cavitation and benign versus malignant status ($p=0.90$).

Neither age nor sex influenced complication rates in the present study ($p=0.11$, $p=0.45$). Complication rates were significantly higher in benign lesions compared to malignant ones ($p=0.023$).

No association was found between lesion diameter or chest-wall distance and the need for repeat biopsy ($p=0.089$, $p=0.94$).

The most common complications of PTLB are pneumothorax and parenchymal hemorrhage. Less frequent complications include hemothorax, chest-wall hematoma, and vasovagal reactions. Rare

complications include air embolism, hemoptysis, cardiac tamponade, and malignant seeding along the biopsy tract.^[9,15,16] In the present study, complication rates increased significantly with greater volumes of traversed parenchyma ($p=0.001$), whereas tumor diameter had no significant impact on complication development ($p=0.127$).

Pneumothorax is the most common complication, with a reported incidence of 0 to 61%.^[15,16] Tube thoracostomy rates range from 1.5 to 21%.^[16,17] Retrospective studies highlight lesion size, biopsy tract length, and operator experience as key risk factors for pneumothorax.^[18] In our cohort, variability in operator expertise may have influenced complication rates. Lesions closer to the chest wall were associated with fewer complications ($p=0.01$). Pneumothorax occurred in 16.1% of procedures. More than half of the patients who developed complications required only oxygen therapy, while tube thoracostomy was performed in 7.29% of all procedures. Patients who underwent tube thoracostomy had a significantly higher repeat biopsy rate compared to the overall group (35% vs. 22%; $p=0.04$).

Intrapulmonary hemorrhage is reported as the second most frequent complication, with an incidence of 1.5 to 21%.^[19,20] Studies evaluating the risk factors for developing parenchymal hemorrhage emphasize lesion size, intrapulmonary biopsy-tract length, and the number of pleural passes as significant contributors.^[21,22] In our series, intraparenchymal hemorrhage was detected in eight (0.1%) patients.

Hemoptysis incidence in the literature ranges from 1.1 to 5%.^[23] In our cohort, hemoptysis developed in four (0.1%) patients. Hemoptysis is due to alveolar bleeding and is usually self-limiting. It is sufficient for the harvest to lie on the biopsy side. If it continues, antitussives can be started.

A significant association between age and pneumothorax has been reported in the literature, attributed to decreased lung compliance and increased emphysema with advancing age.^[24] In our cohort, emphysema did not significantly increase complication risk ($p=0.17$). We believe that the significantly shorter chest-wall distance in emphysematous patients ($p=0.01$) may have mitigated this risk.

Hemothorax results from injury to intercostal or pulmonary arteries and may require surgical intervention. In our cohort, hemothorax occurred in

one (0.1%) patient. Air embolism, cardiac tamponade, bronchopleural fistula, pulmonary torsion, and vasovagal reaction are rare complications.^[25,26] These complications were not observed in any of our patients. Tumor seeding along the biopsy tract, particularly in subpleural biopsies, has been reported in the literature.^[27] Tumor seeding was not detected in any of our patients. No mortality occurred in our series.

This study has several limitations. First, the retrospective design may have introduced selection bias and limited the ability to control for confounding factors. Second, the study was conducted in a single tertiary referral center, which may restrict the generalizability of the findings to other institutions or broader patient populations.

In conclusion, computed tomography-guided tru-cut lung biopsy is a reliable diagnostic method with a high diagnostic yield and low complication rate. Our experience suggests that thoracic surgeons can achieve outcomes comparable to those reported in the literature, with the added benefit of on-site surgical expertise for complication management. Increased experience in this field is likely to enhance diagnostic efficiency and improve patient safety.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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