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Effectiveness and predictors of complications after CT-guided percutaneous transthoracic biopsy of lung changes

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Abstract

CT-guided lung biopsy is a vital interventional radiological procedure for diagnosing pulmonary lesions. This minimally invasive technique has revolutionized the approach to evaluating lung nodules and masses, providing crucial information for the management of various pulmonary diseases, particularly lung cancer.

This retrospective study included 286 patients to whom lung biopsy was performed, we correlated age, sex, tumor location, size, smoking status and the existence of emphysema with the appearance of complications of the procedure.

Success rate of procedure was 86.3%, and complications were observed in 74,1%. We found that emphysematous changes ($p>0.001$) and active smoking status ($p=0.01$) to be significantly associated with the risk of pneumothorax development.

In conclusion, CT-guided lung biopsy is a valuable diagnostic tool, but the awareness, prevention and management of complications are vital for safe and effective patient care. Ongoing research and improved techniques continue to enhance the safety and efficacy of this procedure, making it an invaluable asset in the field of interventional radiology.

Key words: Lung cancer, biopsy, complication pneumothorax

Introduction

Given the increasing number of lung changes identified, a major challenge for radiologists, oncologist, pulmonologists, and thoracic surgeons is the ability to differentiate between benign and malignant lesions. Percutaneous lung nodule biopsy, a minimally invasive procedure that plays a crucial role in the diagnosis and management of pulmonary nodules. These nodules, which are small, round or oval-shaped growths in the lungs, can be benign or malignant. Detecting and diagnosing them accurately is crucial for appropriate patient care and planning future treatment. Early treatment is always in focus, and the characterization of a malignant nodule, when it is still small, greatly increases the chances of effective and curative treatment. With the development of technology, computer tomograhphy (CT) becomes an available, fast and effective method for diagnosing pathological changes in the lungs. Interventional methods guided by CT in the chest can be divided into: diagnostic, therapeutic and marking methods. One of the significant advantages of percutaneous lung biopsy is minimal invasivenes. Unlike traditional open surgical biopsies, which require large incisions and longer recovery times, percutaneous biopsies are performed using small needles inserted through the skin. This results in less trauma to the surrounding tissues, reduced pain, and faster recovery for the patient. Additionally, because it is less invasive, percutaneous biopsy carries a lower risk of complications such as bleeding and infection. In this paper we aim to determine the correlation of certain morphological characteristics such as the size of the tumor, its location, the existence of emphysema and demographic characteristics and lifestyle habits with the eventual occurrence of complications of this procedure. (1,2,3) (Figure 1)

Figure 1. Percutaneous lung biopsy

In this paper we highlighted three major complications: pneumothorax, hemorrhage, and embolism. Pneumothorax, resulting from pleural penetration, can lead to lung collapse, while hemorrhage may occur due to vascular injury within the lung parenchyma or pleura. (Figure 2) Moreover, pulmonary embolism, though rare, is a life-threatening complication

resulting from embolic material dislodgment. Managing these complications is essential for ensuring patient safety and successful biopsy outcomes. Small pneumothoraces can be observed, while larger ones may require intervention, including chest tube insertion. Hemorrhage management may involve bronchial artery embolization or surgical exploration. (Figure 3) In the case of embolism, prompt diagnosis and treatment are crucial, with anticoagulation or thrombolytic therapy as possible options. (Figure 4).

Figure 2. Partial pneumothorax postbiopsy

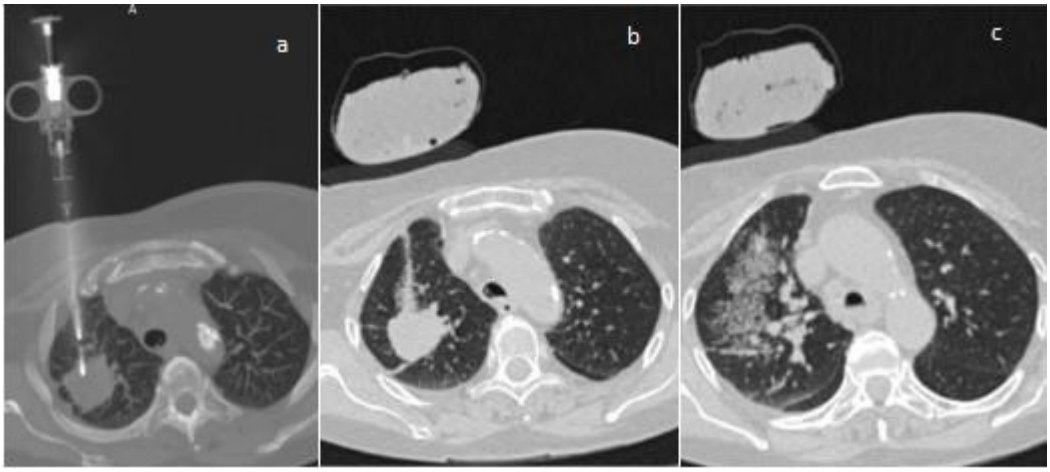

Figure 3. a. CT guided lung biopsy b. linear hemorrhage in needle trajectory c diffuse hemorrhage in lung parenchima

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Figure 4. Gas inclusion in left ventricule

Since the complications can be more or less life-threatening, it is necessary to familiarize with the correct protocols for both performing the procedure and preparing the patient for it. And, if complications occur, timely recognition of the same and treatment is necessary.

Materials and methods

Patients

The study included 286 consecutive patients that underwent CT guided transthoracic biopsy for diagnosis of lung lesions at the Radiology Department of our Clinic.

Biopsy was performed with semi automatic core biopsy needles of 16 and 18 Gauge caliber. The materials obtained by the procedures were transfered to Pathology Department in formaldehide solution. Complications were routinely assesed.

To assess procedure-related pneumothorax, a CT was routinely performed at the end of the procedure. In cases where no pneumothoraxes were detected, posteroanterior (PA) lung radiographs were obtained after 24 hours following the procedure. Pneumothoracies requiring intervention were assessed by thoracic surgeon and depending on lung collapse exsufflation was performed or chest tube was placed.

Apperance of ground glass opacity around the target lesion and on the needle route following the biopsy was diagnosed as pulmonary hemorrhage.

Lesion size was divided into 2 groups according to their size - ≥3cm and <3cm.

Statistical analysis was conducted using SPSS v26 software. Factors hypothesized to affect procedure complications were assessed using the chi-square ($\chi 2$) test. A significance level of $p < 0.05$ was used to determine statistical significance.

Data

Data was retrieved from a hospital-based registry of the Radiology Department at Clinic for Pulmonology that prospectively collects the data of demographical, clinical, radiographical and procedural information of the patients undergoing interventional procedures.

All data were collected anonymously. Retrospective analysis of gathered data is waived ethical approval. The study was performed in accordance with the Declaration of Helsinki.

Results

Among 286 included patients, 55% were male. The ages ranged from 16 – 89 years and the average age was 63.71 years. Most of the patients were either former (n=113; 39.5%) or current smokers (n=96 ;33.5%). Definitive pathohistological diagnosis was observed in 247 cases (86.3%). In terms of lesion size 46.2% (n=132) were greater then 3cm while 53.8 (n=154) had a smaller diameter then 3 cm. Complications were observed in 212 (74.1%) patients. The most common complication was hemorrhage (55.2%; n=158), followed by pneumothorax (36.7%; n=105). Only 3.8% (n=11) of evidenced pneumothoracies required intervention while the rest were overt and resolved spontaneously without any worsening of clinical situation.

Hemoptysis occurred in 4.2% (n=12) of patients. No cases of massive hemoptysis were observed, and all instances of recorded hemoptysis were transient.

In cases of massive parenchymal hemorrhage and hemoptysis patients were administered 1 ampule of tranexamic acid in bolus, after that if needed one more was given trough infusion. No patients that experienced hemorrhage required blood transfusions, embolization or surgical exploration.

Embolism was evidenced in 2.1% (n=6) of cases. Two patients experienced gas embolism in brain vascular structures. Unfraternally for one of them it turned out to be lethal. (Table 1)

Table 1 Clinical and demoghraphic charachteristic of patients

N = 286	N (%)
Mean age at treatment start (range) [years]	63.71 (16 – 89)
Sex	
Male	158 (55.2%)
Female	128 (44.8%)
Smoking status	
Current	96 (33.5%)
Former smoker	113(39.5%)
Non-smoker	78 (27.2%)
Emphysema	
No Emphysema	149(52%)
Centrilobular	126(44%)
Other	11(4%)
Histological diagnosis obtained	
Yes	247(86.3%)
No	39(13.6%)
Biopsied lobe	
Right upper lobe	75 (26.2%)
Middle lobe	34 (11.8%)
Right lower lobe	36 (12.5%)
Left upper lobe	88 (30.7%)
Left lower lobe	53(18.5%)
Lesion size	
<3cm	154 (53.8%)
≥3cm	132 (46.2%)
Complications	
No complications	74 (25.9%)
Pneumothorax	105 (36.7%)
Requiring chest tube/exuflation	11 (3.8%)
Haemorrhage	158 (55.2%)
Haemoptysis	12 (4.2%)
Embolism	6(2.1%)

The factors that could have led to complication rates such as age (>70 years), sex, smoking status, emphysematous changes and lesion size were evaluated. The mentioned factors were not found to be significantly associated with hemorrhage, embolization or hemoptysis. However, emphysematous changes ($p>0.001$) and active smoking status ($p=0.01$) were found to be significantly associated with the risk of pneumothorax development. (Table 2). The

occurrence of complications in general (p=0.67), including pneumothorax specifically (p=0.91), was not determined to be a risk factor for the inability to obtain a definitive pathohistological diagnosis. (Table 2)

Table 2. Correlation of pneumothorax occurence rate with risk factors

	Patients with pneumothorax (105)	Patients without pneumothorax (181)	P value
Age			0.39
<70years	74 (70.5%)	136 (75.1%)	
≥ 70 years	31 (29.5%)	45 (24.9%)	
Sex			0.32
Male	62 (59%)	96 (53%)	
Female	43 (41%)	85 (47%)	
Emphysema			*>0.001*
Present	65 (61.9%)	72(39.7%)	
Not present	40(38.1%)	109(60.3%)	
Smoking status			*0.01*
Current	45 (42.9%)	51(28.2%)	
former or never-smoker	60 (57.1%)	130 (71.8%)	
Histological confirmation			0.91
Obtained diagnosis	91(86.6%)	156(86.2%)	
Diagnosis not obtained	14 (13.4%)	25(13.8%)	
Tumor size			0.38
<3cm	53 (50.4%)	101 (55.8%)	
≥3cm	52(49.6%)	80 (44.2%)	

Discussion

The high success rate of the procedure of 86.3% correlates with larger studies done earlier. The percentage of complications of 74.1% seems high, but let's take into account that the percentage of minor complications is 64% and major complications are 10.1%. These results speak in favor of the justification of performing the procedure. (4,5,6).

Pneumothorax, the accumulation of air in the pleural space between the lung and the chest wall, is a common complication of CT-guided lung biopsy. It typically results from inadvertent pleural penetration during the biopsy procedure. When a needle or probe is inserted

into the lung tissue to obtain a sample, there is a risk of piercing the visceral pleura, allowing air to escape from the lung into the pleural space. This can lead to partial or complete lung collapse and present symptoms such as dyspnea (shortness of breath), chest pain, and hypoxia. Small pneumothoraces can often be managed conservatively with close observation, supplemental oxygen, and serial chest X-rays to monitor lung re-expansion. It is reported to occur in up to 20-30% of cases. Notable risk factors include the size and location of the lesion, the number of pleural passes, and underlying lung conditions such as emphysema. (6,7, 8).

Larger pneumothoraces may require intervention, such as needle aspiration or chest tube insertion, to remove the accumulated air and re-inflate the lung. In severe cases, surgical repair may be required to close the pleural defect. In our patient cohort, only 3.8% required intervention, which is in line with the findings from a meta-analysis by Heerink et al., where pneumothoraces requiring intervention were evident in up to 16% of cases. (8 iz med podmlatka) A much higher incidence of postprocedural pneumothoraces requiring intervention of 22% was reported by Wattanasatesiri T et al. (9)

In our cohort, pneumothorax occurred in 36.7% of cases, which is higher than that reported in a meta-analysis evaluating complication rates of CT-guided lung biopsy. (8) This may be attributable to the high prevalence (48%) of emphysematous changes in our patient group. In a study by Yun et al. that included 354 patients who underwent CT-guided core needle lung biopsy, the authors reported pneumothoraces in 26% of cases, while emphysematous changes were evident in only 17.2% of patients involved. (7) On the other hand, in the control arm of a study by Najafi et al. that evaluated the PEARL approach (positioning biopsy-side down, needle removal during expiration, autologous blood patch sealing, rapid rollover, and pleural patching) for CT-guided lung biopsy, pneumothorax occurred in 37% of patients, and emphysematous changes were present in 47% of cases, which is very similar to our cohort. While the authors found that the PEARL approach reduced rates of pneumothorax, patient recruitment in our cohort preceded their publication. (10)

Emphysema and active smoking status were found to be significantly associated with the risk of pneumothorax development. Emphysema has been widely recognized as a risk factor due to the presence of weakened and hyperinflated lung tissues that are more susceptible to rupture during needle insertion. (11,12) However, Shiekh et al. did not find emphysema to be a risk factor for the development of pneumothorax following CT-guided needle biopsy. In contrast to our findings, they reported age and size of the lesions as risk factors. The authors did recognize that among patients with emphysema who develop pneumothorax, chest tube placement and intervention were more frequently warranted than in those who do not have emphysema. (13)

Smoking is associated with the development of emphysema. In a study by Pompe et al., the authors found current smoking status to be associated with emphysema progression in almost all GOLD stages of COPD (chronic opstructive pulmonary disease). The authors also mention that smoking-related lung abnormalities may still progress even after smoking

cessation. This is why a detailed radiographical evaluation of emphysematous changes is warranted in order to minimize the risk of procedural complications. (11,12)

The second most frequent complication was the visualization of hemorrhage in the lung parenchyma, which occurred in 55.8% of patients. The classification was subjective on the spot and in the case of minor hemorrhages, other than turning the patient to the biopsy side and placing a cold compress on the skin, no other measures were taken. In the case of more extensive hemorrhages in the lung parenchyma, one ampoule of tranexamic acid was applied in a bolus and, if necessary, another one through the infusion system. Considering the way this procedure is performed, and considering that in order to obtain a sufficient amount of sample, it is necessary to use needles with a thickness of 16 or 18 gauge, the occurrence of this type of complication is almost inevitable except for lesions that were in contact with the thoracic wall or in its immediate vicinity. (14,15)

Considering that not a single hemorrhage in our patients, and rarely in the literature, we find that this internal complication, as well as laminar pneumothoraxes that are spontaneously reabsorbed, can be labeled as side effects of the procedure itself.

Pulmonary embolism typically arises from the manipulation of lung tissue during the biopsy, which can dislodge pre-existing clots or introduce air or tissue fragments into the venous circulation. Once these embolic materials reach the pulmonary vasculature, they can obstruct blood flow, leading to pulmonary embolism. Symptoms may include dyspnea, chest pain, hemoptysis, and hemodynamic instability. A large number of smaller gas emboli are decomposed in segmental blood vessels and the heart and are not even diagnosed on control CT scan. However, in the case of aspiration of a large amount of gas into the vascular structures, obstruction of the main arteries can occur whitch could lead to fatal outcomes.(16,17,18)

In meta analyses conducted by Siguimotto et al. there were shown no related death to procedure complications but showed many severe respiratory failure and ARDS- that did not occur during our procedures. This meta Analise used 13 studies that included 574 patient which is not while we had 286 as single center experience performed by one doctor which prompts that technique and experience can influence outcomes. Unfortunately, severe complications such as gas emboli in brain are sometimes inevitable. (19)

Conclusion

As seen in our and many more studies smoking status and destruction of lung parenchima by emphysematous changes can severly increase the risk of pneumothorax. Before each procedure, it is necessary to plan the route of the needle to the lesion and anticipate all possible complications. In the context of lung biopsy complications, particularly pertinent to patients with emphysema and those who smoke, additional considerations come into play. Emphysema, characterized by damaged and fragile lung tissue, poses an increased risk of

complications such as prolonged air leaks and respiratory distress post-biopsy. Moreover, smoking exacerbates these risks due to compromised lung function and impaired healing capacity.

Despite these challenges, the diagnostic benefits of lung biopsy in guiding treatment decisions cannot be understated. Close collaboration between pulmonologists, radiologists, and respiratory therapists is essential to tailor procedural strategies that minimize risks while maximizing diagnostic yield. Emphasizing patient education on smoking cessation and respiratory health management further enhances post-biopsy recovery and long-term outcomes. Thus, while acknowledging the complexities involved, proactive management and patient-centered care remain integral in navigating the intricacies of lung biopsy in this vulnerable patient population.

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