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CHEST IMAGING

ORIGINAL ARTICLE

Factors influencing the total procedure time of CT-guided percutaneous core-needle biopsies of lung nodules: a retrospective analysis

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PURPOSE

This study aims to investigate the factors that influence total procedure time when performing computed tomography (CT)-guided percutaneous core-needle lung biopsies.

METHODS

This is a cross-sectional study of 673 patients, who underwent a CT-guided percutaneous core-needle biopsy at a tertiary care center from March 2014 to August 2016. Data on patient, nodule, and procedural factors and outcomes were collected retrospectively. Univariate linear regression and a multivariate stepwise linear regression were utilized for analysis.

RESULTS

Factors most strongly associated with prolonged procedure duration include 20-gauge needle use when compared with 18-gauge needle use (estimated difference in time = 1.19), collecting additional core biopsies (estimated difference in time = 1.10), decubitus nodule side up (DNSU; estimated difference in time = 1.42), and supine positioning (estimated difference in time = 1.16) relative to decubitus nodule side down positioning, and increased nodule distance from the skin surface (estimated difference in time = 1.03). Increased nodule length (estimated difference in time = 0.93) was associated with reductions in procedure duration. Prolonged procedure time was associated with an increased rate of pneumothorax (odds ratio (OR) = 1.02; $P < .0001$) and decreased rate of pulmonary hemorrhage (OR = 0.97; $P < .0001$).

CONCLUSION

The use of 20-gauge biopsy needle, collecting additional core biopsies, DNSU and supine positioning, smaller nodule size, and increasing nodule distance from the skin surface were associated with increased procedure time for CT-guided core needle biopsies of lung nodules. Prolonged procedure time is associated with a higher rate of pneumothorax and a lower rate of pulmonary hemorrhage.

Computed tomography (CT)-guided biopsy is the preferred technique for obtaining lung tissue through the use of aspiration and/or cutting needles.[1] The primary use of CT-guided percutaneous core biopsies of the lung is to collect and analyze tissue for malignant potential or establish the pathological foundation for the abnormal lung tissue. The reported ranges of sensitivity, specificity, and accuracy of core-needle lung tissue biopsies establishing benign or malignant characteristics of collected tissue are 85.7%-97.4%, 88.6%-100.0%, and 89.0%-96.9% respectively.[2] Moreover, CT-guided core lung biopsies provide tissue samples essential for identifying the presence of specific oncogenic driver mutations, such as epidermal growth factor receptor, anaplastic lymphoma kinase, and programmed death-ligand 1, necessary for targeted immunotherapy of malignant tumors.[3]

An understanding of the various patient, nodule, and procedural factors that influence the duration of these procedures will enable physicians to provide better patient care and help inform patients before undergoing a CT-guided core lung biopsy. Moreover, models predicting procedure length could be valuable to optimize scheduling for interventional radiology departments. However, the current literature investigating factors that influence CT-guided lung biopsies procedure times is minimal and needs further exploration. To our

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knowledge, there is no current literature investigating factors associated with procedure time. However, some studies have shown smaller lesions sizes to be associated with prolonged procedure time as these lesions encompass a smaller target area that demands more technical needle readjustments.[1,4,5] Unfortunately, these studies did not investigate procedure time with other factors, such as nodule location or smoking history, that may also influence procedure time.

Likewise, there is no current literature to our knowledge that investigates the relationship between procedure duration and complications. The 2 most common complications following a CT-guided percutaneous lung biopsy are pneumothorax and pulmonary hemorrhage. The rate of pneumothorax following a CT-guided percutaneous lung biopsy ranges from 17% to 26.6%, with 1%-14.2% of these patients requiring chest tube placement to treat the pneumothorax.[1,6-10] Meanwhile, the reported incidence of pulmonary hemorrhage ranges from 4% to 27%.[1,6-10] Given the prevalence of these complications, identifying any association between procedure time and complications is also of importance.

For the purposes of our study, we intend to determine the factors that influence the procedure time of a conventional CT-guided core lung biopsy. However, this study also aims to investigate other factors that may influence procedure time, such as patient age or body mass index (BMI), as well as any potential correlations between procedure duration and outcomes.

Main points

- Various procedural, lung nodule, and patient-related variables were found to have an association with total duration for the completion of computed tomography (CT)-guided core needle lung biopsies.
- Positioning patients in the decubitus nodule side down orientation and decreasing the total distance between the lung nodule and skin surface were most strongly associated with reductions in total procedure duration.
- The utilization of 20-gauge needles most strongly prolonged procedure duration, and the use of 18-gauge needles should be considered for efficiency and larger yield of tissue for biopsy.
- Additional factors associated with shorter procedure times include lower patient body mass index, chronic obstructive pulmonary disorder, involvement of a resident or fellow, larger nodules, and acquiring fewer biopsy samples.
- Longer biopsy time was associated with a higher odds of pneumothorax although further studies are required to determine causality.

Methods

Patients

This cross-sectional study analyzed the electronic medical record of patients undergoing CT-guided core-needle biopsy between March 2014 and August 2016 at a large tertiary care hospital. Of the 798 patients, data were utilized from 673 patients who met our inclusion criteria. Exclusion criteria included biopsies not located within the lung (i.e., chest lymph node, pleural nodule, rib, scapula, or adrenal gland), being younger than 18 years of age, fine-needle aspirate biopsy only without core samples, canceled or prematurely terminated biopsies, or inadequate documentation. Criteria for undergoing biopsy collection were based on the clinical judgment of the ordering practitioner or performing radiologist. We incorporated patients from the same data set used for our prior study by Kolderman et al.[13] comparing outcomes between the use of 20-gauge and 18-gauge core biopsy needles with the intention of further advancing medical knowledge by analyzing a different aspect of our data on this patient population. The study was approved by the Institutional Review Board of the hospital (IRB protocol number: 2016-232). Additionally, this retrospective study met regulatory criteria to waive the collection of patient informed consent.

Multivariate and univariate statistical analysis was completed to determine if age, BMI, gender, history of smoking, lobar location of nodule, sidedness of the lung nodule, nodule size, composition, history of the chronic obstructive pulmonary disorder (COPD), inpatient or outpatient procedure location, biopsy needle gauge, lung nodule distance from the skin surface, lung nodule distance from the pleural surface, patient operative positioning, resident/fellow participation, and the number of core biopsies obtained affected the duration of the procedure time. Using our data on procedure duration, an analysis was subsequently conducted to determine if procedure time was associated with the development of a pneumothorax, pneumothorax requiring a chest tube, pulmonary hemorrhage, and whether the biopsy yielded diagnostic or non-diagnostic findings. Complications were identified by the presence on CT immediately following biopsy or during the chest x-ray 2 hours following the completion of the core-needle biopsy.

Variables

For this study, the procedure time was defined as the amount of time elapsing from preliminary imaging to localize the target lesion to the time of the last CT image following biopsy needle removal.[11] The distance between the lung nodule and the skin or pleural surface was measured along the needle path. Nodule length was defined as the largest axial span of the nodule and width was obtained from the perpendicular measurement to the length. The presence of COPD was indicated by clinical history and/or CT findings. Pulmonary hemorrhage was graded based on size with small hemorrhages occupying less than one-third of a lobe and large hemorrhages occupying more than two-thirds of a lobe. Decubitus positioning that places the patient laterally on the examination bed with the targeted nodule in the dependent lung was referred to as the decubitus nodule side down (DNSD) position. A decubitus orientation with the targeted nodule in the anti-dependent lung was defined as decubitus nodule side up (DNSU) position. Nodule composition was defined by morphology on imaging as either a consolidation, ground-glass opacification, solid or semisolid when a nodule had heterogeneous components of solid and ground-glass opacities.

Technique

All CT-guided core-needle biopsies were completed with intermittent sequential CT acquisitions (SOMATOM Sensation 10, Siemens Healthcare). The vast majority of the procedures were performed by a radiology resident or fellow under the supervision of staff radiologists, and a minority were performed without trainee involvement. Computed tomography fluoroscopy is not routinely used at our institution; although, this technique may be used under rare circumstances at the discretion of the performing radiologist.

Patients received conscious sedation as it allows patients to maintain a regular breathing pattern, reduce patient anxiety, and ensure the patient remains largely motionless throughout the procedure. Patient positioning and needle path are selected to minimize the distance the needle must traverse to reach the targeted nodule and avoid critical intrathoracic structures, such as large airways, vessels, and pulmonary fissures.[12] Next, 1% buffered lidocaine is utilized as a local anesthetic to minimize patient discomfort throughout the procedure.

At our institution, the coaxial methodology is preferred for lung biopsies as this technique reduces the number of pleural punctures for the procedure.[1] All core biopsies completed with the coaxial technique utilized a semiautomated biopsy needle with either an 18-gauge core biopsy needle with a 17 gauge introducer or a 20-gauge core biopsy needle with a 19-gauge introducer (Temno; Bauer Medical).[13] Selection of either 20-gauge or 18-gauge needle use is based on the discretion of the performing radiologist. First, the introducer needle is inserted into the patient subcutaneously and a CT image is obtained to ensure an appropriate needle trajectory. Then, the introducer needle is swiftly advanced through the pleura toward the targeted nodule. Between the sequential advancement of the introducer toward the nodule, CT images are taken to ensure the nodule is sufficiently reached before sampling. Upon appropriate placement, the smaller cutting needle is then inserted into the introducer needle, the core biopsy is obtained, and the core biopsy is then placed in a 10% formalin solution for an off-site anatomic pathology evaluation. The total number of core biopsies collected during these procedures is based on the clinical judgment of the performing radiologists.

Following the withdrawal of the introducer needle, the patient is promptly placed on a stretcher with the side of which the biopsy occurred in a dependent position to reduce the risk of pneumothorax, as suggested in recent literature.[14] The patient is then monitored in the post-procedure unit and underwent anterior–posterior chest radiograph within 2 hours of the procedure to monitor any potential post-procedure complications. Patients that developed a pneumothorax were either carefully monitored or underwent chest tube placement based on the presence of symptoms and the size of the pneumothorax. Patients reporting post-procedural symptoms, such as shortness of breath, were continuously monitored, while asymptomatic patients were discharged or returned to their respective hospital units.

Statistical analysis

Continuous variables, such as patient's age and biopsy duration, were presented as mean ± standard deviation (SD), median, and minimum and maximum values. Meanwhile, categorical variables, such as a patient history of COPD and resident participation, were presented as percentages and counts. A univariate, linear regression model using the natural log of the procedure time was completed to directly analyze continuous and categorical variables against procedure time. A multivariate also using a linear regression model with the natural log of the procedure time was carried out to identify factors with an association with procedure time. The results of the multivariate analysis were interpreted through the use of exponentiated beta estimates and CIs. This analysis was carried out using a stepwise regression with Schwarz Bayesian criterion (SBC) to pick the model with the best fit, and the natural log of the procedure time values was done to ensure a normal distribution. The model fit was assessed with the use of the scaled Pearson chi-square. Logistic regression was used to compare post-procedural complications with procedure time through the use of odds ratios and CIs. Univariate and multivariate analysis reference group selection for nominal variables was based on frequency, thus variables with higher frequencies of occurrence were selected as the reference group for that specific comparison. The data analysis for this paper was generated using SAS software (© 2016 SAS Institute Inc).

Results

Before the application of exclusion criteria, a total of 798 patients were identified to participate in this study. Once applied, 675 nodules from 673 patients were included in the final analysis (Table 1). The overall mean procedure time was 36.93 ± 19.2 minutes. The mean age of all applicants was 69.78 ± 11.6 years with 53.3% (n = 360) being females. The mean BMI of the included patients was 27.00 ± 6.4 kg/m^2. The majority of patients in this study also reported a current or previous history of smoking (n = 513, 76.0%) and had their procedure performed in an outpatient setting (n = 613, 90.8%). The majority of the enrolled patients were found to have diagnostic biopsy samples with only a 6.8% (n = 46) non-diagnostic rate. Table 1 further depicts the summary of demographic data for the pool of patients enrolled in this study.

Following a univariate, linear regression analysis using the natural log of the procedure time (Table 2), subjects with a history of COPD experienced a reduction in procedure duration by 12.8%, as well as resident/fellow participation, reduced procedure time by 14.8%. Moreover, with each 1 cm increase in nodule length and width, a reduction was observed in procedure time by 7.3% and 6.5%, respectively. Procedure time was prolonged in patients with each 1 kg/m^2 increase in BMI by 0.7%, for each 1 cm of the nodule from the skin surface by 4.4%, and for each centimeter of the nodule from the pleural surface by 5.6%. Biopsies performed with a 20-gauge needle increased the biopsy time by 29% compared to an 18-gauge needle, patients positioned in the DNSU compared to those in the DNSD increased biopsy time by 44.4%, and supine patients increased procedure time by 16.4% compared to the DNSD patients. Patients positioned in the prone position did not achieve a statistically significant difference from those placed in the DNSD position. When treating the collection of multiple (4 or more) core biopsies as continuous, each additional core biopsy collected increased procedure time by 8.46%.

Multivariate analysis was completed with a stepwise linear regression model using the natural log of the procedure time and SBC selection criteria to further identify variables with associations with biopsy time (Table 3). Relative to an 18-gauge needle, utilizing a 20-gauge needle was found to increase procedure time by 18.75%. Patients positioned in the DNSU position increased biopsy time by 41.8%, while the supine position increased biopsy time by 15.57% relative to the DNSD position. For each additional core biopsy collected, procedure time was increased by 9.68%. Meanwhile, for each centimeter increase in nodule length, there was a 6.16% decrease in procedure time, and each centimeter increase in nodule distance from the skin increased procedure time by 2.66%.

Table 1. Demographic data

Variable	Response	
Age	n	675
	Mean ± SD	69.78 ± 11.6
	Median	71.00
	Min, Max	30.00, 98.00
BMI		
	Mean ± SD	27.00 ± 6.4
	Median	26.62
	Min, Max	13.10, 54.25
Gender	Female	360 (53.3%)
	Male	315 (46.7%)
Smoking history	No	162 (24.0%)
	Yes	513 (76.0%)
Location of nodule	Lingula	17 (2.5%)
	Left lower lobe	127 (18.8%)
	Left upper lobe	141 (20.9%)
	Right lower lobe	147 (21.8%)
	Right middle lobe	44 (6.5%)
	Right upper lobe	199 (29.5%)
Length of nodule (cm)		
	Mean ± SD	2.58 ± 2.0
	Median	1.90
	Min, Max	0.50, 16.00
Width of nodule (cm)		
	Mean ± SD	2.36 ± 1.8
	Median	1.70
	Min, Max	0.40, 15.60
Nodule composition	Consolidation	21 (3.1%)
	Ground glass	32 (4.7%)
	Solid	524 (77.6%)
	Semisolid	98 (14.5%)
Clinical or imaging history of COPD	No	264 (39.1%)
	Yes	411 (60.9%)
Inpatient or outpatient biopsy	Inpatient	62 (9.2%)
	Outpatient	613 (90.8%)
Biopsy needle gauge	18	173 (25.6%)
	20	502 (74.4%)
Distance from skin surface (cm)		
	Mean ± SD	7.20 ± 2.7
	Median	7.10
	Min, Max	0.40, 17.00
Distance from pleural surface (cm)		
	Mean ± SD	2.39 ± 2.2
	Median	2.00
	Min, Max	0.00, 10.10
Patient positioning	DNSD	320 (47.4%)
	DNSU	66 (9.8%)
	Prone	33 (4.9%)
	Supine	256 (37.9%)
Resident/fellow participation	No	58 (8.6%)
	Yes	617 (91.4%)
Number of core biopsies obtained	n	675
	Mean ± SD	4.22 ± 0.9
	Median	4
	Min, Max	1,5
Total procedure time (min)	N	675
	Mean ± SD	36.93 ± 19.2
	Median	31.00
	Min, Max	8.00, 130.00
Diagnostic or non-diagnostic findings	Diagnostic	629 (93.2%)
	Non-diagnostic	46 (6.8%)
Pneumothorax	No	492 (72.9%)
	Yes	183 (27.1%)
Pneumothorax requiring chest tube	No	148 (80.9%)
	Yes	35 (19.1%)
Pulmonary hemorrhage	None	156 (23.1%)
	Small	505 (74.8%)
	Large	14 (2.1%)

SD, standard deviation; BMI, body mass index; COPD, chronic obstructive pulmonary disorder; DNSD, decubitus nodule side down; DNSU, decubitus nodule side up.

Post-procedural outcomes were also analyzed for associations with procedure time (Table 4). Overall, each 1-minute increase in procedure time was correlated with a 2.2% higher odds of pneumothorax and a lower odds of pulmonary hemorrhage by 2.6%. The rate of pneumothorax for the 675 nodule biopsies performed was 27.1% (n = 183) with 5.2% (n = 35) of the total enrolled patients developing pneumothorax requiring a chest tube. The mean procedure time of patients developing pneumothorax was reported to be 43.00 ± 21.4 minutes, while the patients that did not develop pneumothorax reported a mean procedure time of 34.68 ± 17.8 minutes. The odds of developing small and large pulmonary hemorrhages were 74.8% (n = 505) and 2.1% (n = 14), respectively, with a mean procedure time of 34.52 ± 17.6 minutes. While the majority of biopsies performed were later found to have diagnostic pathological findings (93.2%, n = 629), diagnostic biopsies (odds ratio [OR] = 1.00; *P* = .76; 95% CI = 0.99-1.02) and the development of pneumothorax requiring chest tube (OR = 1.00; *P* = .57; 95% CI = 0.98-1.01) were not found to have any statistically significant association with procedure time.

Discussion

Patient BMI and COPD were found to have an association with biopsy procedure time on univariate analysis. In patients with increased BMI, increased procedure time may be attributed to increased difficulty in localizing lesions, maintaining needle trajectory, and increasing nodule distance from the skin due to the increased presence of subcutaneous and visceral adipose

Table 2. Univariate analysis and associations with biopsy time

Parameter	Level	Mean	Standard deviation	Estimated difference in time	*P*
Sex	Female	36.61	17.9	Reference group	
	Male	37.3	20.52	0.99	.87
Smoking history	No	37.67	18.48	Reference group	
	Yes	36.7	19.38	0.95	.28
COPD history	No	39.49	18.91	Reference group	
	Yes	35.29	19.15	0.87	.0003
Biopsy setting	Inpatient	34.39	17.5	Reference group	
	Outpatient	37.19	19.31	1.08	.24
Needle gauge	18	29.92	14.08	Reference group	
	20	39.35	20.07	1.29	<.0001
Resident	No	42.66	21.55	Reference group	
	Yes	36.39	18.84	0.85	.02
Nodule location	Upper	37.6	19.67	Reference group	
	Lower	35.83	18.67	0.96	.25
	Middle	38.15	18.46	1.02	.74
Nodule composition	Solid	37.34	19.2	Reference group	
	Consolidation	28.76	10.71	0.82	.06
	Ground glass	35.28	12.45	1.01	.9
	Semisolid	37.06	21.73	0.98	.77
Patient position	Decubitus nodule side down	33.13	16.67	Reference group	
	Decubitus nodule side up	49.05	24.81	1.44	<.0001
	Prone	35.79	19.49	1.05	.56
	Supine	38.71	18.93	1.16	.0001
Number of samples	>Median of 4	40.24	20.49	Reference group	
	≤Median of 4	33.68	17.16	1.08	<.0001
Age	>Median of 71	35.48	17.55	Reference group	
	≤Median of 71	38.29	20.48	1	.24
BMI	>Median of 26.62	38.51	20.14	Reference group	
	≤Median of 26.62	35.36	18.01	1.01	.01
Nodule length	>Median of 1.9	33.07	18.53	Reference group	
	≤Median of 1.9	40.54	19.05	0.93	<.0001
Nodule width	>Median of 1.7	33.68	18.8	Reference group	
	≤Median of 1.7	40.14	18.99	0.93	<.0001
Distance from skin surface	>Median of 7.1	40.12	20.43	Reference Group	
	≤Median of 7.1	33.9	17.35	1.04	<.0001
Distance from pleural surface	>Median of 2	40.1	19.89	Reference group	
	≤Median of 2	33.85	17.91	1.06	<.0001

COPD, chronic obstructive pulmonary disorder; BMI, body mass index.

tissue. Meanwhile, the relative hyperinflation of patients with COPD may result in decreased nodule mobility during biopsy accounting for decreased procedure time.

Nodule length and width were found to have an association with procedure duration, consistent with the current literature.[1,4,5] Nodules smaller in size are known to be more difficult to localize requiring more technical skill and increased needle readjustments, ultimately leading to increased biopsy durations.[1,4,5] Similar logic may apply to our findings regarding nodule distance from the skin and pleural surfaces. Nodules requiring a longer needle trajectory are more susceptible to patient movements and needle misdirection as the needle traverses through lung parenchyma. Ultimately, more time may be spent localizing nodules and performing needle readjustments for nodules with longer trajectories relative to nodules that are closer to the pleural and skin surfaces. However, nodule width and distance from the pleural surface were only found to have a significant association with univariate analysis.

Procedural factors were found to have the largest influence on biopsy duration. Patients in the DNSU position experienced a 44.4% increase in biopsy duration relative to patients in the DNSD position. Likewise, patients in the supine position experienced a 16.4% increase in biopsy duration relative to those in the DNSD position. This is intuitive as the DNSD position results in decreased respiratory excursion and decreased mobility of the nodule, while the DNSU position would result in increased mobility. Nodule side down positioning results in stabilizing forces that are favorable for biopsies, such as decreased alveolar size, reduced collateral ventilation between alveoli, and maintenance of the parietal and visceral pleura positioning. In addition, placing patients in a nodule side down position during or following the collection of CT-guided needle biopsies reduces pneumothorax incidence.[14-20]

The collection of each additional core biopsy sample and the use of a 20-gauge core relative to the 18-gauge needle were also found to be strong risk factors for increased biopsy time. The use of a 20-gauge needle biopsy may prolong procedure duration due to the decreased structural rigidity of the 20-gauge needle, thus mandating additional needle trajectory readjustments and decreasing the volume of biopsy tissue requiring additional samples to be taken. However, one must also consider that use of 18-gauge needles has been associated with an increased risk for systemic air embolisms when performing CT-guided core-needle biopsies of lung nodules.[21]

Resident and fellow participation were found to decrease biopsy duration by 14.8% on univariate analysis. Having more than one operator assisting with biopsy set up, sample acquisition, and patient care likely expedite biopsy time. Moreover, this

Table 3. Multivariate stepwise log-linear regression with SBC selection analysis and associations with biopsy time

Parameter	Level	Estimated difference in time	95% CI	*P*
Needle gauge	18 G	Reference group		
	20 G	1.19	(1.10, 21.04)	<.0001
Patient position	Decubitus nodule side down	Reference group		
	Decubitus nodule side up	1.42	(1.27, 1.59)	<.0001
	Prone	1.04	(1.00, 1.21)	.6
	Supine	1.16	(1.08, 1.24)	<.0001
Number of samples	>Median of 4	Reference group		
	≤Median of 4	1.1	(1.06, 1.14)	<.0001
Nodule length	>Median of 1.9	Reference group		
	≤Median of 1.9	0.94	(0.92, 0.95)	<.0001
Distance from skin surface	>Median of 7.1	Reference group		
	≤Median of 7.1	1.03	(1.01, 1.04)	<.0001

Table 4. Procedure time affecting post-biopsy outcomes

Variable	Response	Procedure time n, mean ± SD	Odds ratio	95% CI	*P*
Diagnostic	No	46, 36.07 ± 18.7	Reference group		
	Yes	629, 36.99 ± 19.2	1.003	(0.99, 1.02)	.76
Pneumothorax	No	492, 34.68 ± 17.8	Reference group		
	Yes	183, 43.00 ± 21.4	1.02	(1.01, 1.03)	<.0001
Pneumothorax requiring a chest tube	No	148, 43.44 ± 20.7	Reference group		
	Yes	35, 41.13 ± 24.4	1	(0.98, 1.01)	.57
Pulmonary hemorrhage	None	519, 34.52 ± 17.6	Reference group		
	Large/small	156, 44.95 ± 21.9	0.97	(0.97, 0.98)	<.0001

SD, standard deviation.

finding may be explained as residents and fellows may be involved in less technically challenging biopsies, unlike smaller, deeper nodules which are technically challenging and more likely to be completed by more experienced operators. However, more data must be collected to better understand this finding as this study occurred at a teaching hospital with the majority of the cases involving fellow and/or resident physician participation (91.4%, n=617).

Associations between pulmonary hemorrhage and pneumothorax development with procedure time were reported in the univariate, log-linear regression analysis. The rate of pneumothorax was found to increase by 2.2% for each minute increase in procedure time, meanwhile, the rate of pulmonary hemorrhage was found to decrease by 2.6% for each minute increase in procedure time. Prior studies have found mixed associations between total needle dwell time, or total time the needle was inserted, and the development of pneumothorax or pulmonary hemorrhage.[7,22,23] Perhaps, the pneumothorax rate increased with procedure duration as the pleural surface was subjected to a longer duration of needle manipulation resulting in a larger pleural defect and ultimately leading to pneumothorax development. Conversely, procedure time may be lengthened secondary to pneumothorax that develops during the biopsy. Intra-procedural pneumothorax could have resulted in extra time for patient monitoring or treatment with CT-guided needle aspiration. Further investigations would be required to establish the effect of procedure time on pneumothorax. The association of increased pulmonary hemorrhage in shorter biopsies is unclear but may be caused by more rapid manipulations in lung parenchyma resulting in increased bleeding. No statistically significant associations were found between diagnostic biopsy samples and pneumothorax development requiring chest tube insertion with procedure duration.

Limitations of this study are due to the retrospective design and lack of generalizability as the findings reported are limited to one teaching institution, and they would need further data from other unaffiliated institutions to ensure our findings apply to other hospitals. Moreover, bias may be implicated in the design of this study as features, such as needle gauge size and resident/fellow participation, are subject to attending physician preference. However, the bias in these modifiable factors is lessened as most cases involved resident or fellow participation with nearly 50 potential residents/fellows adding variation to the procedural variables of our data set. Furthermore, the participation of resident/fellowship physicians in the majority of the biopsies of this study makes this study less applicable to more experienced radiologists independently performing these procedures. More data must be collected on cases with non-diagnostic findings and the development of pneumothorax requiring chest tubes to more accurately conclude these post-biopsy outcomes and their association with total biopsy procedure time.

Despite these limitations, this study provides valuable insight into the current literature on CT-guided core biopsies. The strength of this study is indicated by a large number of enrolled participants allowing us to report more reliable and accurate findings following statistical analysis. Additionally, the strength of our findings is further highlighted when adjusting for multiple comparisons, which reported identical findings to the univariate analysis, except for the exclusion of BMI and resident/fellow participation. Most importantly, the study provides information on an area in which there is no currently existing literature.

In conclusion, procedural factors were found to have the largest associations with procedure duration. Reduction in biopsy time was most strongly associated with DNSD patient positioning and shorter length of biopsy trajectory from the skin surface to the nodule. Involvement of a resident or fellow during the biopsy was also associated with biopsy time reduction. In addition, utilizing a larger, 18-gauge biopsy needle was associated with a reduction in biopsy time when compared to the smaller 20-gauge needle. Reduction in biopsy time was also associated with larger nodules, lower patient BMI, and COPD. This information is useful not only for patient consultation but also for procedure schedule optimization.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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