Risk Factors of Pneumothorax and Bleeding*
Multivariate Analysis of 660 CT-Guided Coaxial Cutting Needle Lung Biopsies

Kee-Min Yeow, MD; I-Hao Su, MD; Kuang-Tse Pan, MD; Pei-Kwei Tsay, PhD; Kar-Wai Lui, MD; Yun-Chung Cheung, MD; and Andy Shau-Bin Chou, MD

Background: The results of studies identifying the risk factors for pneumothorax and bleeding in CT-guided coaxial lung needle biopsies were inconsistent and some were even contradictory. All reported series were small with patient populations averaging about 200.

Study objectives: To determine the risk factors for pneumothorax and bleeding after CT-guided coaxial cutting needle biopsy of lung lesions.

Design: Retrospective analysis.

Methods: We reviewed 660 biopsy procedures. The risk factors for pneumothorax and bleeding were determined by multivariate analysis of variables related to patient demographics, lung lesions, biopsy procedures, and the individual radiologist.

Results: The main complications were pneumothorax (23%; 155 of 660 procedures), chest tube insertion (1%; 9 of 660 procedures), and hemoptysis (4%; 26 of 660 procedures), with no patient mortality. The highest pneumothorax rate correlated with a lesion size of < 2 cm, a lesion depth of 0.1 to 2 cm, and less experienced radiologists. The highest bleeding risk correlated with a lesion size ≥ 2 cm, a lesion depth of ≥ 2.1 cm, and the absence of pleural effusion.

Conclusions: The risk factors for highest pneumothorax rate are lesion size < 2 cm, a subpleural lesion depth of 0.1 to 2.0 cm, and a less experienced radiologist. The risk factors for highest bleeding rate are lesion size > 2 cm, lesion depth > 2.1 cm, and lung lesions not associated with a pleural effusion.

Key words: bleeding; CT; lung biopsy; pneumothorax; risk analysis

Abbreviations: CI = confidence interval; OR = odds ratio

The current practice of percutaneous CT-guided coaxial cutting needle lung biopsy obtains high diagnostic accuracy both for malignant and benign lung lesions at acceptably low complication rates without the need for an on-site pathologist.1–10 CT-guided coaxial cutting needle lung biopsy is safe, but pneumothorax and bleeding are the two most frequently encountered complications.1–10 The patients’ risk for complication after CT-guided coaxial needle biopsy may be identified by risk factor analysis.6,7,11–14 Unfortunately, the results of risk analysis reported by some studies6,11–14 are variable and often times contradictory. Although no scientific explanation has been given for the difference, however, all the studies are relatively small, and as a consequence their results may not have sufficient statistical power.15,16 In this report, we have attempted to identify the risk factors for pneumothorax and bleeding by performing a retrospective review of 660 consecutive CT-guided coaxial cutting needle lung biopsies. Risk factors were determined by multiple logistic regression of variables related to patient demographics, lung lesions, biopsy procedures, and the individual radiologist, all of which were thought to influence the occurrence of pneumothorax or bleeding. Our secondary aim was to provide an evidence-based risk

*From Department of Diagnostic Radiology, Chang Gung Memorial Hospital (Drs. Yeow, Su, Pan, Lui, Cheung, and Chou); and the Department of Public Health-Biostatistics (Dr. Tsay); Chang Gung University, Kwei Shan, Tao Yuan, Taiwan, Republic of China.

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Correspondence to: Kee-Min Yeow, MD, No. 5, Fu Shing St, Kwei Shan, Tao Yuan 333, Taiwan, Republic of China; e-mail: kmyeow@adm.cgmh.org.tw
Materials and Methods

Study Population

From March 1995 to August 2001, a cohort of 660 consecutive CT-guided percutaneous coaxial cutting needle biopsies for focal lung lesions in 649 patients was subjected to a statistical analysis of the risk factors for pneumothorax and bleeding. Twelve patients refused to undergo repeat biopsies. Repeat biopsies (10 patients had two biopsies, and 1 patient had three needle biopsies) were considered to be new procedures in the calculations, as variables selected were different in each procedure. There were 424 men and 225 women, with a mean age of 62.6 years.

Inclusion Criteria for Biopsy

All patients referred for percutaneous needle lung biopsy had focal lung lesions presenting as a nodule, a mass, or a mass-like consolidation. Patients had normal platelet counts, prothrombin time, and activated prothrombin time within 3 days of undergoing the needle biopsy and could tolerate a recumbent position. A pulmonary function test was not required by our biopsy protocol. Informed consent was obtained after the benefits and risks of needle lung biopsy and the alternatives of diagnosis were explained to patients and family members. No institutional review board approval was required. After a brief explanation of the steps involved in percutaneous needle lung biopsy, the patients were instructed to stay calm, and to abstain from talking and coughing during the procedure and during the 4-h observation period. No conscious sedation was used. Our exclusion criteria were lung lesions < 5 mm in greatest diameter, patients who could not follow verbal or visual instruction, and patients or family members who could not accept procedure-related risks.

Biopsy Procedure

A standard CT-guided coaxial cutting needle biopsy technique was used.17 A dedicated CT scanner (HiSpeed Advantage; GE Medical Systems; Milwaukee, WI) and a coaxial needle system with a fixed 1.3-cm cutting trough (Temno; Bauer Medical; Clearwater, FL) were used. No CT-fluoroscopic guidance was used. Most patients had contrast-enhanced chest CT scans available for review before the biopsy procedures. From the preview of existing or new localization CT scans, an optimal needle path was planned. A needle path through a nonaerated lung was used whenever possible. After local anesthesia and a small incision, a coaxial needle guide was inserted under intermittent CT guidance with its trajectory pointing toward the lung lesion. A fine, quick pierce of the pleural surface was made. Almost all biopsies were performed with a single pleural puncture. Each radiologist had a free choice of needle size ranging from 20 to 16-gauge, but a 20-gauge cutting needle was more commonly used in lung lesions < 2 cm. At least three core specimens were obtained by cutting a fixed 1.3-cm long specimen via a coaxial needle guide that was inserted at least 5 mm into the focal lung lesions.

At the completion of the needle biopsy, the coaxial needle guide with its stylet in place was withdrawn back into the chest wall, while CT scans were obtained to detect any occurrence of a postbiopsy complication. A pneumothorax was considered to be present on CT scans or chest radiographs when there was any visible retraction of the pleural surface away from the parietal pleura. Any immediate occurrence of a moderate pneumothorax, which was defined as a collapse of the lung surface > 2 cm from the site of the needle puncture, was aspirated by the reinserter of the coaxial needle guide. For outpatients, upright chest radiographs were obtained at the end of the 4-h observation period, and asymptomatic patients with no or minimal pneumothoraces (see definitions) were discharged from the hospital. Delayed symptomatic pneumothoraces of ≥ 30% and occurring after the patients left our CT scan suite were treated by chest tube insertion in our emergency department or by the referring physician after the patients were admitted into the wards. Almost all needle biopsies were performed with patients in the supine or prone position for reasons of stability, and patients were placed routinely in the supine position after needle biopsy, irrespective of the site of their chest wall punctures, for the patients’ comfort. Our percutaneous lung needle biopsies were at first performed by a radiologist who was designated as the pioneer radiologist. Soon, each radiologist covered 1 day of the 5 day per week lung biopsy schedule, and patients were scheduled at random. We did not perform fine-needle aspiration in the study period because it was difficult to coordinate the visit of an on-site cytologist to our CT suite in our institution.

Definitions and Selection of Study Variables

Patient Factors: A sign of emphysema on CT scans was defined as the presence of centrilobular or panlobular emphysema, bullae, and blebs in the lungs selected for needle biopsy. Immediate postbiopsy pneumothorax while the patient was still on the CT scan table was graded as mild (lung surface retraction of ≤ 2 cm), moderate (measured lung surface retraction of between 2 and 4 cm), and severe (lung surface retraction of ≥ 4 cm).6 New-onset haziness along the needle tracts, around lung lesions, and in lung parenchyma after needle biopsies was considered to be needle tract, perilesional, and lung parenchyma bleeding, respectively. Hemothysis and patients’ vital signs were recorded prospectively in the biopsy report. Bleeding complications were graded as mild (hemorrhage presenting as haziness along needle tracks or in adjacent air spaces on the CT scans), moderate (occurrence of fewer than five episodes of hemothysis estimated at < 30 mL blood or minimal hemothorax), and severe (hemothysis or hemothorax associated with hemodynamic instability). Chest wall thickness was measured from the skin surface to the pleural surface along the needle path.

Lesion Factors: Lesion size was measured along the maximum long-axis diameter, and lesion depth was measured from the point of pleural puncture to the nearest edge of the lung lesion along the needle path using lung window display.8 Lesion necrosis was defined as a liquefied portion or a nonenhancing low-density area measuring < 20 Hounsfield units. A cavity was defined as an area within a lung lesion that was filled with air on prebiopsy CT scans.

Biopsy Technical Factors: The needle size was defined by the size of the cutting needle. The coaxial outer needle guide was one gauge larger. The number of cutting specimens was defined as the number of core tissues obtained but not the number of throws (triggers) performed, because the number of specimens was consistently recorded in the radiologic reports. The needle-pleural angle was the acute angle between the needle and pleural surface.19 The biopsy puncture sites on the pleural surfaces were positioned down or up at random because the patients were routinely placed in the supine position for their comfort.

Radiologist Factor: Radiologists who had performed ≥ 30 biopsy procedures were selected for the analysis of their individual diagnostic yields and complication rates to avoid learning
curve bias. One was labeled the pioneer, the rest were designated as radiologists A, B, C, and D. The five selected radiologists performed 93% of all CT-guided coaxial cutting needle biopsies (613 of 660 procedures) of focal lung lesions in the study period.

**Study Design and Data Analysis for Risk factors**

A statistician performed data analysis using a statistical software package (SPSS; SPSS Inc; Chicago, IL) with the full collaboration and clinical feedback of the relevance of statistical results by radiologists. Descriptive statistics, selected variables related to patients, lung lesions, biopsy technique, and individual radiologist were analyzed according to procedures associated with or not associated with pneumothorax and bleeding. The statistical significance that was calculated from the mean of a continuous variable was analyzed using two-tailed Mann-Whitney U tests. The categorized variables were analyzed using two-tailed the Pearson $\chi^2$ test. Statistically significant factors for pneumothorax and bleeding derived from univariate analysis (ie, the following variables with p values < 0.05: lesion size; lesion depth; age; emphysema on CT scan; radiologists; needle-pleural angle; and chest wall thickness) were selected for multivariate analysis using multiple logistic regression. Variables with p values of > 0.1 were rejected during forward selection on multiple logistic regression. Multicollinearity (ie, the interaction between factors related to each other) was analyzed for apparent insignificant factors with p values of > 0.05 using multiple logistic regression. Confounding factors (ie, the interaction between factors with no direct relationship) were also analyzed. Only variables found to be significant by multiple logistic regression, the so-called risk factors, were analyzed for clinical relevance and implication. After risk factors were obtained by multivariate analysis, a more detailed analysis of the influence of lesion size on needle size selection, the radiologist’s preference of needle size, and the radiologist’s influence on the pneumothorax rate for lesion sizes of $\leq$ 2.0 cm were performed using contingency tables.

**Results**

From initial univariate analyses, significant risk factors affecting the incidence of pneumothorax were lesion size ($p < 0.001$), lesion depth ($p < 0.001$), age ($p = 0.003$), emphysema seen on CT scan ($p = 0.007$), radiologists ($p = 0.011$), needle-pleural angle ($p = 0.036$), and chest wall thickness ($p = 0.048$), while significant risk factors affecting the incidence of pulmonary bleeding were lesion size ($p < 0.001$), lesion depth ($p < 0.001$), presence of pleural effusion ($p < 0.001$), chest wall thickness ($p = 0.005$), and needle size ($p = 0.018$). The results of further multivariate analyses are shown below.

**Complications**

**Pneumothorax and Its Risk Factors:** Pneumothorax occurred in 155 of the 660 biopsy procedures (23%). Of those, 92% were mild (144 of 155 procedures), 7% were moderate (10 of 155 procedures), and < 1% were severe (1 of 155 procedures) [Table 1]. Six moderate-to-severe pneumothoraces occurred while patients were still on the CT scan table, and five pneumothoraces were successfully converted to mild pneumothoraces by air aspiration using the coaxial needle guide. One patient with recurrent air leaks had symptoms requiring the insertion of a chest tube. Eight patients with mild-to-moderate pneumothoraces at the end of the biopsy procedure progressed and developed symptoms over time. Chest tubes had to be inserted for the resolution of symptomatic pneumothoraces in 5% of patients with pneumothoraces (9 of 155 patients) and in 1% of all needle biopsies after air aspiration by the needle guide (9 of 660 procedures).

Significant risk factors for pneumothorax in increasing order of the p values obtained by multiple logistic regression (Table 1) were lesion size ($p < 0.001$; OR [OR] for a lesion size of $\leq$ 2 cm was about 11 times higher than that for a lesion size of $\geq$ 4.1 cm; 95% confidence interval [CI], 2.05 to 53.34), lesion depth ($p < 0.001$; OR for lesion depth of 0.1 to 2.0 cm was about seven times higher than for those abutting the pleura; 95% CI, 3.05 to 16.65; and OR for lesion depth of $\geq$ 2.1 cm was about four times higher than for those abutting the pleura; 95% CI, 1.60 to 11.93), the pioneer radiologist obtained the lowest pneumothorax rate ($p = 0.002$; OR for the rest of the radiologists was 2 to 2.6 times higher).

The results of further analyses using a contingency table and the Fisher exact test showed a significant difference in the needle size used for different lung lesion size, with smaller needles used for smaller lesions (69% of lung lesions $\leq$ 2 cm were sampled using the 20-gauge cutting needles) [$p < 0.001$]. There was also a significant preference of needle size exhibited by individual radiologists ($p < 0.001$). The pioneer attending radiologist used the 20-gauge needles in 98% of cases, the two other attending radiologists (labeled as radiologists B and C) used the 18-gauge needles in about 80% of their cases, while the chief resident radiologist (labeled as radiologist D) used the 16-gauge needles in 65% of cases. For lung lesions > 2 cm in size, there was a random selection of needle sizes (ie, 20 to 16 gauge) by individual radiologists. The pioneer radiologist obtained the lowest pneumothorax rate at 17%. When lung lesions were $< 2$ cm, most radiologists used the 20-gauge needles, but all radiologists, including the pioneer radiologist, obtained an average high pneumothorax rate of 32 to 33%.

Patient’s age, emphysema seen on CT scan, chest wall thickness, lesion cavitation, needle size, location of lung lesions, presence of pleural effusion, number of cutting specimens, needle-pleural angle, and patient position after needle biopsy were not associated with an increased risk of pneumothorax. The use of a large-bore 16-gauge needle (Temno; Bauer Medi-
Interaction of Risk Factors

Interaction existed between lesion depth and lesion size. A further investigation by correlation analysis revealed a negative correlation between lesion size and lesion depth (r = −0.38; p = 0.001). This negative correlation existed for various lesion depths and sizes. The results suggested that when lung lesions got larger, they were closer to the lung surface.

Bleeding Complication and Its Risk Factors

Pulmonary bleeding occurred in 30% of procedures (201 of 660 procedures). Among these procedures, 86% of bleeding complications were mild (173 of 201 procedures) [visualized only by CT scan as lung parenchyma or needle track bleeding], 4% were moderate (26 of 660 procedures) [patient presented with hemothorax estimated at < 30 mL of blood], and 0.2% were severe (1 of 660 procedures) [ie, mild hemothorax; the patient showed a disturbance of consciousness of uncertain etiology, but vital signs were stable soon after resuscitation]. The cause of conscious disturbance may be due to a combination of factors related to old age (the patient was 72 years old), fasting state, and pain level. No patient had a persistent unstable cardiovascular status that required blood transfusion.

Significant risk factors for bleeding (Table 2), demonstrated as increasing p values, were lesion size (p < 0.0001; OR for a lesion size of ≤ 2 cm was about six times higher than for a lesion size of ⩾ 4.1 cm; 95% CI, 3.39 to 11.68), lesion depth (p < .0001; OR was about six times higher for a lesion depth of 2.1 cm was 10 times higher than that for lesions abutting the pleura; 95% CI, 5.63 to 17.70), and the absence of pleural effusion (p = 0.004; OR was about six times higher than that when a pleural effusion was present; 95% CI, 1.74 to 20.28). The results of further analyses using a contingency table and t test showed that the mean (± SD) lung lesion size (5.7 ± 2.4 cm) of patients with pleural effusions was significantly (p < 0.001) larger than that for patients without pleural effusion (mean lesion size, 4.3 ± 2.0 cm). The mean lesion depth of patients with pleural effusions (1.0 ± 1.6 cm) was significantly (p = 0.057) shallower than that of patients without

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### Table 1—Risk Factors Affecting Pneumothorax After Needle Lung Biopsy: Results of Multiple Logistic Regression*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pneumothorax Rate, %†</th>
<th>β-Coefficient</th>
<th>SE</th>
<th>Wald Test</th>
<th>Degree of Freedom</th>
<th>p Value†</th>
<th>OR‡</th>
<th>95% CI‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesion size, cm (n = 660)</td>
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</tr>
<tr>
<td>≤ 2.0 (n = 80)</td>
<td>33 (26/80)</td>
<td>2.35</td>
<td>0.83</td>
<td>7.99</td>
<td>1</td>
<td>0.005</td>
<td>10.5</td>
<td>2.05-53.34</td>
</tr>
<tr>
<td>2.1–4.0 (n = 280)</td>
<td>30 (86/280)</td>
<td>1.94</td>
<td>0.43</td>
<td>19.82</td>
<td>1</td>
<td>&lt;0.001</td>
<td>6.9</td>
<td>2.96–16.21</td>
</tr>
<tr>
<td>≥ 4.1 (n = 291)</td>
<td>15 (43/291)</td>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
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<tr>
<td>Lesion depth, cm (n = 660)</td>
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<tr>
<td>0 (n = 255)</td>
<td>13 (33/255)</td>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
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<tr>
<td>0.1–2.0 (n = 225)</td>
<td>29 (65/225)</td>
<td>1.97</td>
<td>0.43</td>
<td>20.95</td>
<td>1</td>
<td>&lt;0.001</td>
<td>7.2</td>
<td>3.08–16.65</td>
</tr>
<tr>
<td>≥ 2.1 (n = 180)</td>
<td>32 (57/180)</td>
<td>1.47</td>
<td>0.51</td>
<td>8.25</td>
<td>1</td>
<td>0.004</td>
<td>4.4</td>
<td>1.60–11.93</td>
</tr>
<tr>
<td>Radiologists (n = 613)¶</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.002</td>
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<tr>
<td>Pioneer (n = 242)</td>
<td>17 (40/242)</td>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
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<tr>
<td>A (n = 107)</td>
<td>32 (34/107)</td>
<td>0.94</td>
<td>0.28</td>
<td>10.99</td>
<td>1</td>
<td>0.001</td>
<td>2.6</td>
<td>1.47–4.48</td>
</tr>
<tr>
<td>B (n = 110)</td>
<td>26 (29/110)</td>
<td>0.93</td>
<td>0.30</td>
<td>9.63</td>
<td>1</td>
<td>0.002</td>
<td>2.5</td>
<td>1.41–4.52</td>
</tr>
<tr>
<td>C (n = 85)</td>
<td>26 (22/85)</td>
<td>0.68</td>
<td>0.32</td>
<td>4.58</td>
<td>1</td>
<td>0.032</td>
<td>2.0</td>
<td>1.06–3.70</td>
</tr>
<tr>
<td>D (n = 69)</td>
<td>30 (21/69)</td>
<td>0.96</td>
<td>0.33</td>
<td>8.26</td>
<td>1</td>
<td>0.004</td>
<td>2.6</td>
<td>1.36–5.01</td>
</tr>
</tbody>
</table>

Interaction

Colinear relationships

| Lesion depth and size |                  |               |     |           |                  | 14.54    | 4   | 0.006   |
| D = 0.1–2.0; S ≤ 2.0 | −2.45            | 0.95          | 6.58| 1         | 0.010             |          |     |        |
| D = 0.1–2.0; S ≥ 2.1 | −1.89            | 0.56          | 11.26| 1        | 0.001             |          |     |        |
| D ≥ 2.1; S ≤ 2.0    | −1.31            | 1.00          | 1.72 | 1        | 0.189             |          |     |        |
| D ≥ 2.1; S = 2.1–4.0 | −1.32            | 0.62          | 4.45 | 1        | 0.035             |          |     |        |

Constant for logistic regression

|                  | −3.68 |

* p = 0.057 significant.
† Values in parentheses given as No. of pneumothoraces/No. of lesions of that size.
‡ The lowest OR in the group has the lowest risk ratio of 1.0.
¶ The reference group has the lowest risk.
§ Missing data. Only radiologists who have performed at least 30 needle lung biopsies were included for analysis.
puerphothorax rates for radiologists with varying expertise. How-

to patients, there is no difference in pneumothorax

a 17% pneumothorax rate, which is in contrast to the

rest of the radiologists who had an average pneu-

mothorax rate of 29%. This result suggests that if a

large-bore 16-gauge needle (Temno; Bauer Medical) with an increased risk of bleeding. The use of a

emphysema seen on CT scan were not associated

with lung lesions of

highest pneumothorax rate of 33% occurs in patients

mothorax and bleeding complications are inde-

pendent of each other, so they are considered sepa-

rately in the following discussion.

Pneumothorax Risk

Small lesion size is a significant risk factor for pneumothorax. There is a gradual increase in pneu-

mothorax risk as lung lesions become smaller. The highest pneumothorax rate of 33% occurs in patients

with lung lesions of ≤ 2 cm. In this subgroup of

patients, there is no difference in pneumothorax rates for radiologists with varying expertise. How-

ever, for lesions ≥ 2 cm the pioneer radiologist had a 17% pneumothorax rate, which is in contrast to the

rest of the radiologists who had an average pneumo-

thorax rate of 29%. This result suggests that if a

standard biopsy procedure protocol is followed by all

radiologists, experience may help to lower the inci-
dence of pneumothorax after a CT-guided coaxial

cutting needle lung biopsy until a critical lung lesion

size of smaller than 2 cm is reached. In considering

the needle biopsy of small lung lesions, Cox et al.20

who used the CT-guided coaxial fine-needle tech-
nique, obtained a similar higher pneumothorax rate

of 60% for 123 lung lesions ≤ 2 cm compared with a

31% pneumothorax rate in 233 biopsies for larger

lesions. Contrary to the reports cited above, the

study by Laurent et al10 showed no significant dif-

ference between the 15% pneumothorax rate for 67

lung lesions ≤ 2 cm in size compared to the 16%

pneumothorax rate for 135 larger lung lesions. How-

ever, Laurent et al10 recognized that needle biopsy

for lung lesions < 2 cm were technically more diffi-
cult, requiring a longer procedure time that might potentially increase the risk for pneumo-

thorax.10

The second risk factor for pneumothorax is lesion

depth. There is an abrupt rise in pneumothorax rates from lesions abutting the pleural surface (13%) to those occurring once the aerated lung is violated (29%). A sevenfold higher risk of pneumothorax for biopsies of subpleural lesions located between 0.1 and 2.0 cm below the surface is especially evident, while the risk drops down to a 4.4 times higher risk for deeper lung lesions. Our pneumothorax rate increased abruptly once the aerated lung was violated, but with the finding that there was no further increase in rate with increasing lesion depth is in accordance with the results obtained by Haramati2 and Cox et al.20 The subpleural lung lesions are not only risky for pneumothorax, their biopsies are dif-

Table 2—Risk Factors Affecting Bleeding After CT-Guided Coaxial Cutting Needle Lung Biopsy: Multiple Logistic Regression Analysis

<table>
<thead>
<tr>
<th>Variables</th>
<th>Bleeding Rate, %</th>
<th>β-Coefficient</th>
<th>SE</th>
<th>Wald Test</th>
<th>Degree of Freedom</th>
<th>p Value</th>
<th>OR</th>
<th>95% CI</th>
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<tbody>
<tr>
<td>Lesion size, cm (n = 660)</td>
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<tr>
<td>≤ 2.0 (n = 80)</td>
<td>66 (53/80)</td>
<td>1.54</td>
<td>0.32</td>
<td>34.20</td>
<td>2</td>
<td>&lt; 0.0001†</td>
<td>6.3</td>
<td>3.39–11.68</td>
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<tr>
<td>2.1–4.0 (n = 289)</td>
<td>37 (108/259)</td>
<td>0.74</td>
<td>0.23</td>
<td>10.26</td>
<td>1</td>
<td>0.001</td>
<td>2.1</td>
<td>1.33–3.28</td>
</tr>
<tr>
<td>≥ 4.1 (n = 291)</td>
<td>14 (40/291)</td>
<td>Reference</td>
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<td>0 (n = 255)</td>
<td>8 (20/235)</td>
<td>Reference</td>
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<td>1.0</td>
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<tr>
<td>0.1–2.0 cm (n = 225)</td>
<td>36 (81/225)</td>
<td>1.43</td>
<td>0.29</td>
<td>25.04</td>
<td>1</td>
<td>&lt; 0.0001</td>
<td>4.2</td>
<td>2.39–7.31</td>
</tr>
<tr>
<td>≥ 2.1 (n = 180)</td>
<td>56 (100/180)</td>
<td>2.30</td>
<td>0.29</td>
<td>62.08</td>
<td>1</td>
<td>&lt; 0.0001</td>
<td>10.0</td>
<td>5.63–17.70</td>
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<tr>
<td>Pleural effusion (n = 658)†</td>
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<tr>
<td>(–)</td>
<td>33 (198/604)</td>
<td>1.78</td>
<td>0.63</td>
<td>8.10</td>
<td>1</td>
<td>0.004†</td>
<td>5.9</td>
<td>1.74–20.28</td>
</tr>
<tr>
<td>(+)</td>
<td>6 (3/54)</td>
<td>Reference</td>
<td></td>
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<td>Constant for logistic regression</td>
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*See legend of Table 1 for explanations of some categories. (–) = without; (+) = with.
†Pearson’s χ² test.
‡Missing data: two small pleural opacities either due to encapsulated effusion or local pleural thickening could not be differentiated, so they were excluded.
difficult to perform. To reduce the high risk of pneumothorax and to increase the success of needle biopsy for small subpleural lesions, Tanaka et al have suggested the use of a longer oblique transpulmonary needle path. In their randomized controlled trial of 67 subpleural lung lesions <2.5 cm in size, they managed to lower the pneumothorax rate and obtain a higher success rate by taking a longer oblique needle path through the aerated lung to provide room for needle path correction and anchorage. This recommendation apparently violates the results obtained by Saji et al and Ko et al, who reported an increased pneumothorax rate associated with a needle pleural angle of <80°. However, our study revealed that the slightly significant effect of needle pleural angle on the pneumothorax rate noted in univariate analysis is dominated by the effect caused by small lesion size. Our analysis (not shown) reveals that lung lesions <1.5 cm are often approached at a significantly smaller needle-pleural angle. Our clinical observation revealed that the direct needle path to subpleural lung lesions <1.5 cm in size is often obscured by the overlying ribs, making an oblique needle path unavoidable.

The third risk factor for pneumothorax is the radiologist’s experience. The pioneer radiologist in general obtained a significantly lower pneumothorax rate (17%) than the rest of the radiologists (average pneumothorax rate, 30%) who used a variety of needle sizes. When the lung lesion size was <2 cm in size, all radiologists had an average pneumothorax rate of 33%, even though 69% of the biopsies were performed using the smallest 20-gauge needle. The above results show that the pneumothorax rate was not affected by needle size. This is in accordance with the results of Swischuk et al. Similarly, the 16-gauge needle did not increase the risk of pneumothorax, but the sample size of 49 biopsies using that needle was relatively small to draw a valid conclusion. The clinical implication is that various needle sizes may be used and that they may be just as safe, but we recommend the use of the smallest needle whenever possible.

Bleeding Risk

Our study shows that small lesion size is a risk factor for bleeding, and that lung lesions <20 mm are associated with the highest bleeding risk. Laurent et al using a coaxial 20-gauge automated cutting needle, reported a similar result. He obtained a 43% alveolar hemorrhage rate and a 6% hemoptysis rate in 67 biopsies of lung nodules <20 mm in size, compared with a 14% alveolar hemorrhage rate and a 5% hemoptysis rate in 135 biopsies of larger lesions. However, embedding the cutting needle into lung lesions without violating the aerated lung and avoiding the trauma incurred by the rapidly firing needle used in an automated gun are important precautions in avoiding unnecessary bleeding complications.

The second risk factor for bleeding found in our study is lesion depth. Bleeding risk was 10-fold higher when >2 cm of an aerated lung was traversed in contrast to lesions abutting the pleura, because small, deeply located lung lesions are more likely to be surrounded by aerated lung with its accompanying pulmonary vessels. As the coaxial needle guide traverses a longer needle path across the aerated lung, it is common to see bleeding along the needle tract on postbiopsy CT scans. Although bleeding can be life-threatening and alarming to patients, our study revealed that 86% of bleeding occurs merely as asymptomatic alveolar hemorrhaging or needle tract bleeding that is visible on a CT scan after needle guide removal.

The third risk factor for bleeding in our study is the absence of a pleural effusion on the side of needle biopsy. Contrary to our intuition, there was no increased risk of bleeding in a percutaneous needle lung biopsy when a pleural effusion was present. Our results suggest that lung lesions that are complicated with a pleural effusion are generally larger in size and closer to pleural surfaces, and thus are associated with a lower risk of bleeding. On the other hand, the higher bleeding risk associated with lung lesions surrounded by aerated lung probably has been overemphasized, because minor bleeding along needle tracks and alveolar hemorrhages, which account for 56% of pulmonary bleeding, are relative minor. The clinical implication is that it may safe to perform a cutting needle lung biopsy in the presence of a pleural effusion.

Factors such as needle size, the presence of cavitary lesions, and the number of cutting specimens do not appear to affect bleeding rate. The effect of the above factors on bleeding rate may be alleviated by our routine embedding of the cutting needle trough into the solid part of lung lesions, which provides an effective tamponade to bleeding.

Our study has some shortcomings. The individual radiologist’s preference for a needle path and a variety of needle sizes, based on expertise level, is difficult to evaluate. Needle path selection among radiologists may vary for a particular lesion. As such, a different needle path will affect all of the variables selected for statistical analysis in this model. It is apparent that the selection of needle size is partly determined by lesion size and is influenced by the radiologist’s preference and by whether lesions are surrounded by aerated lung. From our analysis, 69% of lung lesions <2 cm in size were sampled using
the 20-gauge cutting needles, while 57% of lung lesions > 4 cm in size (28 of 49 lesions) were sampled using the 16-gauge cutting needles. Despite the above shortcomings, a risk model built on multiple logistic regression analysis allowed us to explore the pathogenesis of pneumothorax and bleeding complications after CT-guided coaxial cutting needle lung biopsies. Complications may be preventable when individual risk factors affecting pneumothorax and bleeding are well-understood.6,18

In conclusion, in CT-guided coaxial cutting needle lung biopsy, the risk factors affecting pneumothorax rate are lesion size, lesion depth, and the radiologist, and the risk factors affecting bleeding complications are lesion size, lesion depth, and the absence of pleural effusions. The pathogenesis and risk of pneumothorax and bleeding can be deciphered using a risk model that is derived from results obtained by multiple logistic regression. Our results may be applicable for risk management in CT-guided coaxial cutting needle lung biopsies to avoid unnecessary complications.

REFERENCES

7 Miller JA, Pramanik BK, Lavenhar MA. Predicting the rates of success and complications of computed tomography-guided percutaneous core-needle biopsies of the thorax from the findings of the preprocedure chest computed tomography scan. J Thorac Imaging 1998; 13:7–13