Complications with Endobronchial Ultrasound with a Guide Sheath for the Diagnosis of Peripheral Pulmonary Lesions

Manabu Hayama    Takehiro Izumo    Yuji Matsumoto    Christine Chavez    Takaaki Tsuchida    Shinji Sasada
Respiratory Endoscopy Division, Department of Endoscopy, National Cancer Center Hospital, Tokyo, Japan

Key Words
Bronchoscopy · Complications · Endobronchial ultrasound with a guide sheath · Radial endobronchial ultrasound · Transbronchial biopsy

Introduction
Bronchoscopy is a widely performed procedure that is generally safe. In the past, its use for the diagnosis of peripheral pulmonary lesions (PPLs) has been limited by a low diagnostic yield [1]. As the years went by, improvements have been made [2]. In fact, a recent meta-analysis reported a 70% diagnostic yield of bronchoscopy for PPLs with the use of new guided techniques, including electromagnetic navigation bronchoscopy, radial endobronchial ultrasound (R-EBUS), EBUS with a guide sheath (EBUS-GS), virtual bronchoscopic navigation and ultra-thin fiber; among these, the highest pooled diagnostic yield of 73.2% was attributed to EBUS-GS, which enables confirmation of the location of a lesion and repeated procurement of tissue samples from the same position [3]. Moreover, we have recently reported the diagnostic utility of EBUS-GS for ground-glass opacity (GGO) lesions [4, 5]. This evidence shows that, indeed, EBUS-GS is now becoming a common procedure for the diagnosis of PPLs which was difficult to attain by conventional bronchoscopy.

Along with the widespread application of EBUS-GS, an increase in problems associated with the procedure may be expected, especially at the learning curve phase. Until now, there have been few reports that cited procedural complications [6–8], but the majority of the avail-
able literature on EBUS-GS for PPLs focused on the diagnostic yield. In our clinical experience, we hypothesize that precise PPL localization and the use of a guide sheath may reduce the risk of puncturing the visceral pleura and the risk of bleeding through a tamponade effect of the guide sheath after transbronchial sampling. In this study, we evaluated the complications associated with EBUS-GS for PPLs and the durability of EBUS-GS devices.

**Patients and Methods**

**Subjects and PPL Characters**

The medical records of all patients who underwent EBUS-GS for the diagnosis of PPLs between September 2012 and August 2014 at the National Cancer Center Hospital, Tokyo, Japan, were reviewed. This study was a retrospective chart review and, therefore, the Institutional Review Board of the National Cancer Center approved the study without the need to obtain informed consent of each participant. Written informed consent for bronchoscopy was obtained from all patients.

PPL was defined as an abnormal growth surrounded by pulmonary parenchyma and as bronchoscopically invisible. The size of each PPL was determined by measuring the largest diameter on cross-sectional computed tomography (CT) images. The distance from the lateral edge of each PPL to the costal pleura was recorded. The lesion character was categorized as solid, part solid or pure GGO, based on CT scan attenuation. Virtual bronchoscopic navigation systems (Ziostation2®, Ziosoft Ltd., Tokyo, Japan; LungPoint®, Bronchus Ltd., Mountain View, Calif., USA, or BF-NAVI®, Olympus Ltd., Tokyo, Japan) were used when the target bronchi were small and difficult to trace [9].

**EBUS-GS Procedures**

EBUS-GS procedures were carried out using either one of the following bronchoscopes (Olympus Ltd.): BF-IT260, BF-260, BF-P260, BF-F260, BF-ITQ290, BF-Q290, BF-P290, LF-TP, or BF-Y0053, which is a new middle-range bronoscope with a 5.1-mm outer diameter and a 2.6-mm working channel [10]. A large (K-203) or small (K-201) guide sheath kit (Olympus Ltd.) was respectively used in combination with a large R-EBUS probe (UM-S20-20R; Olympus Ltd.) or a small R-EBUS probe (UM-S20-17S; Olympus Ltd.). A small guide sheath was chosen when the lesion was ≤30 mm and close to the visceral pleura or when the lesion was very small (solid ≤10 mm or pure GGO ≤15 mm) [10].

All bronchoscopies were performed via the oral route under local anesthesia with intravenous administration of midazolam for mild sedation. During the procedure, oxygen was delivered to the patient via a nasal cannula, and continuous pulse oximetry was routinely used to monitor oxygen saturation and pulse rate. Blood pressure was intermittently measured.

Upon insertion of the scope to reach the target bronchus, the guide sheath together with the R-EBUS probe was inserted through the working channel and advanced under X-ray fluoroscopic guidance. If the target lesion was not detected by EBUS, the probe was manipulated under fluoroscopic guidance until an acoustic signal was generated. EBUS images before transbronchial sampling were categorized into 3 patterns (fig. 1): ‘within’ (the probe was located in a bronchus that was inside the lesion), ‘adjacent to’ (the probe was located in a bronchus that ran alongside the lesion) or ‘invisible’ (the probe was not able to reach the lesion) [11]. After localizing the lesion by EBUS, the probe was removed while the guide sheath was kept in place for subsequent sampling by brush and forceps, also under X-ray fluoroscopic guidance.

Transbronchial needle aspiration through a guide sheath (GS-TBNA) was additionally performed when the operator deemed that the sample amount was insufficient. GS-TBNA procedures were performed using a 13-mm-long 21-gauge needle with a metallic sheath (NA-1C-1; Olympus) through a large guide sheath. The length of the large guide sheath was adjusted by cutting the proximal end by about 30 mm to adapt the length of the needle sheath and facilitate the insertion of the needle apparatus for TBNA [12].

Rapid on-site evaluation of the specimen was routinely performed. After collecting adequate samples, the guide sheath was left in place for 2 min for hemostasis before it was eventually removed. The procedure time was recorded from the point when the
scope has passed the vocal cords to its withdrawal out of the tra-
chea. Final diagnoses were established by pathologic evidence
from EBUS-GS, EBUS-TBNA, CT-guided transthoracic needle bi-
opsy or surgery, by microbiological analysis, or by clinical follow-
up of >3 months.

When the collected specimen showed malignancy or specific
benign findings with compatible subsequent clinical outcomes,
EBUS-GS was considered as diagnostic. When a sample was not
adequate (e.g., peripheral lung tissue, peribronchial tissue), EBUS-
GS was designated as nondiagnostic.

All EBUS-GS procedures were performed by expert bronchos-
copists or trainees with enough experience on conventional bron-
choscopy and EBUS-GS assistance. During all the procedures, the
trainees were supervised by the experts [13, 14].

Postprocedure Course
All bronchoscopy procedures were performed on an outpatient
basis, except if there were other reasons for admission. After every
procedure, the patient was observed at a recovery room for 2 h un-
til discharged. Chest X-ray was performed only when the patient
reported any symptoms suggestive of pneumothorax [15], because
previous studies reported that routine chest X-ray to detect pneu-
mothorax was not necessary for all patients after bronchoscopy
[16, 17]. A major complication was defined as an event which ne-
cessitated premature termination of the procedure or symptom-
atic postprocedural sequela, including pneumothorax, hemor-
rhage, infection, air embolism or another untoward life-threaten-
ing outcome [18]. Breakage of the guide sheath and/or the radial
probe was also recorded.

Statistical Analysis
Descriptive statistics are presented as frequency, percentage
and median (range). Correlations of study variables were per-
formed with EZR (Saitama Medical Center, Jichi Medical Univer-
sity, Saitama, Japan), which is a graphical user interface for R (The

Results
Overall, EBUS-GS procedures were performed for 965
PPLs. A summary of patient characteristics and EBUS-GS
findings is shown in table 1. The study population had a
median age of 69 years and mostly consisted of male pa-
tients. The median lesion size and the median distance
from the costal pleura was 25 and 6 mm, respectively. A
large guide sheath kit was used for 590 lesions (61.1%).
The EBUS image before sampling was ‘within’ in 544 le-
sions (56.4%), ‘adjacent to’ in 283 lesions (29.3%) and ‘in-
visible’ in 138 lesions (14.3%). In addition to brushing or
forceps biopsy, GS-TBNA was performed for 165 lesions
(17.1%). The median procedure time was 22 min. Malig-
nancy was the final diagnosis in 744 lesions (77.1%). The
overall diagnostic yield was 64.4% (623 of 965 PPLs).

Overall, major complications after EBUS-GS occurred
in 13 patients (1.3%; table 2). There were 8 patients (0.8%)

with pneumothorax, and 3 (0.3%) of them required chest
tube drainage. Five patients (0.5%) developed pulmonary
infection. There was no case of significant hemorrhage
which necessitated premature termination of the proce-
dure, air embolism, tumor seeding, or procedure-related
death.

A clinical course summary of the 13 cases with com-
plifications is shown in table 3. The patients were 59–81
years of age and were predominantly male. Six cases had

| Table 1. Baseline characteristics of patients who underwent EBUS-
GS for the diagnosis of PPLs (n = 965) |
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Age, years</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Size, mm</td>
</tr>
<tr>
<td>Distance from costal pleura, mm</td>
</tr>
<tr>
<td>Character</td>
</tr>
<tr>
<td>Solid</td>
</tr>
<tr>
<td>Part solid</td>
</tr>
<tr>
<td>Pure GGO</td>
</tr>
<tr>
<td>Guide sheath kit type</td>
</tr>
<tr>
<td>K-203, large</td>
</tr>
<tr>
<td>K-201, small</td>
</tr>
<tr>
<td>EBUS image</td>
</tr>
<tr>
<td>Within</td>
</tr>
<tr>
<td>Adjacent to</td>
</tr>
<tr>
<td>Invisible</td>
</tr>
<tr>
<td>Procedure time, min</td>
</tr>
<tr>
<td>Final diagnosis</td>
</tr>
<tr>
<td>Malignant lesion</td>
</tr>
<tr>
<td>Benign lesion</td>
</tr>
<tr>
<td>Not determined</td>
</tr>
</tbody>
</table>

Data are presented as the median (range) or number (%).

| Table 2. Complications and equipment broken during EBUS-GS for
PPLs (n = 965) |
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Complication</td>
</tr>
<tr>
<td>Pneumothorax</td>
</tr>
<tr>
<td>Pulmonary infection</td>
</tr>
<tr>
<td>Significant hemorrhage</td>
</tr>
<tr>
<td>Air embolism</td>
</tr>
<tr>
<td>Tumor seeding</td>
</tr>
<tr>
<td>Equipment broken</td>
</tr>
<tr>
<td>Radial probe broken</td>
</tr>
<tr>
<td>Guide sheath broken</td>
</tr>
</tbody>
</table>

Data are presented as number (%).
underlying lung diseases, including emphysema and rheumatoid lung disease. The lesion size ranged from 17 to 63 mm. All 8 cases with pneumothorax (cases 1–8) had PPLs that were adjacent to the visceral pleura or major fissure; among these, only 4 (50%) could be localized by EBUS ‘within’. All the 8 patients who developed pneumothorax had suggestive symptoms right after EBUS-GS procedures. Moreover, there was no patient who did not undergo chest X-ray on the day of EBUS-GS and developed pneumothorax after discharge. Among the 5 cases with pulmonary infections (cases 9–13), 2 had cavitary lesions and 1 was adjacent to a bulla. Particularly, these pulmonary infections were pneumonia (n = 1), lung abscess (n = 3) and empyema (n = 1). In these 5 patients, infectious symptoms (e.g., fever, cough, dyspnea or chest pain) appeared within 2 weeks after EBUS-GS, and no other etiology was found on the review of the medical records. All 13 cases with complications recovered after specific treatment.

In the 2-year study period, 4 R-EBUS probes (0.4%) were broken during the procedure: 3 of 375 (0.8%) small R-EBUS probes and 1 of 590 (0.2%) large R-EBUS probes. There were no adverse events during the time the probe was broken, and no breakage of the guide sheath was observed.

**Representative Cases**

An 80-year-old male (case No. 7; table 3) was referred for pathologic diagnosis of a right middle lobe part-solid nodule measuring 17 mm (fig. 2). The nodule was adjacent to the visceral pleura and major fissure, and there were underlying emphysematous changes. EBUS-GS was performed but the nodule could not be visualized by EBUS (invisible). Under X-ray fluoroscopic guidance, brushing was performed once and forceps biopsy 7 times. After the procedure, the patient complained of chest pain, and pneumothorax was revealed on chest X-ray. He required 1 week of admission with chest tube drainage.

A 64-year-old female (case No. 10; table 3) was referred to our department for gene analysis of a primary lung adenocarcinoma that increased in size despite chemotherapy (fig. 3). The tumor was a 32-mm solid mass with cavity in the right S1. After the EBUS probe was located within the mass, brushing was performed 2 times followed by forceps biopsy 6 times. Eleven days after the procedure, the patient complained of chest pain, and pneumothorax was revealed on chest X-ray. He required 1 week of admission with chest tube drainage.

### Table 3. Clinical course of the 13 cases with complications

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age, years</th>
<th>Gender</th>
<th>Comorbidity</th>
<th>Size, mm</th>
<th>Character</th>
<th>Location</th>
<th>EBUS image</th>
<th>Complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70</td>
<td>Female</td>
<td>None</td>
<td>25</td>
<td>Part solid</td>
<td>Left S6</td>
<td>Invisible</td>
<td>Pneumothorax without chest tube drainage</td>
</tr>
<tr>
<td>2</td>
<td>81</td>
<td>Female</td>
<td>None</td>
<td>63</td>
<td>Solid</td>
<td>Left S1+2</td>
<td>Adjacent to</td>
<td>Pneumothorax without chest tube drainage</td>
</tr>
<tr>
<td>3</td>
<td>76</td>
<td>Male</td>
<td>Emphysema</td>
<td>41</td>
<td>Solid</td>
<td>Right S3</td>
<td>Within</td>
<td>Pneumothorax without chest tube drainage</td>
</tr>
<tr>
<td>4</td>
<td>61</td>
<td>Male</td>
<td>Emphysema</td>
<td>21</td>
<td>Solid</td>
<td>Right S4</td>
<td>Invisible</td>
<td>Pneumothorax without chest tube drainage</td>
</tr>
<tr>
<td>5</td>
<td>77</td>
<td>Female</td>
<td>Diabetes mellitus</td>
<td>38</td>
<td>Part solid</td>
<td>Right S1</td>
<td>Within</td>
<td>Pneumothorax without chest tube drainage</td>
</tr>
<tr>
<td>6</td>
<td>59</td>
<td>Female</td>
<td>None</td>
<td>31</td>
<td>Part solid</td>
<td>Right S1</td>
<td>Within</td>
<td>Pneumothorax with chest tube drainage</td>
</tr>
<tr>
<td>7</td>
<td>80</td>
<td>Male</td>
<td>Emphysema</td>
<td>17</td>
<td>Part solid</td>
<td>Right S4</td>
<td>Invisible</td>
<td>Pneumothorax with chest tube drainage</td>
</tr>
<tr>
<td>8</td>
<td>80</td>
<td>Male</td>
<td>Rheumatoid arthritis</td>
<td>23</td>
<td>Solid</td>
<td>Right S8</td>
<td>Within</td>
<td>Pneumothorax with chest tube drainage</td>
</tr>
<tr>
<td>9</td>
<td>69</td>
<td>Male</td>
<td>Emphysema</td>
<td>33</td>
<td>Part solid</td>
<td>Left S4</td>
<td>Within</td>
<td>Pneumonia requiring admission</td>
</tr>
<tr>
<td>10</td>
<td>64</td>
<td>Female</td>
<td>Lung adenocarcinoma</td>
<td>32</td>
<td>Solid (with cavity)</td>
<td>Right S1</td>
<td>Within</td>
<td>Lung abscess requiring admission and surgery</td>
</tr>
<tr>
<td>11</td>
<td>76</td>
<td>Male</td>
<td>Emphysema</td>
<td>30</td>
<td>Solid (adjacent to a bulla)</td>
<td>Right S9</td>
<td>Within</td>
<td>Lung abscess requiring admission and surgery</td>
</tr>
<tr>
<td>12</td>
<td>63</td>
<td>Male</td>
<td>None</td>
<td>38</td>
<td>Solid (with cavity)</td>
<td>Right S2</td>
<td>Within</td>
<td>Lung abscess requiring admission</td>
</tr>
<tr>
<td>13</td>
<td>79</td>
<td>Female</td>
<td>None</td>
<td>54</td>
<td>Solid</td>
<td>Right S2</td>
<td>Within</td>
<td>Empyema requiring admission</td>
</tr>
</tbody>
</table>
Complications with EBUS-GS for the Diagnosis of PPL

Discussion

EBUS-GS for PPL diagnosis is now becoming a widespread procedure. A considerable amount of the literature that mainly focused on diagnostic yield has been published. To the best of our knowledge, this is the first report about complications and device durability of the procedure. Based on our results, EBUS-GS was a tolerable procedure and the devices were durable. The overall complication rate was 1.3% and included pneumothorax and pulmonary infection. The rate of breakage of R-EBUS probes was also low (0.4%), and no breakage of the guide sheath was shown.

Pneumothorax is one of the major complications after transbronchial biopsy (TBB) [19–21]. A nationwide survey in Japan showed that the rate of pneumothorax after TBB for PPLs was 0.63% [22]. Our result on pneumothorax risk (0.8%) was just about similar and may be accounted for by the close location of the PPL to the visceral pleura or major fissure. Moreover, localization of the EBUS within a lesion was possible in only 4 of 8 patients who developed pneumothorax. A recent study reported that the probe position adjacent to the lesion was an independent risk factor for pneumothorax after R-EBUS-guided TBB [23]. This suggests that even with the use of EBUS-GS, we should still be aware of the risk of pneumothorax for lesions close to the visceral pleura or fissure, especially when the lesion cannot be precisely detected by EBUS.

Hemorrhage is another major complication after TBB. Although the majority of hemorrhages spontaneously resolved or required local vasoconstrictor therapy only [15, 24], severe hemorrhage after TBB has been reported to occur on rare occasions (0.73–2.8%) [18, 19, 21]. In the present study, there was no case of significant hemorrhage which required us to terminate the procedure prematurely. Wedging the guide sheath in the target bronchus may

Fig. 2. An 80-year-old male who developed pneumothorax after EBUS-GS. a A 17-mm solid nodule in the right S4 was adjacent to the costal pleura and major fissure. b The radial probe could not reach the nodule. c X-ray fluoroscopic image of EBUS-GS TBB. d Chest X-ray after the procedure revealed right pneumothorax (arrows).
have helped stop the bleeding during TBB, in addition to the advantage of sufficient specimen procurement.

The risk for pulmonary infection was 0.5% in the present study. Fever after bronchoscopy is common, but a chest X-ray was rarely indicated [15, 25]. Although the presence of cavitation or bulla may have influenced post-procedural infections, an additional explanation could be contamination from repeated insertion of sampling devices through the guide sheath. Further studies are necessary to evaluate the possibility of increased risk for infection by using a guide sheath.

The Japanese nationwide survey [22] reported that 47.2% of all facilities experienced breakage of the bronchoscope and/or devices during the study period; therefore, all devices should be carefully handled especially when performing new methods like EBUS-GS. In the present study, we found that the R-EBUS probe could be broken on rare occasions and that small R-EBUS probes were more fragile than large R-EBUS probes. To minimize the cost, proper handling and gentle insertion of the R-EBUS probe and guide sheath during EBUS, localization and sampling of the PPLs are recommended. Further, it is important to keep the long axis of the bronchoscope and the long axis of the guide sheath always aligned to prevent kinks and breakage. Nevertheless, in the instances that the R-EBUS probes were broken, there was no adverse reaction to the patient.

The diagnostic yield in the present study was similar to those reported in previous studies [6, 7, 26]. The target lesions were close to the costal pleura (median distance: 6 mm), and 138 ‘invisible’ lesions (14.3%) were also included in the present study. These situations may have contributed to the diagnostic success; therefore, careful case selection is warranted.

This study has several limitations. First, it was a retrospective analysis in a single institute. Second, the procedures were not performed by the same bronchoscopist. Further multicenter prospective studies would be ideal.

In conclusion, EBUS-GS is a tolerable procedure for PPL sampling and the devices are durable.
Complications with EBUS-GS for the Diagnosis of PPL

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The authors have no conflicts of interest to disclose.

References