Bilateral lung nodules resection by image-guided video-assisted thoracoscopic surgery: A case series

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Abstract

Background

We demonstrated the safety and feasibility of image-guided video-assisted thoracoscopic surgery (iVATS) of bilateral lung lesions in a hybrid operating room.

Methods

This study was a retrospective analysis of a case series. A total of 7 patients with 15 small lung nodules underwent bilateral iVATS between July 2018 and May 2019. All procedures were completed within a single anesthesia procedure and performed in a hybrid operating room that had a cone-beam computed tomography (CT) apparatus equipped with a laser navigation system. The lesion characteristics, operation methods, and peri-operative clinical outcomes were summarized.

Results

A total of 7 patients with 15 resected lung nodules were analyzed. The most common pathological result of our bilateral iVATS was metastasis. The median length of hospital stay was 5 days (range from 3 to 10 days). The median right chest tube duration was 2 days (range from 1 to 8 days), and the median left chest tube duration was 3 days (range from 2 to 5 days). Only one patient had a complication during his hospitalization period. There was no surgery-related mortality observed.

Conclusions

The bilateral iVATS procedure seems to be a feasible, safe and cost-effective approach for successful resection of bilateral lung lesions.

Introduction

Over the past decades, video-assisted thoracoscopic surgery (VATS) resection for small lung nodules has been adopted more and more widely because of its optimized perioperative outcome and its acceleration of postoperative recovery (1, 2). However, small lung nodules, especially ground glass opacities (GGOs), are difficult to palpate and obtain during the surgery. Accurately localizing small lesions before the operation is thus an important issue (1–10). Several techniques have been developed for localizing peripheral small lung lesions; the list of techniques includes percutaneous image-guided injection of a dye (methylene blue, patent blue vital dye, barium sulphate, etc.) and image-guided placement of microcoils or hook wires (1-3, 6-8). In the traditional way, patients were sent to an imaging room (usually guided by multidetector CT) for the lesion localization and then
transferred to an operating room for the surgery. Nonetheless, concerns had been issued concerning the dislodgement of markers, the dissemination of dyes to lung parenchyma during patient transferal and the procedure gap between localization and surgery (2, 3, 8).

Several studies about image-guided video assisted thoracoscopic surgery (iVATS) have focused on the application of hybrid operating rooms, which provide multimodality and real-time imaging guidance to improve the localization problems and surgical procedures (1–6). Those studies developed iVATS workflows to combine lesion localization and resection in a single surgical session. Intraoperative nodule localization allows one to complete localization and surgery without an anesthesia gap. Therefore, patient transferal and repositioning, marker dislodgement, and the potential risks of bleeding and pneumothorax are avoided (1–3, 6). The overall perioperative outcomes are comparable to traditional CT-room-guided surgery and makes iVATS an attractive alternative (2–6). However, the application of iVATS for bilateral pulmonary nodule localization and resection has not been explored. Patients who underwent bilateral lung nodule resection suffered from longer surgical duration and hospital stays and higher risks of anesthesia-related complications, pneumothorax and hemothorax, and moreover, there were more concerns about loss of lung functions. The advantages of iVATS in a hybrid room especially provide extra benefits for patients needing bilateral lung nodule resection.

In this case series, we described the feasibility and safety of bilateral small lung nodule resection via iVATS in a hybrid room. To our best knowledge, this article was also the first study focusing on a bilateral application of iVATS.

Material And Methods

Patients

We did a thorough chart review retrospectively from July 2018 to May 2019. There were 109 patients receiving iVATS surgery for their lung nodules, and 7 of them had bilateral iVATS. The inclusion criteria for our study were (1) presence of a GGO > 5 mm in size with or without solid components on follow-up CT images, (2) enlarged nodule size during follow-up periods, (3) distance of the lesion to the pleura less than 3 cm, and (4) suspected metastatic lung lesion. Patients were excluded from review if they were (1) under 18 years old, (2) received unilateral iVATS surgery only, or (3) refused to
sign the consent of research protocol. The Institutional Review Board of the Changhua Christian Hospital approved the study protocol (IRB-191201).

**iVATS surgical technique**

All patients were admitted 1 day before surgery for preoperative preparation and management. At the initiation of the whole procedure, general anesthesia was first induced and our patients were then positioned in a lateral decubitus position, depending on the location of the lesion, for the dye localization and iVATS surgery. When deciding on which laterality to start, we chose the easier side or expected smaller resection side first in order to maintain maximal pulmonary volume and function of oxygenation during the other side’s procedure. We performed the surgery with a robotic C-arm cone beam CT (Artis pheno; Siemens Healthcare GmbH, Forchheim, Germany). The localization procedure was performed by one experienced chest surgeon (BY Wang). The patient first held a breath at end-inspiratory phase for the initial cone beam CT scan, and the shortest route for needle insertion to localize the lesion was then planned (Fig. 1). The route was projected with a laser beam on the skin of the patient under the syngo Needle Guidance of a syngo X-Workplace with a three-dimensional view. After measuring the depth, we introduced an 18-gauge coaxial needle into the patient’s chest under the guidance of the cone beam CT during end inspiration breath-hold phase (Fig. 2). A diluted methylene blue dye (0.2 ml) plus normal saline (0.3 ml) were subsequently injected into the lung lesion through the needle. A post-procedural cone-beam CT scan was obtained to confirm an appropriate needle location and make sure no further complication (pneumothorax or hemothorax) arose. After finishing the localization, the patient was positioned in the same position on the table and completely sterilized and then underwent thoracoscopic wedge resection (Fig. 3). All the resections were performed with single-incision VATS. We performed wedge resections for the peripheral nodules. Otherwise, segmentectomy was done for the central nodules to ensure safe margins. A frozen section examination was performed after resection of the nodules. For the lesion of the contralateral lung, the same scanning and localization procedures were processed again and then the lesion was resected. The total operative time was measured from the initiation of image-guided localization to the end of the whole surgery (after final suturing for
epidermis closure). All procedures were completed in a single general anesthesia event in one hybrid operative room.

Data collection and statistical analysis
The study variables summarized in our series include patients’ clinical demographic data (age, gender), lesion characteristics (laterality, size, depth of nodule to pleura, pathological results), operation methods (wedge resection, segmentectomy, or lobectomy), and peri-operative clinical outcomes (length of hospital stay, chest tube duration, postoperative complication). They were all extracted from clinical documentation.

Results
Patient Demographics and Clinicopathologic Characteristics
All the background information and perioperative details of our patients were listed in Table 1. A total of 7 patients with 15 resected lung nodules were enrolled and analyzed in our series; 3 of them were females and the other 4 were males. The median age was 60 years old (ranged from 47 to 68 years old). Only one patient had two lesions over his right lung; others had one lesion over each side of their lungs. The median operative time for bilateral nodules was 245 minutes (ranged from 165 to 345 minutes). The median nodule size of the right lung was 8.5 mm (range from 5 to 11 mm), and the median nodule size of the left lung was 11 mm (range from 6 to 15 mm). The median distance from the right pulmonary nodule to the pleural surface was 10.5 mm (range from 5 to 14 mm), and the median distance from the left pulmonary nodule to the pleural surface was 17 mm (range from 7 to 26 mm). Among the 15 nodule resections, 3 of them were segmentectomies, and the other 12 were wedge resections. None of the patients received lobectomy due to concerns of accidental great loss of lung function.
Table 1
Clinical demographic data and management

| Case | Age  | Gender | Tumor location | OP time (min) | Nodule size (mm) | Distance to the pleura (mm) | OP method |
|------|------|--------|----------------|---------------|------------------|-----------------------------|-----------|
| 1    | 60   | Female | RLL + LLL      | 296           | 9 / 7            | 13 / 9                     | RLL: wedge, LLL: wedge |
| 2    | 47   | Male   | RUL + LLL      | 231           | 6 / 7            | 5 / 7                      | RUL: wedge, LLL: wedge |
| 3    | 64   | Female | RUL + LLL      | 345           | 5 / 12           | 14 / 22                    | RUL: wedge, LLL: segmentectomy |
| 4    | 60   | Male   | RLL + LLL      | 265           | 8 / 11           | 11 / 24                    | RUL: wedge, LLL: segmentectomy |
| 5    | 63   | Male   | RLL + LUL      | 165           | 7 / 9 / 6        | 10 / 26                    | RUL: wedge, LLL: wedge |
| 6    | 57   | Male   | RML + LUL      | 245           | 11 / 15          | 10 / 26                    | RUL: wedge, LLL: segmentectomy |
| 7    | 68   | Female | RLL + LUL      | 197           | 9 / 12           | 10 / 17                    | RUL: wedge, LLL: wedge |

OP: operative, RUL: right upper lobe, RML: right middle lobe, RLL: right lower lobe, LUL: left upper lobe, LLL: left lower lobe

Table 2 presented the pathological results and clinical outcomes of our patients. The majority of the lesions resected in our study were metastatic lesions (e.g., 8 of 15 lesions had hepatocellular carcinoma); 5 of these were primary lung cancers (3 were adenocarcinomas, one was adenocarcinoma in situ, and the other one was squamous cell carcinoma). Only two lesions were benign. All lesions in our study were partially solid or mixed ground glass, and their average size was 8.93 mm. The average length of hospital stay was 5.43 days (ranged from 3 to 10 days). On average the right chest tube duration was 3 days, and the average left chest tube duration was 3.43 days. Furthermore, only one of the 7 patients had a complication (right hydrothorax) during his hospitalization period. The complication was treated and resolved by the time of discharge from the hospital. No surgery-related mortality was observed.
Table 2
Outcomes of bilateral localization at hybrid room

| Case | Pathology                     | Length of hospital stay (day) | Length of chest tube removal (day) | Complication         |
|------|-------------------------------|-------------------------------|-----------------------------------|----------------------|
| 1    | RLL,LLL: SCC, metastasis     | 10                            | R: 8, L: 3                        | Right hydrothorax    |
| 2    | RUL: AIS, LLL: inflammation   | 3                             | R: 1, L: 2                        | None                 |
| 3    | RUL,LLL: AC, metastasis      | 6                             | R: 4, L: 5                        | None                 |
| 4    | RUL,LLL: AC, metastasis, RUL,LLL: HCC, metastasis RML: inflammation, LUL: HCC, metastasis RLL,LUL: AC, metastasis | 6, 4 | R: 3, L: 5, R: 2, L: 3, R: 1, L: 2, R: 2, L: 4 | None, None, None, None |

RUL: right upper lobe, RML: right middle lobe, RLL: right lower lobe, LUL: left upper lobe, LLL: left lower lobe, SqCC: Squamous cell carcinoma, AIS: adenocarcinoma in situ, AC: adenocarcinoma, HCC: hepatocellular carcinoma

Discussion

We introduced a single center experience of 7 successful bilateral iVATS procedures on bilateral lung nodules. This study presented some potential benefits of bilateral iVATS surgery: (1) successful and complete resections of bilateral lung nodules in a single anesthesia procedure in one hybrid operating room, (2) dramatic decreases in operation time and surgical risk (e.g., hemothorax or pneumothorax related to inadequate puncture) due to no need to transport patients from the CT procedure room to the operating room, especially for patients with bilateral lung lesions, and (3) generally optimal postoperative outcomes (e.g., acceptable length of hospital stay and chest tube duration).

Furthermore, one-time bilateral localization with traditional CT guiding techniques is not feasible because possible catastrophic bilateral pneumothorax or hemothorax might occur after the localization procedure. Even if these complications did not happen, in the traditional way patients have to be hospitalized twice and receive surgery twice for their bilateral lung lesions. All these problems can be minimized or waived by applying our novel bilateral iVATS approach.

Several studies had described image-guided video assisted thoracoscopic surgery with marking in real time, in single suite, and immediate resection in a hybrid operating room. Those trials summarized many advantages of iVATS, such as (1) iVATS provides a less invasive approach and results in less discomfort for patients and improved postoperative recovery and general satisfaction; (2) complete and minimal resection of early lung cancer with optimal margin, allowing maximal preservation of patients’ lung volume and function; (3) single use of anesthesia and the use of only one room improve
both perioperative outcomes (e.g., shorter operative duration and length of hospital stay) and general cost-effectiveness; and (4) iVATS encourages early cancer treatment (1–6). However, none of these studies demonstrated the utility of iVATS for bilateral lung nodule resection. We believed this is the first case series describing bilateral iVATS with optimal clinical outcomes.

The marker for nodule localization in this study is methylene blue because it is clearly visualized on the surface of lung parenchyma and requires no extra equipment. According to previous studies, other contrast agents with larger molecular weight and larger particle size, including indocyanine green, indigo carmine, and lipiodol, may migrate slower into tissues. The higher-density contrast agents, like iopamidol and lipiodol, have been associated with allergic reactions to the contrast medium, local inflammation at the site of injection, and contrast embolization (7, 11, 12).

All lesions in our study were partially solid or mixed ground glass, and their average size was 8.93 mm. Those features often cause difficulty in making a definite diagnosis from image-guided biopsies, and surgery may also be difficult due to it being hard to palpate lesions during surgery. With the application of iVATS procedures, especially bilateral approaches, we can expect a significant increase in the number of complete resections of early lung cancers due to advantages in time and cost effectiveness, and thus other necessary treatment would be promoted, which may lead to improved overall cancer-related mortality.

Some limitations of our study are considered. First, the relatively small sample size may result in inevitable bias. Second, the postoperative follow-up periods were limited to being within the hospitalization period. Furthermore, a longer follow-up duration for a larger study group should be used to further explore the clinical outcomes of cancer-related morbidity and mortality. Finally, detailed cost-effectiveness analyses comparing bilateral iVATS with other bilateral techniques or iVATS of unilateral lung nodules should also be performed.

Conclusion
We described an approach for bilateral lung nodules that involves using image-guided localization and performing immediate marker-guided thoracoscopic resection for lung cancer in a hybrid operating
room. The bilateral iVATS procedure seems to be a feasible, safe and cost-effective approach for successful resection of bilateral lung lesions.

Abbreviations
iVATS
image-guided video-assisted thoracoscopic surgery
CT
computed tomography
GGOs
ground glass opacities

Declarations

Ethics Approval and consent to participate
The Institutional Review Board of the Changhua Christian Hospital approved the study protocol (IRB-191201). All participants have signed the consent of research protocol.

Consent for Publication
All the consent to publish have be obtained from our participants.

Availability of supporting data
The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests
The authors declare that they have no competing interests.

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Not applicable.

Authors' contributions
CC Liang and CH Liao both contributed equally to this work, they drafted most of the work regarding the bilateral iVATS application, and each should be accorded first authorship. YF Cheng designed the work. WH Hung, HC Chen, and CL Huang all help collect and analyze the patient data. BY Wang was the major contributor to this article and completed all final revision.

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Not applicable.
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Figures
Figure 1

(a) The lung nodule of #2 patient at right upper lobe (b) The lung nodule of #2 patient at left lower lobe
Figure 2

The localization of lung nodule at hybrid operative room under Artis pheno
Figure 3

(a) The lung nodule of #2 patient under VATS at right upper lobe. The lung nodule of #2 patient under VATS at left lower lobe.