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Robotic-assisted Bronchoscopy and Cone-beam CT

A Retrospective Series

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Key Words: robotic bronchoscopy, cone-beam CT, tool in lesion, fused navigation, peripheral lung nodule, lung cancer

(*J Bronchol Intervent Pulmonol* 2022;29:303–306)

The combination of robotic-assisted bronchoscopy (RAB) and cone-beam computed tomography (CBCT) is an emerging novel technology that can be used for diagnosing peripheral lung lesions. The ability to diagnose and stage a suspected, peripheral, difficult to reach lung lesions in a single procedure made RAB with CBCT an interesting procedure of choice. Overall, RAB has been increasingly utilized for the evaluation of challenging lung lesions, otherwise difficult to reach and sample effectively. Despite advancements in technology and improved diagnostic yields over previous approaches, computed tomography to body divergence remains one of the major limitations for any electromagnetic navigation bronchoscopy (ENB) case where virtual targeting may be affected. Combining the use of ENB with radial probe endobronchial ultrasound (RP-EBUS) and fluoroscopy can aid in lesion diagnosis.[1] In the literature, diagnostic yields ranging from 71% to 90% with the use of CBCT in conjunct with ENB with or without RP-EBUS have been in published.[1–4] This experience was performed as a single-center retrospective study, consecutive patients in which RAB (Monarch; Auris, Redwood City, CA) was utilized to diagnose challenging lung lesions. This was conducted as a QI project, as part of a review of an internal interventional pulmonology database—consent was waived per institutional review board. The ability of the robotic platform to reach challenging areas of concern is facilitated primarily by proprietary fused navigational technology, leveraging airway optical recognition, electromagnetics, and robotic kinematic information. This approach resulted in real-time correction of airway pathways aimed at successful target localization.

For these combined cases, RAB+CBCT candidacy was evaluated by a lung nodule multidisciplinary team based on case complexity, size, and target location, among other factors. These cases required intubation and general anesthesia, as per usual protocol at our institution for bronchoscopic procedures that require chemical paralysis. We performed an initial CBCT spin before RAB navigation, to evaluate target stability or enlargement and to check isocentering. After successfully navigating to the target lesion, RP-EBUS (Olympus, PA) was performed in all patients to evaluate ultrasonograpic imaging, and then a biopsy instrument was to the target lesion. A fine needle (PeriView, Olympus, PA) was then advanced into the target and the instrument position was visualized with the use of a CBCT spin to determine the location with respect to lesion and adjustments made if necessary.

For case selection, we established certain criteria prompting consideration for a combined approach based on combinations of the following factors: (1) nearest airway >2 cm from target lesion, (2) noncentral lesions with contraindications for transthoracic needle aspiration, (3) suspected difficulty to locate with traditional bronchoscopic approaches, (4) lung lesions located in the middle or outer third of the lung with the need for

Received for publication April 1, 2021; accepted March 16, 2022.
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Disclosure: G.C.-N. and J.P.E. are educational consultants for Auris. The remaining authors declare no conflict of interest or other disclosures.
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DOI: 10.1097/LBR.0000000000000860

endobronchial ultrasound staging, (5) distal lesions without a suspected endobronchial component and no bronchus sign, (6) target location beyond the fourth-generation bronchus, (7) at least intermediate suspicion for lung cancer or other etiologies that required tissue acquisition. For this study, we analyzed: (1) feasibility; (2) navigation success; (3) navigation time and total procedure time; (4) tool in lesion confirmation; (5) intraprocedural and postprocedural complications; (6) systems accuracy and precision. Feasibility was defined as the ability for these technologies to function as intended within the required procedural space, without significant interference or prohibitive maneuvering of any equipment tool in lesion confirmation was performed by visualizing any tool (radial probe, forceps, needle) in contact with targeted area—irrespective of RP-EBUS signal. A total of 20 pulmonary lesions suspected of being malignant were analyzed (Table 1). These cases were completed with an average of 2.4 CBCT spins. All lesions were successfully accessed by instruments, with CBCT confirming 100% tool in lesion before sample acquisition. We utilized RP-EBUS on all cases: 10/20 cases demonstrated a concentric lesion, 5/20 had eccentric features, and 5 demonstrated no abnormal RP-EBUS signal. In cases without an RP-EBUS signal, only transbronchial needle aspiration specimen acquisition was attempted—as other instruments could follow paths of least resistance—as indicated by the RP-EBUS probe signal.

In average, the navigation time to reach the lesion was 9.8 minutes (range: 3 to 41 min). The average RAB procedure time was 36.4 minutes (range: 15 to 66 min). All cases were able to be completed successfully without malfunction, interference, or registration errors (100% compatible technologies). The majority of the biopsied lesions were malignant (Table 2). Overall, sensitivity for malignancy in our study was calculated at 86.6% (true positive for malignancy = 13; total positives for malignancy TP+FN = 15). We observed a higher incidence of lung adenocarcinoma followed by squamous cell lung cancer. Of 7 initially nondiagnostic cases, 5 cases proved to be benign on follow-up (Table 3). Two other cases required subsequent interventions after a nondiagnostic RAB with CBCT to obtain the final diagnosis. There were no complications within our cohort. In addition, we observed 100% compatibility for this combined technology approach and an excellent safety profile. Navigational success was achieved in all cases, and leveraging the CBCT guidance tool to lesion relationship was able to be confirmed in all patients. Our navigational success and tool in the lesion were confirmed in all cases, accounting for 100% precision and target access accuracy. Given our findings, we hypothesize that nondiagnostic cases could be attributed to: (1) sampling tool efficacy, (2) need for additional tissue acquisition, and (3) effectiveness of histopathologic and microbiological analysis.

TABLE 1. Patient and Lesion Characteristics

	n/N (%)
Patients (N)	20
Age [mean (± SD)]	70 (± 7)
Sex (male)	7/20 (35)
BMI [mean (± SD)]	28 (± 4)
COPD	8/20 (40)
CAD	2/20 (10)
History of cancer	8/20 (40)
Smoking history	16/20 (80)
Current smoker	7/20 (35)
Lesion size [mean (± SD)] (mm)	22 (± 7)
Solid lesions	17/20 (85)
Mixed ground glass and solid lesions	2/20 (10)
Pure ground glass lesions	1/20 (5)
Bronchus sign present	10/20 (50)
Lesion location	
Left lung	12/20 (60)
LUL	9/20 (45)
LLL	3/20 (15)
Right lung	8/20 (40)
RUL	4/20 (20)
RML	1/20 (5)
RLL	3/20 (15)
Peripheral one third	8/20 (40)
Middle one third	10/20 (50)
Proximal one third	2/20 (10)

BMI indicates body mass index; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; LLL, left lower lobe; LUL, left upper lobe; RLL, right lower lobe; RML, right middle lobe; RUL, right upper lobe.

TABLE 2. Histopathologic Results of the Patients Who Underwent RAB With CBCT-guided Biopsies

	n/N (%)
Biopsy results from RAB with CBCT	
Adenocarcinoma	10/20 (50)
Squamous cell carcinoma	3/20 (15)
Nondiagnostic	7/20 (30)
Reactive cells	1/20
Nondiagnostic	4/20*
Atypical cells	1/20†
Non-necrotizing granulomatous inflammation	1/20

*One of these biopsies was a false negative with a positive finding for malignancy at 3 months' follow-up.

†Positive for malignancy on linear endobronchial ultrasound biopsies.

CBCT indicates cone-beam computed tomography; RAB, robotic-assisted bronchoscopy.

TABLE 3. Follow-up on Nondiagnostic Biopsies

Patient #	Biopsy Results	Additional Procedures Performed After Nondiagnostic Bronchoscopy	Nodule Size (mm)	Location of the Nodule With Respect to Lung Parenchyma	Location	Lesion Categorized as	Follow-up and Relevant Past Medical History
1	Reactive cells	None	9	Medial one third	LUL	NA Need for follow-up	3 and 12 mo follow-up CT scans demonstrated stable 9 mm nodule
2	Nondiagnostic	Yes	14	Central one third	LUL	False negative	3 mo follow-up CT chest showed increased size nodule in LUL, leading to repeat RAB with EBUS, consistent with metastatic colon carcinoma
3	Nondiagnostic	No	28	Lateral one third	RML	Labeled as indeterminate at the time of index procedure	12 mo follow-up CT chest showed decreasing in size of the lung nodule to 14 mm and more ground glass in nature compared with prior CT chest
4	Atypical cells	Yes	16	Central one third	LUL	False negative	After nondiagnostic RAB, the patient underwent CT-guided percutaneous biopsy which was nondiagnostic. Given clinical concern for malignancy, the patient underwent surgical wedge resection—consistent with squamous cell carcinoma
5	Non-necrotizing granulomatous inflammation (NNGI)	No	11	Lateral one third	RUL	Benign	3 mo CT follow-up studies demonstrated reduction in nodule size with resolution of mediastinal lymphadenopathy. Linear EBUS biopsies consistent with NNGI in 3/3 mediastinal lymph node stations
6	Nondiagnostic	Yes	19	Peripheral one third	LLL	Need further follow-up	RAB biopsies consistent with reactive cellular changes. This nodule was rebiopsied by TTNA, demonstrated a fibroelastotic scar of apical cap type
7	Nondiagnostic	No	15 45		LLL LUL	Benign	Targeted LLL lesion had resolved at the time of procedure. Previously radiated area at LUL was biopsied and demonstrated postradiation changes

CT indicates computed tomography; EBUS, endobronchial ultrasound; LLL, left lower lobe; LUL, left upper lobe; NA, not available; RAB, robotic-assisted bronchoscopy; RML, right middle lobe; RUL, right upper lobe; TTNA, transthoracic needle aspiration.

In conclusion, the combined use of RAB and CBCT is a safe, precise, and feasible strategy to access peripheral lung lesions. Technical advantages of RAB as enhanced bronchoscope structural stability while utilizing sampling tools, ability to visualize the passage of tools in peripheral airways, and enhanced needle trajectory, appear to be advantageous when compared with other available approaches. The addition of real-time imaging guidance likely enhances our ability to acquire tissue samples from peripheral targets. Precision and accuracy will prove paramount in our success for future bronchoscopic therapeutic approaches in peripheral lung cancer.

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