

Robotic-Assisted Bronchoscopy:

Changing the Diagnostic Landscape

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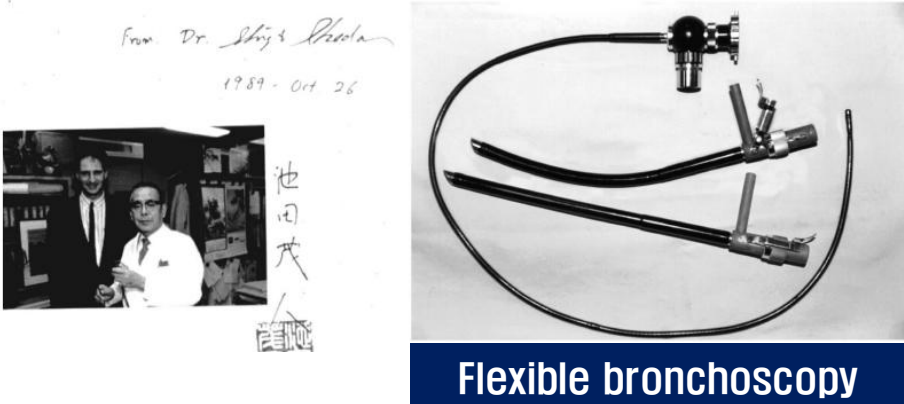
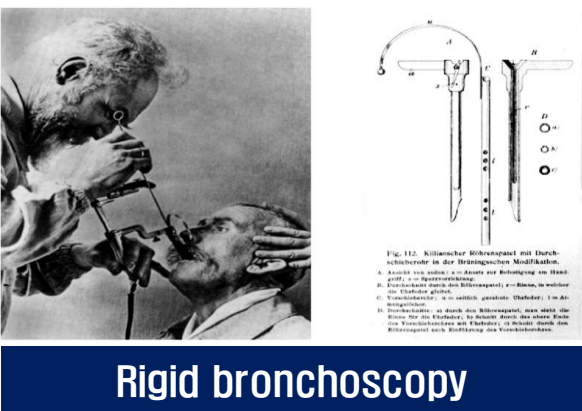
충남대학교병원 호흡기알레르기내과

Lung cancer school 2026 | August 22, 2026



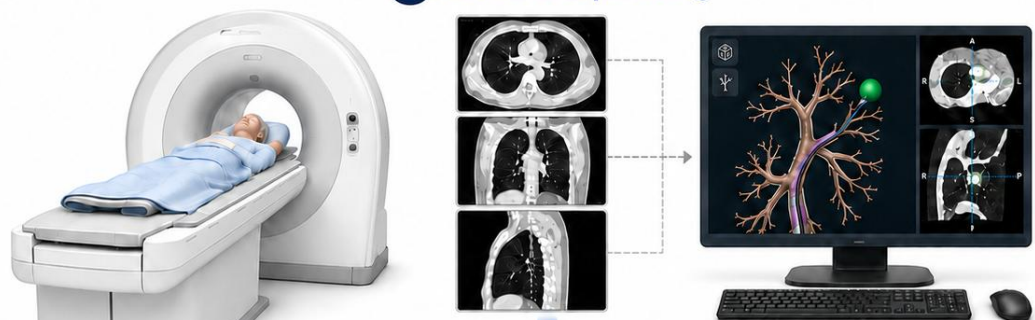
Evolution of Bronchoscopy

- 1897: Rigid bronchoscopy (Killian G) [1]
- 1965: Transbronchial pulmonary biopsy (TBLB) (Andersen HA) [2]
- 1966: Flexible bronchoscopy (Ikeda S) [3]
- 1967: Transbronchial approach to PPL under fluoroscopic guidance (Tsuboi E) [4]
- 1974: BAL (Reynolds HJ) [5]
- 1983: TBNA (Wang KP) [6]
- 1984: Laser for therapeutical bronchoscopy (Dumon JF) [7]
- 1996: Radial EBUS (Becker HD) [8]
- 2002: Radial EBUS miniprobe for PPL (Herth FJF) [9]
- 2003: Valves for Bronchoscopic Volume Reduction (Toma T) [10]
- 2003: EBUS-TBNA (Krasnik M) [11]
- 2004: Bronchial thermoplasty for asthma (Cox PG) [12]
- 2006: Electromagnetic Navigation Bronchoscopy (Schwarz J) [13]
- 2007: Confocal Microscopy (Thiebertville L) [14]
- 2009: Cryobiopsy (Bablak A, Hetzel J) [15]
- 2009: EUS-B-FNA (Hwangbo B) [16]
- 2014: Cone Beam CT for PPL (Hohenforst-Schmidt W) [17]
- 2018: Robotic bronchoscopy (Rojas-Solano JR) [18]

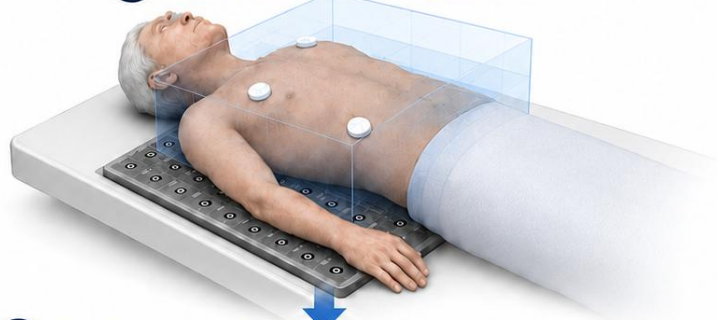


Before Robotics: Navigation and 3D Confirmation

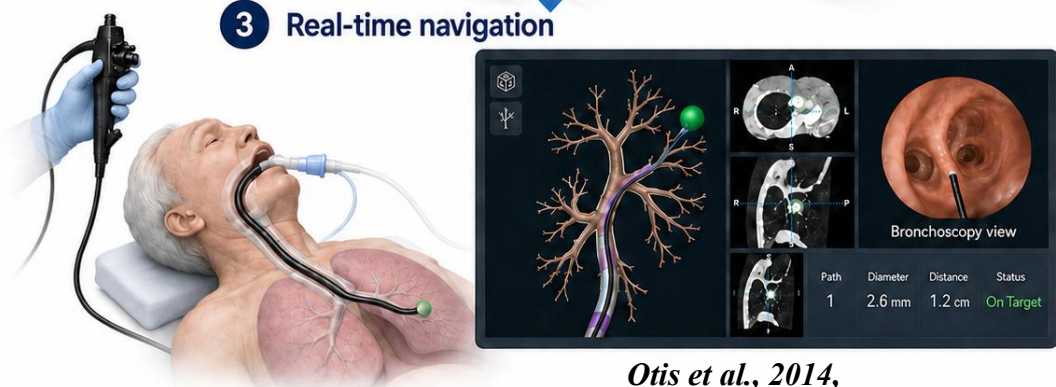
1 CT-based planning



2 Electromagnetic registration



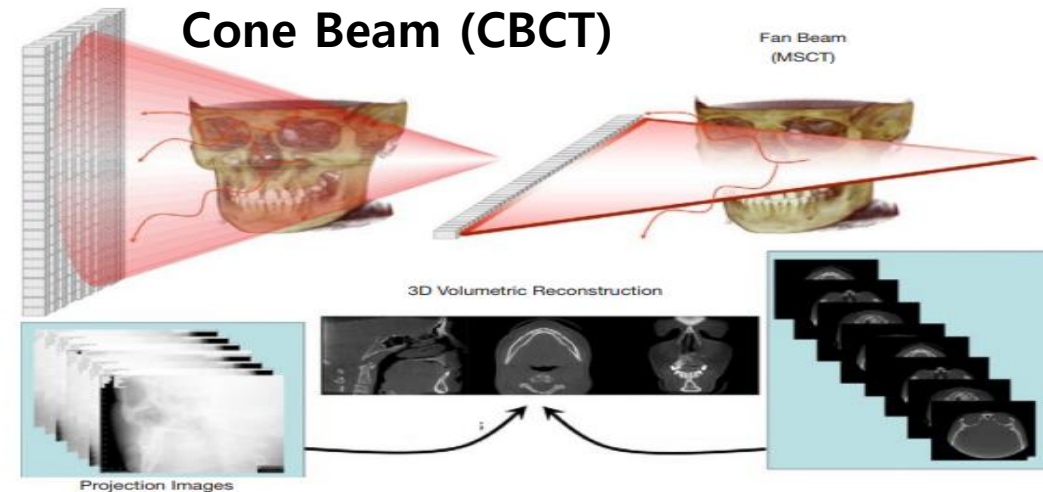
3 Real-time navigation



Otis et al., 2014,
Thoracic and Cardiovascular Surgery

ENB: Navigation to the Target

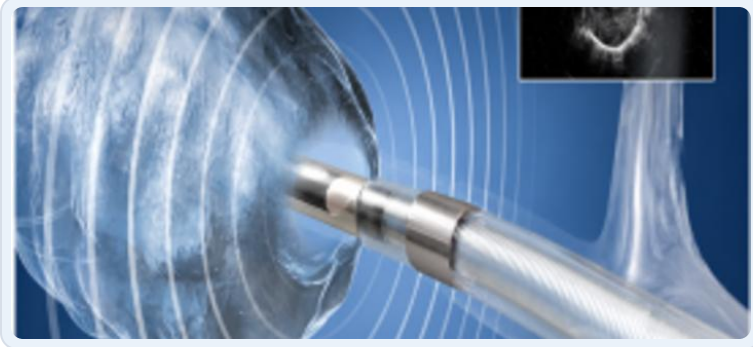
Cone Beam (CBCT)



CBCT : Confirmation at the Target

Setser et al., 2020, JTD

Limitation of Pre-Robotic Bronchoscopy



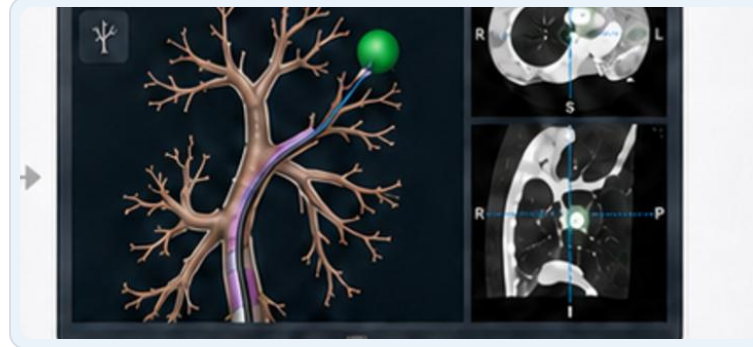
Radial EBUS

Lesion localization

- Localizes the lesion only after airway access
- Probe is withdrawn before tissue sampling

POSITION-DEPENDENT YIELD

Within lesion 87% | Adjacent 42%



ENB

Virtual navigation

- Relies on a pre-procedure CT-derived target
- Susceptible to CT-to-body divergence

VIRTUAL TARGET $\neq$ ACTUAL TARGET

Navigation alone cannot confirm tool-in-lesion



CBCT

3D confirmation

- Provides a snapshot, not continuous guidance
- Adds radiation, space, and workflow burden

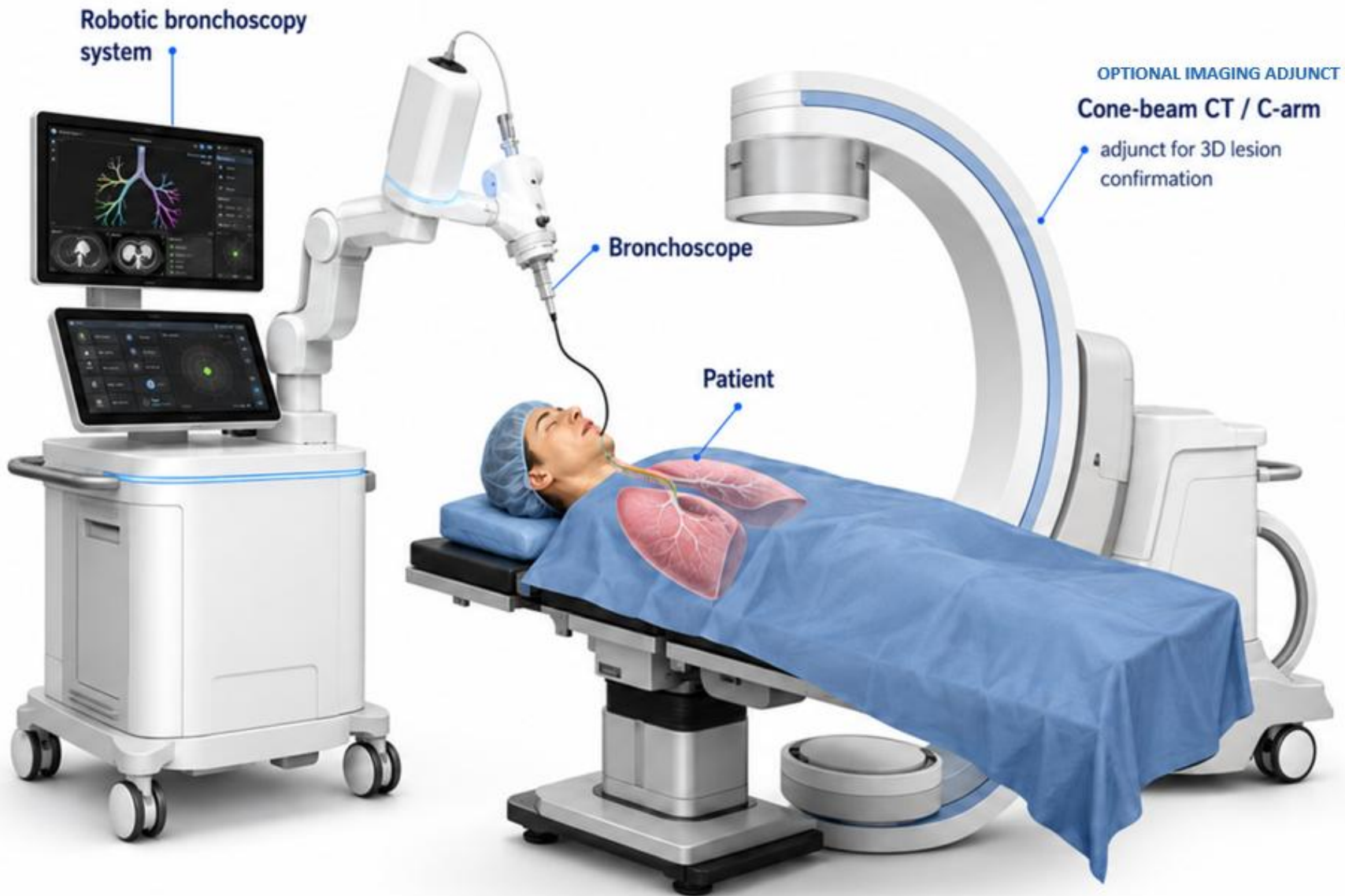
CONFIRMATION $\neq$ STEERABILITY

Tool position is confirmed, but access is not improved

No single modality provided navigation, stable distal access, and confirmation in one workflow

Unmet need: steerable and stable access to difficult-to-reach pulmonary lesions

What is Robotic Assisted Bronchoscopy (RAB)?



**Robotic bronchoscopy =
Navigation + Steerability + Stability**



1) Navigation

CT-based pathway planning
with real-time positional feedback



2) Steerability & Reach

Active distal articulation
through complex airway anatomy



3) Stability

Maintains catheter position
during tool exchange and sampling

***Designed for precise access and tissue acquisition
in difficult-to-reach pulmonary lesions.***

R Robot = navigation + steerability + stability

3D CBCT = optional intraprocedural 3D confirmation

Clinical Evidence - BENEFIT Trial (CHEST, 2021)

Prospective multicenter pilot study | Monarch platform | 5 centers | n = 54 | Median lesion size: 23 mm

****Primary end point :**

Successful lesion localization with the use of radial probe endobronchial ultrasound (R-EBUS) imaging and incidence of procedure related adverse events

How the study was performed

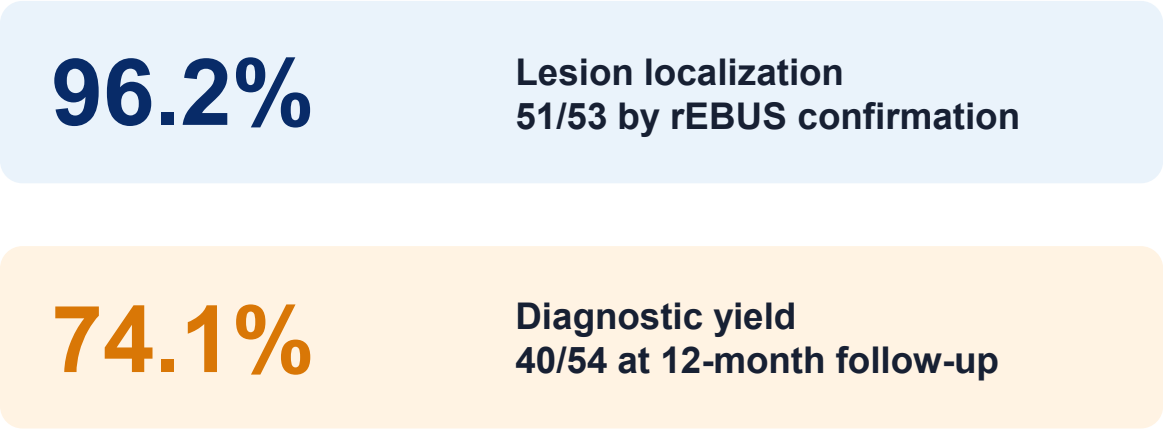
- 1

Navigate
Direct vision + ENB + fluoroscopy
- 2

Confirm
rEBUS localization of the target
- 3

Sample
TBNA ×3; forceps biopsy if ROSE was nondiagnostic

Primary result and the clinically important gap



Safety **Pneumothorax** 3.7% **Chest tube** 1.9%

No other significant adverse events

Robotic bronchoscopy demonstrated feasible and safe lesion access, but successful navigation did not guarantee diagnostic tissue acquisition.

Clinical Evidence - Shape-Sensing RAB Study (CHEST, 2022)

Single-center postmarketing experience | Ion platform | 130 patients | 159 lesions | Median lesion size: 18 mm

****Primary end point :** Diagnostic yield of ssRAB sampling per individual pulmonary lesion

How the study was performed

- 1

Navigate

CT planning + real-time shape sensing navigation
- 2

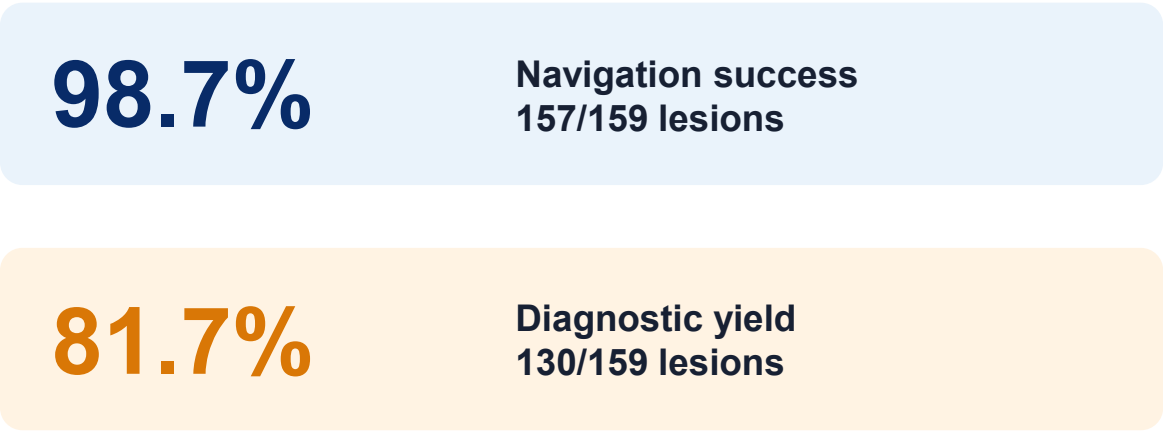
Confirm

rEBUS +/- 2D/3D fluoroscopy
- 3

Sample

TBNA in 96.9% +/- forceps biopsy; ROSE in all cases

High Navigation Success, Size-Dependent Yield



Safety Overall complications 3.0% Pneumothorax 1.5%

ssRAB achieved high navigation success and diagnostic yield with a low complication rate, but diagnostic yield was 26.1 percentage points lower for lesions ≤ 2 cm than for lesions > 2 cm (69.6% vs 95.7%).

Clinical Evidence - CONFIRM Study (THORAX, 2026)

Prospective multicenter observational study | Ion + mobile CBCT | 6 centers | n = 155 | PPN ≤20 mm | Median size: 14 mm

****Primary end point :** Tool-in-lesion, diagnostic yield, sensitivity for malignancy, and procedural safety

How the study was performed

- 1

Navigate
CT planning + real-time shape sensing navigation
- 2

Confirm
rmCBCT confirms tool-in-lesion and updates targeting
- 3

Sample
Transbronchial biopsy; nonmalignant cases followed for 12 months

Near-Universal TIL, High Strict Yield

99.4%

Tool-in-lesion
154/155 procedures

89.0%

Strict diagnostic yield
138/155 by ATS/ACCP criteria

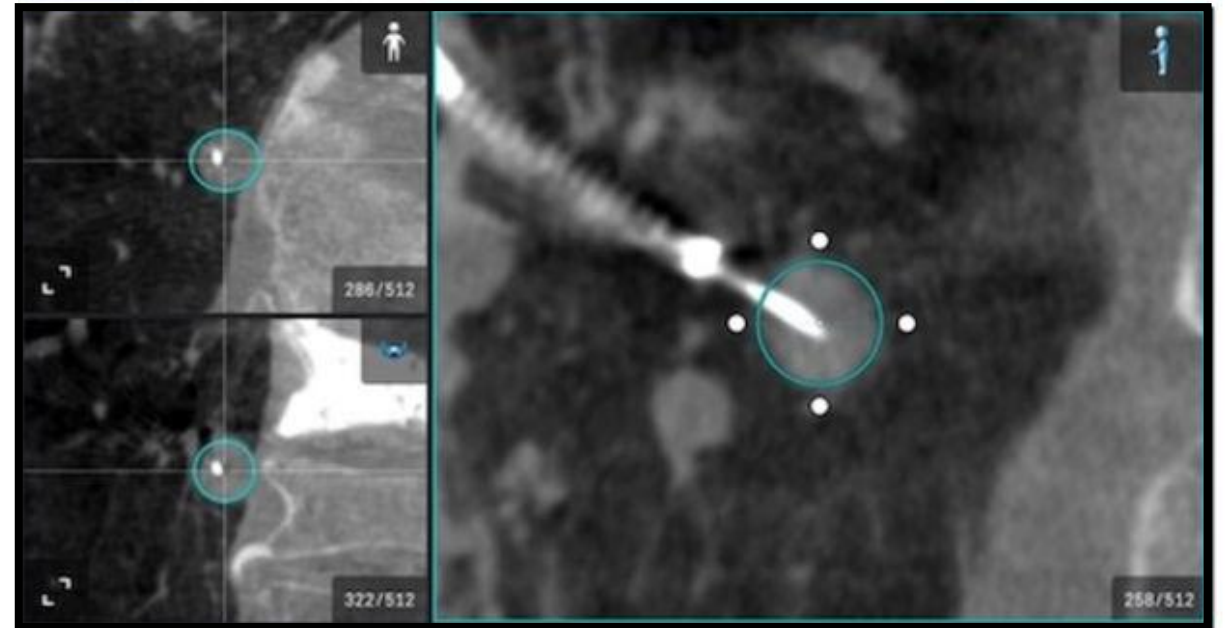
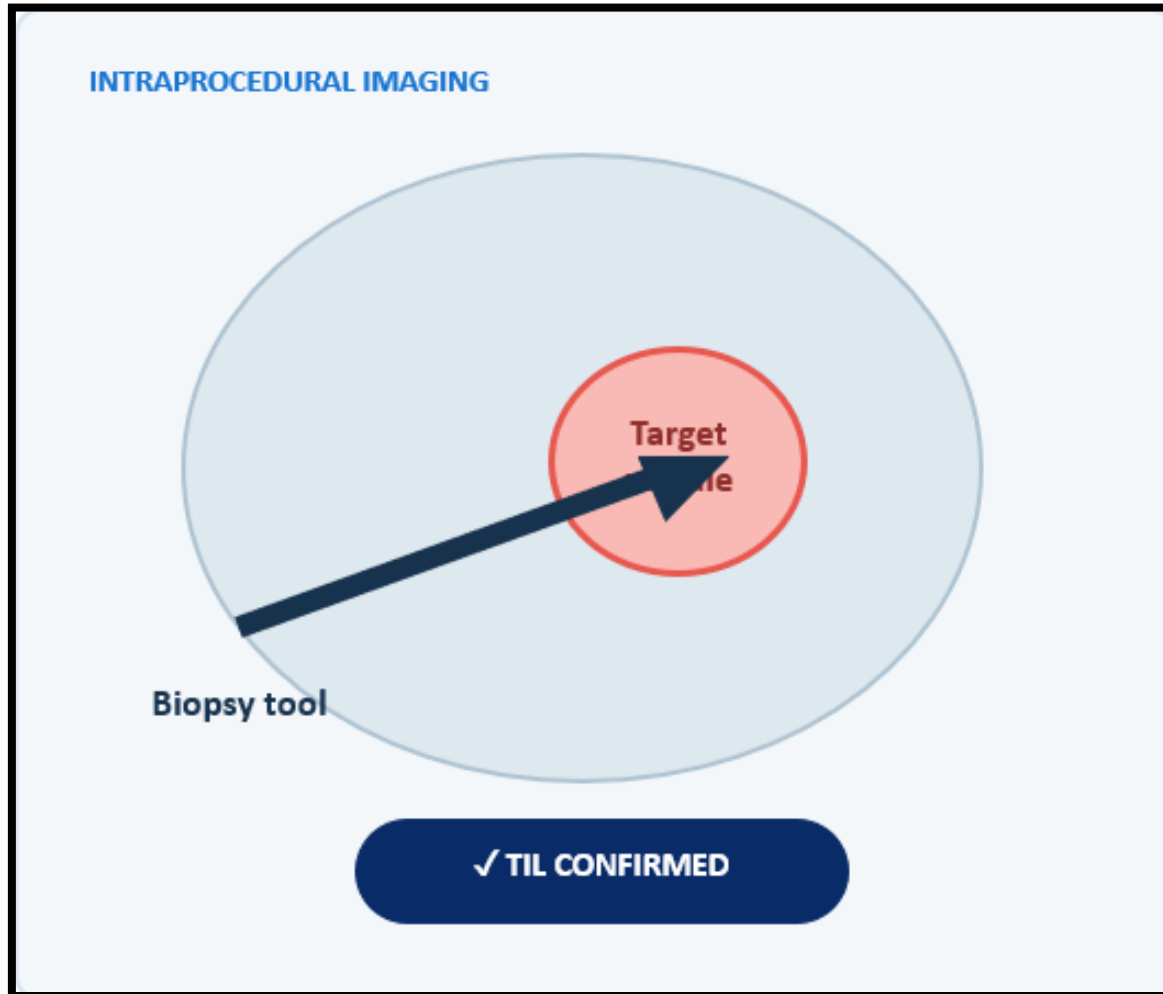
Safety

Sensitivity for malignancy 91.5%

Pneumothorax 0%

Integrated ssRAB–mCBCT achieved near-universal tool-in-lesion confirmation and 89.0% strict diagnostic yield in small nodules, with no pneumothorax.

Tool-in-lesion (TIL)



DIRECT CONFIRMATION

CBCT / mobile CBCT
Tomosynthesis ± augmented fluoroscopy

SUPPORTIVE, BUT NOT DEFINITIVE

rEBUS confirms probe-lesion relationship
Navigation display estimates catheter position
from preprocedural CT

Evidence Landscape: RAB With Routine CBCT vs Without Standardized CBCT

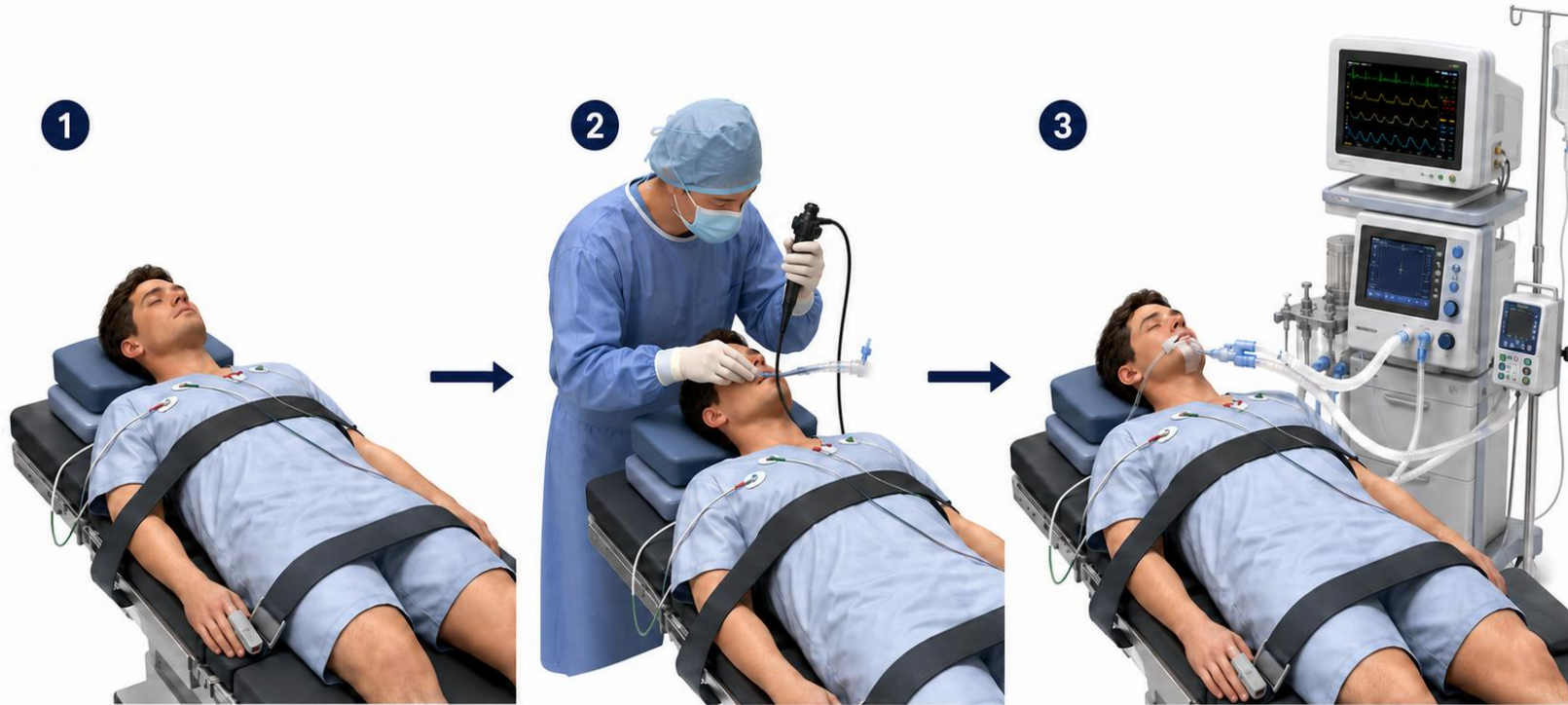
CBCT as Primary 3D Guidance						CBCT Absent, Optional, or Non-integrated					
Study	n	Lesion	Target confirmation	Diagnostic yield	PTX	Study	n	Lesion	Target confirmation	Diagnostic yield	PTX
Reisenauer 2022	30	17.5 mm median	TIL 96.7%	93.3%*	0%	Fielding 2019	29	12 mm mean	Target reached 96.6%	79.3%*	0%
Bashour 2024	67	17 mm median	34.3% → 98.6% with mCBCT	29.9% → 86.6%*	0%	BENEFIT 2021	54	23 mm median	rEBUS localization 96.2%	74.0%*	3.7%
CONFIRM 2026	155	14 mm median all ≤20 mm	TIL 99.4%	89.0% strict ATS/ACCP	0%	TARGET 2025	679	20.9 mm mean	Reached 98.7% rEBUS 91.7%	61.6% strict 83.2% conventional	2.8%
Chan 2026	200	13 mm median	TIL 99.0%	85.0% strict 92.0% accuracy	0.5%	RELIANT RAB arm, 2025	203	18 mm median	No standardized TIL CBCT optional 54.2%†	77.8% lesional tissue	2.0%

* Study-specific yield definition. † In RELIANT, CBCT was discretionary and not integrated; it was used in 54.2% of RAB cases.

Routine CBCT provides near-universal confirmation of the tool–lesion relationship.

Its independent effect on diagnostic yield remains unproven without randomized, protocol-mandated imaging comparisons.

Robotic Bronchoscopy Workflow: ① Patient Preparation



****Goal: Maintain a stable airway and reproducible lung volume for accurate navigation.**

1. Secure Patient Positioning

Supine positioning, fixation to the procedure table, and standard monitoring

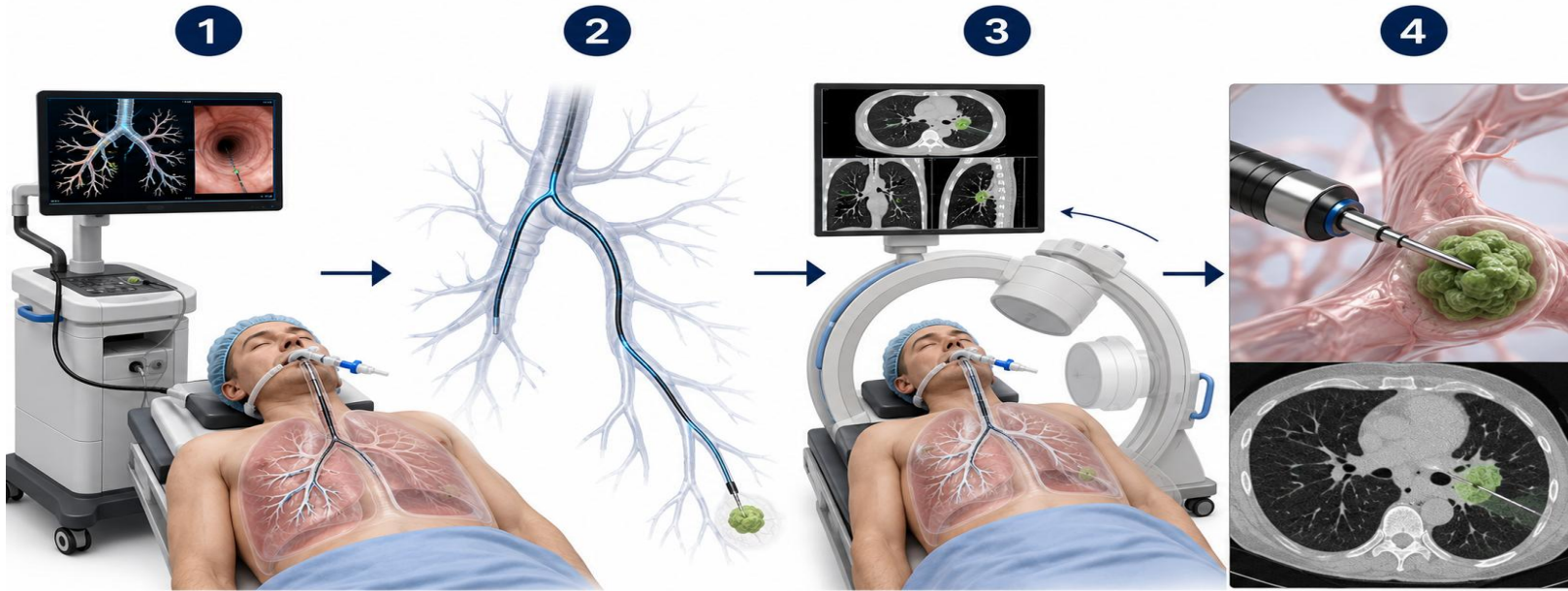
2. Bronchoscope-guided Intubation

Induction of general anesthesia and intubation with a platform-compatible endotracheal tube

3. Controlled Ventilation

Neuromuscular blockade and controlled ventilation to minimize respiratory motion

Robotic Bronchoscopy Workflow: ② Intraprocedural confirmation



****Navigation provides access; CBCT provides confirmation.**

1. System Docking and Registration

Robotic bronchoscope connection and synchronization with the CT-derived airway map

2. Navigation to the Target

Advance and stabilize the robotic catheter near the planned lesion

3. CBCT Target Confirmation

Confirm the actual lesion location and correct for CT-to-body divergence

4. Tool-in-Lesion Confirmation

Insert the biopsy tool and repeat CBCT or augmented fluoroscopy to verify tool position

Robotic Bronchoscopy Workflow: ③ Sample & Finish



1. Tissue Acquisition

Acquire tissue using needle, forceps, cryobiopsy after tool-in-lesion confirmation

2. Specimen Assessment

ROSE and specimen preparation for pathology, microbiology, and molecular testing

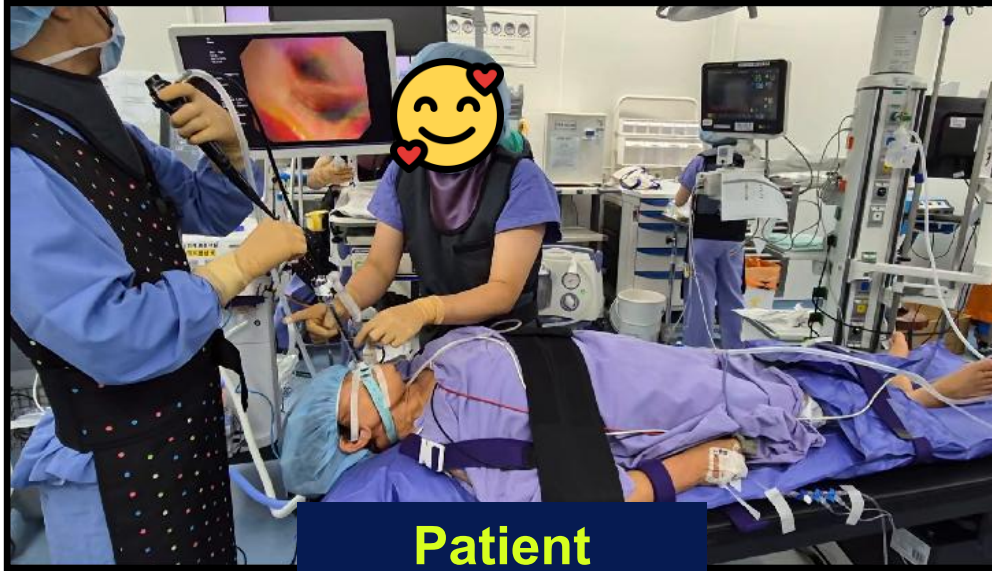
3. Hemostasis and Airway Toilet

Confirm hemostasis and perform suctioning $\pm$ bronchial washing/BAL when indicated

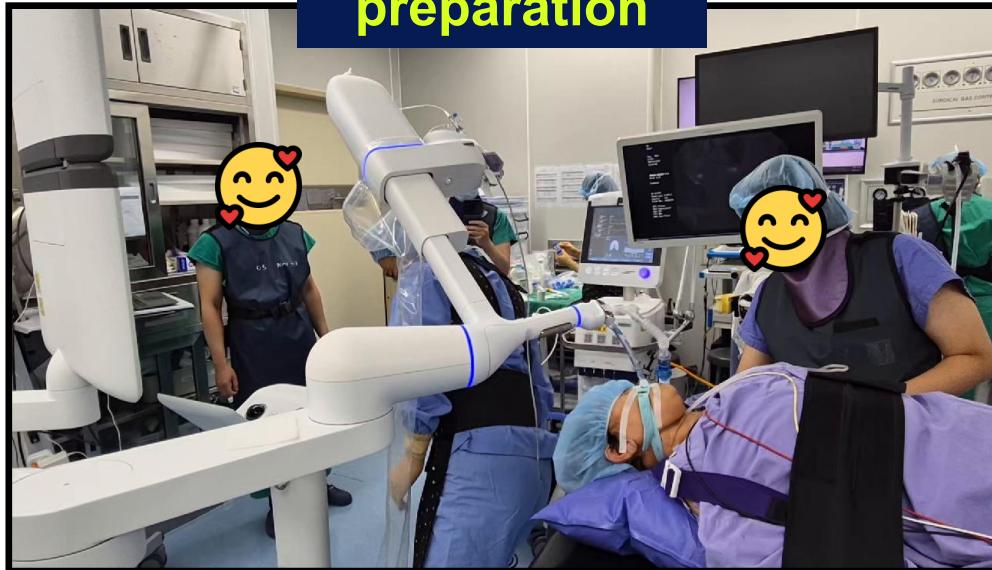
4. Undocking and Recovery

Withdraw the robotic catheter, emerge from anesthesia, extubate, and transfer to recovery

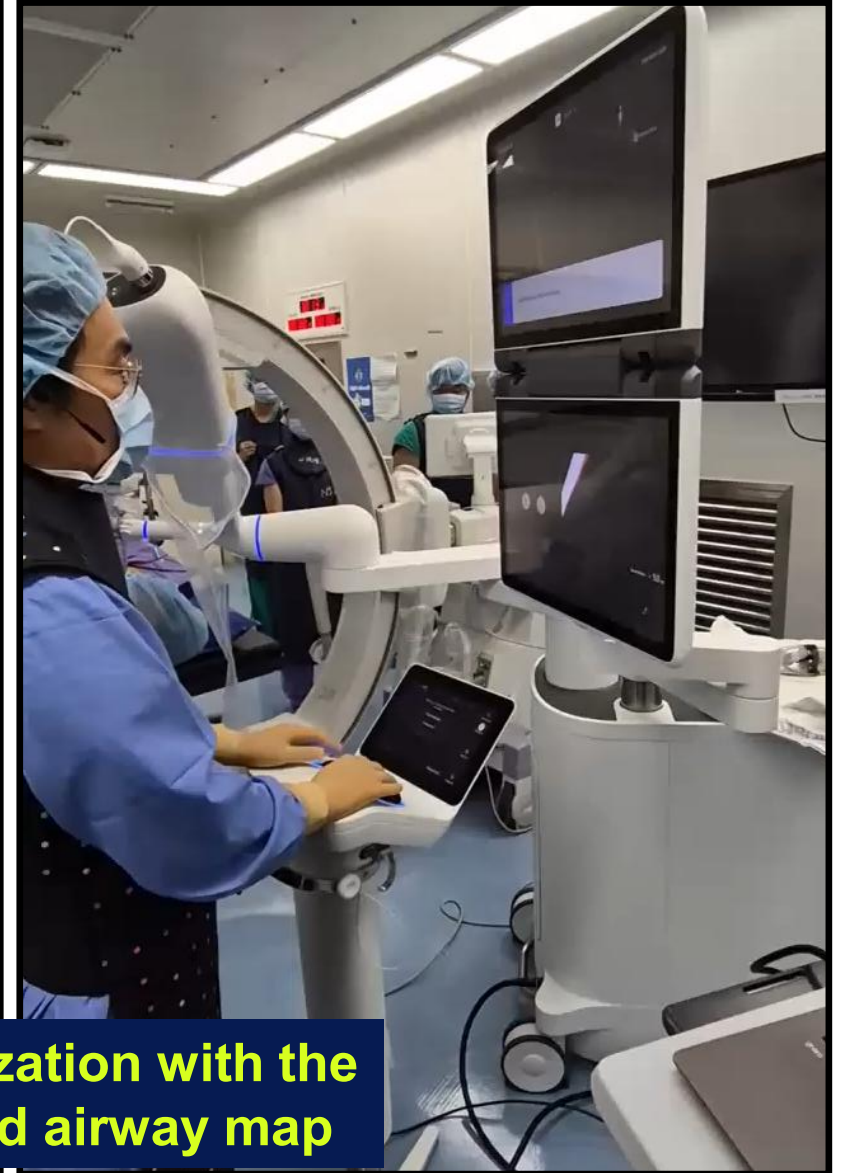
Robotic Bronchoscopy Workflow – Prepration & Synchronization



**Patient
preparation**



**Synchronization with the
CT-derived airway map**



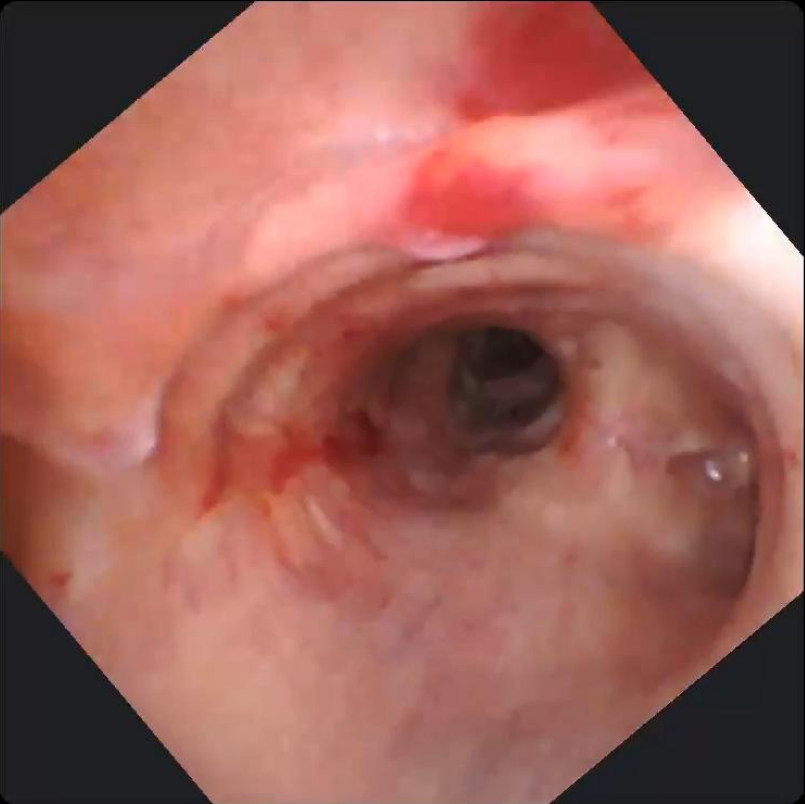
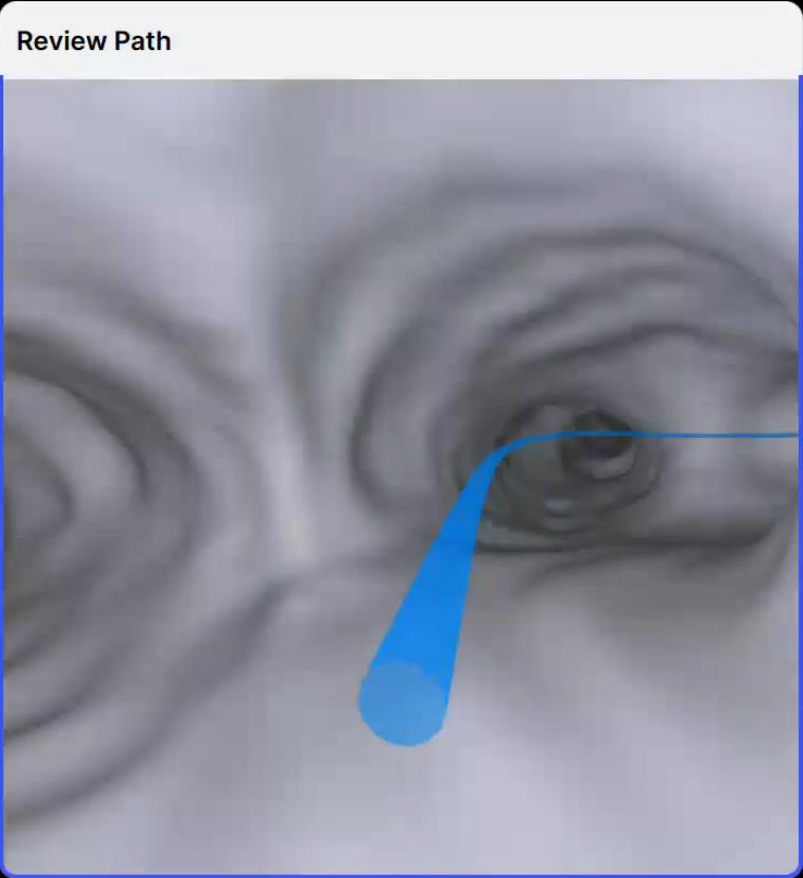
Robotic-Assisted Bronchoscopy in Practice: Case1 (56/F)



Target : RUL apical segment (about 10mm)

Robotic-Assisted Bronchoscopy in Practice: Case1 (56/F)

① Navigate to the planned target





Distance To Target Edge

Near	Far
63 mm	-- mm

Pleura Border

-- mm

Reference Area

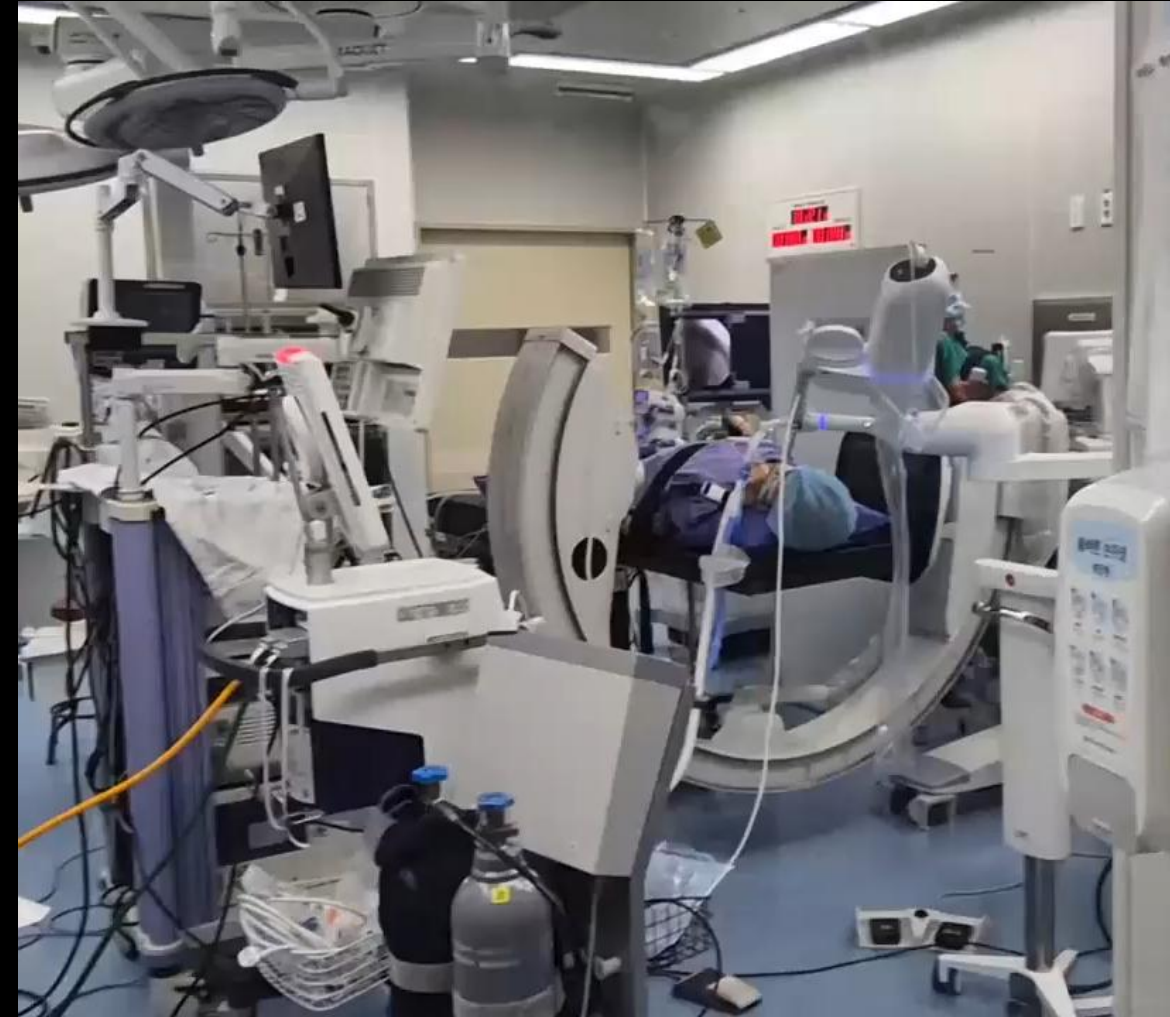
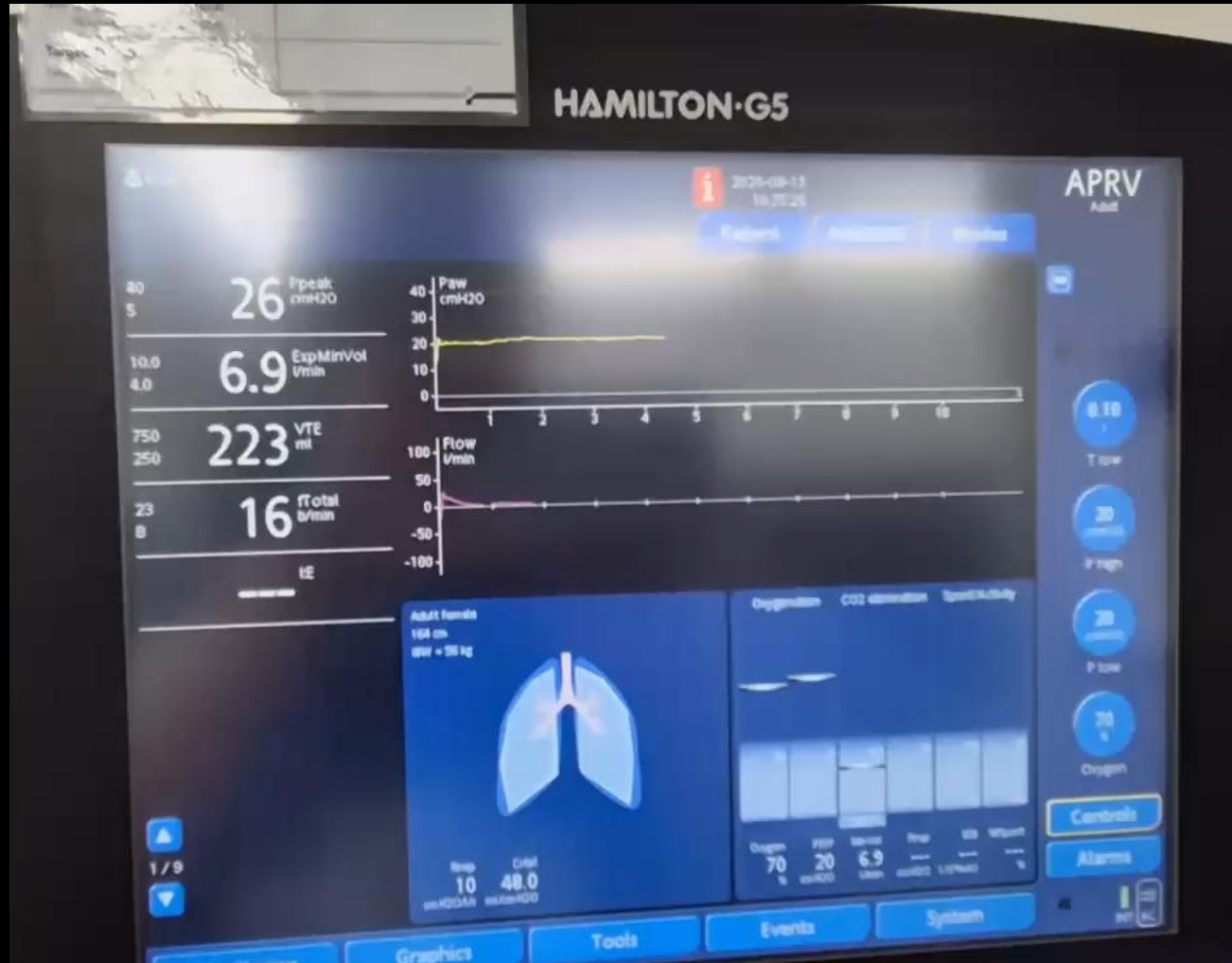
Near	Far	Point
-- mm	-- mm	-- mm

Bend Radius > 50 mm



Robotic-Assisted Bronchoscopy in Practice: Case1 (56/F)

② Acquire CBCT at the target – Breath holding / Acquire CBCT



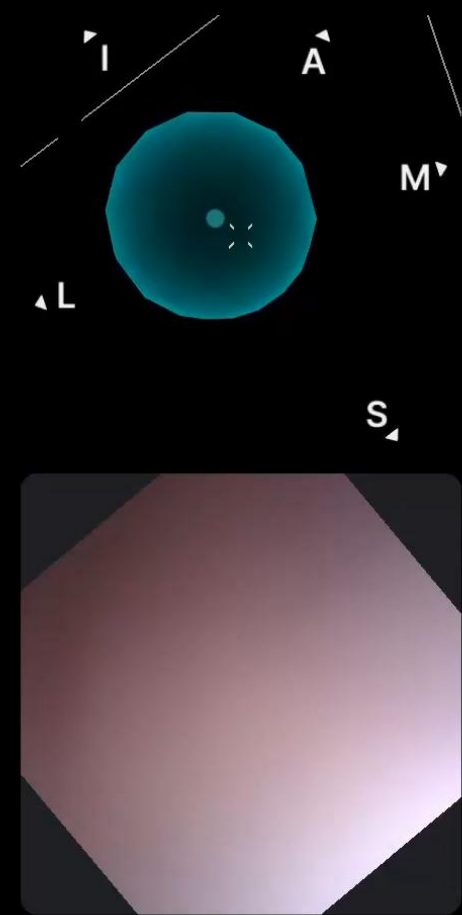
Robotic-Assisted Bronchoscopy in Practice: Case1 (56/F)

② Acquire CBCT at the target



Robotic-Assisted Bronchoscopy in Practice: Case1 (56/F)

③ Update artificial target in RAB



MIP

S

R

L

I

Fluoro Reference

5.371

0.00

24.53

8%

3%

Gy cm^2

mGy/min

mGy

● Live Image

● Reference Image

Distance To Target Edge

Near	Far
8 mm	18 mm

Pleura Border

16 mm

Reference Area

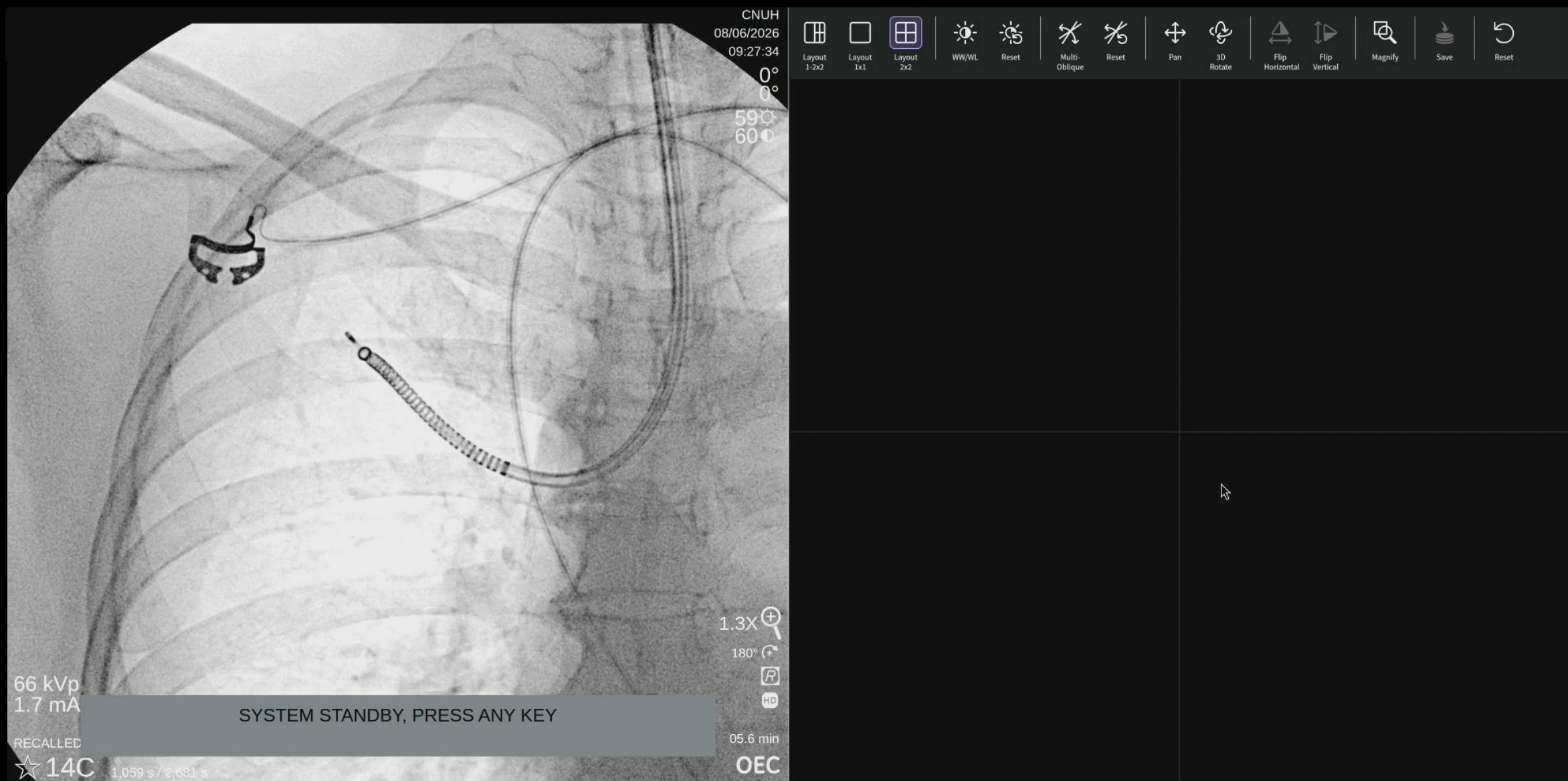
Near	Far	Point
-- mm	-- mm	-- mm

Bend Radius

10 mm

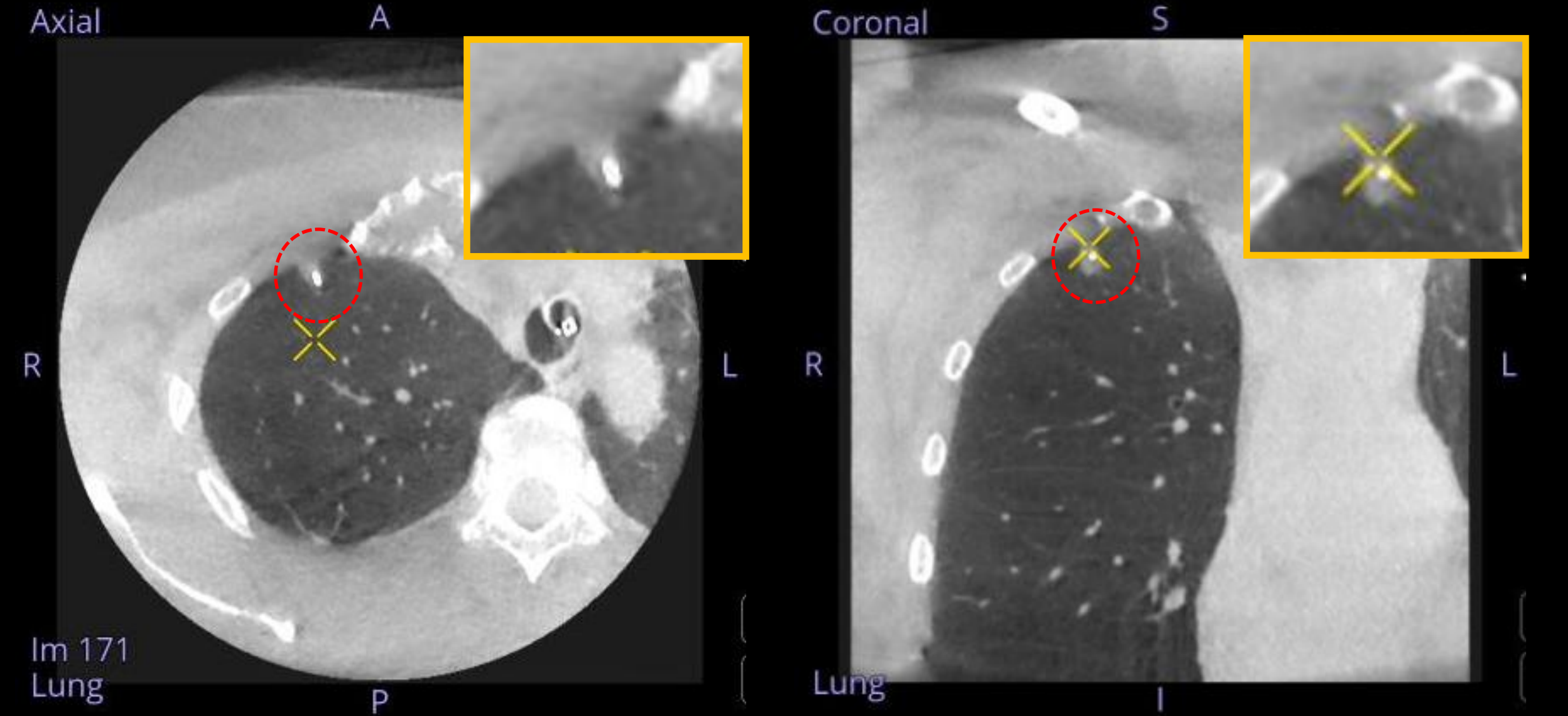
Robotic Bronchoscopy in Practice: Case1 (56/F)

③ Confirm tool in lesion before biopsy



Robotic Bronchoscopy in Practice: Case1 (56/F)

③ Confirm tool in lesion before biopsy



Robotic Bronchoscopy in Practice: Case1 (56/F)

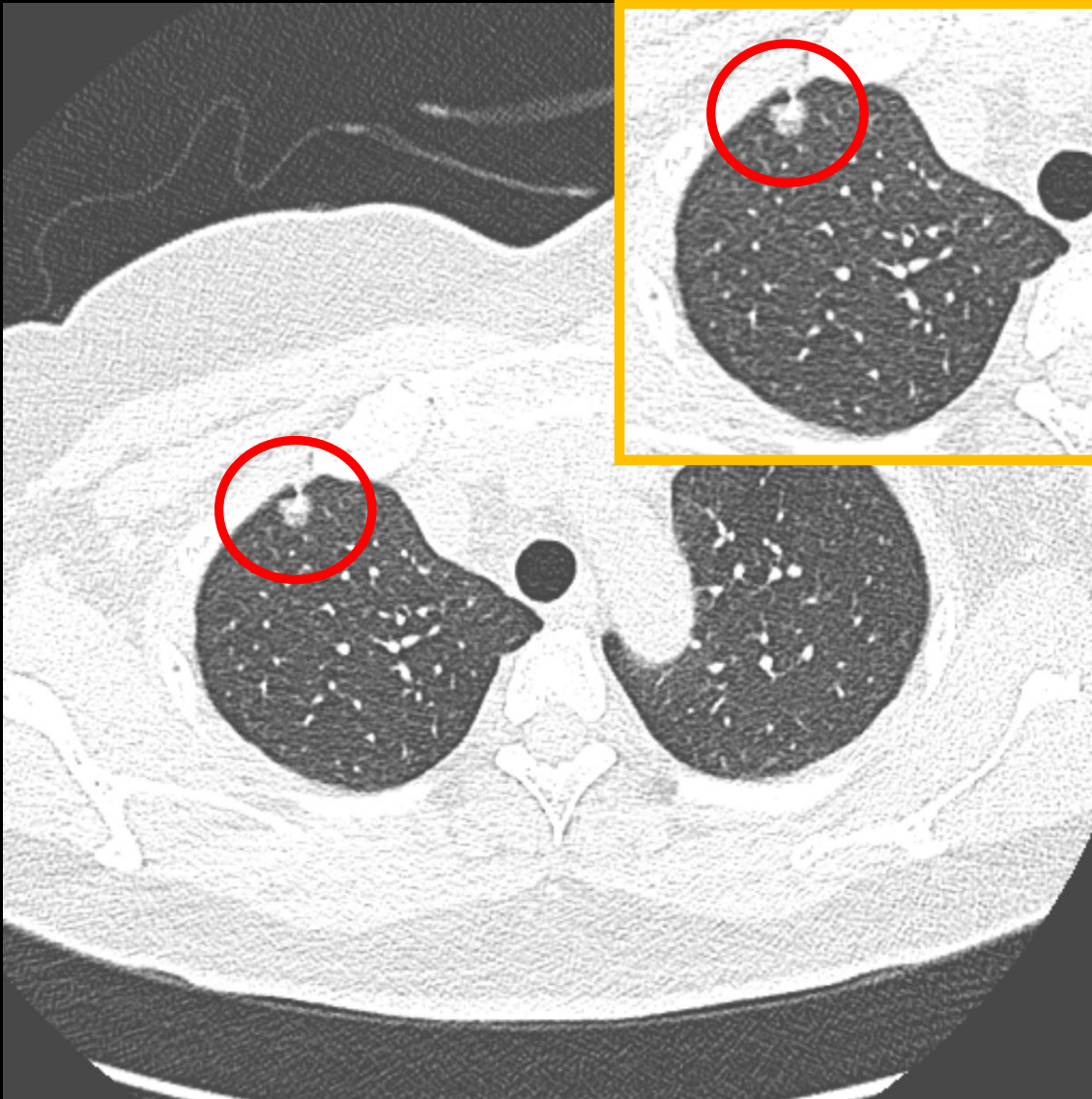
④ Biopsy



⑤ Washing

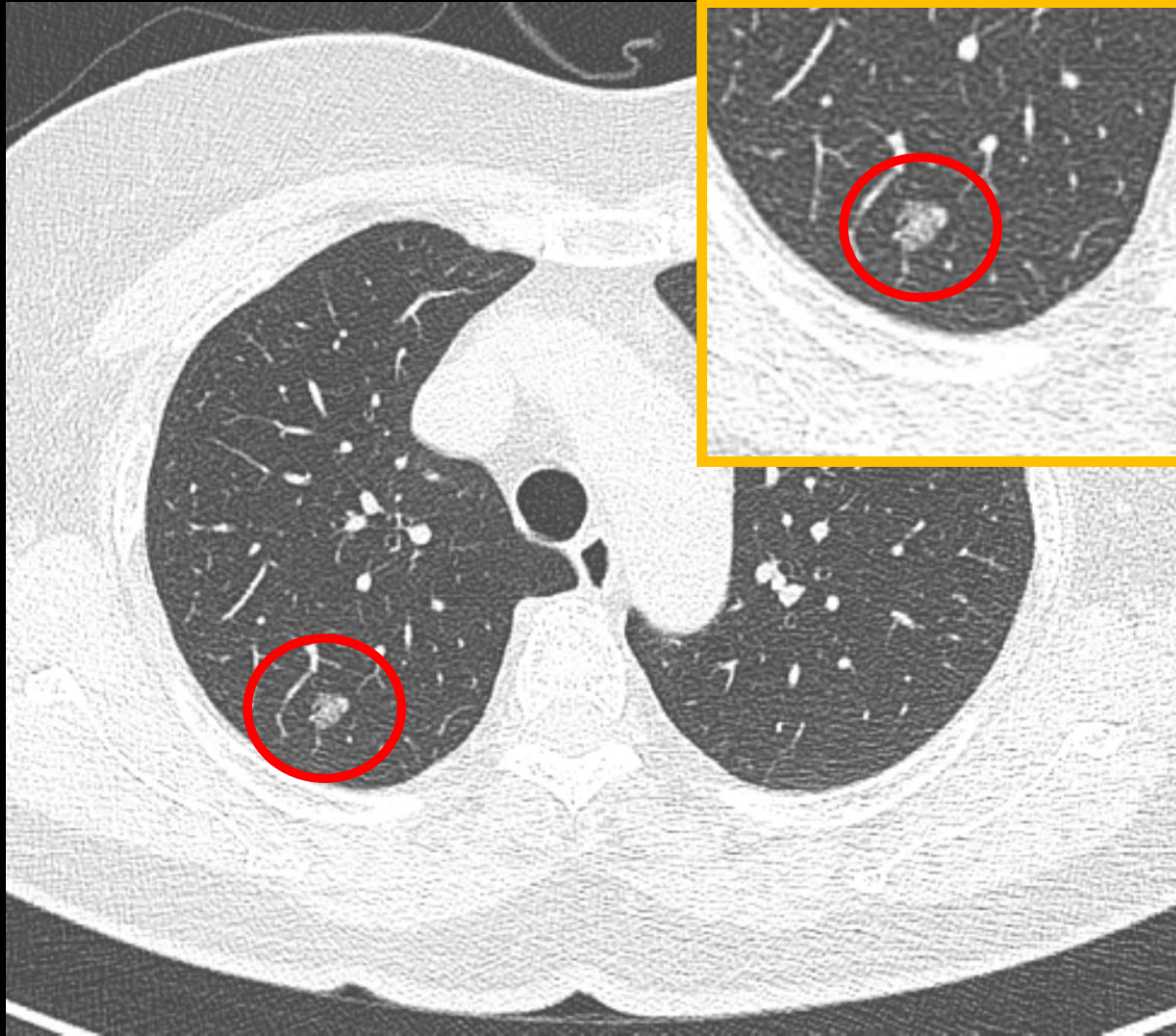


Robotic Bronchoscopy in Practice: Case1 (56/F)

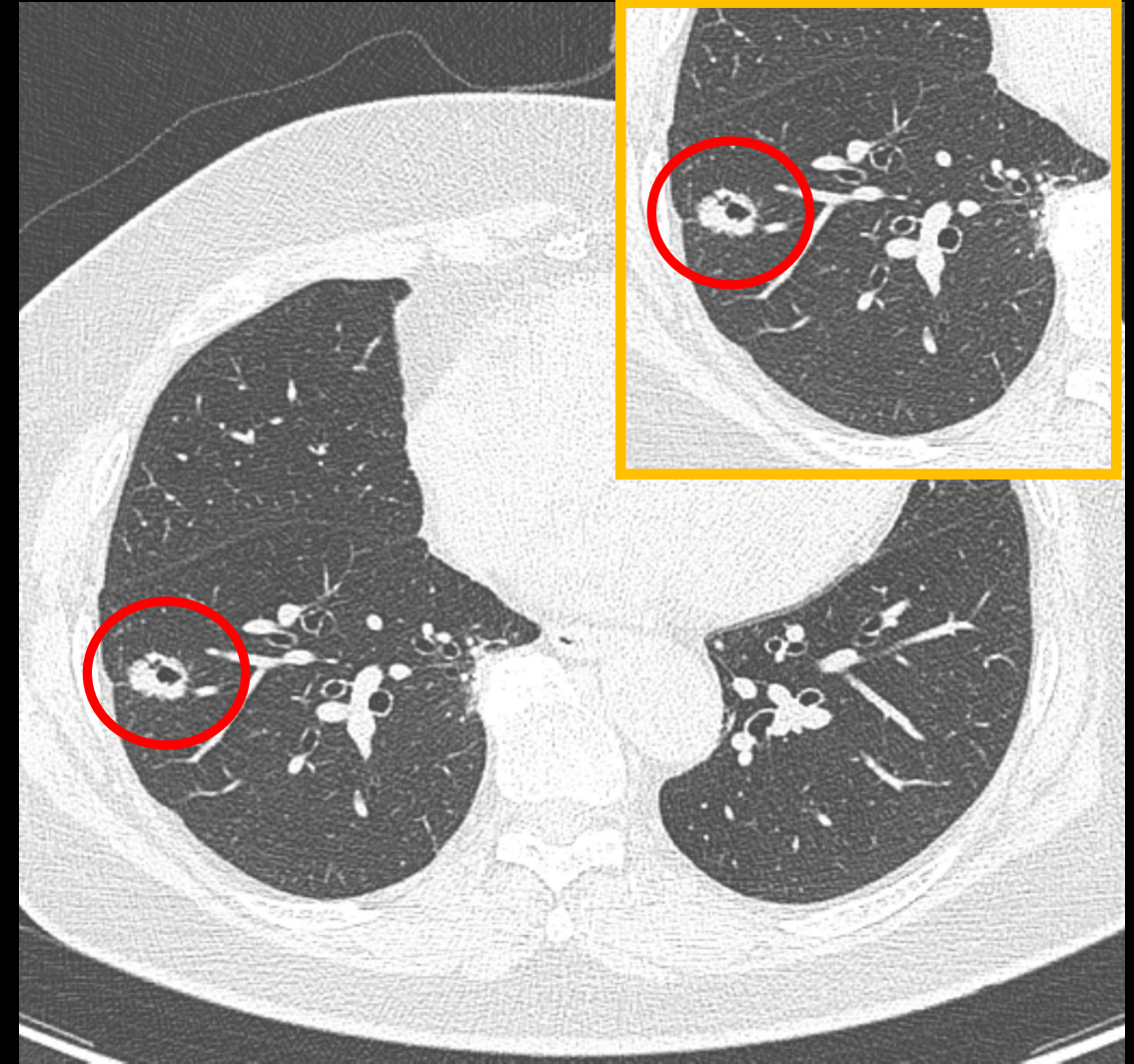


Target : Adenocarcinoma

Robotic Bronchoscopy in Practice: Case2 (71/F)



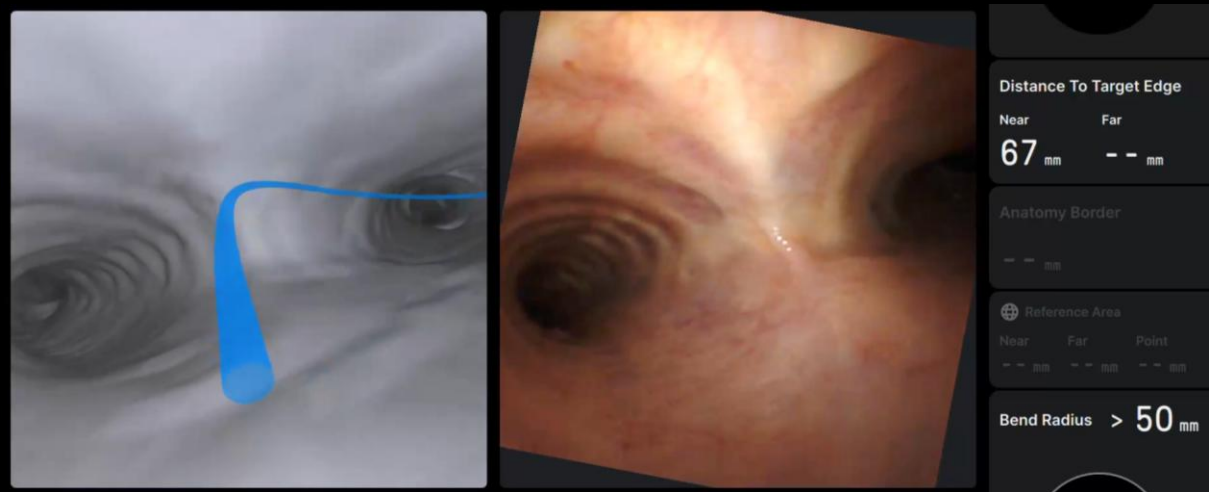
Target 1 : RUL posterior segment (about 8mm)



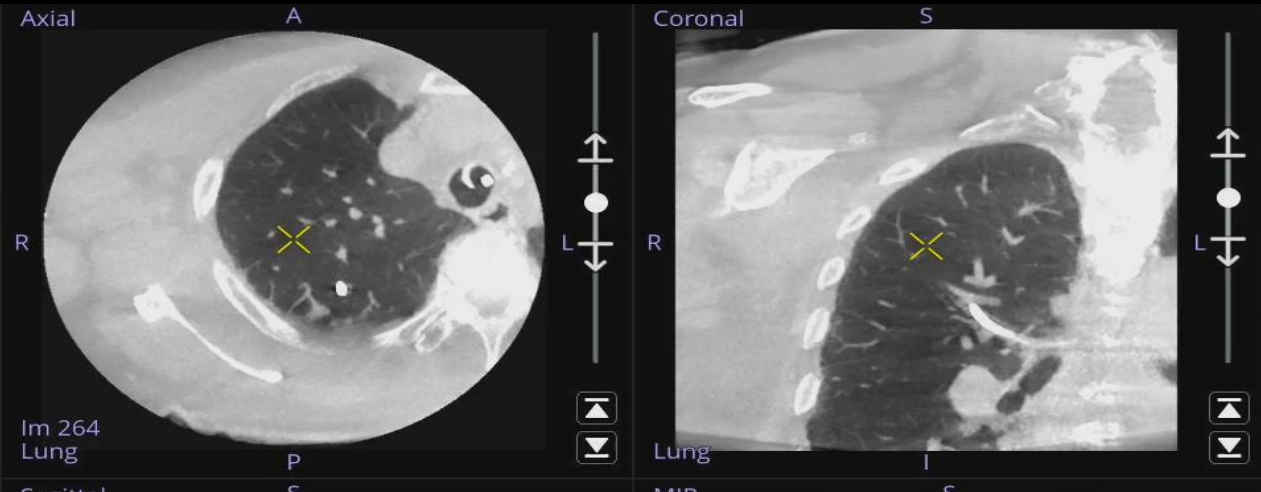
Target 2 : RLL anterior segment (about 15mm)

Robotic Bronchoscopy in Practice: Case2 (Target 1)

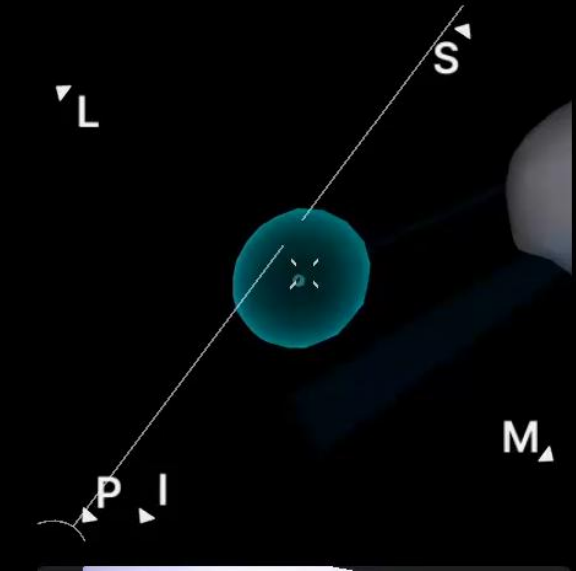
① Navigate to the planned target



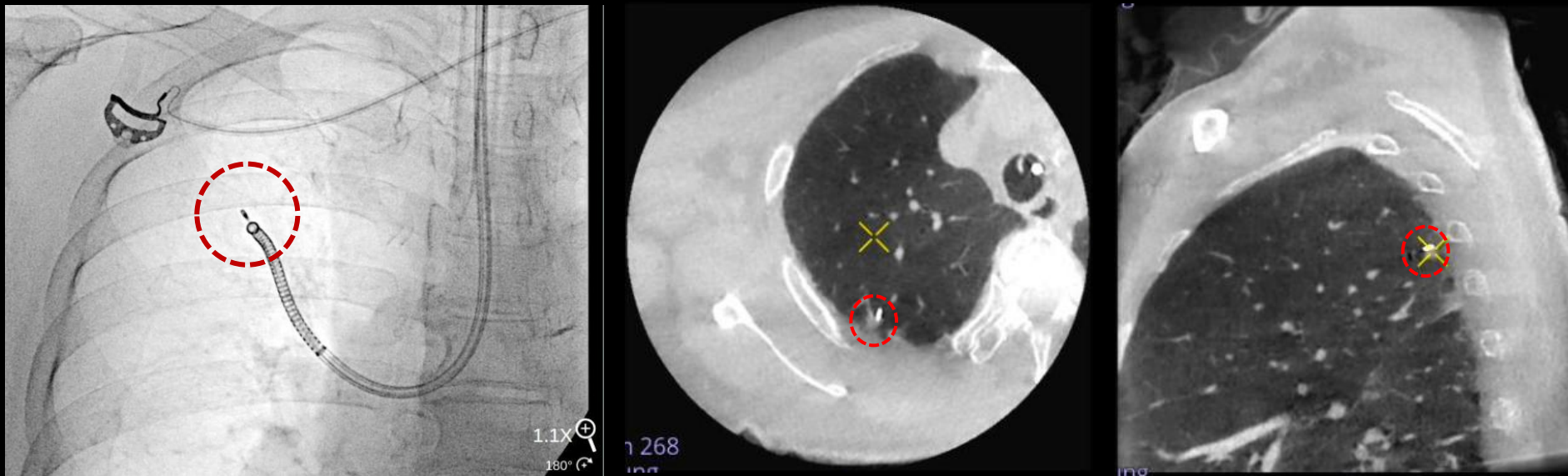
② Acquire CBCT at the target



③ Update artificial target

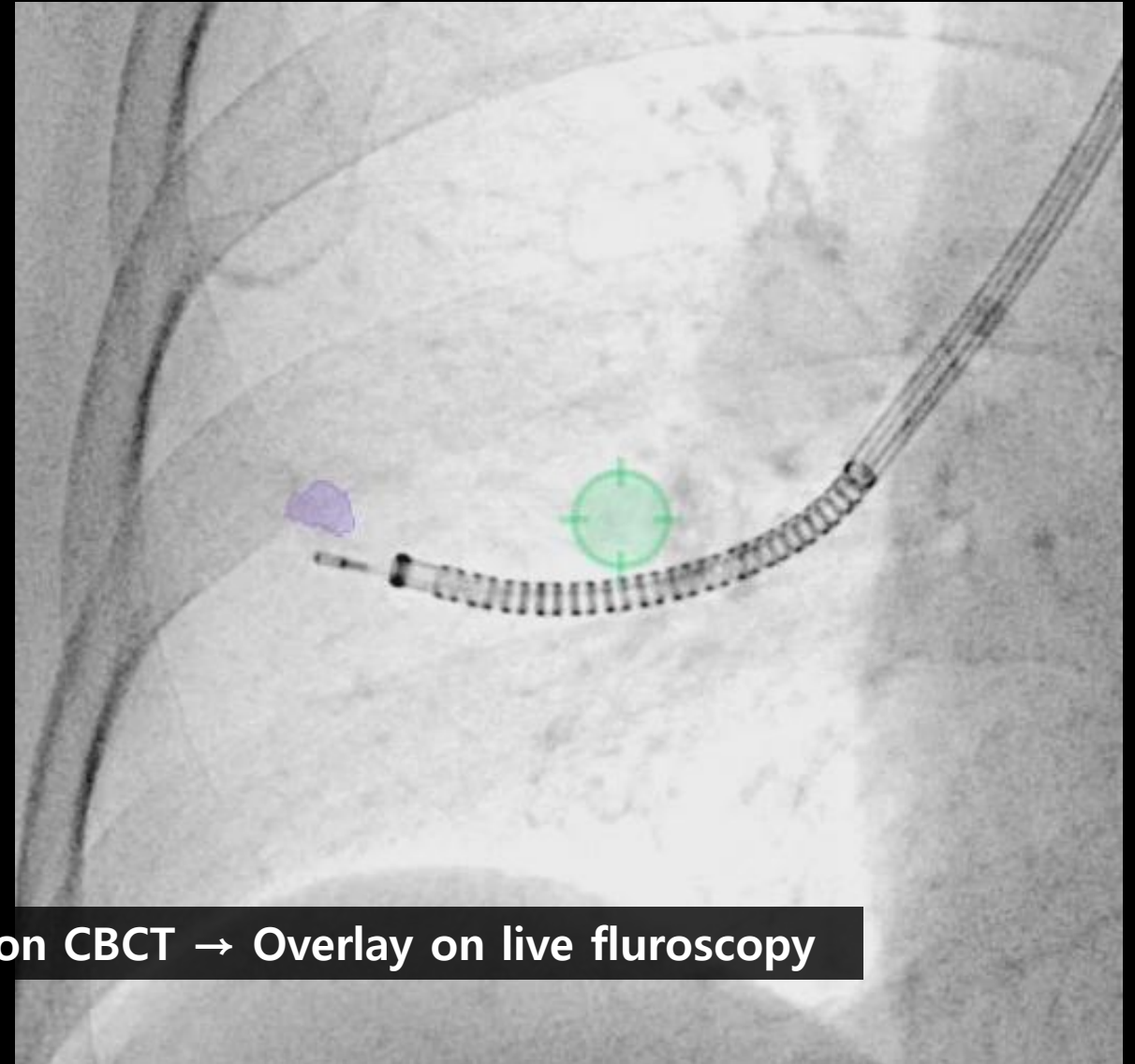


④ Confirm tool-in-lesion before biopsy

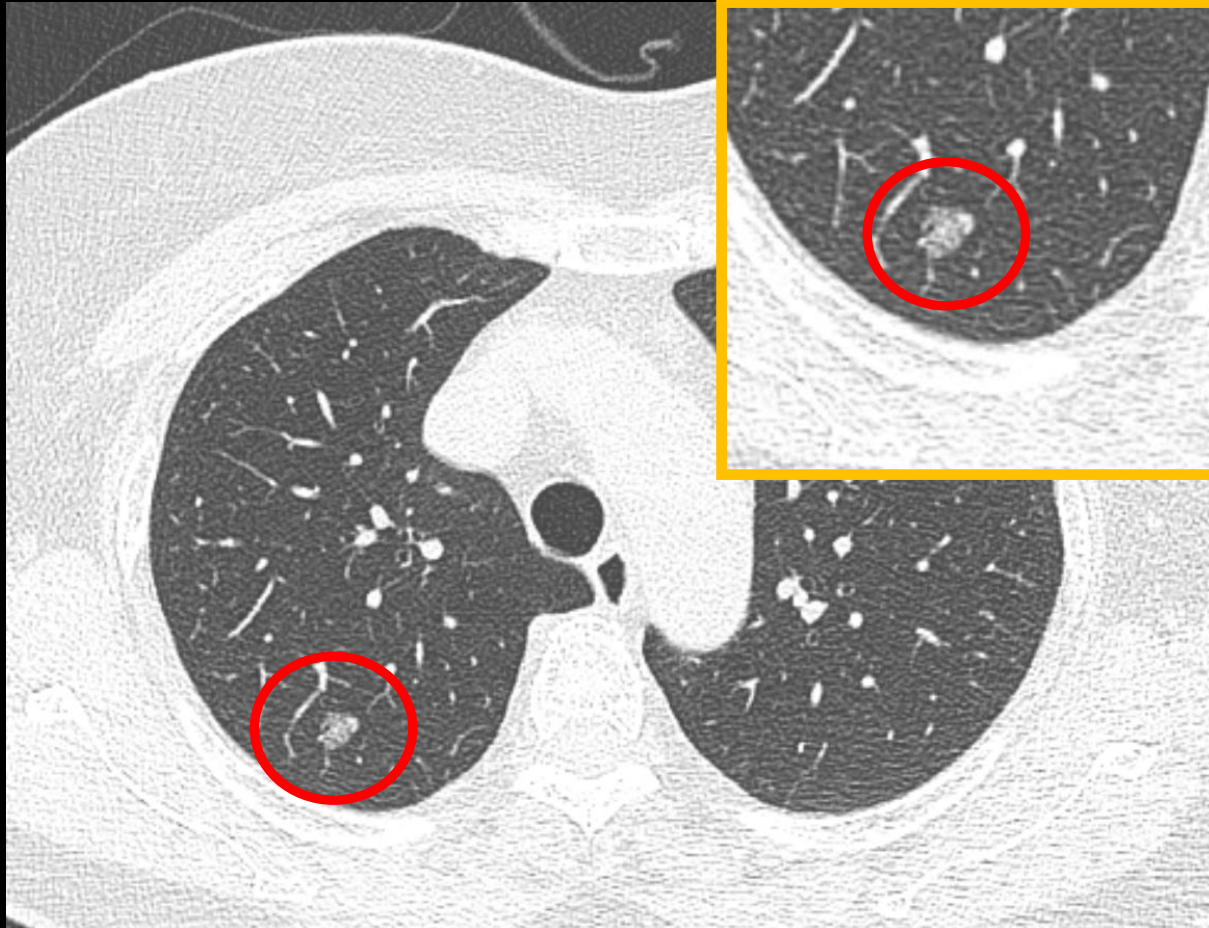


Robotic Bronchoscopy in Practice: Case2 (Target 2)

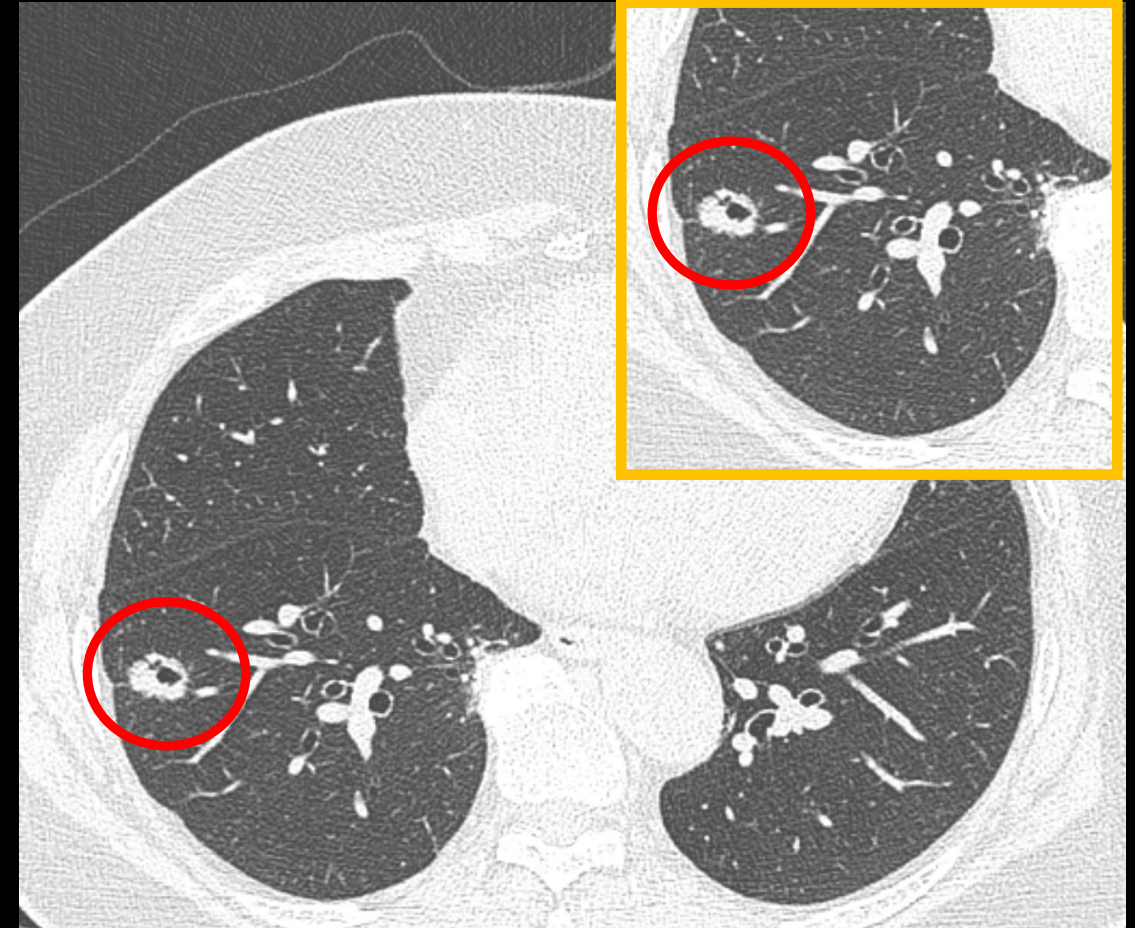
**Augmented Fluoroscopy Guidance



Robotic Bronchoscopy in Practice: Case2 (71/F)



**Target 1 : Adenocarcinoma,
EGFR Exon21 L858R mutation**



**Target 2 : Adenocarcinoma,
KRAS G12D mutation**

Consideration of Robotic Bronchoscopy

Patient selection—not technology alone—determines the clinical value of RAB

Yes RAB is most useful when...

- Tissue diagnosis or molecular profiling is expected to guide treatment
- Histologic confirmation of suspected metastatic disease is required
- The patient is at high risk for surgical complications
- Lesions are multiple, small, peripheral, or otherwise difficult to access
- A benign or inflammatory diagnosis remains clinically plausible

No Upfront surgery may be reasonable

- The lesion is solitary, peripheral, and technically resectable
- The probability of malignancy is high based on clinical and imaging findings
- The patient is medically fit with an acceptable operative risk
- There is no evidence of nodal or distant metastatic disease
- The biopsy result is unlikely to alter the surgical plan

Acknowledgements



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Division of Pulmonology and Allergy

경청해 주셔서 감사합니다.