2026 California Thoracic Society Annual Educational Conference

& Chronic Obstructive Pulmonary Disease Symposium

Thursday March 12, 2026-Sunday March 15, 2026

Earn up to 19 CME/CEU/MOC Credits

Jointly Provided by AKH Inc., Advancing Knowledge in Healthcare and the California Thoracic Society

PORTOLA HOTEL & SPA
AT MONTEREY BAY

Thursday March 12, 2026 (6 CME/CEU/MOC Credits)
COPD Symposium
Friday March 13, 2026 (6.5 CME/CEU/MOC Credits):
Advances in Interventional Pulmonary, Remote Monitoring in Pulmonary and Sleep Medicine, Approach to Symptom Management in Chronic Lung Disease and Critical Care
Saturday March 14, 2026 (6.5 CME/CEU/MOC Credits)
Sepsis and Shock, Extracorporeal Membrane Oxygenation, Inpatient Pulmonary Complications of Cancer Care
Sunday March 15, 2026
Fellow and Resident Track Symposium

California Thoracic Society
ATS Chapter Serving California and Arizona

AKH Inc.
ADVANCING KNOWLEDGE IN HEALTHCARE

California Thoracic Society
Annual Conference
March 12-15, 2026
Portola Hotel and Spa, Monterey, CA

Friday March 13, 2026

Advances in Interventional Pulmonary

8:00 am – 8:10 am: Welcome and Introduction

8:10 am – 8:55 am: Keynote Address – Evolution of Bronchoscopy in Diagnosing Lung Nodules

- **Christine Argento, MD (Johns Hopkins)** - This speaker will discuss the recent advances in bronchoscopy from radial EBUS, to electromagnetic navigation, to robot technologies, and how advancement has improved lung nodule diagnosis.

8:55 am – 9:20 am: Implications of the new TNM9 staging for lung cancer

- **Colleen Channick, MD (UC Los Angeles)** - This speaker will discuss the new TNM staging system, how staging is currently performed, and how to approach staging in the patient with suspected lung cancer.

9:20 am – 9:45 am: Management of Central Airway Obstruction

- **Raed Alalawi, MD (Arizona-Phoenix)**- This speaker will discuss how interventional pulmonary practitioners can manage and treat central airway obstruction.

9:45 am – 10:10 am: The Changing Landscape of Pleural Disease Management

- **Joon Chang, MD (Stanford)** - This speaker will discuss advances in management of pleural disease by the interventional pulmonologist including when to use an intrapleural catheter, and when to use

10:10 am – 10:20 am: Question and Answer

10:20 am – 10:50 am: Break

Remote Monitoring in Lung Disease and Sleep Medicine

10:50 am – 11:15 am: Developing a home spirometry program

- **Steven Hays, MD (UC San Francisco)** - This speaker will discuss how to approach the development of a home spirometry program to monitor lung disease, how to use digital health technologies to integrate results into the EHR.

11:15 am – 11:40 am: Home Non-Invasive Ventilator Monitoring

- **Christal Hawkins, RRT (UC San Diego)** - This speaker will review how to monitor home non-invasive ventilators for compliance and for adequate control of sleep disordered breathing.

11:40 am – 11:55 am: Pro: Virtual Pulmonary Rehabilitation is Ready for Prime Time

- **Aimee Kizziar, RRT (UC Davis)** - This speaker will argue in favor of virtual pulmonary rehabilitation programs.

11:55 am – 12:10 pm: Con: Virtual Pulmonary Rehabilitation is not ready for Prime Time

- **Julia Rigler, BA. RRT (UC San Francisco)** - This speaker will argue against virtual pulmonary rehabilitation programs.

12:10 pm – 12:20 pm: Question and Answer

12:20 pm – 1:00 pm: Awards Ceremony

1:00 pm – 2:00 pm: Lunch

Hands On Session:

2:00 pm – 3:00 pm: Robotic Bronchoscopy **Raed Alalawi, MD (Arizona-Phoenix) & Joon Chang, MD (Stanford)** Cough Monitoring **Lauren Eggert, MD (UCSF)**; Endobronchial Ultrasound **Pranjal Patel, MD (Stanford)**; Home NIV **Krystle Leung, MD (Stanford)**

3:00 pm – 3:20 pm: Break

Approach to Symptom Management in the Pulmonary Patient

3:20 pm – 3:45 pm: Addressing the Unmet Needs of Refractory Chronic Cough

- **Krishna Sundar, MD FCCP FAASM ATSF (UC Davis)** - This speaker will discuss the etiology behind refractory chronic cough and the treatment approaches for management

3:45 pm – 4:10 pm: Frailty in Pulmonary and Critical Care Medicine

- **Jonathan Singer, MD MPH (UC San Francisco)** - This speaker will discuss the concept of frailty and how it impacts health in patients with lung disease. The speaker will also discuss how frailty can change as lung disease is treated.

4:10 pm – 4:35 pm: Palliative Care for the Patient with Chronic Lung Disease

- **Grace Amadi, MD (UC Davis)** - This speaker will discuss how palliative care teams can benefit patients with chronic various lung disease including ILD, COPD, and pulmonary hypertension.

4:35 pm – 5:00 pm: Palliative Care for the Patient with Critical Illness

- **B. Corbett Walsh, MD, MBE (UC Los Angeles)** - This speaker will discuss how palliative care teams can benefit the inpatient with advancing lung disease, the importance of advance care planning, and palliative care in the intensive care unit.

5:00 pm – 5:10 pm: Question and Answer

5:30 pm – 7:00 pm: Women in Pulmonary, Critical Care, and Sleep Medicine (NON-CME) – Food and beverages will be served

California Thoracic Society
ATS Chapter Serving California and Arizona

AKH Inc. Advancing Knowledge in Healthcare

California Thoracic Society Annual Conference
March 12-15, 2026
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Dr. A. Christine Argento is an Associate Professor of Medicine at The Johns Hopkins University where she specializes in Interventional Pulmonology. She graduated from St. George's University School of Medicine, did an Internal Medicine Residency at the University of Medicine and Dentistry in New Jersey, a Pulmonary and Critical Care Fellowship at Yale University and an additional fellowship in Interventional Pulmonology at Duke University.

Her main focus is to diagnose and palliate patients with lung cancer and she deals with pulmonary nodules and pleural disease. Her research involves new technologies that further the field of Interventional Pulmonology, increasing awareness of lung cancer and lung cancer screening, disparities in lung cancer and procedural simulation education for a global community.

She is President of the Association of Interventional Pulmonary Program Directors (AIPPD), is a Founding and Board member of the Women in Interventional Pulmonary group. She also holds leadership roles in national societies such as CHEST, American Thoracic Society (ATS) as well as the American Association of Bronchology and Interventional Pulmonary (AABIP).

Evolution of Bronchoscopy in Diagnosing Lung Nodules

Christine Argento, MD, FCCP, D-AABIP
Director of Bronchoscopy
Interventional Pulmonology
Associate Professor of Medicine
Johns Hopkins University

Disclosures

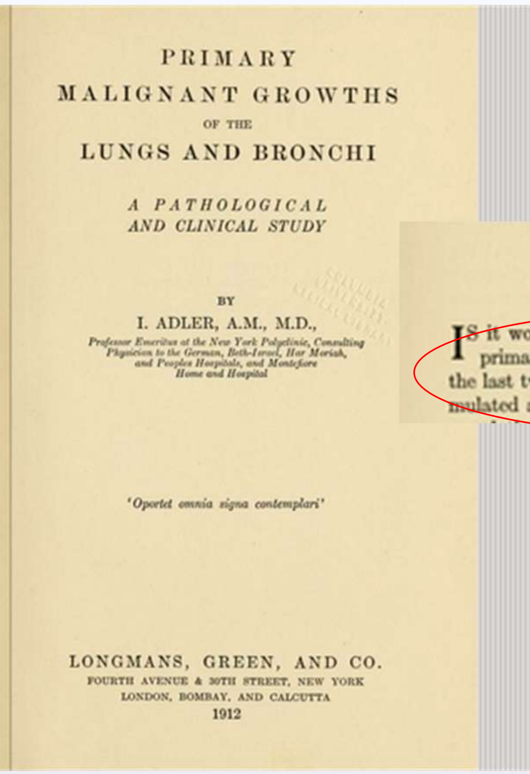
- I have the following relationships with ACCME defined ineligible companies:
  - Olympus
  - Cook
  - AstraZeneca
  - Daiichi Sankyo
  - ERBE
  - BD
- I **WILL NOT** discuss off-label use and/or investigational use of any drugs or devices.

Overview

- Lung Cancer History and Statistics
- Risk Factors
- Lung Cancer Screening
- New Technologies for Lung Cancer Diagnosis and Staging
- Biomarker Testing
- Future

Once a rare disease…"Mountain Sickness"

The 20th Century



PRIMARY
MALIGNANT GROWTHS
OF THE
LUNGS AND BRONCHI

A PATHOLOGICAL AND CLINICAL STUDY

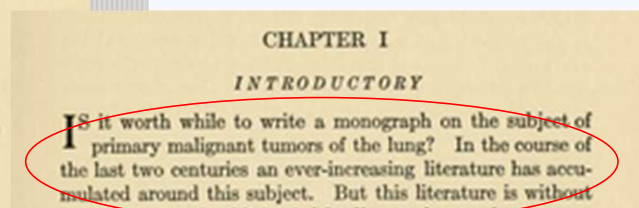
BY

I. ADLER, A.M., M.D.,

Professor Emeritus at the New York Polyclinic, Consulting Physician to the German, Beth-Israel, Har Moriah, and Peoples Hospitals, and Montefiore Home and Hospital

'Oportet omnia signa contemplari'

LONGMANS, GREEN, AND CO.
FOURTH AVENUE & 30TH STREET, NEW YORK
LONDON, BOMBAY, AND CALCUTTA
1912

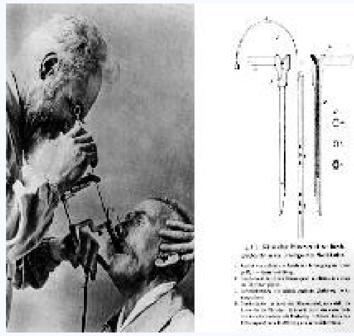


CHAPTER I

INTRODUCTORY

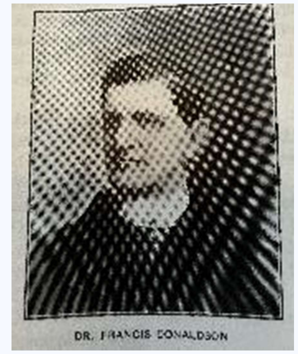
IS it worth while to write a monograph on the subject of primary malignant tumors of the lung? In the course of the last two centuries an ever-increasing literature has accumulated around this subject. But this literature is without

History of IP at Hopkins

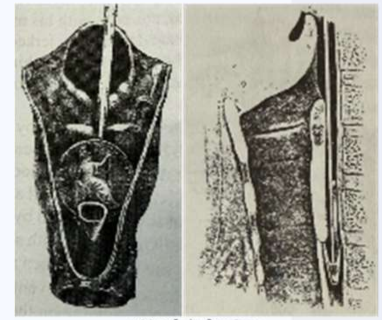


Gustav Killian, "Father of Bronchoscopy: 1897

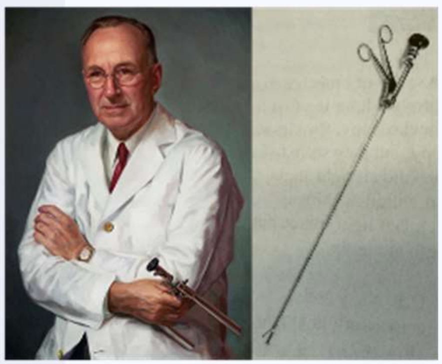
Chevalier Jackson, 1916
Visualization, extraction
FB Mortality 2%



First laryngologist in Maryland :
1863 Professor

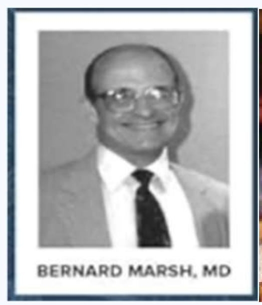


1867: Coin Catcher:
Foreign Body Aspiration Mortality of 35%



Edwin Broyles (1984-1977)
MD, JHUSOM 1919
Trained under Halstead,
Brought bronchoscopy to Hopkins
1963: Broyles Endoscopy Unit
Broyles grasping forceps

1966 Shigeto Ikeda
"more hope with the
bronchoscope"



1969, Wang and Marsh introduce Flexible bronchoscopy to Maryland

- Residents were "head holders" for 500 cases before they were permitted to hold a bronchoscope
- 20 cases every 3 hours for morning session

Bronchoscopic Needle Aspiration Biopsy of Paratracheal Tumors'

KO PEN WANG, PETER TERRY, and BERNARD MARSH

Brief History of TBNA

1949: Eduardo Schieppati performs first TBNA with a 1mm steel needle through a rigid bronchoscope publishes data in the *Review of Argentine Medical Association*

1954: At Hopkins: Rigid TBNA performed for mitral valve evaluation prior to surgery

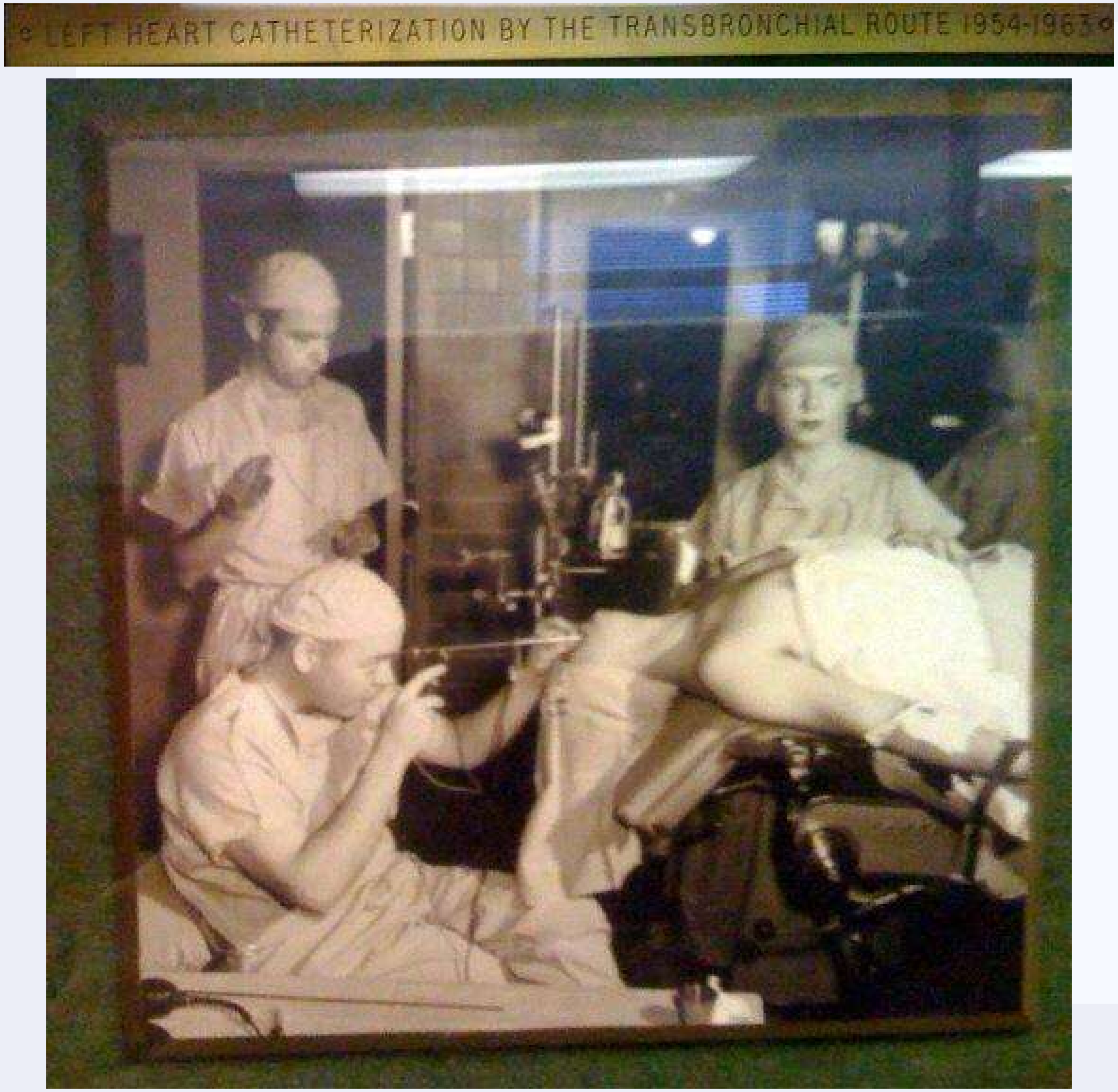
1959 Mediastinoscopy first described by Carlens

- TBNA rarely used/mentioned in the literature

1978: Wang, Terry and Marsh publish *Bronchoscopic needle aspiration biopsy of paratracheal tumors*

Carlens, Dis Chest 36:343-352

Wang, Am Rev Respir Dis. 1978 Jul;118(1):17-21.



Left Heart Catheterization by the Transbronchial Route

Technic and Applications in Physiologic and Diagnostic Investigations

By Andrew G. Morrow, M.D., F.A.C.S., Eugene Braunwald, M.D., J. Alex Haller, Jr., M.D., and Edward H. Sharp, M.D.

Left heart catheterization is proving of increasing importance in the study of a variety of congenital and acquired cardiovascular defects. More than 500 left heart catheterizations have been performed by the transbronchial method without death or serious sequelae. This technic and its usefulness in clinical investigation and in the assessment of valvular heart disease are described.

THE development and application of technics for catheterization of the left side of the heart are proving of increasing importance in the study of patients with many types of cardiovascular disease. Two methods of left atrial puncture are commonly employed. The transbronchial method, devised by Allison and Linden[1, 2] and Facquet et al.[3] and the posterior percutaneous route employed first by Bjork et al.[4] Since 1953 more than 500 transbronchial left heart catheterizations have been performed at the National Heart Institute where the technic has been extended to permit the passage of a catheter into the left ventricle. The present report summarizes our experience with the method and the details of technic and instrumentation that have evolved.

Anatomic Considerations

When the left atrium is of normal size, as in many forms of congenital heart disease and in most patients with isolated aortic valve disease, it lies below and anterior to the carina and main bronchi. The space between the carina and left atrium is occupied only by mediastinal fat and areolar tissue. Irrespective of the degree of left atrial enlargement, the portion of the atrium adjacent to the left bronchus is, in most instances, extrapericardial. The anatomic relations of the normal-sized left atrium to the bronchial tree are shown in figure 1. As the left atrium enlarges, as in mitral valvular disease, it extends in a posterior and superior direction and may come in contact with or even elevate and compress the left main bronchus. The altered relationships of the left atrium to the bronchi in mitral valve disease are illustrated in figure 2.

Equipment and Instrumentation

A standard 7- or 8-mm. bronchoscope is used in adult patients. The transbronchial needle will pass through a 5-mm. full-lumen bronchoscope and an instrument of this size is used in children.

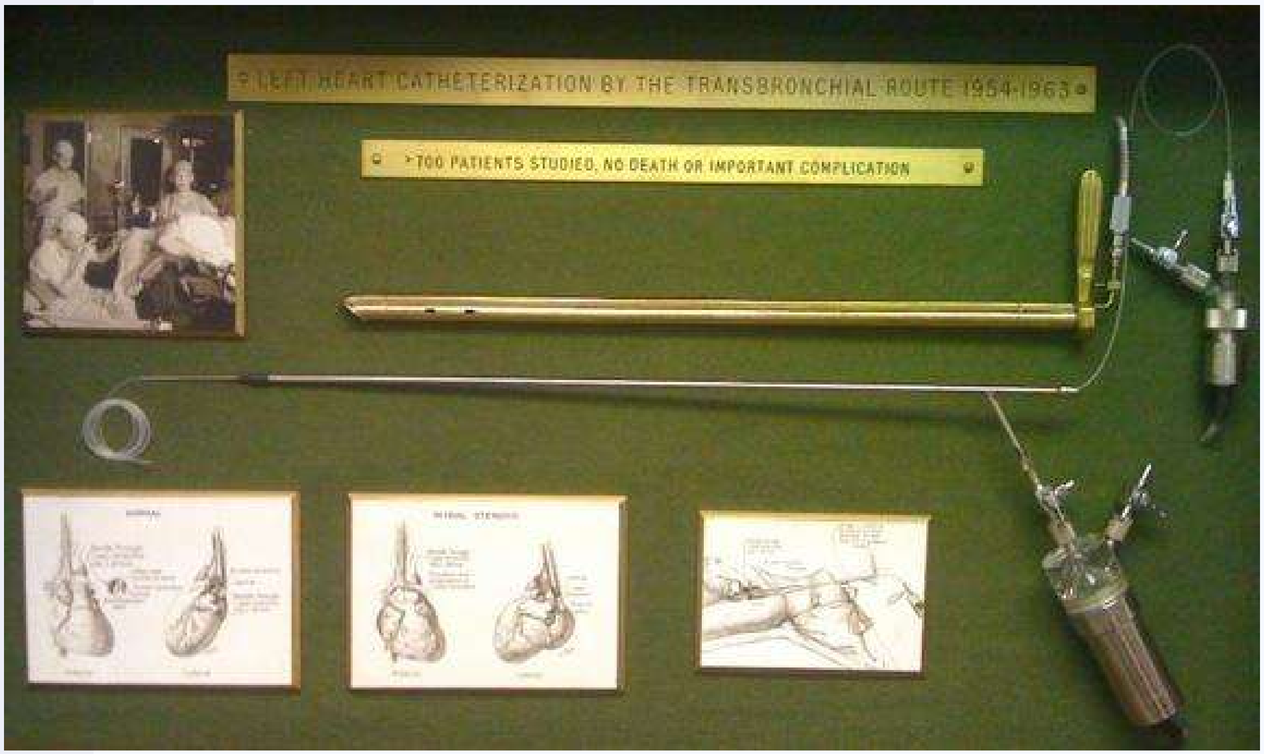
The needle used for bronchoscopic catheterization is illustrated schematically in figure 3.* It consists of an outer tube of stainless steel tubing 4.5 mm. in outside diameter and 50 cm. long, which divides proximally into 2 limbs, each fitted with a female Luer connector. The needle itself is constructed of 17-gage stainless steel tubing and a sleeve 6 cm. from its tip threads into the distal end of the outer tube. The needle point is ground to a 45° bevel and the edges are carefully smoothed to prevent the catheter from being caught or cut. The portion of the needle projecting from the outer tube represents the effective penetrating length of the needle. A safety collar is soldered to the needle just distal to its connection with the outer tube. The remainder of the needle, when assembled, lies inside the outer tube and its proximal end terminates in a funnel-shaped tip that lies within the upper Luer connector of the outer tube. Holes are placed at intervals along the portion of the needle within the outer tube to permit the evacuation of all air from the space between the outer tube and needle and to allow the transmission of pressure pulses from the needle tip to the outer tube.

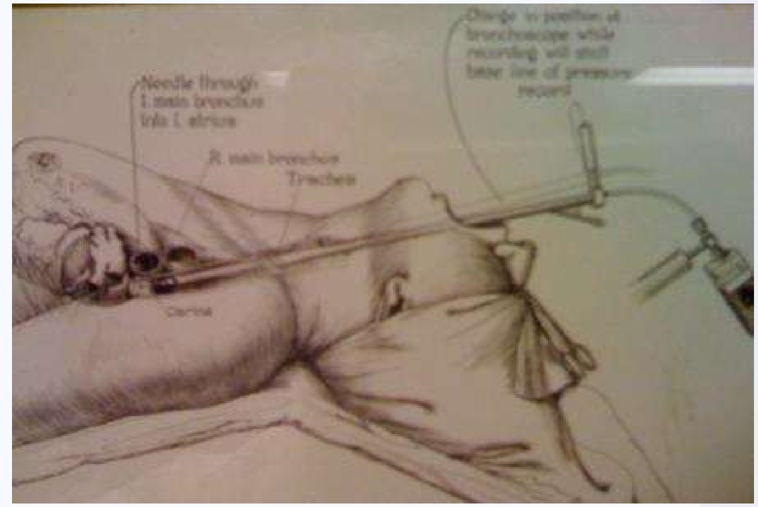
Prior to use the needle and outer tube are assembled and the upper proximal limb of the outer tube is closed with a needle plug. The instrument is sterilized by autoclaving it. The lower proximal limb of the outer tube is connected via a 3-way stopcock to a Statham P23A transducer filled with 70 per cent alcohol.

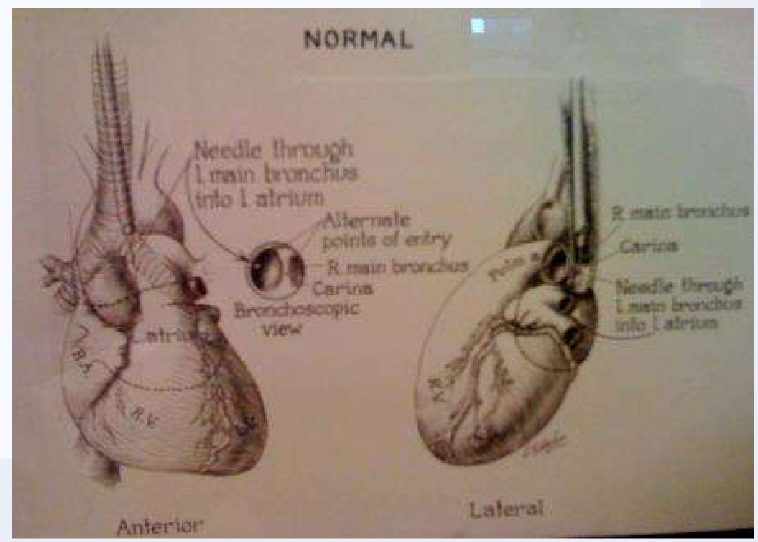
The catheter ordinarily employed is made of poly-

From the Clinic of Surgery, National Heart Institute, Bethesda, Md.

* Manufactured by the Becton-Dickinson Co., Rutherford, N. J.


LEFT HEART CATHETERIZATION BY THE TRANSBRONCHIAL ROUTE 1954-1963
>700 PATIENTS STUDIED, NO DEATH OR IMPORTANT COMPLICATION

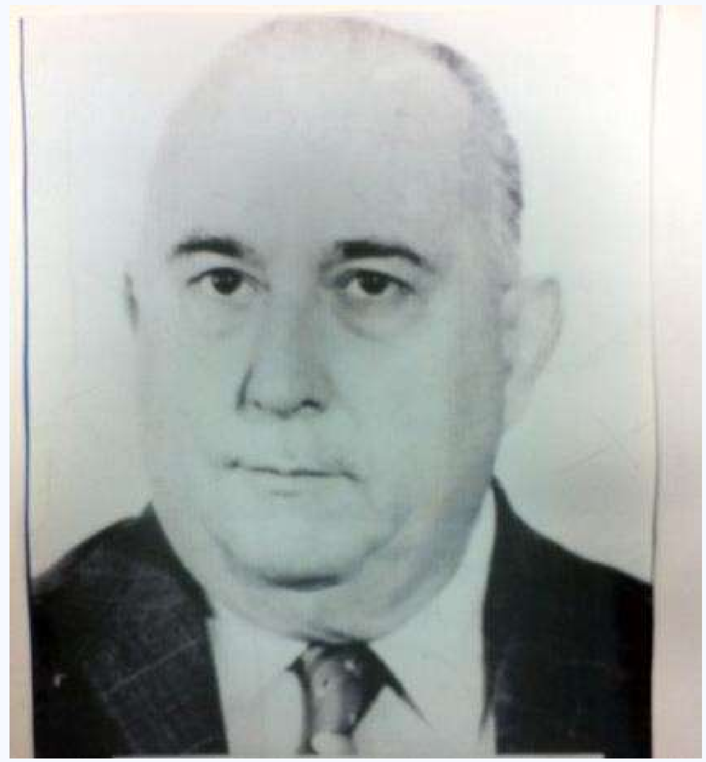

Change in position of bronchoscope while recording will shift base line of pressure record
Needle through L main bronchus into L atrium
R. main bronchus
Trachea
Carina


NORMAL
Needle through L main bronchus into L atrium
Alternate points of entry
R. main bronchus
Carina
Bronchoscopic view
R main bronchus
Carina
Needle through L main bronchus into L atrium
Anterior
Lateral

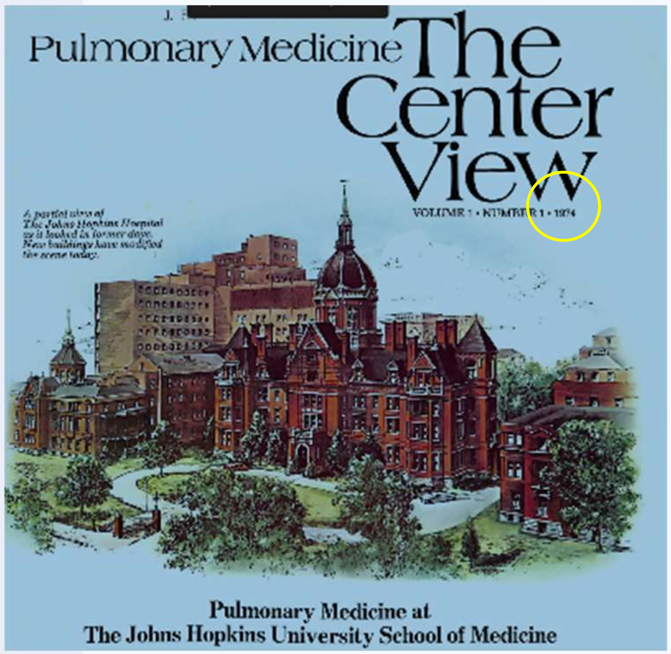
The fathers of TBNA

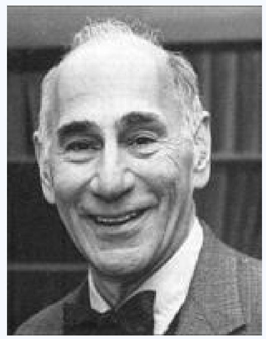
Ko Pen Wang

Eduardo Schieppati



Despite the Innovation: History repeats itself





Solbert Permutt, MD

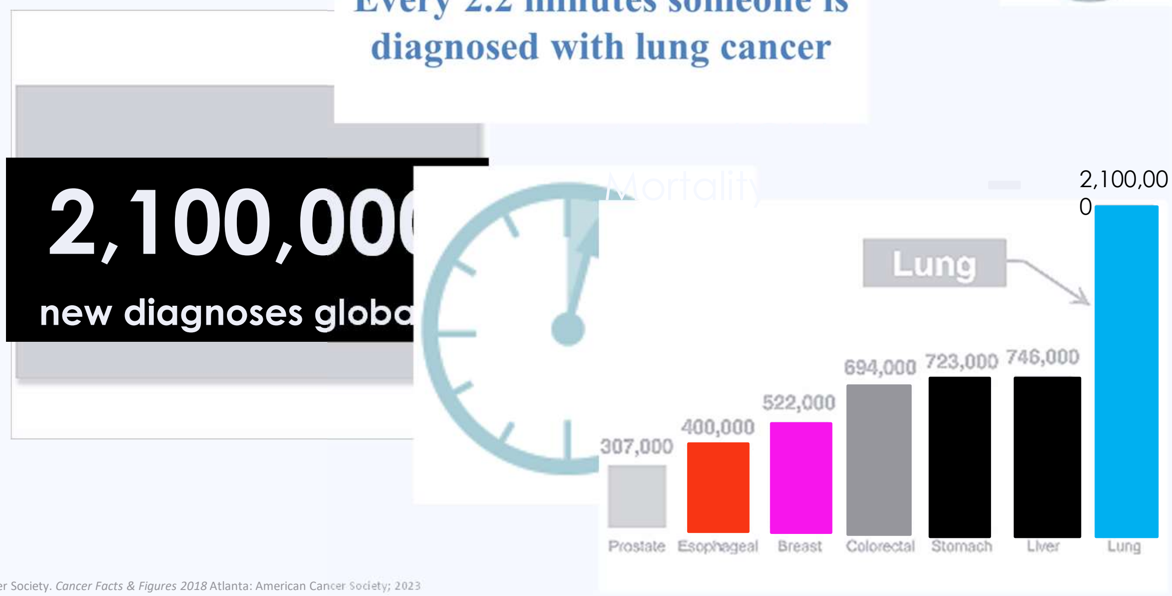
All procedures may not be feasible in all cases

We believe that all of these, and other procedures as well, have a valid place in the diagnostic armamentarium of the medical profession. These rapid advances in diagnostic chest medicine and surgery have outstripped our knowledge of how best to apply them in the individual patient problem. It is the academic institutions with the necessary key people which should determine the indications for, and train physicians in, the appropriate techniques. The Lung Center allows for the appropriate impetus and amalgamation to accomplish such a task. That our objective can be fully or quickly achieved is not easily guaranteed. To determine which procedure is best under which circumstances will not be accomplished in all cases. All procedures may not be feasible in all cases. It is difficult to predict how long a time, or study of how many patients, will be needed to draw significant conclusions, but it is obvious that a systematized, interdisciplinary approach is necessary. What is ultimately needed is a guide for the community physician now faced with a bewildering array of methods, some of which he and his local colleagues can master and some of which will continue to require the facilities of a large medical center.

The rapid growth in the number of diagnostic procedures available for the study of patients with lung disease has led to considerable controversy and confusion over which of these is most applicable in a specific clinical problem. What is *not* needed is another study showing that the results are good with any one particular method. What *is* needed is a study, in expert hands, of a combined approach which will enable us to define which type of lesion needs which procedure in which sequence, in order to facilitate a rapidly arrived at and appropriate diagnosis with the least morbidity for the patient. To the best of our cumulative judgment, we have begun a logical approach to this current problem. These techniques can be expanded to include diffuse lung disease in immunosuppressed hosts, hospital-acquired pneumonia and, possibly, the solitary pulmonary nodule. This approach should not only benefit the patient but may eventually reduce markedly the number of procedures performed, the number of tests currently overloading laboratory services, and the duration of hospital stay which contributes to the high cost of medical care.

Our Why

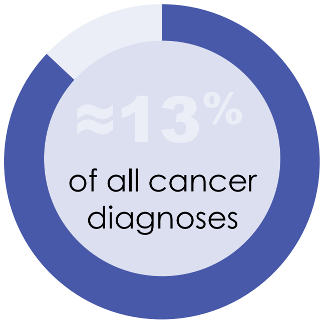
Every 2.2 minutes someone is diagnosed with lung cancer

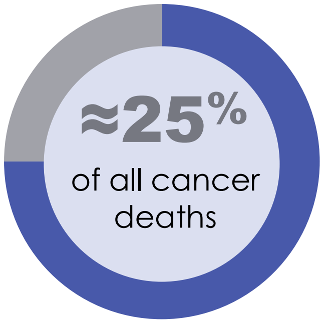


American Cancer Society. *Cancer Facts & Figures 2018* Atlanta: American Cancer Society; 2023

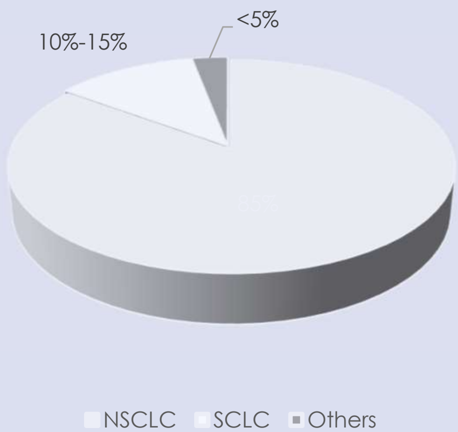
The Burden of Lung Cancer

Lung cancer accounts for

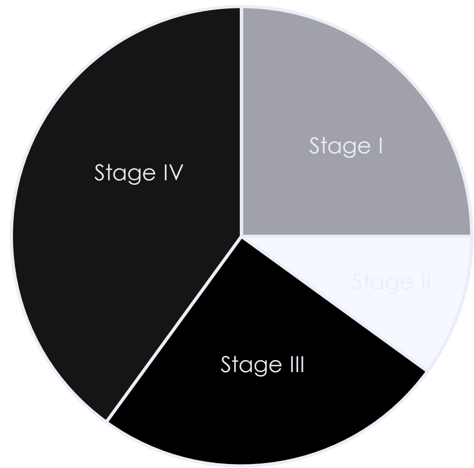




NSCLC accounts for approximately 85% of lung cancers

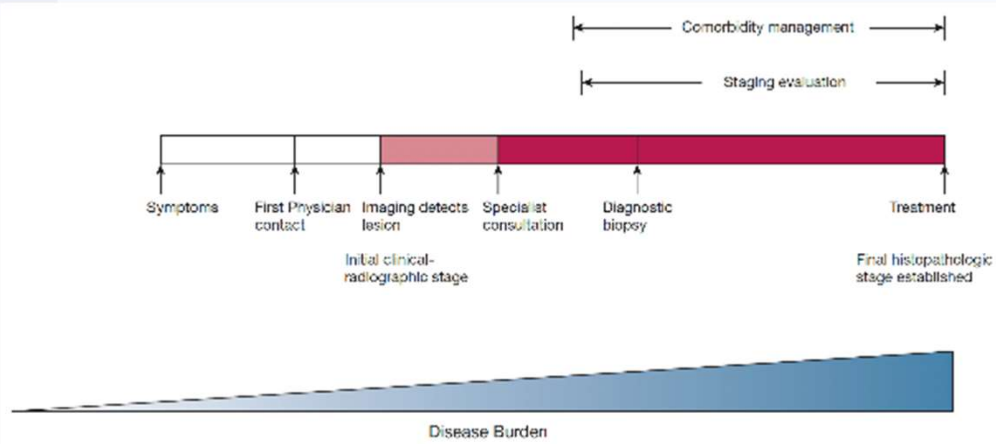


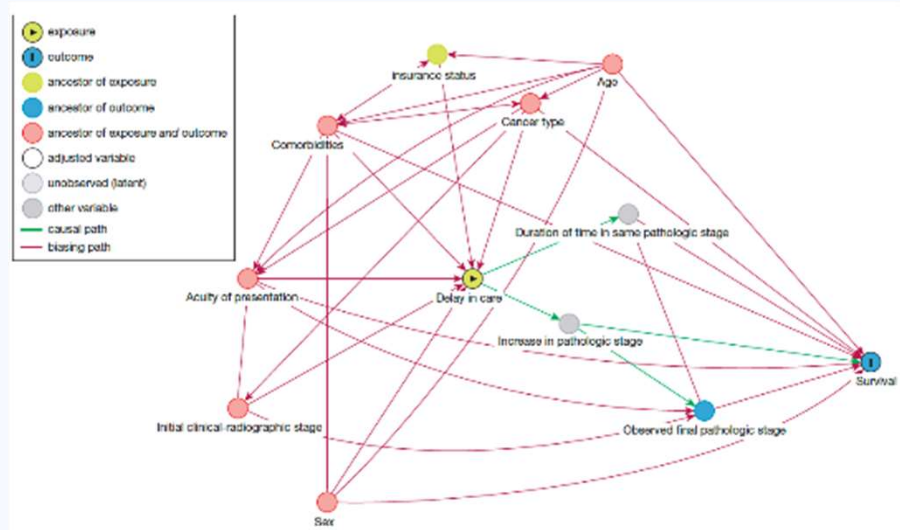
Approximately 75% of patients with NSCLC present at an advanced stage

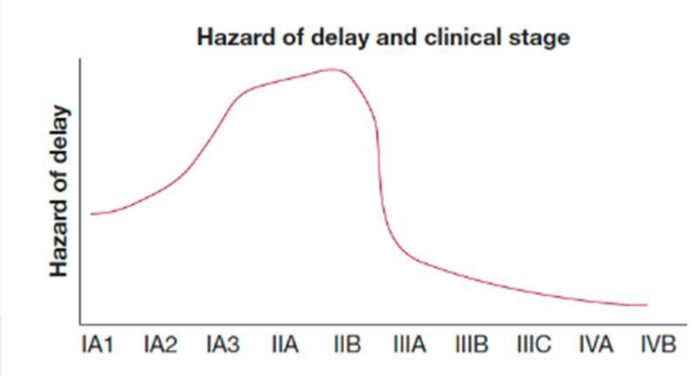


EpiCast Report: Non-Small Cell Lung Cancer (NSCLC)- Epidemiology Forecast to 2025. New York, NY: GlobalData; November 2016.
American Cancer Society. Cancer Facts & Figures 2025. Atlanta, GA: ACS; 2018.

Impact of delays in the diagnosis of lung cancer







Zuniga, Ost Chest, 2025

How can the Interventional Pulmonologist improve outcomes?

TYPICAL TURNAROUND TIME FOR PREDICTIVE BIOMARKER TESTING
(business days)

Sample received by testing laboratory

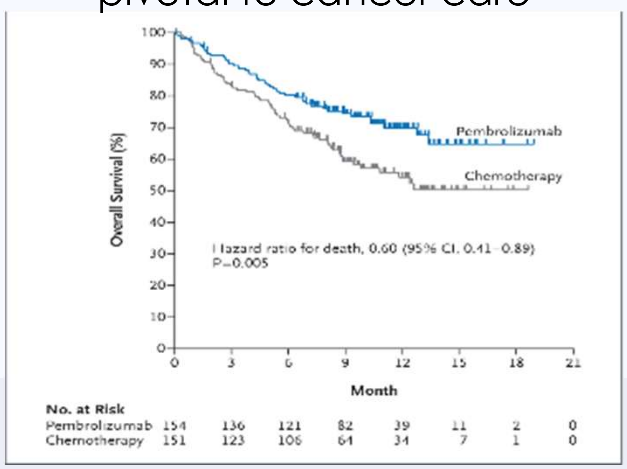
3 4 5 6 7 8 9 10 11 12 13 14

All test results received

IHC testing:
About 1-2 days

Molecular analysis:
Up to 14 days

Next Generation Sequencing (NGS) has become pivotal to cancer care



Forde et al, *NEJM* (2022)
Reck et al, *NEJM* (2016)
Levy BP, et al. *Oncologist*. 2015;20(10):1175-1181.
Dietel M, et al. *Thorax*. 2016;71(2):177-184.
Lindeman NI, et al. *Arch Pathol Lab Med*. 2013;137(6):828-860.
Lindeman NI, et al. *Arch Pathol Lab Med*. 2018;142(3):321-346.

Are there procedural techniques to optimize outcomes?

Stylet Use Does Not Improve Diagnostic Outcomes in Endobronchial Ultrasonographic Transbronchial Needle Aspiration
A Randomized Clinical Trial

Sample Adequacy

		With Stylet: Adequate	With Stylet: Inadequate
Without Stylet	Adequate	151 (77.8%)	18 (9.2%)
	Inadequate	13 (6.7%)	12 (6.1%)

Concordance: 84.0%; 95% CI (78.1-88.9)

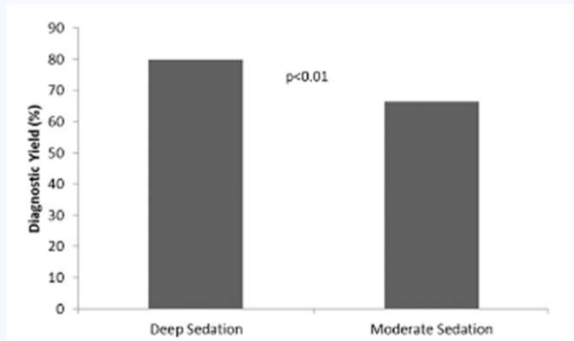
Diagnostic Sample

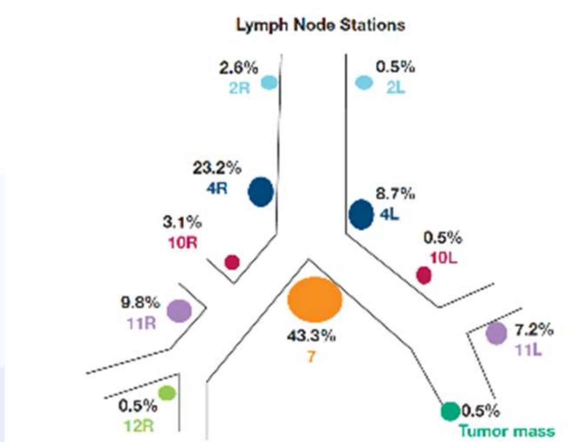
		With Stylet: Diagnostic	With Stylet: Nondiagnostic
Without Stylet	Diagnostic	45 (23.2%)	4 (2.1%)
	Nondiagnostic	5 (2.6%)	140 (72.2%)

Concordance: 95.4%; 95% CI (91.2-97.9)

Comparison of Moderate versus Deep Sedation for Endobronchial Ultrasound Transbronchial Needle Aspiration

Lonny B. Yarmus[1], Jason A. Akulian[1], Christopher Gilbert[1], Stephen C. Mathai[1], Srividya Sathiyamoorthy[2], Sarina Sahetya[3], Kassem Harris[4], Colin Gillespie[5], Andrew Haas[4], David Feller-Kopman[1], Daniel Sterman[4], and Hans J. Lee[1]

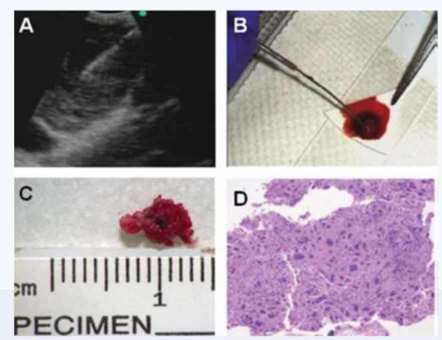




[Thoracic Oncology Guidelines and Consensus Statements] CHEST

Acquisition and Handling of Endobronchial Ultrasound Transbronchial Needle Samples
An American College of Chest Physicians Clinical Practice Guideline

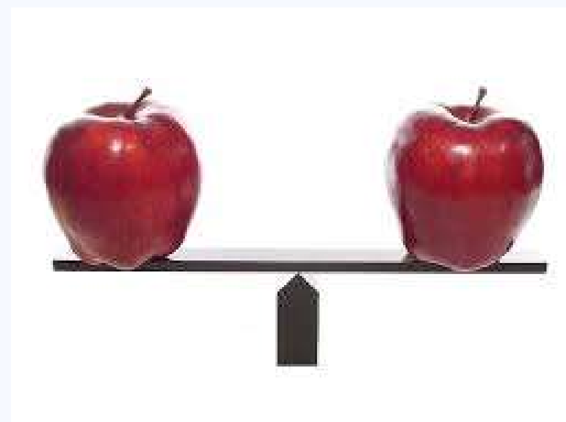
	Patients (n = 85)	P Value
Overall adequacy for mutational analysis, n (%)	81 (95.3)	
Adequacy for mutational analysis by histologic subtype, n (%)		0.004
Adenocarcinoma	75/77 (97)	
NSCLC-NOS	6/8 (75)	
Total number of TBNA passes per procedure*	4 (3–5)	
Adequate with fewer than 4 passes, n (%)	47/49 (96)	
Adequate with 4 or more passes, n (%)	34/36 (94)	
Number of sites sampled*	1 (1–2)	
Median	1	
Size of site sampled, cm†	2.18 ± 1.19	



Yarmus L, Annals ATS 2014
Yarmus, L, et al, JOBIP 2012
Trisolini R, et al. *Chest*. 2015

Innovation in Bronchoscopy: The Journey towards the holy grail

- Single Procedure:
  - Staging
  - Diagnosis
  - Molecular profiling
- Minimally invasive treatment



The NEW ENGLAND JOURNAL *of* MEDICINE

ORIGINAL ARTICLE

Navigational Bronchoscopy or Transthoracic Needle Biopsy for Lung Nodules

R.J. Lentz,[1-3] K. Frederick-Dyer,[4] V.B. Planz,[4] T. Koyama,[5] M.C. Aboudara,[6] S.K. Avasarala,[7] J.D. Casey,[1,8] G.Z. Cheng,[9] P.-F. D'Haese,[10] J.D. Duke,[1,2] E.L. Grogan,[2,11] T.C. Hoopman,[12] J. Johnson,[13] J.M. Katsis,[14] J.S. Kurman,[15] S.-W. Low,[16] K. Mahmood,[17] O.B. Rickman,[18] L. Roller,[1] C. Salmon,[17] S. Shojaee,[1,2] B. Swanner,[1] M.M. Wahidi,[19] C. Walston,[18] G.A. Silvestri,[20] L. Yarmus,[21] N.M. Rahman,[22-24] and F. Maldonado,[1,2] for the Interventional Pulmonary Outcomes Group*

ABSTRACT

AMERICAN THORACIC SOCIETY DOCUMENTS

Assessment of Advanced Diagnostic Bronchoscopy Outcomes for Peripheral Lung Lesions: A Delphi Consensus Definition of Diagnostic Yield and Recommendations for Patient-centered Study Designs

An Official American Thoracic Society/American College of Chest Physicians Research Statement

Anne V. Gonzalez, Gerard A. Silvestri, Daniel A. Korevaar, Yaron B. Gesthalter, Nisha D. Almeida, Alex Chen, Chris R. Gilbert, Peter B. Illei, Neal Navani, Mary M. Pasquinelli, Nicholas J. Pastis, Catherine R. Sears, Samira Shojaee, Stephen B. Solomon, Daniel P. Steinfort, Fabien Maldonado, M. Patricia Rivera, and Lonny B. Yarmus; on behalf of the American Thoracic Society Assembly on Thoracic Oncology and the American College of Chest Physicians

This Official Research Statement was approved by the American Thoracic Society December 2023 and the American College of Chest Physicians September 2023

Role of Staging T1 Tumors

Increased Need for EBUS Staging

- High rate of N2 metastasis among T1 tumors
- No significant relationship between tumor diameter or location (central vs peripheral)
- **Small, peripheral lung cancers may benefit from invasive mediastinal staging

TABLE 2] Lymph Node Metastasis by Tumor Diameter

Tumor Diameter (mm)	Risk of Any LN Metastasis (%)	Percent of N Stage Metastases, No. (%)			
		N1	N2	N3	Total
≤10	19.3	15 (68.2)	7 (31.8)	0 (0.0)	22 (100.0)
>10 and ≤20	20.1	16 (47.1)	16 (47.1)	2 (5.9)	34 (100.0)
>20	26.5	7 (53.8)	4 (30.8)	2 (15.4)	13 (100.0)

DuComb E, et al. CHEST. 158(5):2192-2199 (2020)

Platform Selection

Virtual Bronchoscopy

EMN

- Super Dimension
- Augmented Fluoroscopy (Fluor ody Vision)
- Monarch Robotic Bronchoscop
- Galaxy Robotic Bronchoscopy (*combines integrated tomosynthesis technology and augmented fluoroscopy)

Shape Sensing

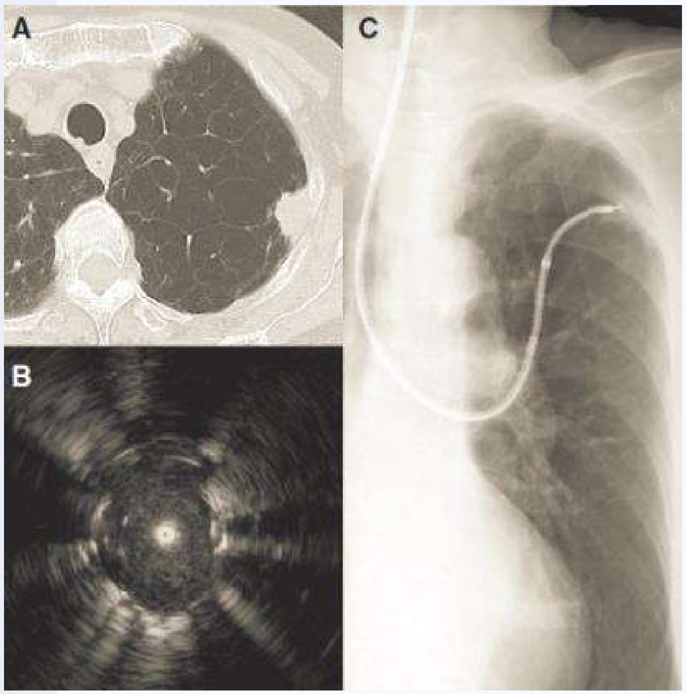
- Ion Robotic Bronchoscopy

Ultrathin Bronchoscopy with Multimodal Devices for Peripheral Pulmonary Lesions

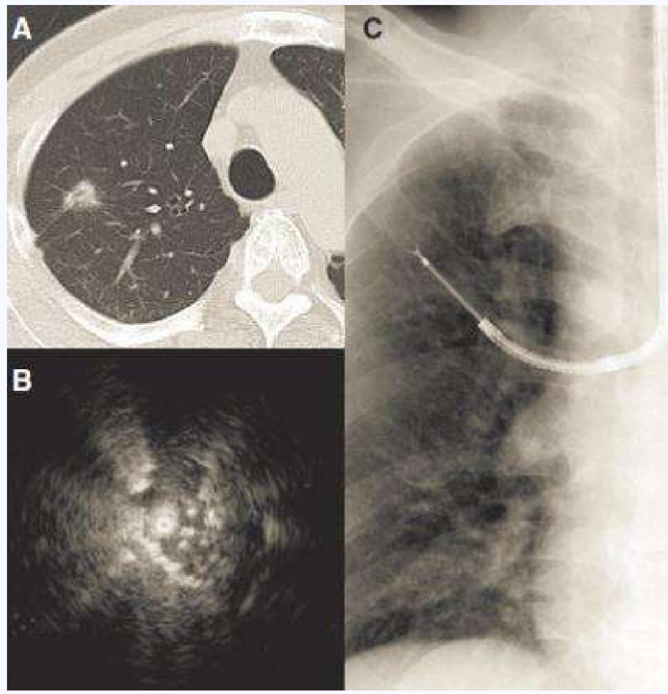
A Randomized Trial

Masahide Oki[1], Hideo Saka[1], Masahiko Ando[2], Fumihiro Asano[3], Noriaki Kurimoto[4], Katsuhiko Morita[5],

3.0 mm OD/1.7 mm WC



4.0 mm OD/2.0 mm WC

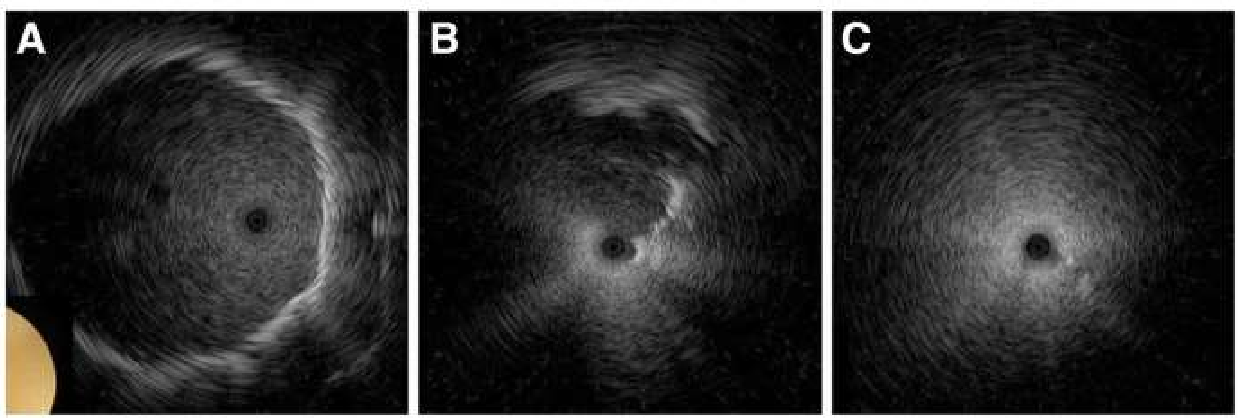


AJRCCM 2015. 192(4): 468-476
Oki, et al. AJRCCM. 2019

Radial EBUS

Ultrasound used in the periphery of the lung
- Introduced through the working channel of the bronchoscope

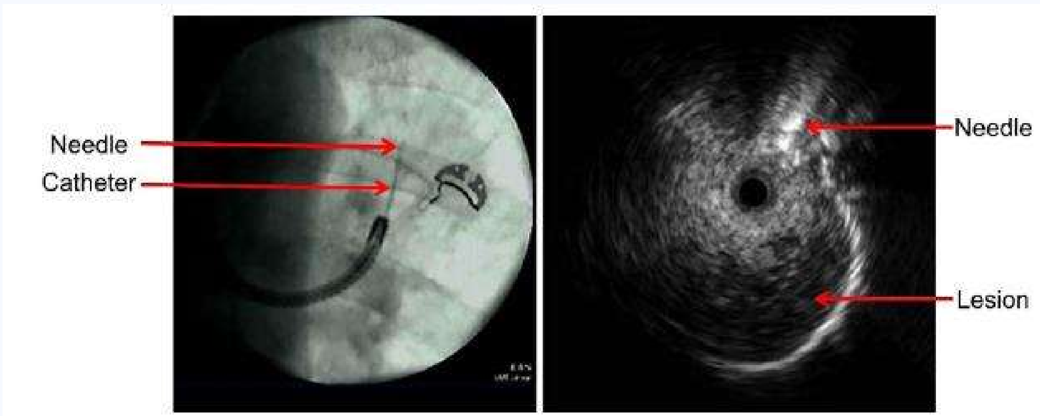
Frequency 20 MHz

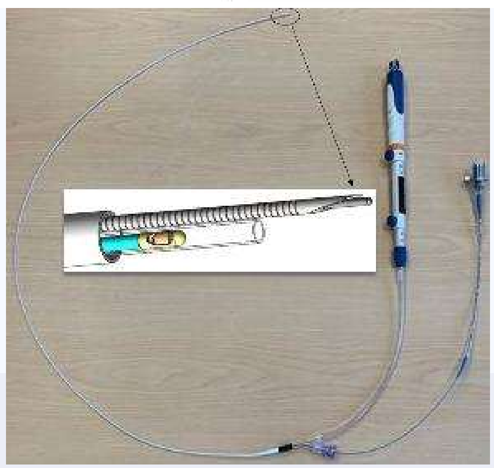


84% Yield 48% Yield

Chen et al. Ann Am Thorac Soc 2014 May; 11(4): 578-82

iNod Boston Scientific

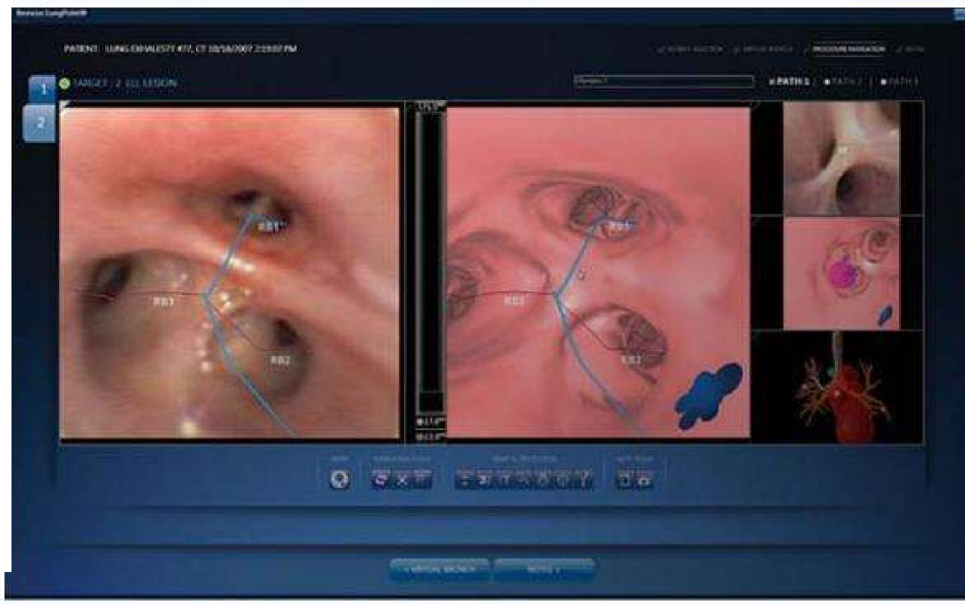


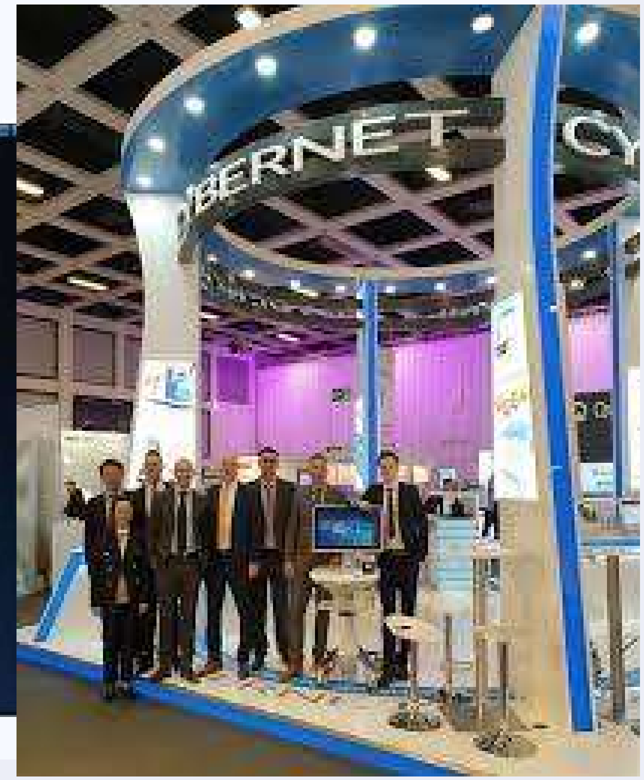


Yarmus et al. Respiration. 2019 ; 98(6): 527–533.

Virtual Navigation

- Pattern Recognition Software





Virtual Bronchoscopy

First author	Year	Study design	VBN system	Bronchoscope external diameter	Confirmation of arrival	Lesion size selection	Lesions, n	Diagnostic yield	Lesions <2 cm, n	Diagnostic yield for lesions <2 cm
Shinagawa [16]	2004	Pro	Not used	2.8 mm	CT	<2 cm	26	65.4%	26	65.4%
Asahina [26]	2005	Pro	Not used	4.0 or 5.3 mm	EBUS	≤3 cm	30	63.3%	18	44.4%
Asano [11]	2006	Pro	Bf-NAVI	2.8 mm	CT	≤3 cm	38	81.6%	26	80.8%
Shinagawa [17]	2007	Pro	Bf-NAVI	2.8 mm	CT	<2 cm	71	70.4%	71	70.4%
Tachihara [29]	2007	Pro	Bf-NAVI	2.8 or 5.2 mm	Flu	≤3 cm	96	62.5%	77	54.5%
Asano [10]	2008	Pro	Bf-NAVI	4.0 mm	EBUS	n/a	32	84.4%	15	73.3%
Eberhardt [33]	2010	Pro	LungPoint	2.8 mm	Non-Flu	n/a	25	80.0%	n/a	n/a
Omiya [30]	2010	Retro	Bf-NAVI	2.8 and 4.0 mm	Flu	≤3 cm	37	75.7%	13	76.9%
Iwano [31]	2011	Retro	Not used	2.8 mm	Flu	n/a	122	78.7%	30	73.3%
Oshige [27]	2011	Pro	Bf-NAVI	4.0 or 5.9 mm	EBUS	n/a	57	84.2%	22	72.7%
Ishida [24]	2011	RCT	Bf-NAVI	4.0 mm	EBUS	≤3 cm	99	80.8%	58	75.9%
Asano [32]	2013	RCT	Bf-NAVI	2.8 mm	Flu	≤3 cm	167	67.1%	114	64.9%
Tamiya [28]	2013	Pro	LungPoint	4.0 mm	EBUS	≤3 cm	68	77.9%	27	74.1%
Summary							868	73.8%	497	67.4%

Respiration 2014; 88:430-440
PLoS ONE 2018; 13(1): e0191590

SuperDimension illumisite System

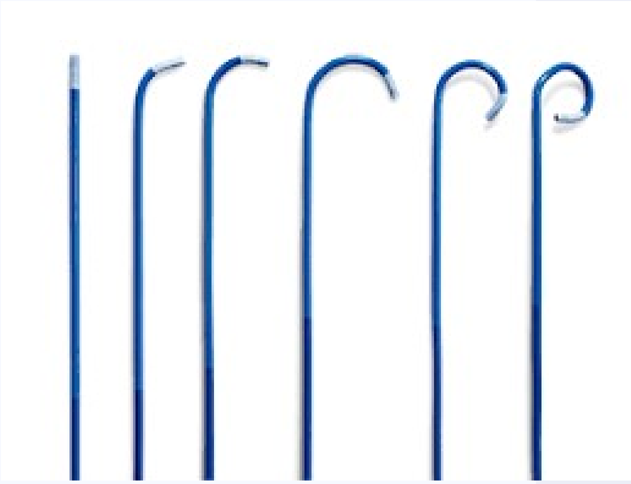
Uses previously performed thin cut non-contrast CT.

Tip-tracked locatable guide (LG) through a catheter system.

LG removed and biopsies are done through the catheter working channel.

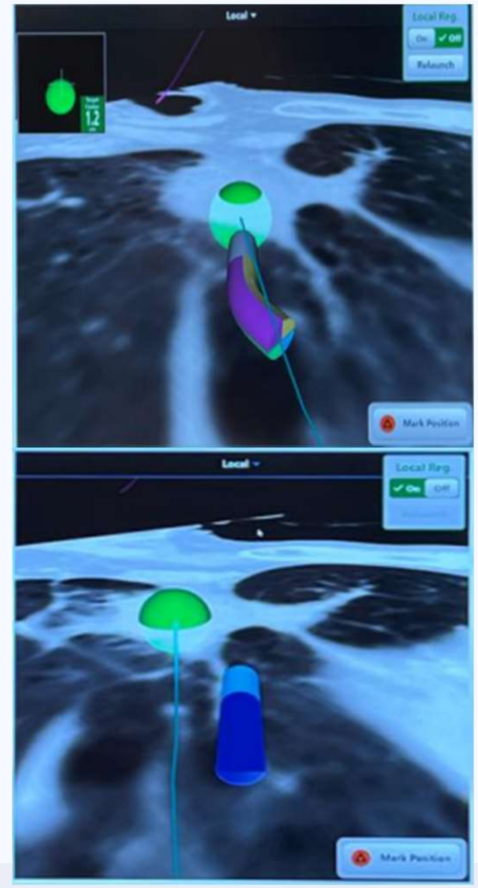
Extended working channel is also tracked and incorporates use of augmented fluoroscopy.

Longest tenure/track record of navigation systems.



Lamptrcht et al Respir Med 2012
Karnak et al Ann Thor Med 2013
Gildea et al Am J Respir Crit Care Med 2006
Ebhardt et al Am J Respir Crit Care Med

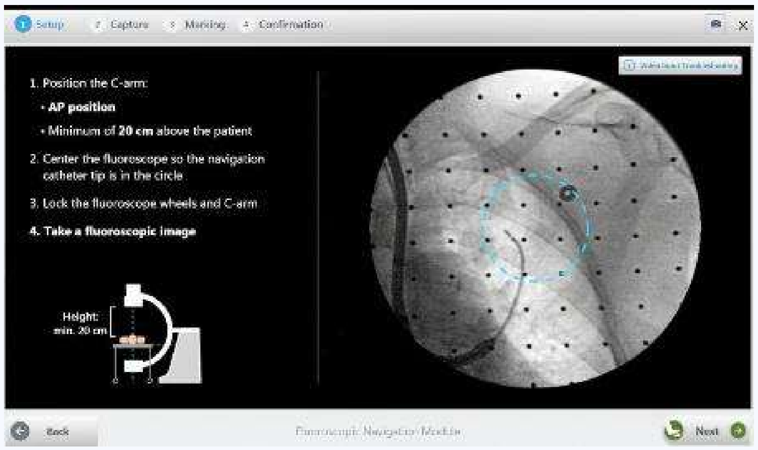
Screen Shot

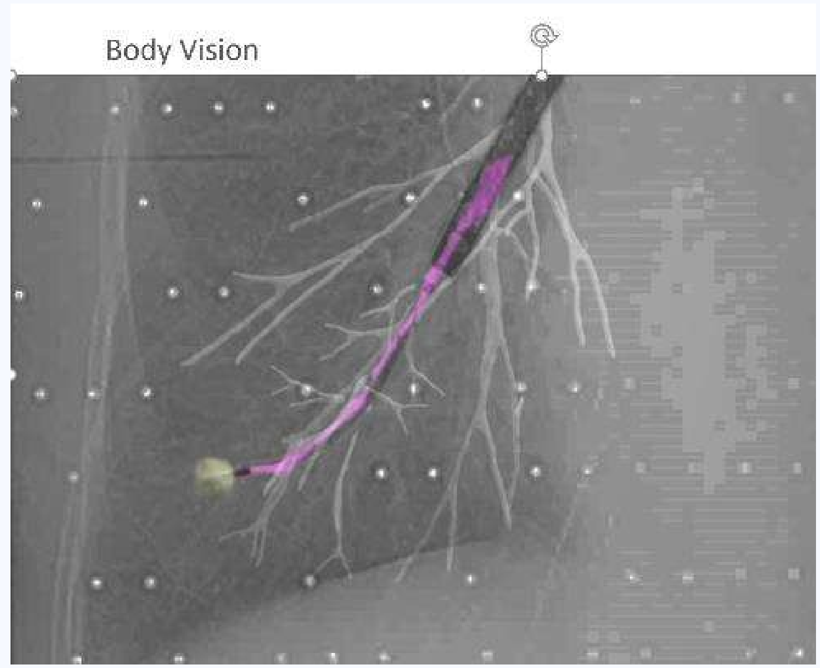


Evidence for SuperDimension

	N	Size	Yield (N)
Ebhardt et al. (2007)	118	< 20 mm	75% (4)
		20-30 mm	50% (50)
		>30 mm	69% (69)
Gildea et al. (2006)	54	< 20 mm	74.1% (31)
		< 30 mm	72.1% (43)
		>30 mm	81.8% (11)
Karnak et al. (2013)	30	<20 mm	93.8% (16)
		> 20mm	89.5% (19)
Lamprecht et al. (2012)	112	<20 mm	75.6% (45)
		> 20mm	89.6% (67)
Avasarala et al. (2021) *	100	<20mm	78% (51)
(Illumisite)		>20mm	80% (49)
Dunn et al. (2023) *	78	<20mm	77% (22)
(Illumisite)		>20mm	91% (56)

Augmented Fluoroscopy





J Bronchology Interv Pulmonol. 2021 Mar 17.
Respirology. 2020 Feb;25(2):206-213

ORIGINAL INVESTIGATIONS

The Diagnostic Accuracy and Sensitivity for Malignancy of Radial-Endobronchial Ultrasound and Electromagnetic Navigation Bronchoscopy for Sampling of Peripheral Pulmonary Lesions

Systematic Review and Meta-analysis

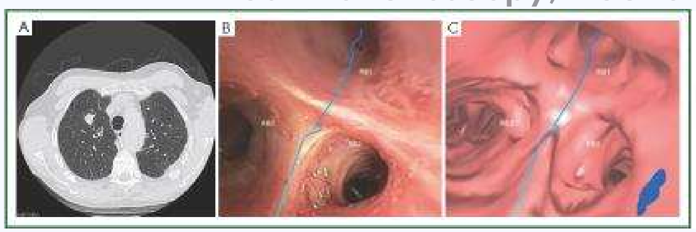
McGuire, Anna L. MD, MSc, FRCSC[*,†]; Myers, Renelle MD[‡]; Grant, Kyle MD, MSc[*,†]; Lam, Stephen MD[‡]; Yee, John MD[*,†] Author Information

Journal of Bronchology & Interventional Pulmonology: April 2020 - Volume 27 - Issue 2 - p 106-121

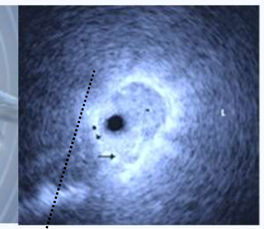
- 41 studies, 2988 nodules
- Sensitivity: R-EBUS: 70.5%, ENB: 70.7%
- Diagnostic Accuracy: R-EBUS: 72.4%, ENB: 76.4%
- Complications for both < 2%

Diagnostic Yield of Guided Bronchoscopy in MC-RCT's

Virtual Bronchoscopy, Electromagnetic Navigation & Radial EBUS







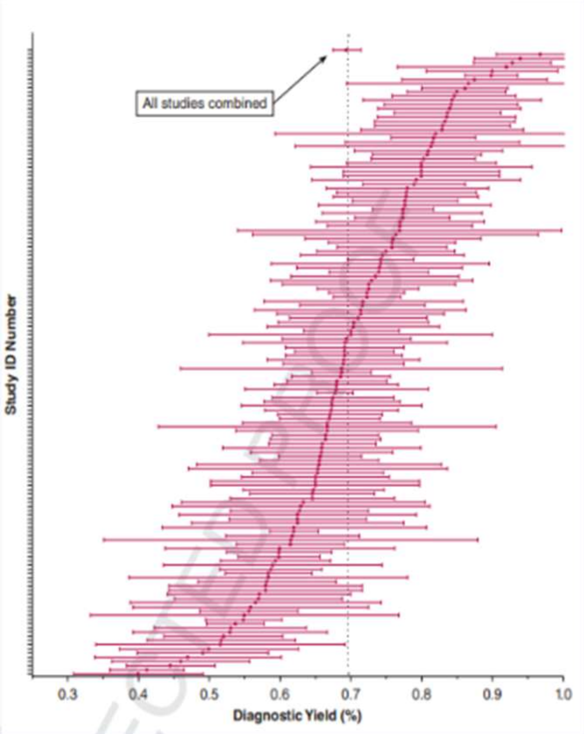
Diagnostic Yield	≤ 2cm Lesions	> 2cm Lesions
Wang Memoli, Meta-analysis (2012)	61%	83%
Zhang, W., Meta-analysis (2015)	NA	72%
Ost AQuIRE Registry (2016)	47%	53%
Folch NAVIGATE Meta-Analysis (2019)	77% pooled sensitivity	

Updated Meta-Analysis 10 years Later

TABLE 4] Study Characteristics and Diagnostic Yield, Summarized Across Types of Technology Used

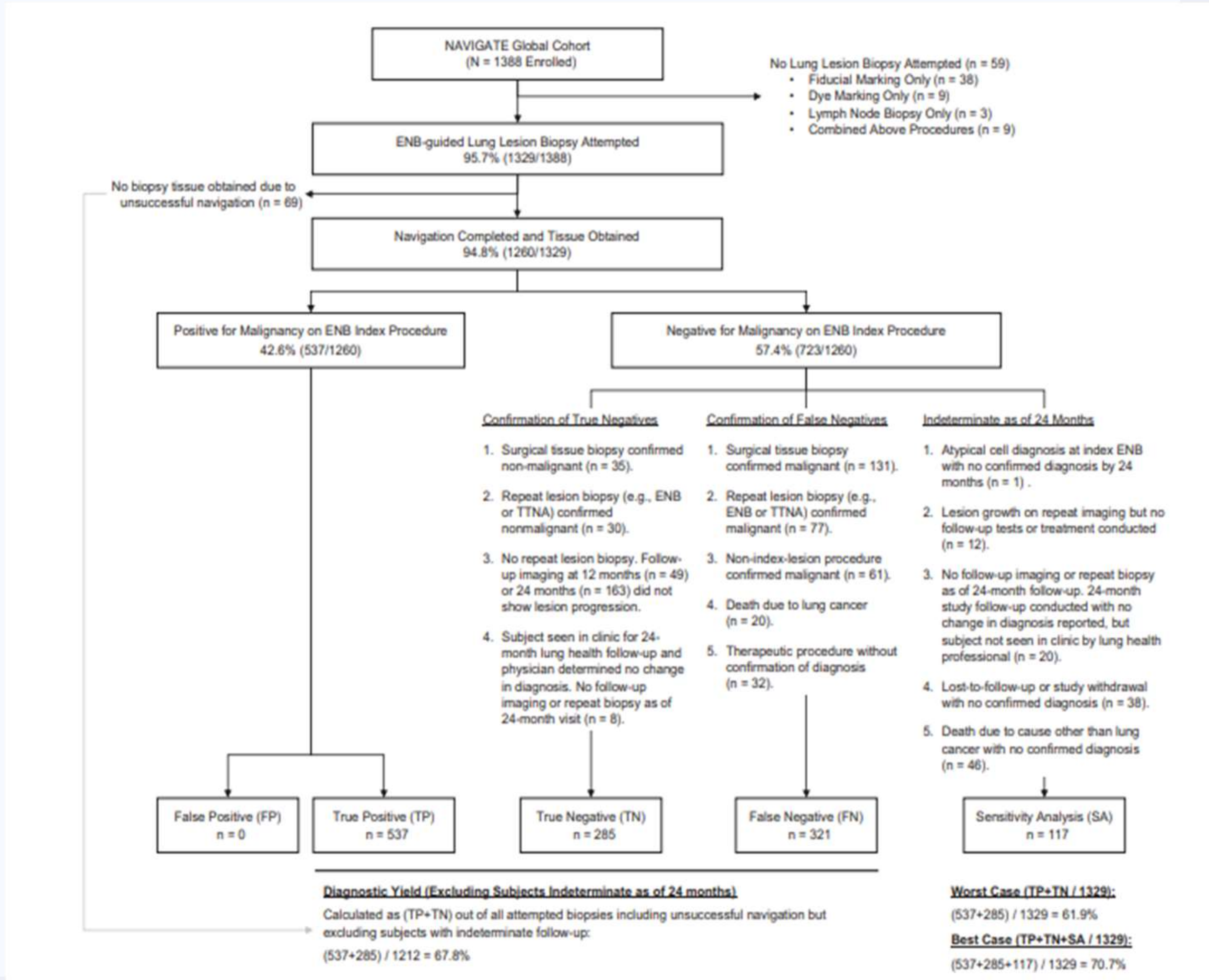
Technology Used	No. of Study Arms	Proportion of Study Arms With High Bias, %	Total No. of Nodules Included	No. of Nodules Per Study, Median (range)	Diagnostic Yield, Mean (95% CI)
R-EBUS ± GS	51	78.4	5,494	83 (11-760)	70.9% (67.9%-73.9%)
ENB	24	75.0	1,952	53.5 (13-279)	74.0% (68.6%-79.4%)
ENB + R-EBUS	15	73.3	2,913	56 (26-1,329)	66.5% (59.8%-73.3%)
VB + R-EBUS	13	76.9	1,048	55 (12-334)	76.4% (72.7%-80.1%)
Ultrathin or thin + VB	10	80.0	795	63 (25-167)	69.9% (62.4%-77.3%)
Ultrathin or thin + R-EBUS	7	42.9	1,133	101 (20-467)	62.6% (55.3%-70.0%)
Other combination	7	57.1	771	63 (31-245)	64.4% (49.0%-79.9%)
Ultrathin or thin	6	50.0	770	104 (20-340)	50.2% (37.3%-63.2%)
Ultrathin + VB + R-EBUS	6	16.7	737	152.5 (32-179)	67.3% (58.4%-76.2%)
Robotic	6	66.7	483	56.5 (15-167)	77.6% (70.4%-84.8%)
VB	4	100.0	293	60.5 (50-122)	72.4% (55.1%-89.7%)

ENB = electromagnetic navigational bronchoscopy; GS = guide sheath; R-EBUS = radial endobronchial ultrasound; VB = virtual bronchoscopy.



Nadjig et al. CHEST 2023 Jan 11; S0012-3692 (23)00030-2

24 Month Follow- Up of NAVIGATE



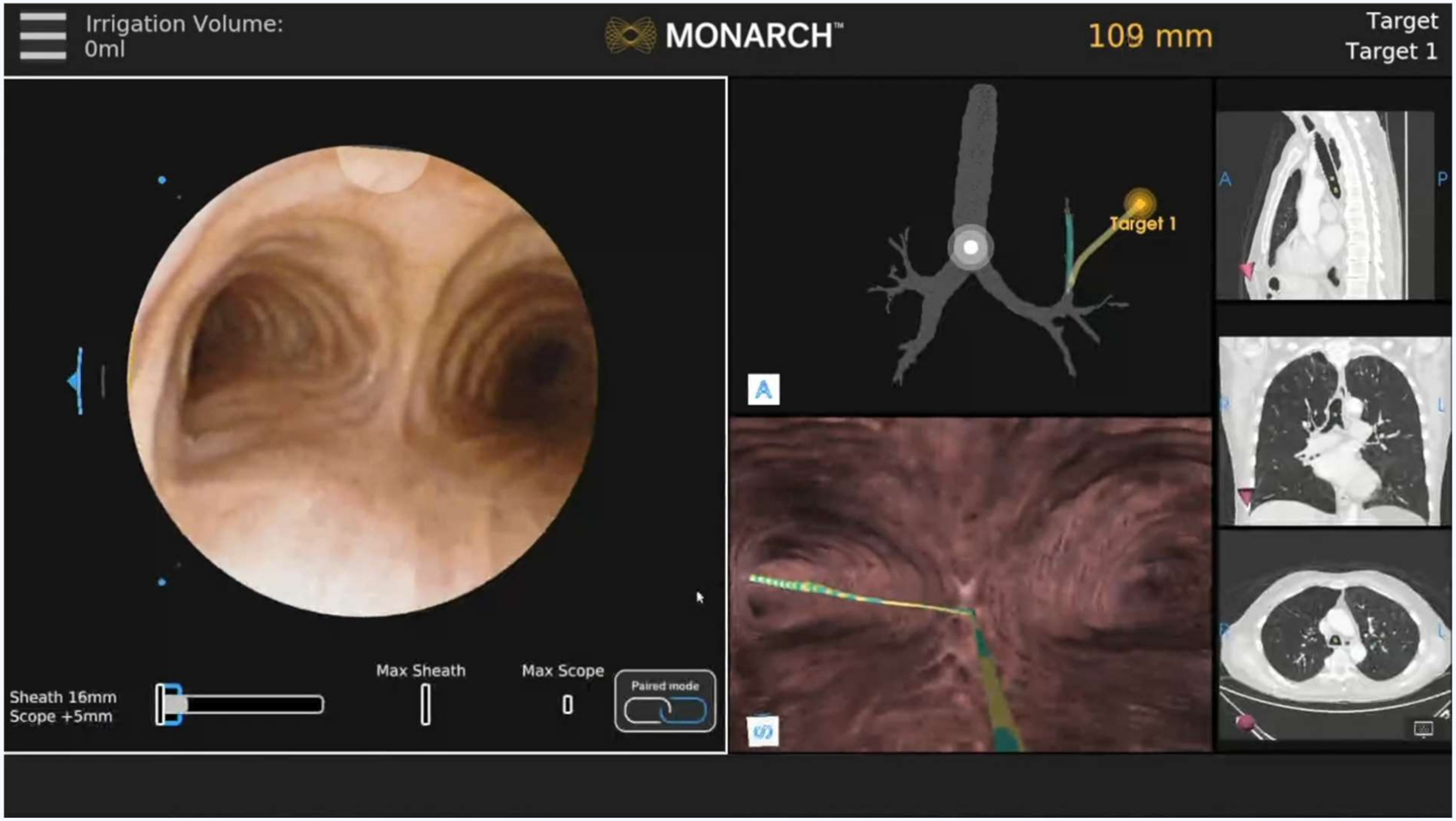
Folch et al. J Thorac Oncol. 2021;16(3):S134–S135.

Robotic-Assisted Bronchoscopy Features	Ion™ Intuitive	Monarch™ Auris	Galaxy™ Noah Medical
Navigation technology	Shape sensing	Electromagnetic navigation	Electromagnetic navigation augmented fluoroscopy
Bronchoscopy	Catheter with removable vision probe (disposable after 5 uses) *	Sheath and bronchoscope with built-in camera (disposable after 2 uses) *	Bronchoscope with built-in camera (single use)
Catheter articulation	180°	180° (sheath: 130°)	180°
Catheter outer diameter	3.5 mm (catheter)	Outer sheath: 6 mm/inner scope: 4.2 mm	4.0 mm
Working channel diameter	2.0 mm	2.1 mm	2.1 mm
Irrigation and aspiration	No	Yes	Yes
CT-to-body divergence correction system	Yes (only with Cios Spin)	No	Yes
Augmented fluoroscopy	No	No	Yes
Tool-in-lesion confirmation	Yes (only when utilizing Cios Spin)	No	Yes
Tactile feedback	No	No	No

* Cleaning and recycling are carried out by Intuitive and Auris for their respective scopes.

Diagnostics (Basel). 2024 Feb 12;14(4):399.

Articulation

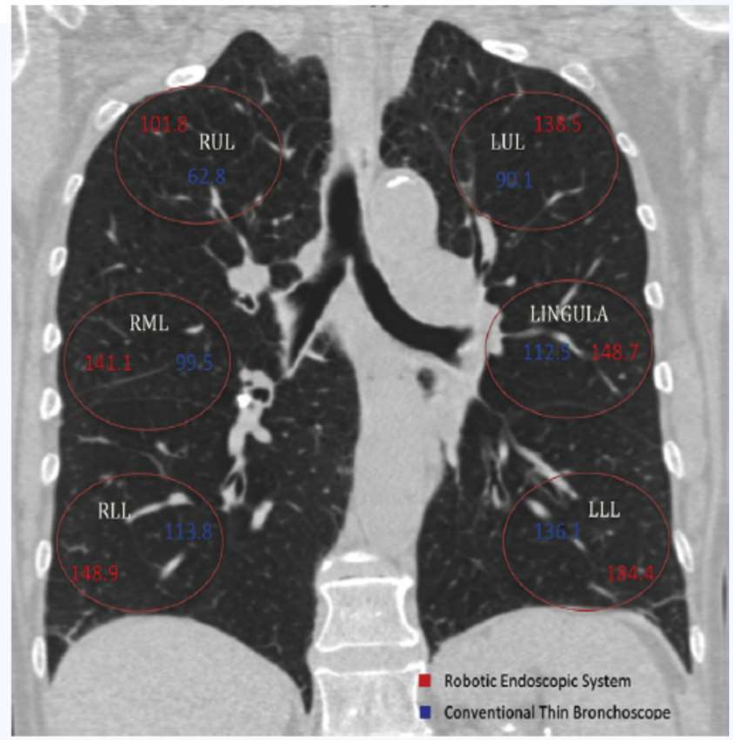


Irrigation Volume:
0ml
MONARCH™
109 mm
Target
Target 1
Target 1
A
P
A
Sheath 16mm
Scope +5mm
Max Sheath
Max Scope
Paired mode

Robotic Endoscopic Airway Challenge: REACH Assessment

Alexander C. Chen, MD, and Colin T. Gillespie, MD

Division of Pulmonary and Critical Care Medicine, Washington University School of Medicine/Barnes Jewish Hospital, St. Louis, Missouri; and Division of Pulmonary and Critical Care, Northwestern University Feinberg School of Medicine, Chicago, Illinois



A Prospective Randomized Comparative Study of Three Guided Bronchoscopic Approaches for Investigating Pulmonary Nodules

The PRECISION-1 Study

Lonny Yarmus, DO; Jason Akulian, MD, MPH; Momen Wahidi, MD; Alex Chen, MD; Jennifer P. Steltz, BS; Sam L. Solomon, BS; Diana Yu, MD; Fabien Maldonado, MD; Jose Cardenas-Garcia, MD; Daniela Molena, MD; Hans Lee, MD; and Anil Vachani, MD; on behalf of the Interventional Pulmonary Outcomes Group (IPOG)[*]

- Prospective, single-blinded study
- Ultrathin scope with REBUS vs EMN vs Robotic Bronchoscopy
- Cadaver models with nodules < 20 mm
- End point was to localize and sample the nodule
    - Also calculated "miss distance"

CHEST 2020; 157(3):694-701

PRECISION-1

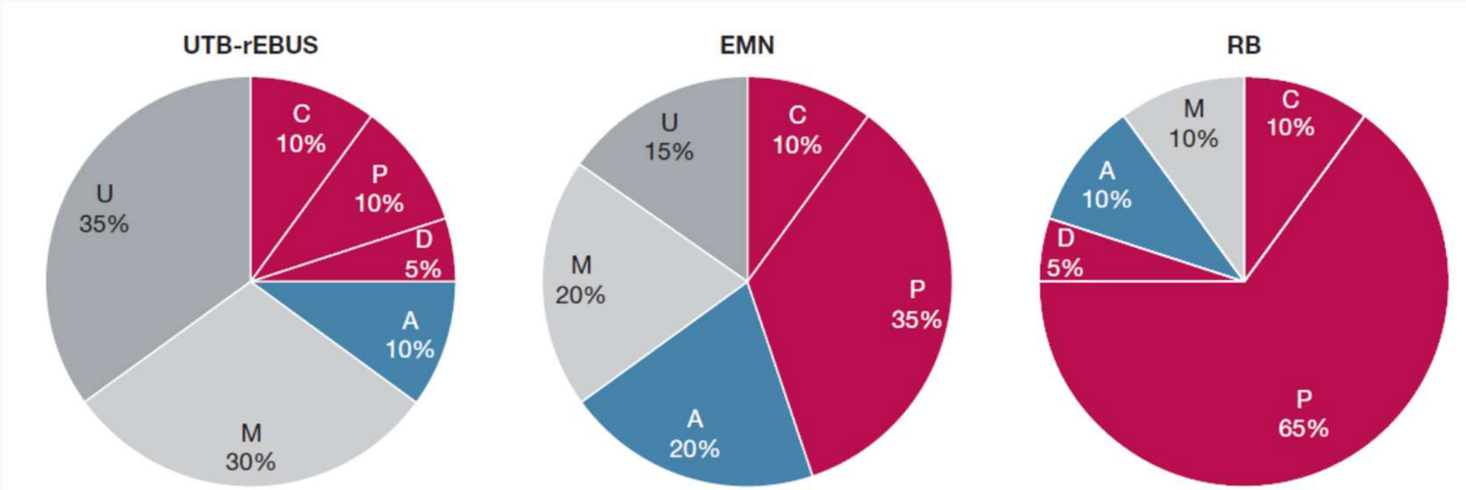


TABLE 1] Localization, Puncture, and Successful Navigation Study Outcomes

Study Arm	No.	Study Outcomes: Localization and Puncture (Primary End Point)[a]	Localization and Puncture (Secondary End Point)[b]	Successful Navigation
		% (No.)	% (No.)	% (No.)
UTB-rEBUS	20	25 (5)	35 (7)	65 (13)
EMN	20	45 (9)	65 (13)	85 (17)
RB	20	80 (16)	90 (18)	100 (20)

Yarmus et al. CHEST 2020; 157(3):694-701

Chaddha *et al. BMC Pulmonary Medicine* (2019) 19:243
https://doi.org/10.1186/s12890-019-1010-8

BMC Pulmonary Medicine

RESEARCH ARTICLE Open Access

Robot-assisted bronchoscopy for pulmonary lesion diagnosis: results from the initial multicenter experience

Udit Chaddha[1*†], Stephen P. Kovacs[2†], Christopher Manley[3], D. Kyle Hogarth[4], Gustavo Cumbo-Nacheli[5], Sivasubramanium V. Bhavani[6], Rohit Kumar[7], Manisha Shende[8], John P. Egan III[9] and Septimiu Murgu[6]

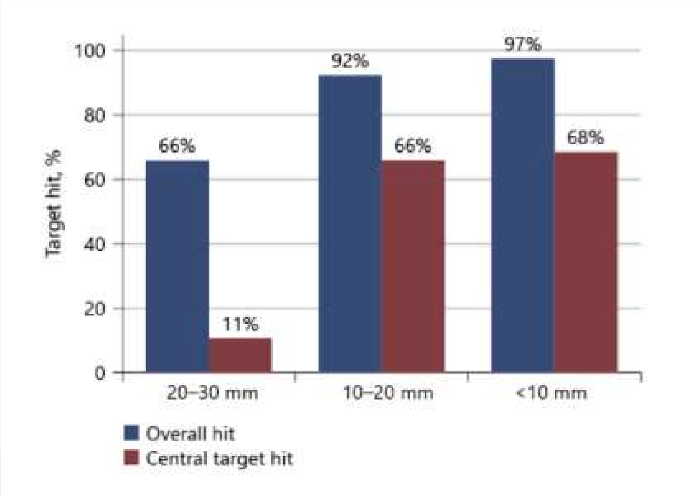
- Not affected by density, size or lobar location

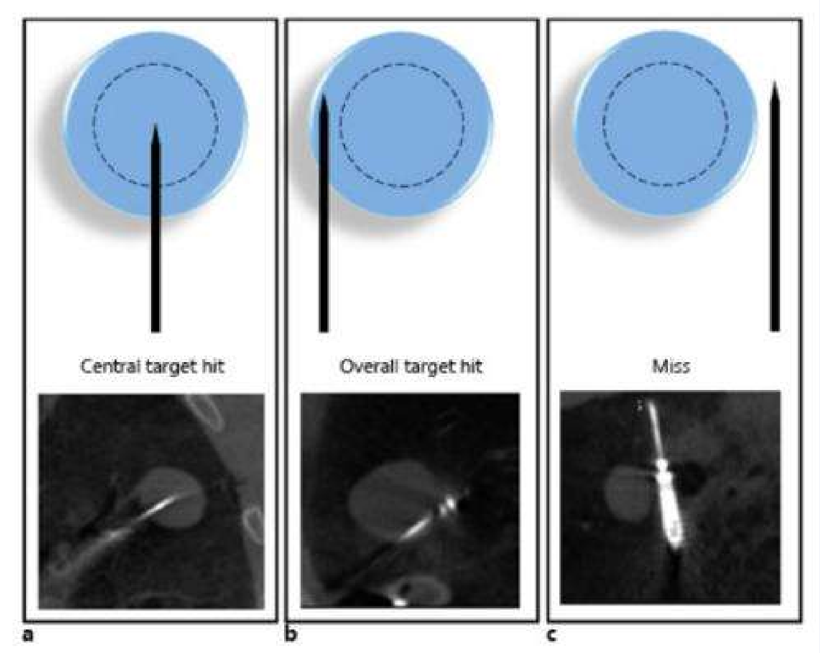
Closer is Better: ACCURACY Trial

Porcine Model: 16 implanted targets

38 procedures

Median nodule: 16mm





Thiboutot, et al. Respiration. 2022

Shape-Sensing Robotic-Assisted Bronchoscopy in the Diagnosis of Pulmonary Parenchymal Lesions

CHEST

- Single Center, prospective enrollment
- 131 cases, 159 targets
- Median nodule size: 18mm
- Diagnostic yield: 82%
- Sn malignancy: 80%
- NPPV: 72%
- PTX rate: 1.3%

Or Kalchiem-Dekel. CHEST 2022

Shape-Sensing Robotic-Assisted Bronchoscopy vs Digital Tomosynthesis-Corrected Electromagnetic Navigation Bronchoscopy

A Comparative Cohort Study of Diagnostic Performance

See-Wei Low, MD; Robert J. Lentz, MD; Heidi Chen, PhD; James Katsis, MD; Matthew C. Aboudara, MD; Samuel Whatley; Rafael Paez, MD; Otis B. Rickman, DO; and Fabien Maldonado, MD

TABLE 4] Factors Associated With Diagnostic Yield Combining Both Platform

Variable	Diagnostic Biopsy (n = 268)	Nondiagnostic Biopsy (n = 72)	Combined (n = 340)	*P* Value
Biopsy platform				.46
DT-ENB	158 (59)	39 (54)	197 (58)	
ssRAB	110 (41)	33 (46)	143 (42)	
Radial ultrasound				< .001
Concentric	121 (46.9)	19 (27.9)	140 (42.9)	
Eccentric	116 (45)	33 (48.5)	149 (45.7)	
No view	21 (8.1)	16 (23.5)	37 (11.3)	
Size, mm	19 (14-29)	15 (12-21)	18 (13-27)	.001
Peripheral one-third location	158 (59)	43 (60)	201 (59)	.91
Bronchus sign	102 (38)	19 (26)	121 (36)	.066
Nodule density				< .001
Solid	234 (87.3)	50 (69.4)	284 (83.5)	
Subsolid	26 (9.7)	19 (26.4)	45 (13.2)	
Ground-glass opacity	8 (3)	3 (4.2)	11 (3.2)	

Data are presented as No. (%) or median (interquartile range), unless otherwise indicated. DT-ENB = digital tomosynthesis-electromagnetic navigation bronchoscopy; ssRAB = shape-sensing robotic-assisted bronchoscopy.

CHEST 2022 Oct 29;S0012-3692(22)04032

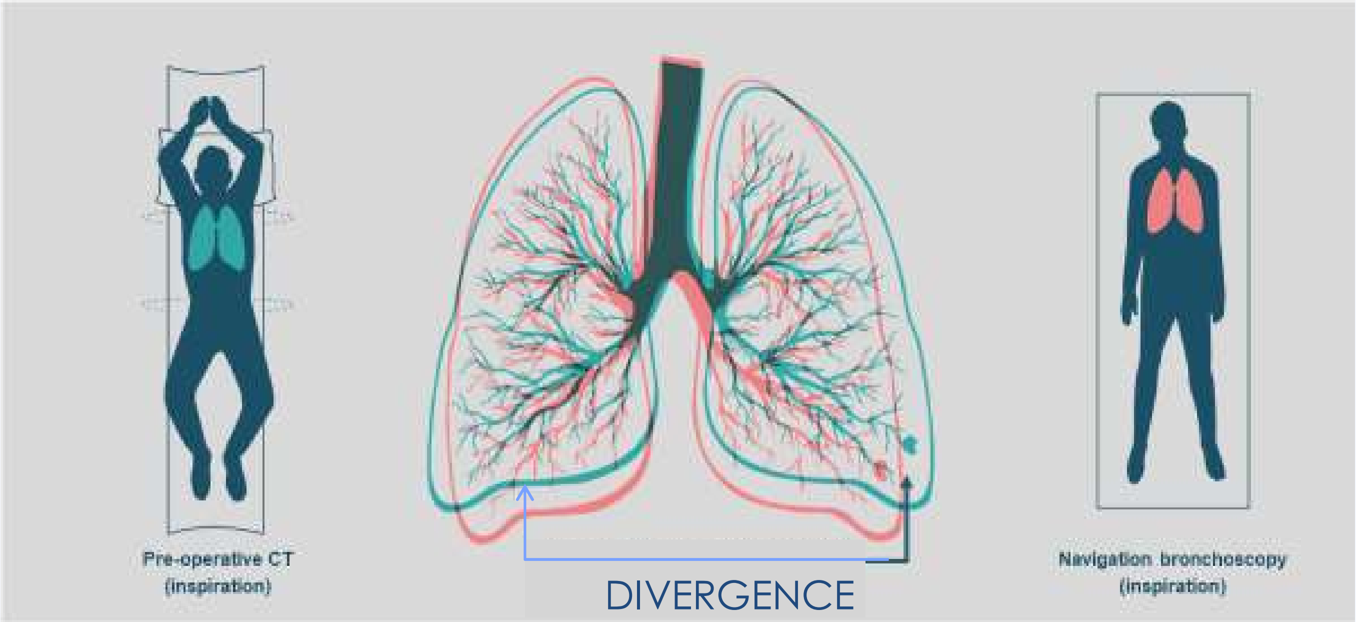
CT: Body Divergence

Discrepancy between the location of a nodule on static imaging and in the dynamic lung itself

- Local atelectasis
- Poor CT scan resolution
- Airway distortion from scope
- Hemorrhage
- Other factors such as pleural effusion

Bhadra et al. J Bronchology Interv Pulm. 2022
Pritchett et al. J Thorac Dis. 2020
Picture from Noah Medical website

CT to Body Divergence



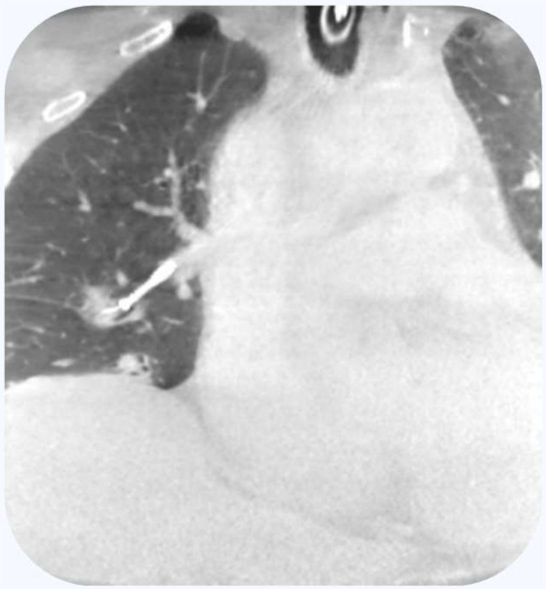
Note: airways and nodules both show mismatch

Pritchett, M. JTO 2018; Suppl (Oct):S403

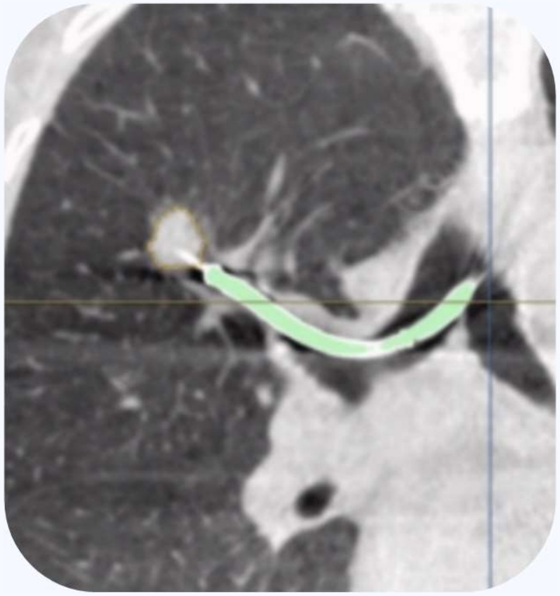
Real-time imaging modalities

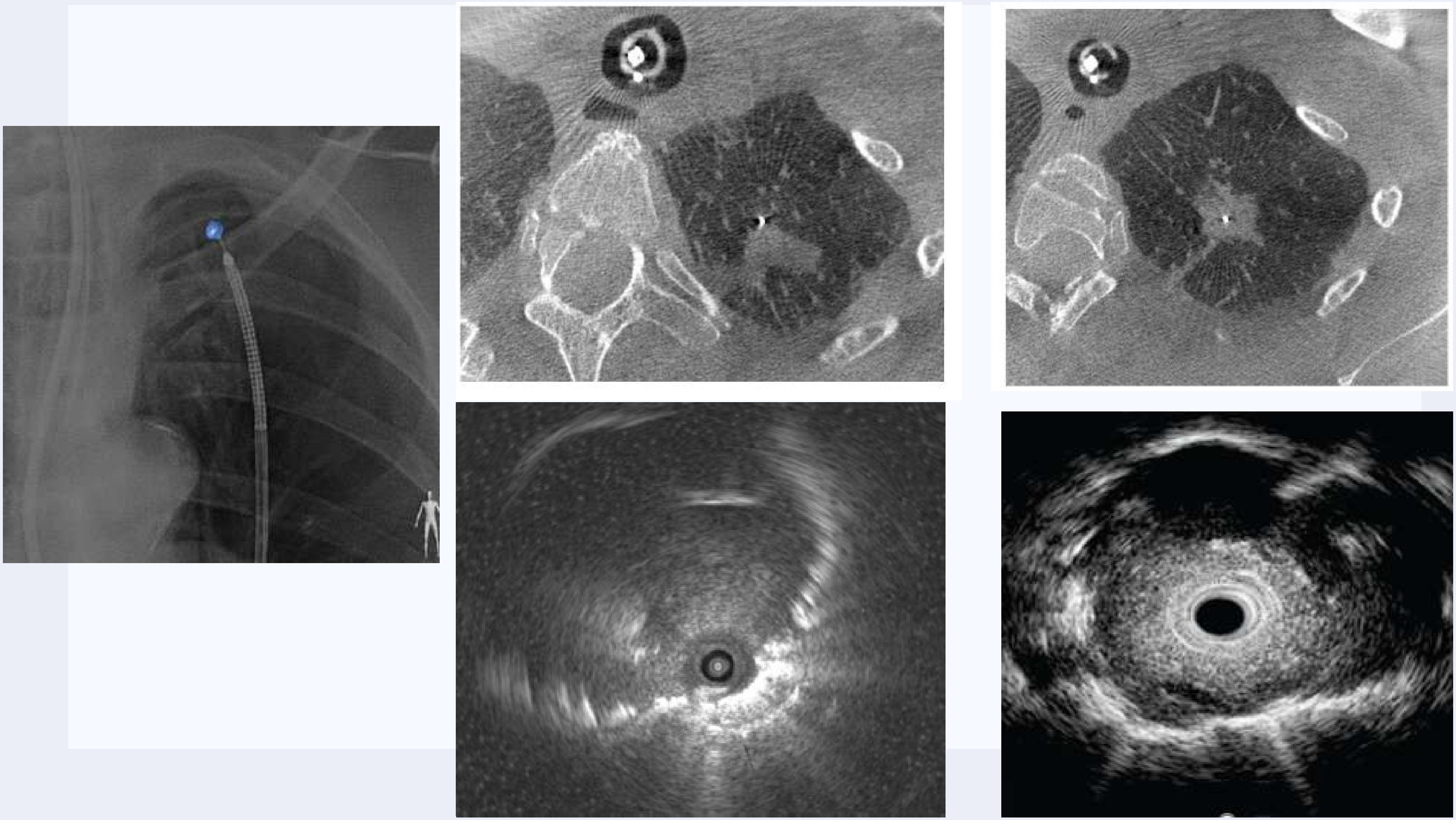
Digital Tomosynthesis

Portable 3D imaging



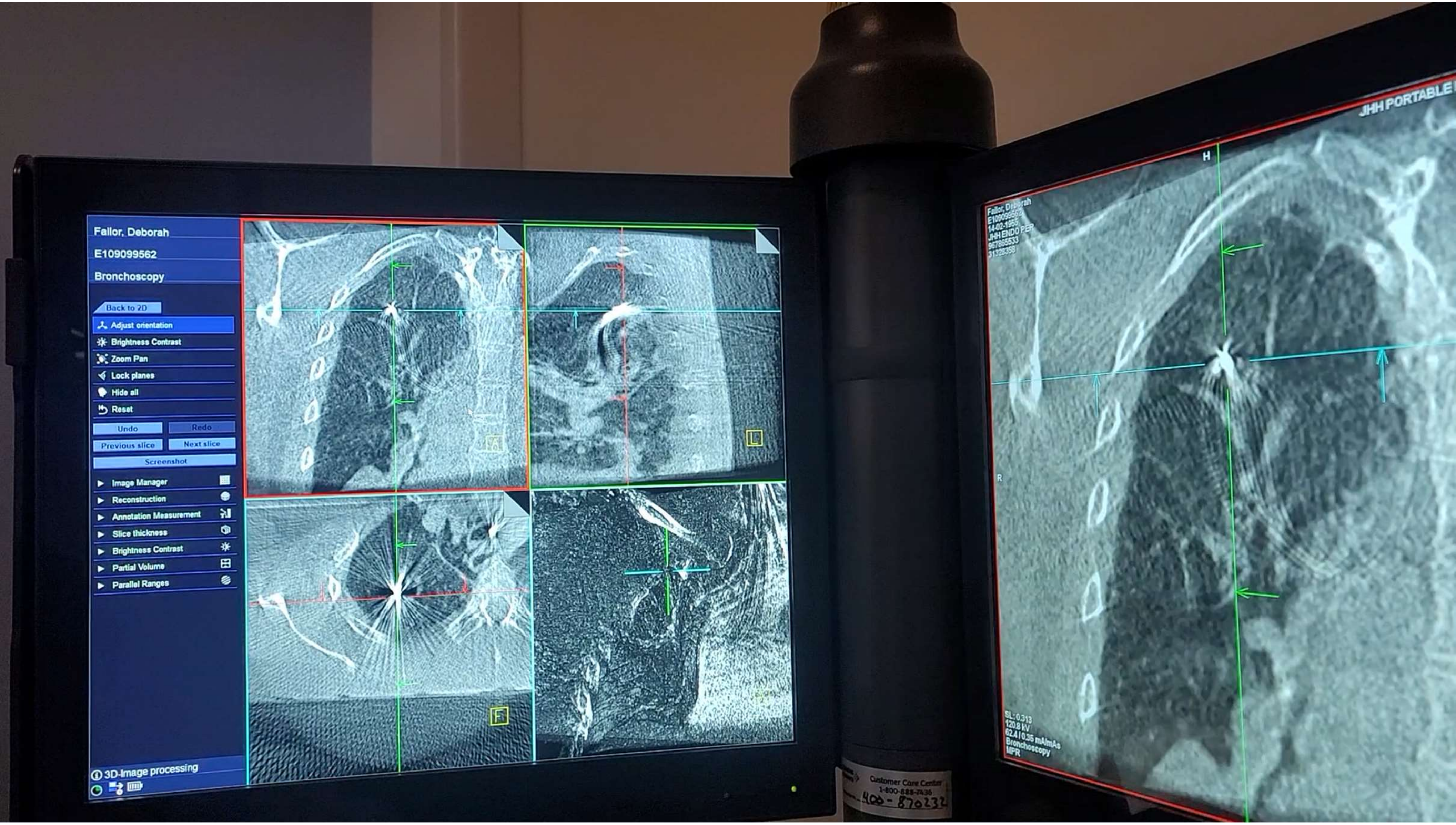
Fixed 3D CBCT





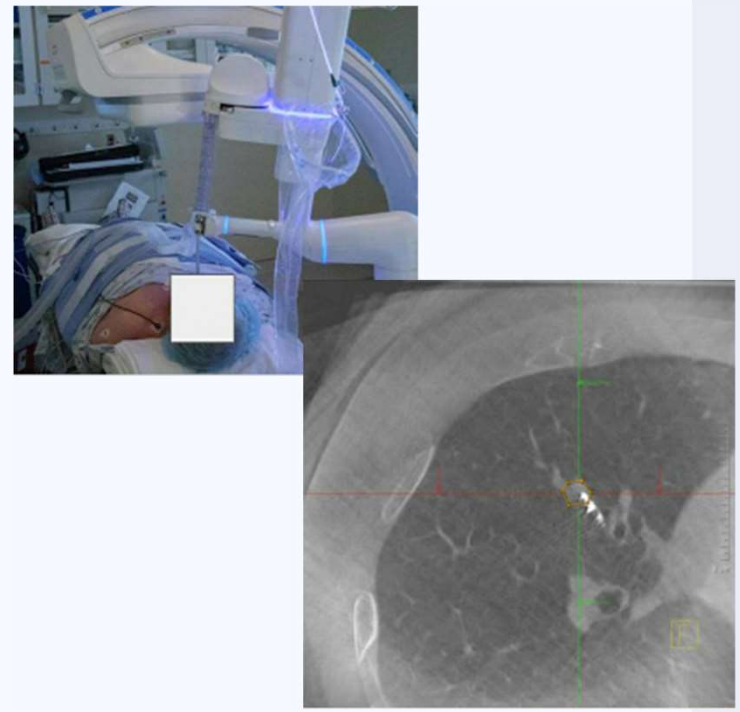
Cone Beam CT and Augmented Fluoroscopy


3D


Fallor, Deborah
E109099562
Bronchoscopy
Back to 2D
Adjust orientation
Brightness Contrast
Zoom Pan
Lock planes
Hide all
Reset
Undo
Redo
Previous slice
Next slice
Screenshot
Image Manager
Reconstruction
Annotation Measurement
Slice thickness
Brightness Contrast
Partial Volume
Parallel Ranges
3D-Image processing
JHH PORTABLE
Customer Care Center


View Scan
Catheter
Target
Review
Preview
210/512
345/512
262
261/512
Target Focus
Undo
Next
Confirm target shape in all views

Do we need advanced imaging with RAB?



Single-center, prospective, pilot study
- 30 lesions with median size 17.5 mm

Median distance from pleura of 14.9 mm

Tool-in-lesion was visualized at the time of the procedure in 29 lesions (96.7%)

Mean number of spins was 2.5 with a mean fluoroscopy time of 8.7 min
- 1 spin for adjustment

No episodes of bleeding or

Mayo Clin Proc Innov Qual Outcomes. 2022 Apr 23;6(3):177-185

Do we need advanced imaging with RAB?

N= 10 lesions in 5 patients using the SS RAB platform in conjunction with the mobile 3D spin.

Tool-in-lesion in 90% of their patients

The relationship between the biopsy tool and lesion was improved in 3 instances (30% of the time) after the subsequent redeployment of the tool

- Based on direct feedback from the intraoperative portable CT imaging

Respirology. 2021;26(1):120–123

Lung
https://doi.org/10.1007/s00408-021-00421-1

INTERVENTIONAL PULMONOLOGY

Robotic-Assisted Navigation Bronchoscopy as a Paradigm Shift in Peripheral Lung Access

Bryan S. Benn[1] · Arthur O. Romero[2,3] · Mendy Lum[4] · Ganesh Krishna[2,4,5]

Received: 18 September 2020 / Accepted: 18 January 2021

- N=52 pts with total of 59 nodules
- Mean size < 2 cm
- Reach 100% **with cone beam CT**
- **Sensitivity for malignancy 84% (31/37)**
- CBCT confirmed proper needle placement within 50 **(85%) lesions**
- **15% of cases needed adjustment based on CBCT**
- **Diagnostic yield 86% (51/59)- infection 9(18%) and inflammation 9 (18%)**
- Pneumothorax 2/52 pts (3.8%); bleeding 0%

$$\frac{\text{Malignant cases at index + Benign Cases at index (both specific and non-specific)}}{\text{Attempted Biopsy}}$$

diagnostics

MDPI

Article

Improving Shape-Sensing Robotic-Assisted Bronchoscopy Outcomes with Mobile Cone-Beam Computed Tomography Guidance

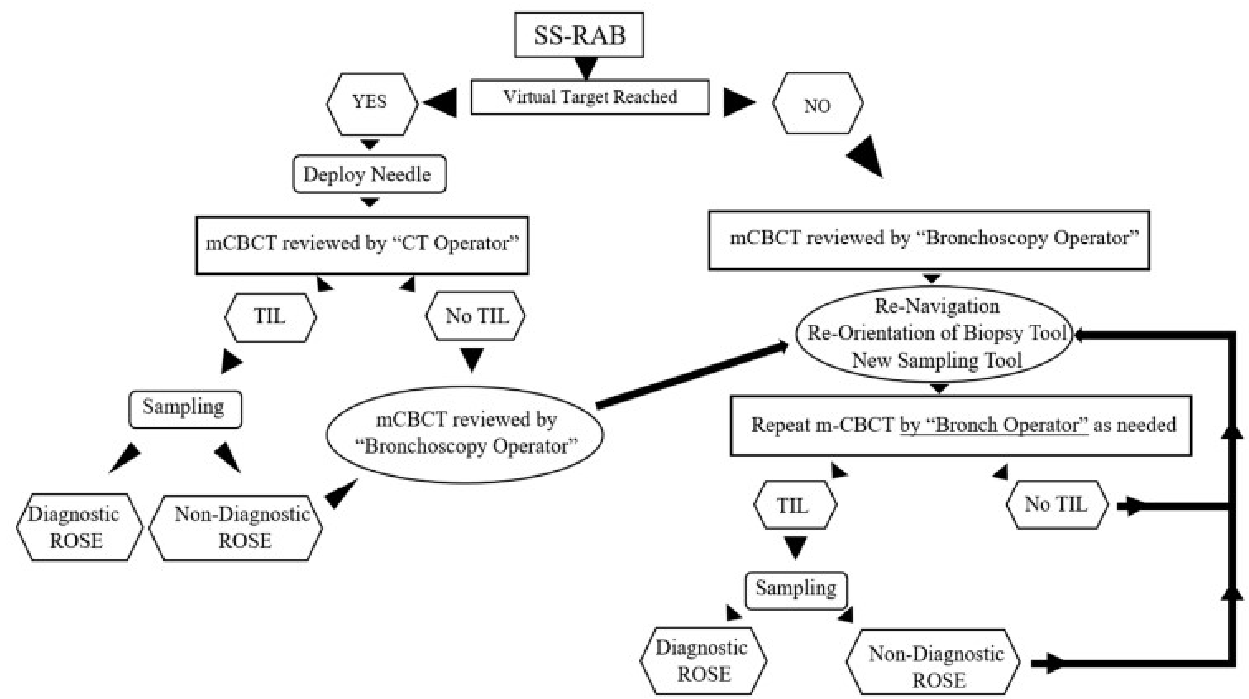
Sami I. Bashour [1], Asad Khan [2], Juhee Song [3], Gouthami Chintalapani [4], Gerhard Kleinszig [5], Bruce F. Sabath [6], Julie Lin [6], Horiana B. Grosu [6], Carlos A. Jimenez [6], Georgie A. Eapen [6], David E. Ost [6], Mona Sarkiss [7] and Roberto F. Casal [6,*]

Median nodule size: 1.7cm

TIL: 34.3% vs 98.6%

97.7% of those without TIL with RAB alone successful with addition of CBCT

DY: 29.9% vs 86.6% (strict definition)



Added Value of a Robotic-assisted Bronchoscopy Platform in Cone Beam Computed Tomography-guided Bronchoscopy for the Diagnosis of Pulmonary Parenchymal Lesions

Brian D. Shaller, MD, Duy K. Duong, DO,† Kai E. Swenson, MD,‡*
*Dwayne Free, RRT, RCP,§ and Harmeet Bedi, MD**

TABLE 3. Procedure Details

Variable	FB-CBCT (n = 100)	RB-CBCT (n = 100)	*P*
Navigation and access instruments	—	—	—
Robotic bronchoscope	—	100	—
Standard or slim bronchoscope	68	—	—
Ultra-slim bronchoscope	34	—	—
Extended working channel	25	—	—
Transbronchial access tool	11	—	—
Total number of CBCT spins	5 (3–6)	3 (2–4)	< 0.001
Tool-in-lesion spin performed	99	88	0.003
Tool-in-lesion confirmation*	—	—	0.059
Inner-third	54	56	—
Outer-third	45	28	—
Outside target	0	2	—
EBUS-staging performed	72	58	0.054
Total procedure duration, min	92 (72–111)	58 (44–70)	< 0.001
Total fluoroscopy duration, min	19 (15–26)	13 (10–17)	< 0.001
Total radiation dose, mGy	279 (169–385)	174 (92–273)	< 0.001
Dose area product, μGy•m^2	8755 (5145–12475)	5114 (2417–8034)	< 0.001
Any complication	7	2	0.170
Complications by type	—	—	0.833
Pneumothorax, observed only	1	0	—
Pneumothorax, requiring chest tube	0	1	—
Bleeding, requiring escalation of care	1	0	—
Respiratory failure, requiring escalation of care	2	1	—
Cardiac event	1	0	—
Other	2†	0	—

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

*In 2 RB-CBCT cases, a tool-in-lesion spin was performed but the result was not documented, and the CBCT images were no longer available for review.

†Other complications were one occurrence of pneumomediastinum without pneumothorax that was followed on an outpatient basis and resolved without intervention, and one occurrence of seizure with hemiplegia in the post-anesthesia care unit that was observed on an inpatient basis and resolved spontaneously.

EBUS indicates endobronchial ultrasound.

Diagnostic performance of Shape-Sensing Robotic-Assisted bronchoscopy with mobile Cone-Beam CT for cystic and cavitary pulmonary lesions

Sebastian Fernandez-Bussy [a,*], Rodrigo Funes-Ferrada [a], Alejandra Yu Lee-Mateus [a], Bryan F. Vaca-Cartagena [a], Alanna Barrios-Ruiz [a], Sofia Valdes-Camacho [a], Mohamed I. Ibrahim [a], Neal M. Patel [a], Britney N. Hazelett [a], Kelly S. Robertson [a], Ryan M. Chadha [b], David Abia-Trujillo [a]

Original research

Diagnostic performance of shape-sensing robotic-assisted bronchoscopy for pleural-based and fissure-based pulmonary lesions

Sebastian Fernandez-Bussy,[1] Alejandra Yu Lee-Mateus ,[1] Alanna Barrios-Ruiz,[1] Sofia Valdes-Camacho,[1] Katherine Lin,[2] Mohamed I Ibrahim,[1] Bryan F Vaca-Cartagena,[1] Rodrigo Funes-Ferrada ,[1] Janani Reisenauer,[3] Kelly S Robertson,[1] Britney N Hazelett,[1] Ryan M Chadha,[4] David Abia-Trujillo [1]

Breaking New Ground in Interventional Pulmonology: Integrating Cone Beam CT and Robotic-Assisted Bronchoscopy for High-Risk Pneumothorax in Peripherally Located Solitary Pulmonary Nodules

Amir R. Reihani [1, 2], Mahshid Zohouri [3], Justin Thomas [4]

Pre-Procedure Planning

There should already be a map in your head before you plan with the software

You must be a master at airway anatomy and be able to follow all airways

Take time with the software to really know all the features

- Airway diameters, distances, orientation etc.

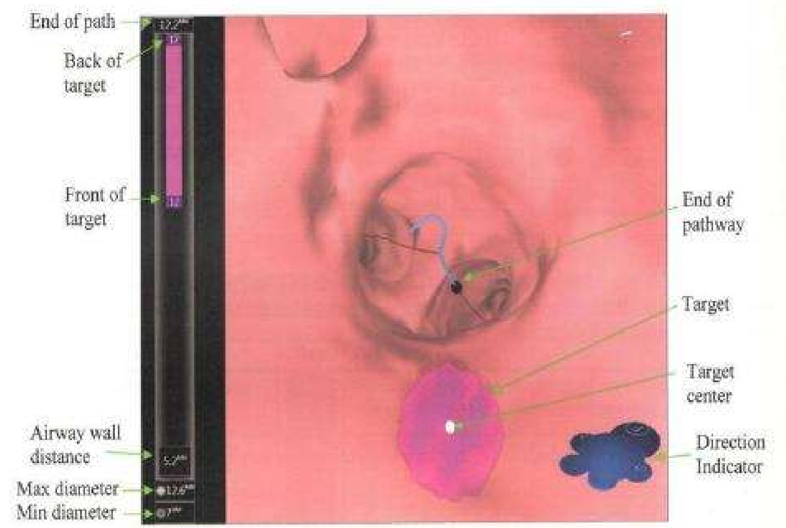


Figure 19: The virtual bronch image with the distance and airway measurement panel, the path to the target (blue line), the end of the pathway (black dot), the target (pink), the target center (white dot), and the bronchoscope direction indicator.

Use Multiple Tools

Technology	Number of Studies	Weighted proportion	95% Confidence Interval	Q P-value
ENB	11	67.0%	(62.6% to 71.4%)	0.21
VB	10	72.0%	(65.7% to 78.4%)	0.01
GS	10	73.2%	(64.4% to 81.9%)	<0.0001
U	11	70.0%	(65.0% to 75.1%)	0.12
R-EBUS	20	71.1%	(66.5% to 75.7%)	<0.0001
All	**39**	**70.0%**	**(67.1% to 72.9%)**	**<0.0001**

ENB=Electromagnetic navigation, VB = virtual bronchoscopy, GS = guide sheath, U = ultrathin bronchoscope, R-EBUS = radial endobronchial ultrasound

Table **1** Sensitivity of each diagnostic procedure for primary lung cancers

	Lung carcinomas 20 mm or less in diameter	***All lung carcinomas***
Brushing	52.4% (65 of 124)	64.8% (321 of 495)
Transbronchial forceps biopsy	45.8% (71 of 155)	56.1% (364 of 649)
Transbronchial forceps biopsy-stamp cytology	61.0% (108 of 177)	72.0% (540 of 750)
Transbronchial fine needle aspiration	75.9% (170 of 224)	86.4% (783 of 906)

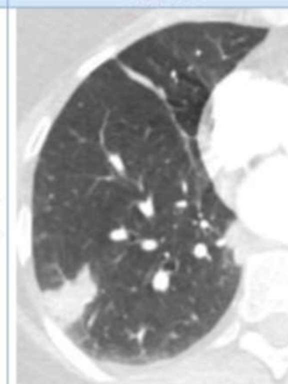
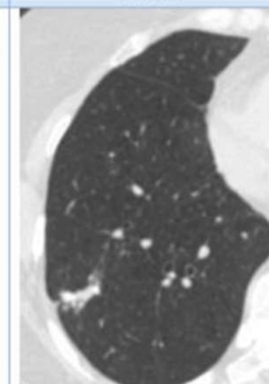
Wang et. al. Chest. 2012 Aug;142(2):385-393.
Iyoda et al. Thorac Cardiovasc Surg 2006; 54(2): 117-119

Same Day CT Imaging

Prospective case series (n=116)

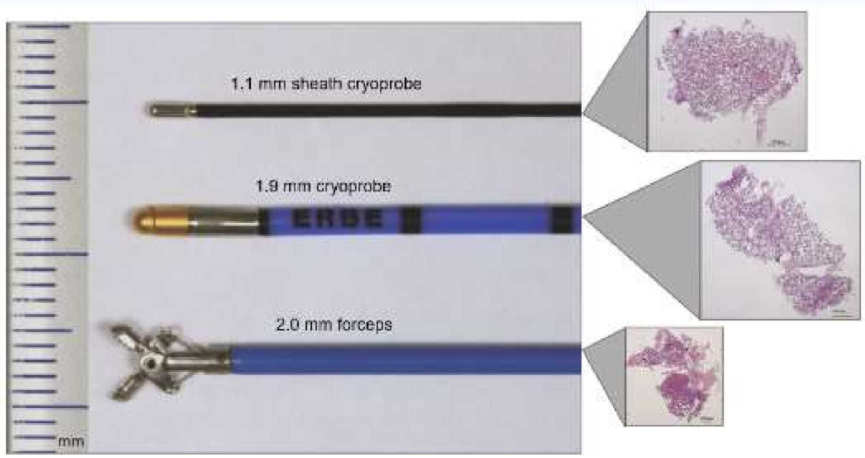
- 6.9% with decrease in size or resolution of lesion
- NNT = 15

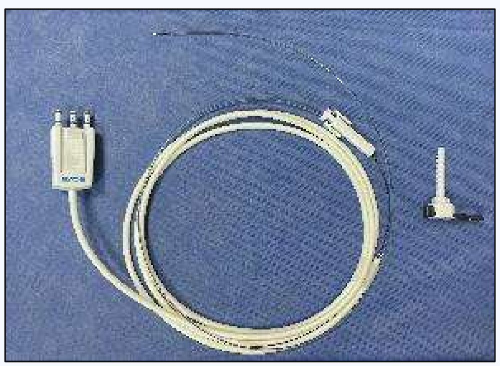
- Benefits of same day CT scan
  - Confirm nodule present and stable
  - Reduce non-diagnostic procedures
  - Maintain closest anatomy to procedure
  - Respiratory Gating

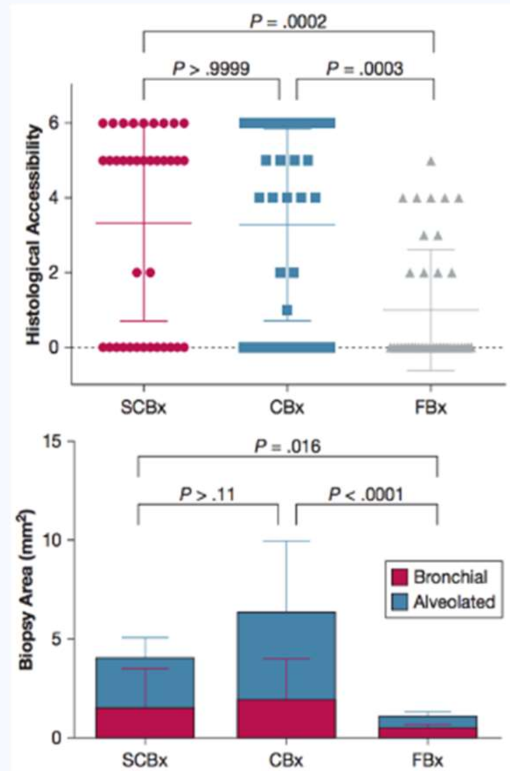
Patient Demographics	Clinical History	Initial Pre-Procedure Scan	Day of Procedure Scan
Age: 54 **Sex**: Female **Smoking**: Former, 20 pack years	54 year old with a history of peptic ulcer disease, rheumatoid arthritis and breast cancer in remission for > 10 yrs incidentally found to have a RUL nodule after CT scanning for chest pain in the ED	 4/28/2015	 5/28/15
Age: 63 **Sex**: Male **Smoking**: Former, 30 pack years	63 year old with a history of Crohn's Disease incidentally found to have a RLL mass on abdominal CT	 7/23/2015	 10/15/2015

Semaan et al, 2016, Annals of American Thoracic Society

Cryobiopsy for Enhanced Tissue Acquisition







Yarmus et al. Chest. 2016

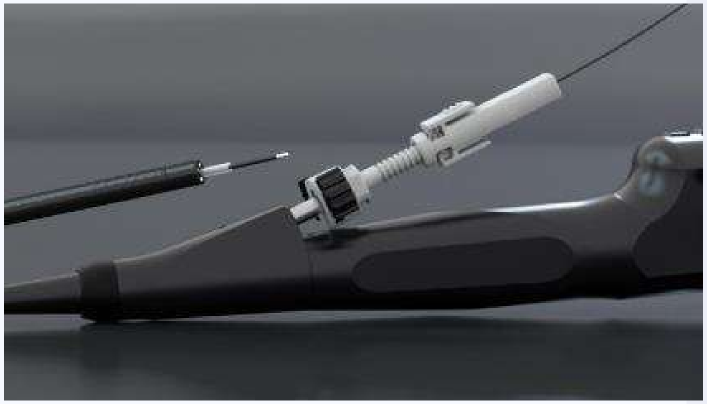
Safety of Cryobiopsy for Peripheral Lesions

Pneumothorax, n (%)	
Grade 1	2 (4)
Grade 2-5*	0
Bleeding, n (%)	
Grade 0	25 (50)
Grade 1	23 (46)
Grade 2	2 (4)
Grade 3*	0
Grade 4*	0
Respiratory failure, n (%)	
Device-related*	0
All-cause	1 (2)

** included in primary outcome*

TABLE 3] Bleeding Rates by Grade and Aspirin Use

Grade	Overall	Use of Aspirin		P Value
		Yes (n = 179)	No (n = 845)	
0 (no bleed)	858 (84)	149 (83)	709 (84)	.37
1	79 (7.7)	10 (5.6)	69 (8.2)	
2	51 (5.0)	12 (6.7)	39 (4.6)	
3	36 (3.5)	8 (4.5)	28 (3.3)	
4	0	0	0	



- Pneumothorax rate: 68/1024 (6.6%)
- Diagnostic Yield: 91% (932/1024)

Herth et al, Chest. 2021
Thiboutot et al. Respiration 2022

ROSE

One RCT showed a 10% increase in success rate for lung cancer genotyping with ROSE during EBUS (though not statistically significant)

Especially important in the periphery where it is difficult to get enough cells for ancillary studies

5 RTCs. – 618 patients:

Diagnostic yield with and without ROSE: No added benefit with ROSE

Needle passes: Significantly fewer needle passes with ROSE: -1.1

Procedure time: No difference

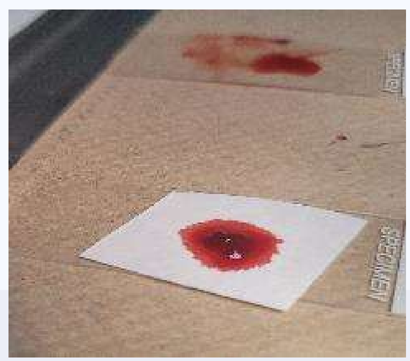
Marcoux. Curr Opin Pulm Med. 2020
Trisolini. CHEST. 2015
Sehgal IS, Chest. 2018 Apr;153(4):929-938
Wahidi MM Chest. 2016 Mar;149(3):816-35.

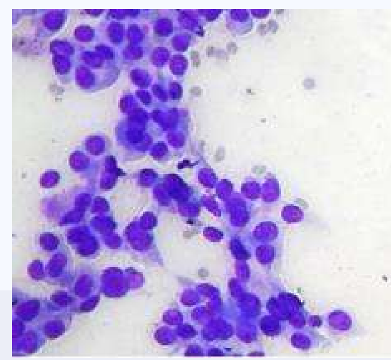
Cytology Processing

Rapid Onsite Cytopathology (ROSE)

Intra-op slide preparation from TBNA sample

Additional passes are obtained for cell block/ clot from the best location



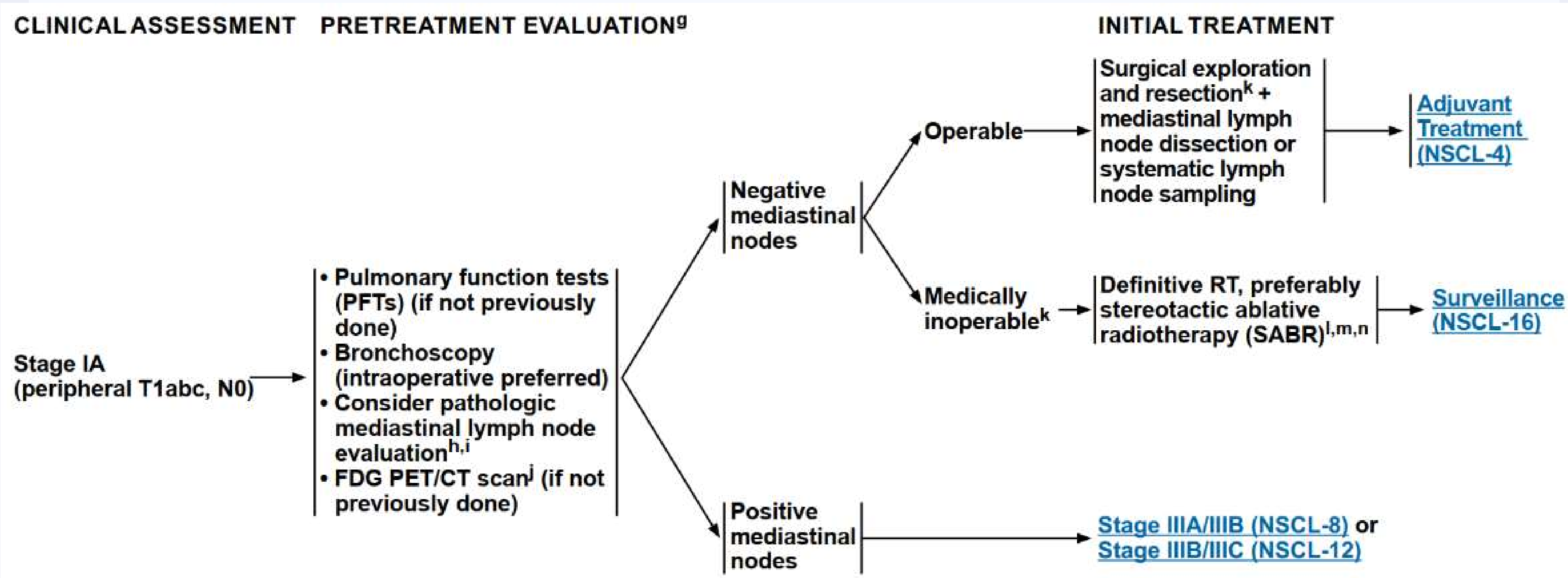


Current State of Early-Stage Treatment

- Surgical resection remains the standard of care

- When patient is not a surgical candidate, options include:
  - Stereotactic body radiotherapy (SBRT)
  - Percutaneous thermal ablation:
    - Radiofrequency Ablation (RF)
    - Microwave Ablation (MWA)
    - Cryoablation
  - Emerging bronchoscopic techniques

NCCN Guidelines



[m] Image-guided thermal ablation (IGTA) therapy (eg, cryotherapy, microwave, radiofrequency) may be an option for select patients not receiving SABR or definitive RT. Principles of Image-Guided Thermal Ablation Therapy (NSCL-D).

Bronchoscopic Technology Under Evaluation

Radiofrequency Ablation (RFA)

Microwave Ablation (MWA)

Photodynamic Therapy (PDT)

Cryotherapy

Vapor Ablation

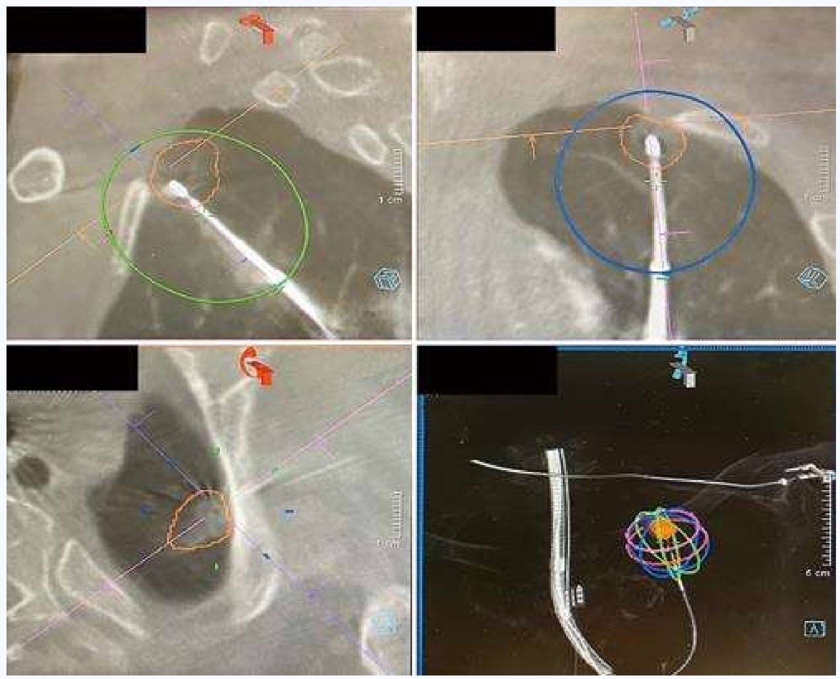
Brachytherapy

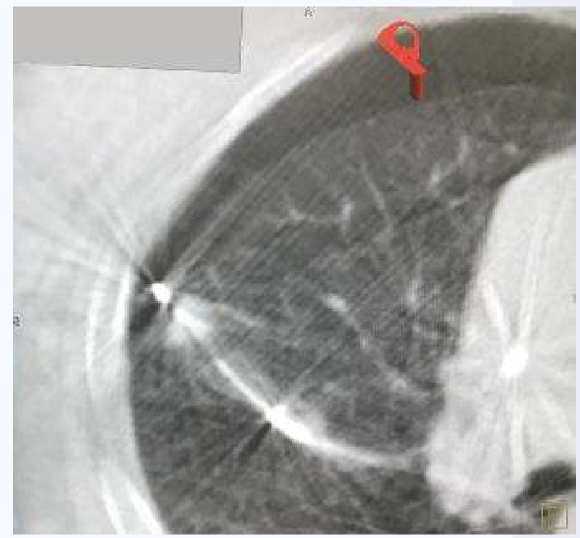
Very limited data on use of these technologies in vivo

Harris, K. Chest 151 (3), 2017: 674-685

Now that we can get there…

- Ablation zones
- Safety
  - Bleeding
  - PTX
  - cavitation
- Efficacy





Thoracic Cancer
Open Access

ORIGINAL ARTICLE | Open Access

Microwave ablation via a flexible catheter for the treatment of nonsurgical peripheral lung cancer: A pilot study

Xie et al. Thorac Cancer. 2022

Respiration

Novel Image-Guided Flexible-Probe Transbronchial Microwave Ablation for Stage 1 Lung Cancer

- Single arm Stage IA NSCLC non-surgical candidates
- Intervention: MWA using ENB with cone beam confirmation
- Planned enrollment: 40 patients
- Primary outcome: "technical success" – radiographic at 30d
- Enrolled: 10 patients
- Study halted after 2 deaths (massive hemorrhage, COPD exacerbation)
- Technical success rate 100%

Pritchett et al. Respiration. 2023

A multicenter open-label phase 1/1b study to evaluate safety, feasibility and early treatment effect of Padeliporfin VTP (Vascular-Targeted Photodynamic Therapy) using RAB/CBCT

Who: cT1N0, <2cm, CT/PET neg mediastinum, surgically resectable

How:

1) Multi D informed consent
2) EBUS/RAB/CBCT with ROSE, if +, Treatment at same procedure
    1) Confirm needle/fiber in lesion by CBCT
    2) Systemic infusion of drug (10 mins)
    3) Activation of light fiber (~15 mins) with dose escalation
3) Research admission for 48 hrs for safety monitoring
4) Resection 5-21 days post procedure

Endpoints: Safety/Feasibility

Bronchoscopic Lung Cancer Treatment

Combined staging, diagnosis and treatment into a single procedur

- Time to Diagn
- Safety
- Cost
- Patient Cente
- PFS/OS

Immediately de ablative therap

Neoadjuvant Th

Immune Primer/Abscopal Effect

Murphy MC, Update on Image-Guided Thermal Lung Ablation: Society Guidelines, Therapeutic Alternatives, and Postablation Imaging Findings. AJR 2022 Mar 23

Take Home Points

Guided Bronchoscopy is evolving rapidly

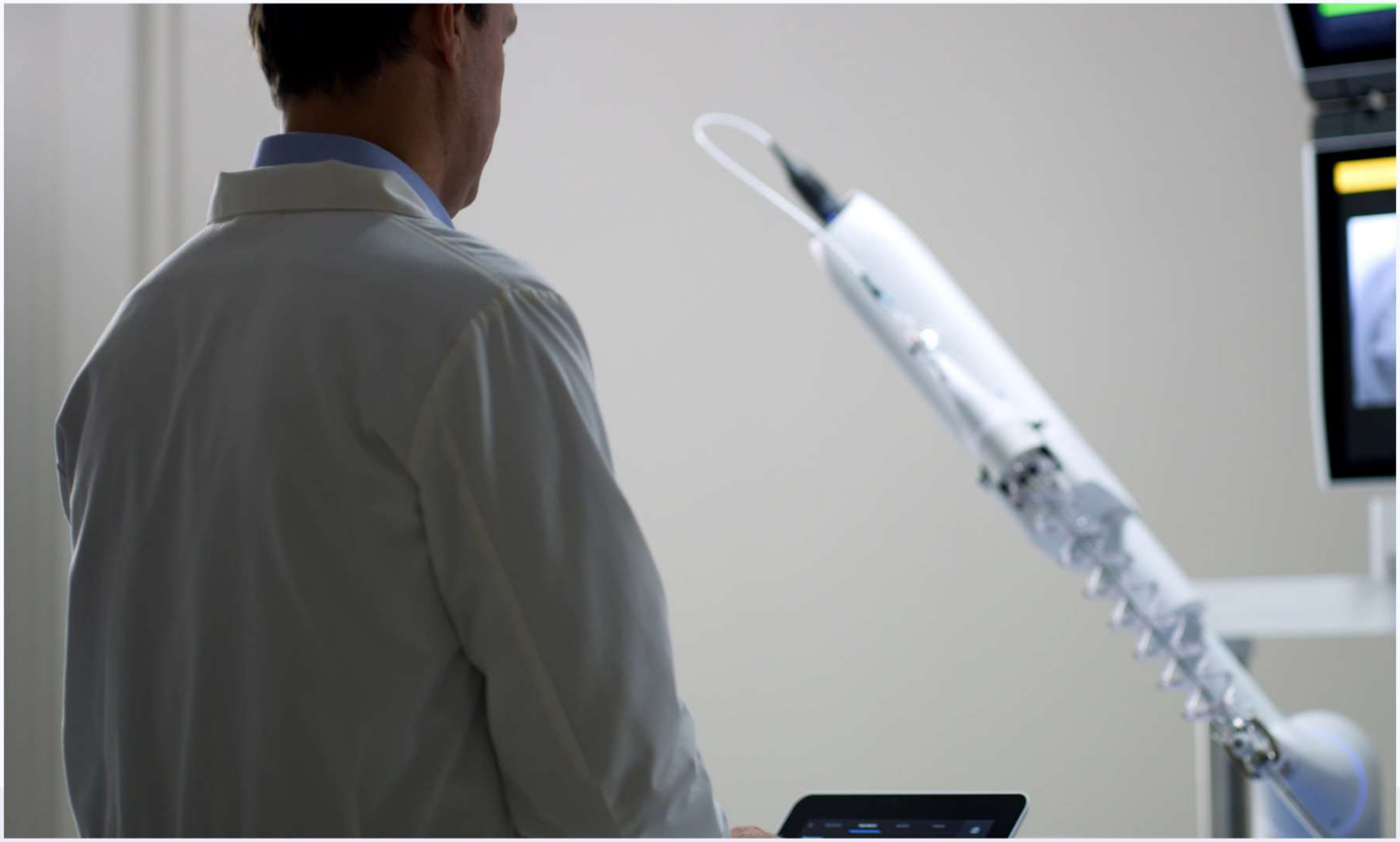
Select your platform according to your needs and options

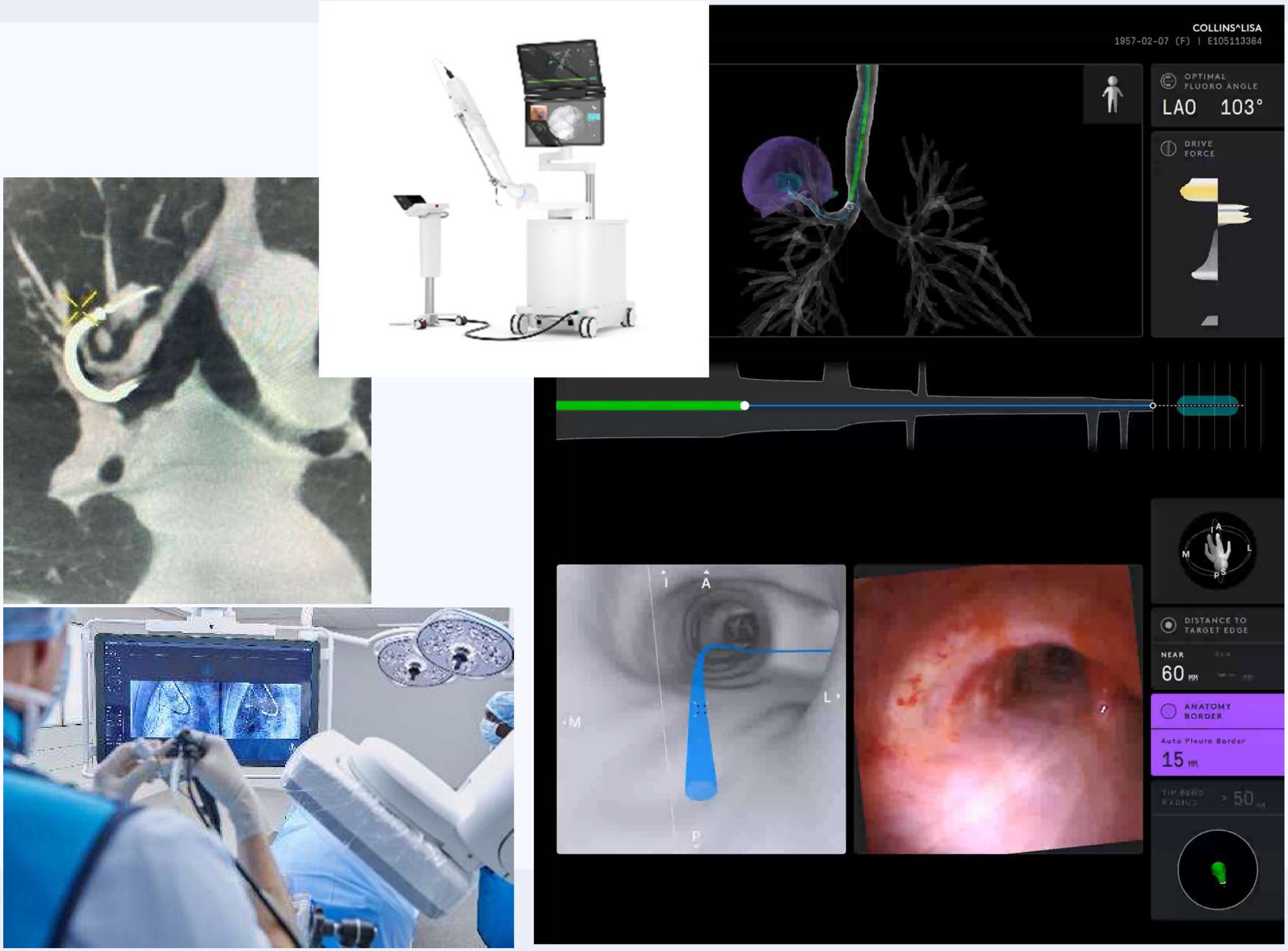
Use a variety of tools and intraprocedural imaging if possible

Make sure to create an adequate cell block

Strong need for robust comparative studies to determine optimal bronchoscopic approach and technique for ablation

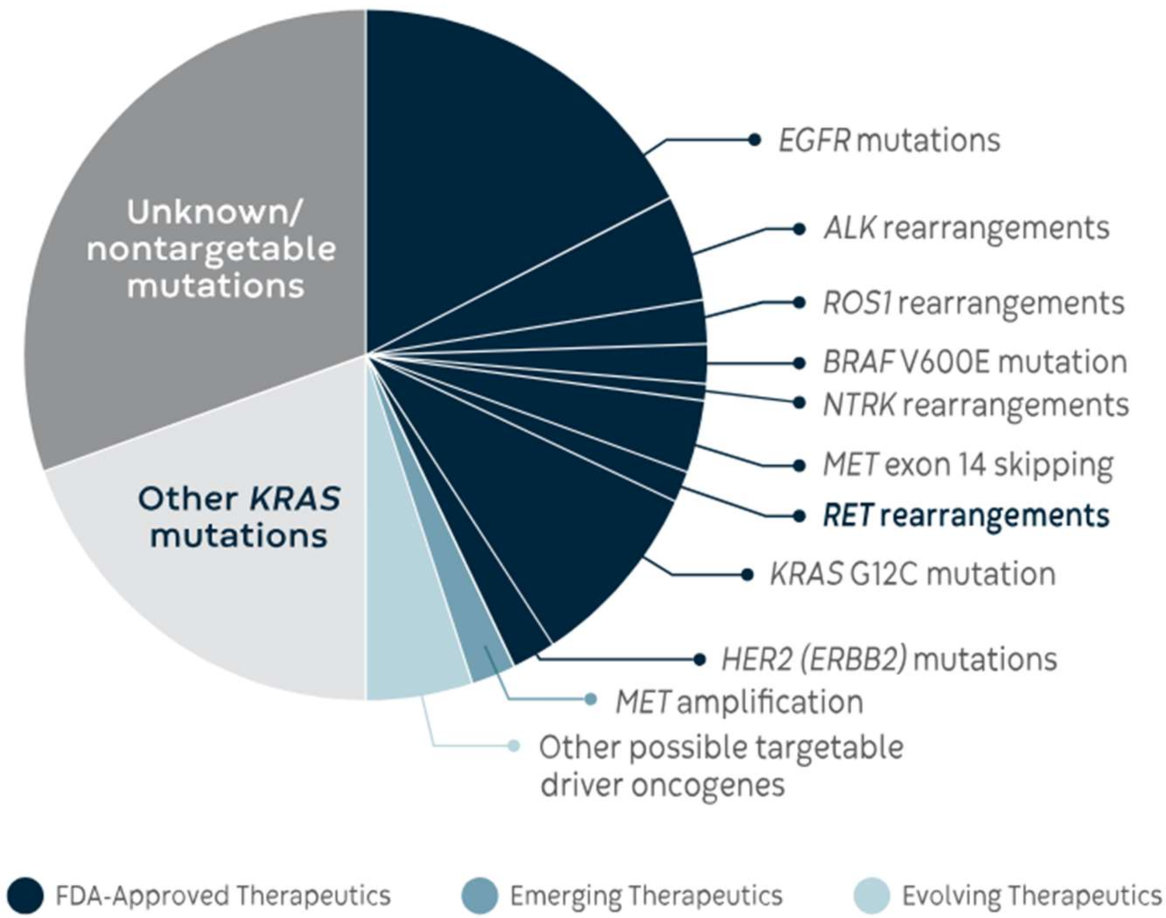
Peripheral Nodules: Robotics




COLLINS^LISA
1957-02-07 (F) | E105113364
OPTIMAL FLUORO ANGLE
LAO 103°
DRIVE FORCE
DISTANCE TO TARGET EDGE
NEAR
60 MM
ANATOMY BORDER
Auto Pleura Border
15 MM

There

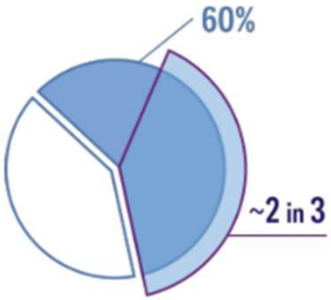
Drive



Unknown/ nontargetable mutations
Other KRAS mutations
EGFR mutations
ALK rearrangements
ROS1 rearrangements
BRAF V600E mutation
NTRK rearrangements
MET exon 14 skipping
RET rearrangements
KRAS G12C mutation
HER2 (ERBB2) mutations
MET amplification
Other possible targetable driver oncogenes
FDA-Approved Therapeutics
Emerging Therapeutics
Evolving Therapeutics

BIOMARKERS ARE COMMON IN NSCLC

METASTATIC NSCLC (mNSCLC)
NONSQUAMOUS



MORE THAN 60%
of patients have oncogenic drivers—and of these patients, about 2 in 3 have an actionable biomarker[1-5a]

[a]Regardless of PD-L1 expression.

STAGES I-III NSCLC

~13% of patients have *EGFR* mutations[6-8]

2%-5% of patients are *ALK*+[6,7,9]

1%-3% of patients have *RET* fusions[6,7,10]

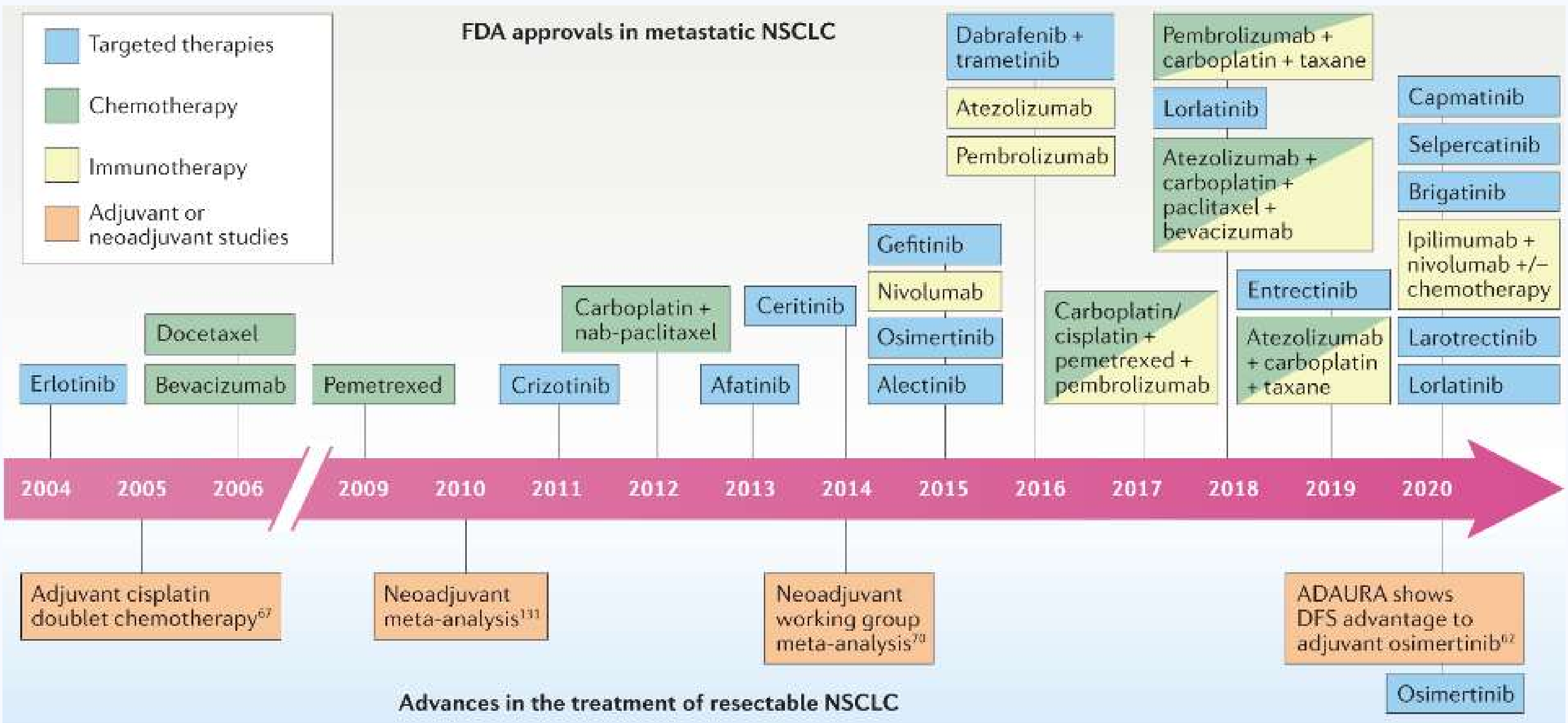
~45% of patients are PD-L1+[11,12]

FDA-approved therapeutics

Emerging therapeutics

Evolving biomarkers include:

- BRAF[13]
- MET[14]
- NTRK[13]
- ROS1[13]



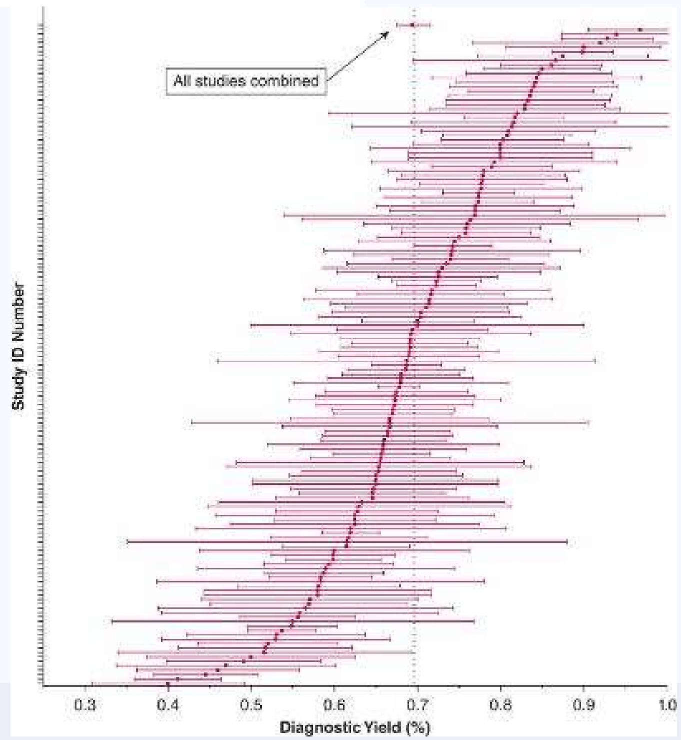
Targeted therapies
Chemotherapy
Immunotherapy
Adjuvant or neoadjuvant studies
FDA approvals in metastatic NSCLC
2004
2005
2006
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Erlotinib
Docetaxel
Bevacizumab
Pemetrexed
Crizotinib
Carboplatin + nab-paclitaxel
Afatinib
Ceritinib
Gefitinib
Nivolumab
Osimertinib
Alectinib
Dabrafenib + trametinib
Atezolizumab
Pembrolizumab
Carboplatin/ cisplatin + pemetrexed + pembrolizumab
Pembrolizumab + carboplatin + taxane
Lorlatinib
Atezolizumab + carboplatin + paclitaxel + bevacizumab
Entrectinib
Atezolizumab + carboplatin + taxane
Capmatinib
Selpercatinib
Brigatinib
Ipilimumab + nivolumab +/– chemotherapy
Larotrectinib
Lorlatinib
Adjuvant cisplatin doublet chemotherapy[67]
Neoadjuvant meta-analysis[131]
Neoadjuvant working group meta-analysis[70]
ADAURA shows DFS advantage to adjuvant osimertinib[62]
Osimertinib
Advances in the treatment of resectable NSCLC

Is there a Gold Standard? Do we know what bronchoscopic yield really is?

Guided Bronchoscopy for the Evaluation of Pulmonary Lesions: An Updated Meta-analysis

Tejaswi R Nadig [1], Nina Thomas [2], Paul J Nietert [3], Jessica Lozier [1], Nichole T Tanner [4], Jessica S Wang Memoli [5], Nicholas J Pastis [6], Gerard A Silvestri [7]

- Total of 16,389 lesions from 126 studies.
- Yield in 2012: 70.5%
- Yield after 2012: 69.2%
- Pooled approaches analyzed
- No significant difference in yield when comparing different technologies.



Silvestri et al, Guided Bronchoscopy for the evaluation of Pulmonary lesions: An Updated Meta-analysis. *Chest 2023*

What happens when we start to randomize and standardize definitions with isolated approaches?

Standard Bronchoscopy With Fluoroscopy vs Thin Bronchoscopy and Radial Endobronchial Ultrasound for Biopsy of Pulmonary Lesions
A Multicenter, Prospective, Randomized Trial

Check for updates

Nichole T. Tanner, MD; Lonny Yarmus, DO; Alexander Chen, MD; Jessica Wang Memoli, MD; Hiren J. Mehta, MD; Nicholas J. Pastis, MD; Hans Lee, MD; Michael A. Jantz, MD; Paul J. Nietert, PhD; and Gerard A. Silvestri, MD

The Impact of Alternative Approaches to Diagnostic Yield Calculation in Studies of Bronchoscopy

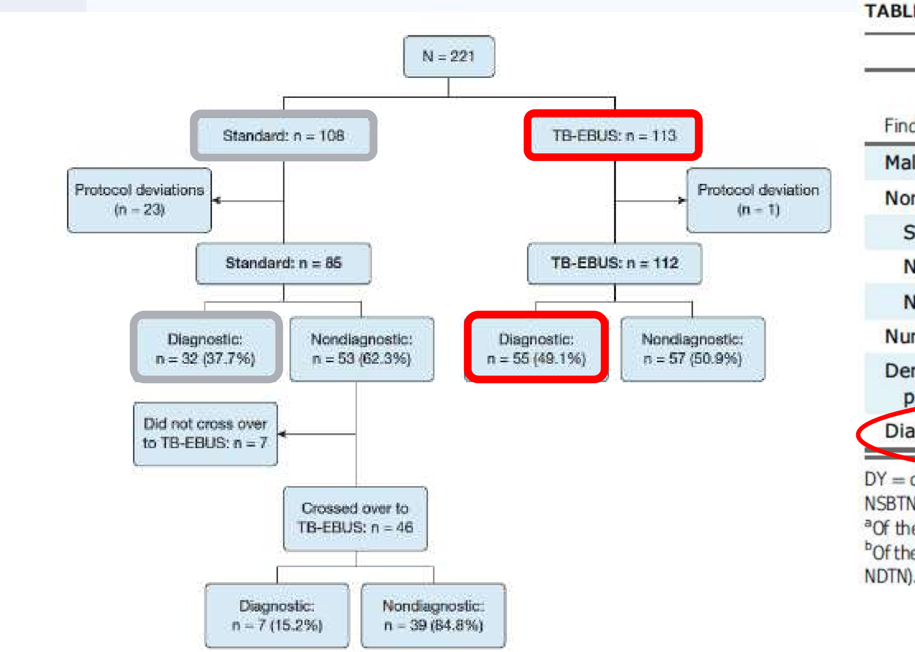


TABLE 1] Bronchoscopy Findings and Calculation of DY in the Hypothetical Cohort

		Classification of TP, TN, and Denominator for DY Calculation				
				Method 3		
Findings at Bronchoscopy (N = 1,000)	No.	Method 1	Method 2	3A	3B	3C
Malignant	611	611 (TP)	611 (TP)	611 (TP)	611 (TP)	611 (TP)
Nonmalignant	389	NA	NA	NA	NA	
Specific benign (SPB)	56	56	56	56	56	56
Nonspecific benign (NSB)	111[a]	NA	74 (NSBTN)	74 (NSBTN)	74 (NSBTN)	74 (NSBTN)
Nondiagnostic (ND)	222[b]	NA	NA	56 (NDTN)	56 (NDTN)	56 (NDTN)
Numerator: TP + TN		667	741	797	797	889
Denominator: total procedures (TO)		1,000	1,000	908[c]	1,000	1,000
Diagnostic yield, %		66.7[d]	74.1[e]	87.8[f]	79.8[g]	88.9[h]

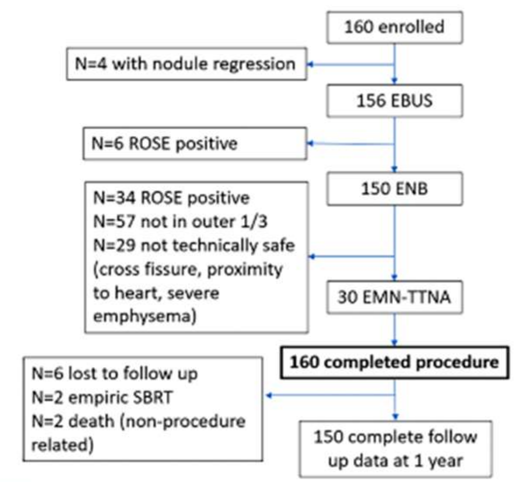
DY = diagnostic yield; LTFU = lost to follow-up; NA = not applicable; ND = nondiagnostic; NDTN = nondiagnostic true negative; NSB = nonspecific benign; NSBTN = nonspecific benign true negative; SPB = specific benign; TN = true negative; TO = total procedures; TP = true positive.
[a]Of the 111 patients with NSB findings at bronchoscopy, 74 were categorized as TNs based on subsequent biopsy or repeat imaging (labeled NSBTN).
[b]Of the 222 patients with ND findings at bronchoscopy, 56 were determined to have benign disease based on subsequent biopsy or repeat imaging (labeled NDTN).

What happens when we isolate approaches and strict outcomes?

ORIGINAL ARTICLE

A Multicenter, Single-Arm, Prospective Trial Assessing the Diagnostic Yield of Electromagnetic Bronchoscopic and Transthoracic Navigation for Peripheral Pulmonary Nodules

Jeffrey Thiboutot[1], Nicholas J. Pastis[3], Jason Akulian[4], Gerard A. Silvestri[5], Alexander Chen[6], Momen M. Wahidi[7], Christopher R. Gilbert[5], Cheng Ting Lin[2], Jenna Los[1], Eric Flenaugh[8], Roy Semaan[9], A. Cole Burks[4], Priya Sathyanarayan[1], Sam Wu[1], David Feller-Kopman[10], George Z. Cheng[11], Raed Alalawi[12], Najib M. Rahman[13], Fabien Maldonado[14], Hans J. Lee[1], and Lonny Yarmus[1]; on behalf of the Interventional Pulmonary Outcomes Group



- Single-arm, prospective, multi-center trial; Dx yield EMN
- Core Pathology and Radiology, 12-month follow up
- **No flouro, radial, or other ancillary guidance**

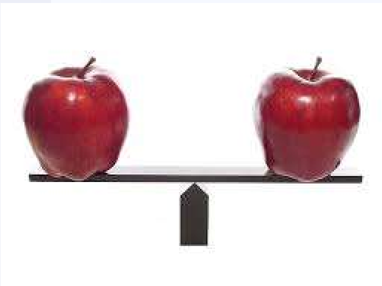
Intervention	Yield
Nodule regression	4/160 (2.5)
EBUS	11/156 (7.1)
ENB	74/150 (49.3)
EMN-TTNA	8/30 (26.7)
ENB + EMN-TTNA	79/150 (52.7)
Overall	94/160 (58.8)

	Strict	Intermediate	Liberal
ENB Yield	49.3%	56%	73.3%

Conclusions: The diagnostic yield for ENB is 49%, which increases to 59% with the addition of same-day CT, EBUS, and EMN-TTNA, lower than in prior reports in the literature. The high complication rate and low diagnostic yield of EMN-TTNA does not support its routine use.

Thiboutut, Yarmus J, 2023, ARJCCM

Interventional Pulmonary Outcomes Group



Assessment of Advanced Diagnostic Bronchoscopy Outcomes for Peripheral Lung Lesions: A Delphi Consensus Definition of Diagnostic Yield and Recommendations for Patient-centered Study Designs

An Official American Thoracic Society/American College of Chest Physicians Research Statement

Anne V. Gonzalez, Gerard A. Silvestri, Daniel A. Korevaar, Yaron B. Gesthalter, Nisha D. Almeida, Alex Chen, Chris R. Gilbert, Peter B. Illei, Neal Navani, Mary M. Pasquinelli, Nicholas J. Pastis, Catherine R. Sears, Samira Shojaee, Stephen B. Solomon, Daniel P. Steinfort, Fabien Maldonado, M. Patricia Rivera, and Lonny B. Yarmus; on behalf of the American Thoracic Society Assembly on Thoracic Oncology and the American College of Chest Physicians

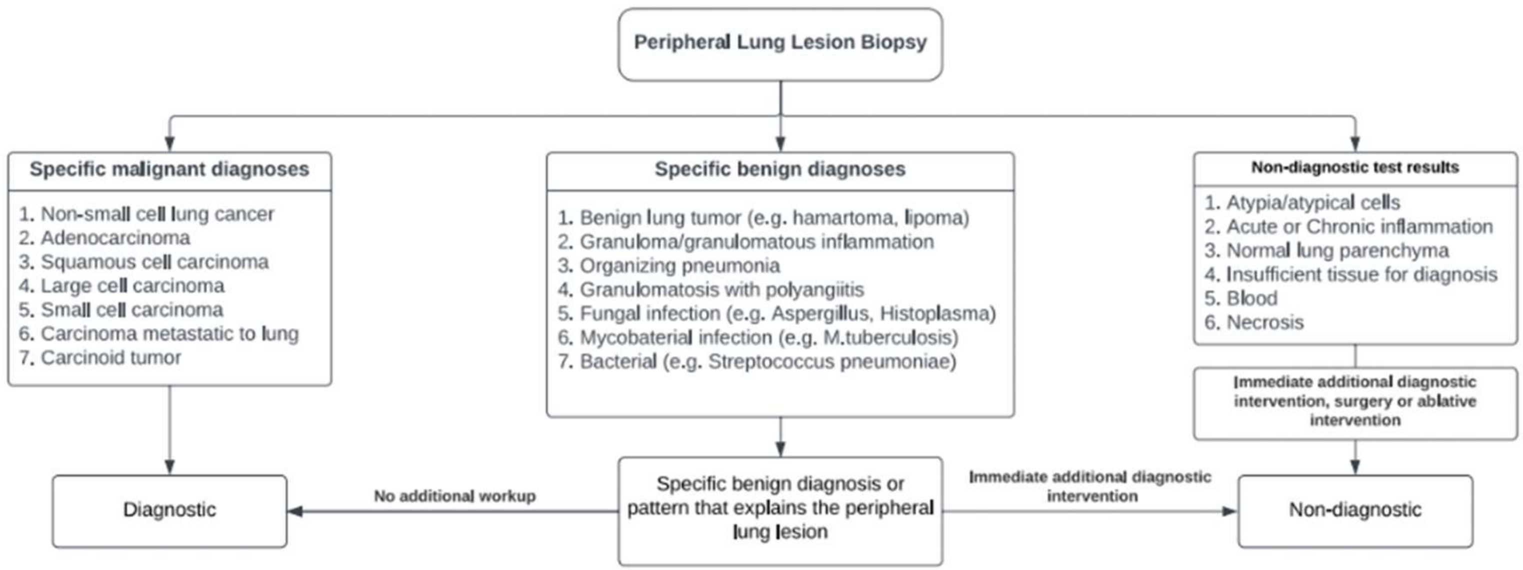
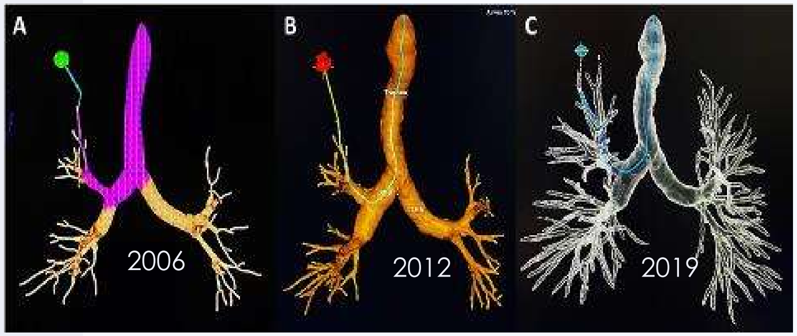
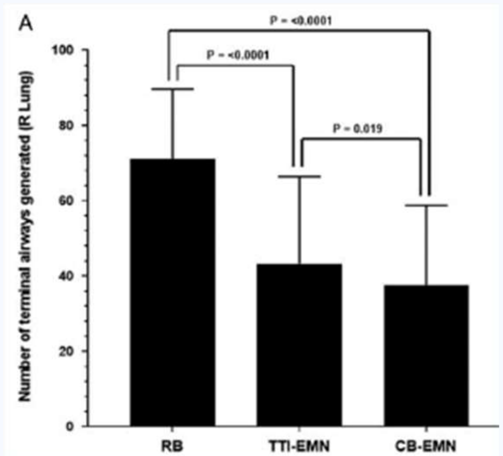


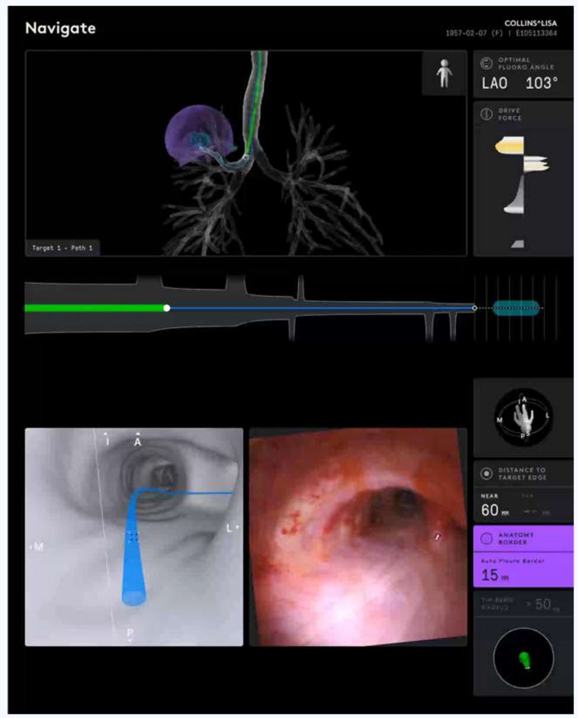
Figure 2. Algorithmic approach to classifying peripheral lung biopsy results.

Standardized trial design and outcome parameters

VERITAS: Can bronchoscopy meet expectations?







Yarmus, L, Annals ATS 2022
Thibboutot J, AJRCCM, 2023

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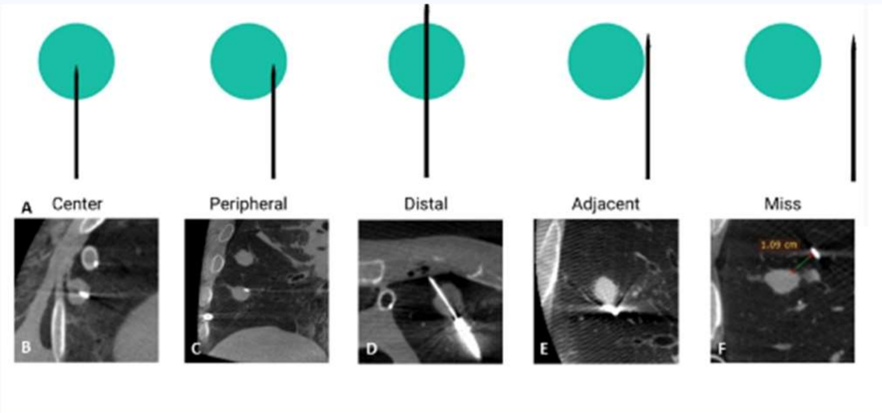
Duke University Medical Center

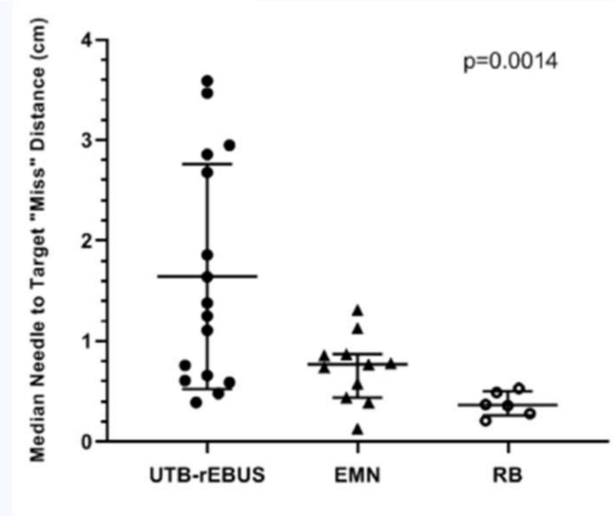
Washington University in St. Louis SCHOOL OF MEDICINE

MICHIGAN MEDICINE UNIVERSITY OF MICHIGAN

VANDERBILT SCHOOL OF MEDICINE

A Prospective Single-Blinded Randomized Comparative Study of Three Guided Bronchoscopic Approaches for Investigating Pulmonary Nodules (The PRECISION-1 Study)



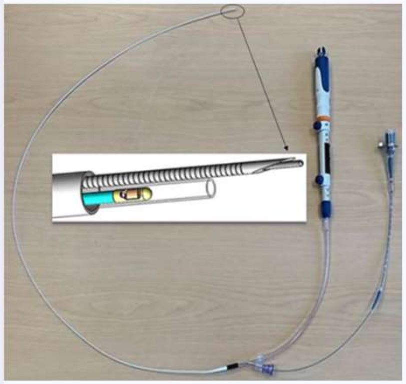


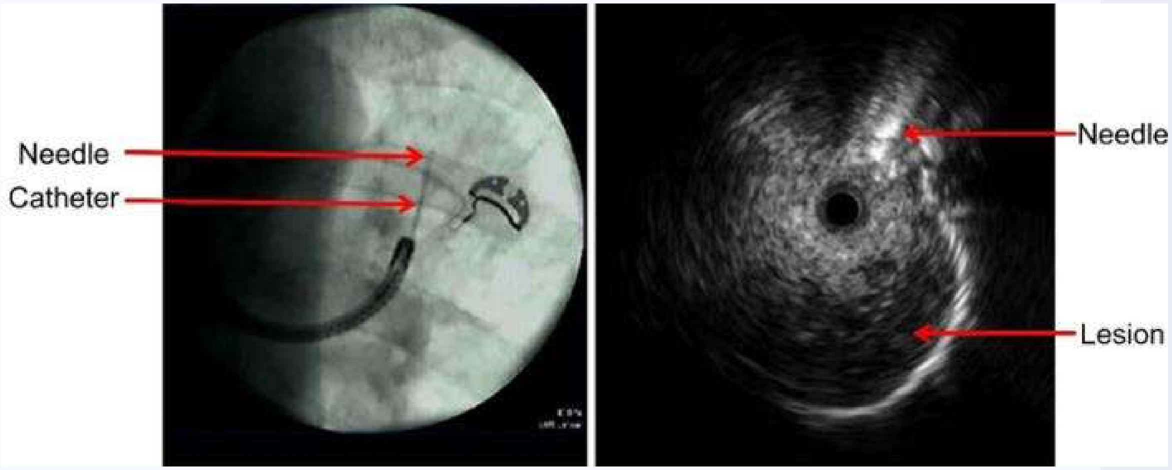
Study Arm	n	Study Outcomes		
		Localization and Puncture (Primary Endpoint)[a] % (n)	Localization & Puncture (Secondary Endpoint)[b] % (n)	Successful Navigation % (n)
UTB-rEBUS	20	25 (5)	35 (7)	65 (13)
EMN	20	45 (9)	65 (13)	85 (17)
RB	20	80 (16)	90 (18)	100 (20)

Yarmus et al, CHEST 2020

IP and Innovation at Hopkins: Have we been limited by our biopsy tools?

First-in-Human Use of a Hybrid Real-Time Ultrasound-Guided Fine-Needle Acquisition System for Peripheral Pulmonary Lesions: A Multicenter Pilot Study





Mallow, Yarmus et al, Respiration, 2019

Cryoprobe Transbronchial Lung Biopsy in Patients After Lung Transplantation

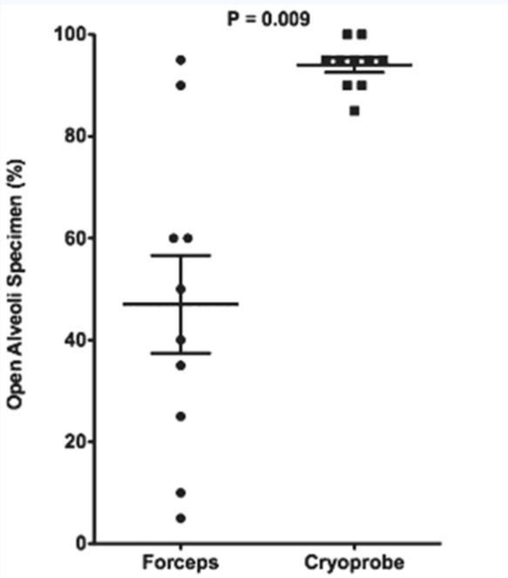
A Pilot Safety Study

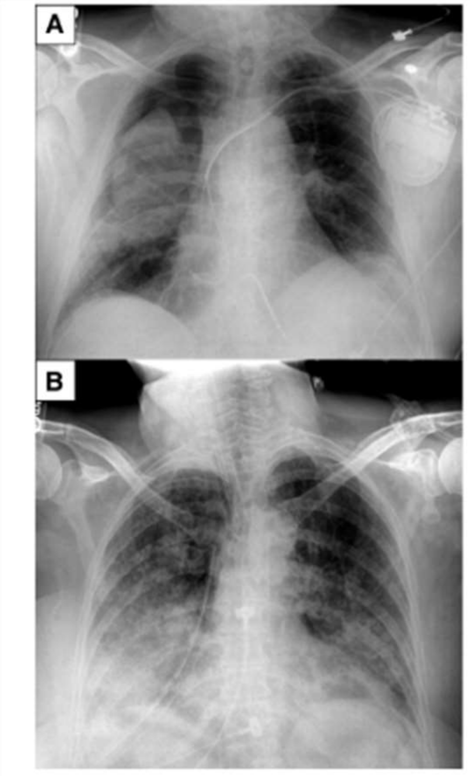
ORIGINAL RESEARCH

High Complication Rate after Introduction of Transbronchial Cryobiopsy into Clinical Practice at an Academic Medical Center

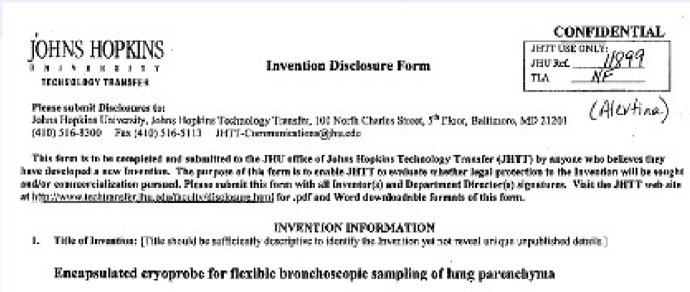
David M. DiBardino, Andrew R. Haas, Anthony R. Lanfranco, Leslie A. Litzky, Daniel Sterman, and Jamie L. Bessich

- Prospective study of lung transplants undergoing surveillance or for cause (rejection) biopsy
- All patients underwent TBBX using forceps (x10) then
  1.9 mm cryoprobe (x5)
- Pneumothorax (1/21); delayed and unable to identify group
- Bleeding
  - Grade 2 (wedging or iced saline): 1/21 in cryoprobe
  - No grade 3 or 4 bleeding (bronchial blocker)





Yarmus et al CHEST 2013;143(3):621-626.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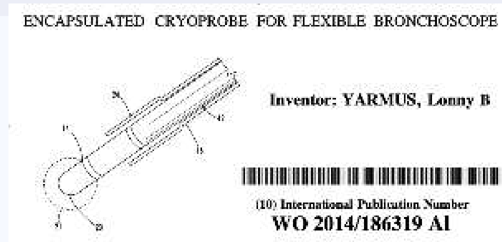
This form is to be completed and submitted to the JHU office of Johns Hopkins Technology Transfer (JHTT) by anyone who believes they have developed a new invention. The purpose of this form is to enable JHTT to evaluate whether legal protection to the invention will be sought and/or commercialization pursued. Please submit this form with all Inventor(s) and Department Director(s) signatures. Visit the JHTT web site at http://www.techtransfer.jhu.edu/facultydisclosure.html for .pdf and Word downloadable formats of this form.

INVENTION INFORMATION

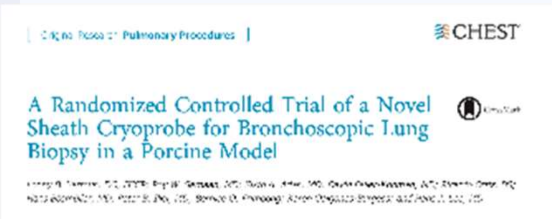
1. Title of Invention: [Title should be sufficiently descriptive to identify the invention yet not reveal unique unpublished details.]

Encapsulated cryoprobe for flexible bronchoscopic sampling of lung parenchyma


ENCAPSULATED CRYOPROBE FOR FLEXIBLE BRONCHOSCOPE

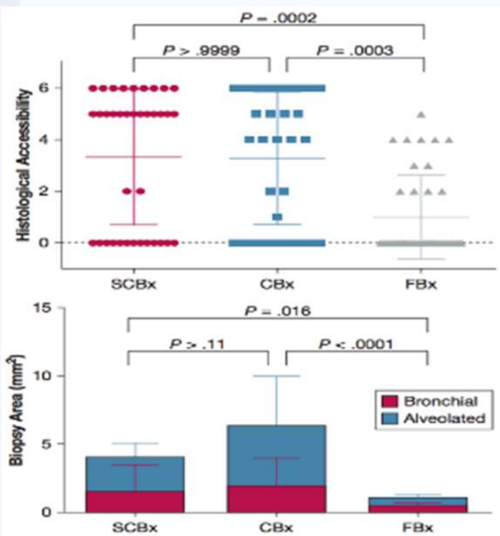
Inventor: YARMUS, Lonny B

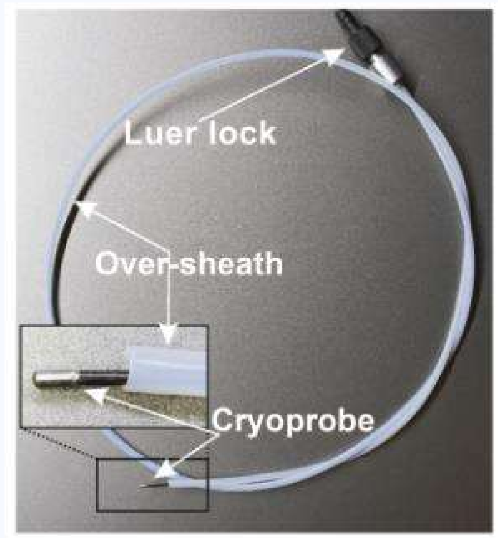
(10) International Publication Number
WO 2014/186319 A1

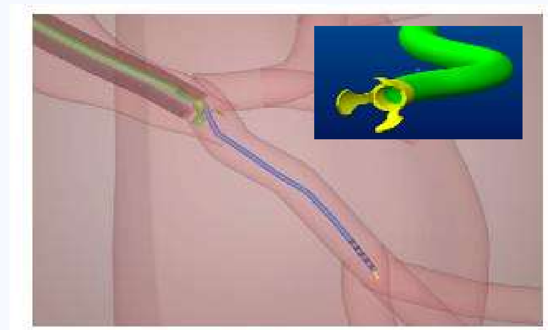

Original Research Pulmonary Procedures

CHEST

A Randomized Controlled Trial of a Novel Sheath Cryoprobe for Bronchoscopic Lung Biopsy in a Porcine Model



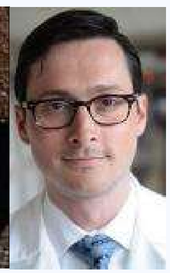





U.S. FOOD & DRUG

FROSTBITE-1 – Phase 1 trial

- Peripheral CBx with 1.1mm probe
- Any indication (ILD, LTxp, lung nodule)
- Pre-defined safety outcome with stopping
- and FDA retraction rules



FROSTBITE-2 – RCT

- 500 patients
- Largest RCT in Bronchoscopy
- Completed enrollment

Respiration

Interventional Pulmonology

Respiration 2022;101:1131–1138
DOI: 10.1159/000525876

Safety and Feasibility of a Sheath Cryoprobe for Bronchoscopic Transbronchial Biopsy: The FROSTBITE Trial

Jeffrey Thiboutot[a] Peter B. Illei[b] Fabien Maldonado[c] Christopher M. Kapp[c]
Andrew DeMaio[c] Hans J. Lee[a] David Feller-Kopman[d] Robert J. Lentz[c]
Priya Sathyanarayan[a] Najib M. Rahman[e] Gerard A. Silvestri[f] Lonny Yarmus[a]
on behalf of the Interventional Pulmonary Outcomes Group

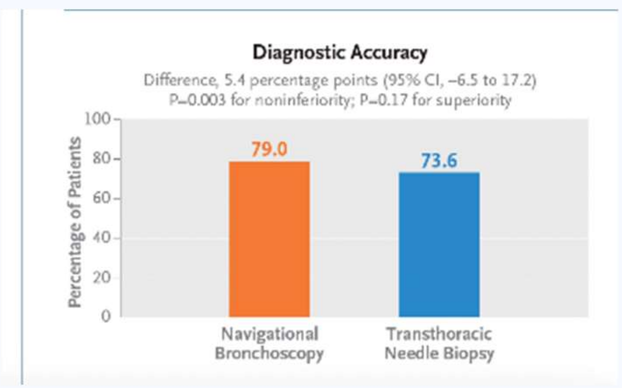
Table 2. Complications		
Pneumothorax, n (%)		
	Grade 1	2 (4)
	Grade 2-5*	0
Bleeding, n (%)		
	Grade 0	25 (50)
	Grade 1	23 (46)
	Grade 2	2 (4)
	Grade 3*	0
	Grade 4*	0
Respiratory failure, n (%)		
	Device-related*	0
	All-cause	1 (2)

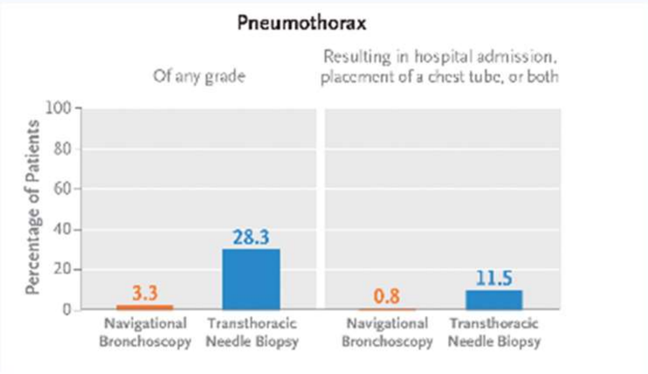
** included in primary outcome*

Navigation Endoscopy to Reach Indeterminate Lung Nodules versus Transthoracic needle Aspiration (VERITAS)

- Bronchoscopy yield 70-80%; complications ~5%
- CT-TTNA yields reported >90%, complications ~30%
- Need for comparative effectiveness trials

- **Design**: Multicenter RCT Navigational bronchoscopy vs. CT-guided needle biopsy
- Noninferiority of NB to CT-TTNB for **Diagnostic accuracy/Diagnostic yield**:





Lentz et al, NEJM 2025

Interventional Pulmonary Outcomes Group

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VERITAS

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CLINICAL INVESTIGATION

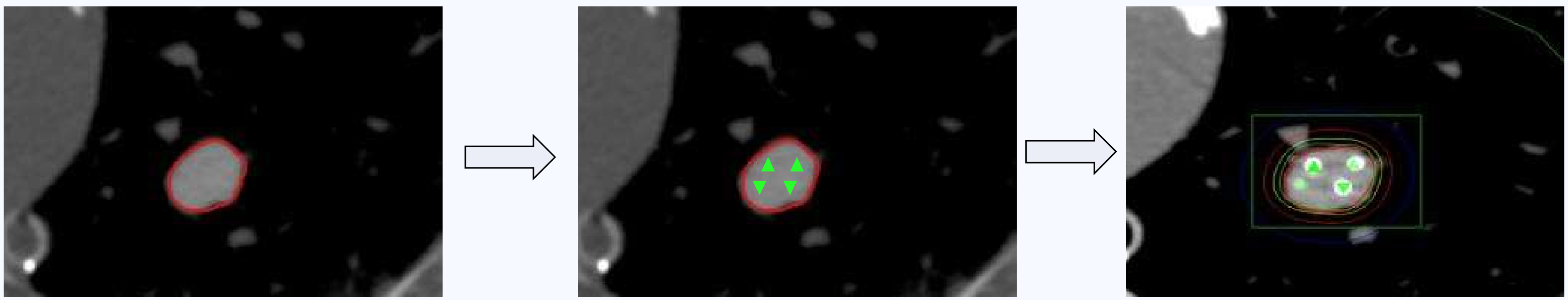
Brachytherapy Seed Placement by Robotic Bronchoscopy with Cone Beam Computed Tomography Guidance for Peripheral Lung Cancer: A Human Cadaveric Feasibility Pilot

Ardian Latifi, MD,[a] Michael Roumeliotis, PhD,[b] Sarah Quirk, PhD,[c] Ulysses G. Gardner, MD,[b] Travis Ferguson, MD,[d] Daniel Y. Song, MD,[b] and Lonny Yarmus, DO[a]

Table 1 Brachytherapy and SBRT dosimetry

Dose metric	Brachytherapy mean (± SD)	SBRT mean (± SD)	*P* value
V95% (%)	96.6 (± 1.9)	98.0 (-)	-
Conformity ($V95\%/V_{PTV}$)	1.2 (± 0.1)	1.0 (± 0.1)	-
Conformity ($V50\%/V_{PTV}$)	2.3 (± 0.4)	4.0 (± 0.3)	*P* << .001*
Conformity ($V25\%/V_{PTV}$)	5.0 (± 0.7)	17.5 (± 2.2)	*P* << .001*

Abbreviations: PTV = planning target volume; SBRT = stereotactic body radiation therapy; Vx% = Percent of planning volume covered by x% of prescription dose.
* Indicates statistical significance.
Target coverage and target conformity (V95%) were designed to be similar, so differences in normal tissue conformity are used for comparison.



- CT scans obtained

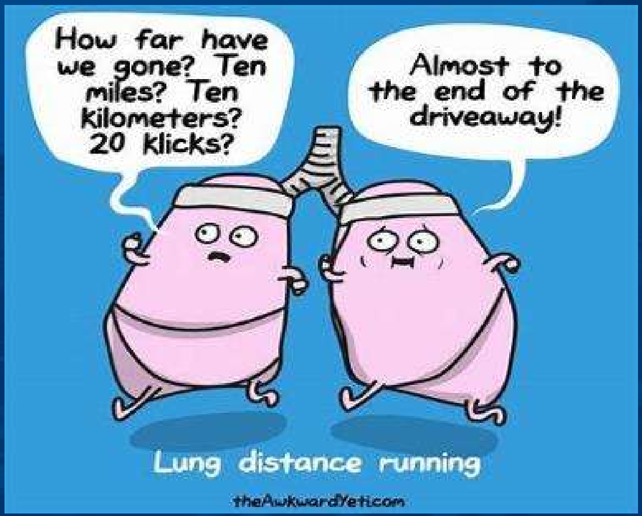
- BT plans created
- 41 seed plans
- Target dose 100 Gy

- Intubated/ventilated
- RB-CBCT implantation
- Dosimetry Calculated

- Mean pseudotumor size: 1.5cm
- 41 BT seeds placed → 96% accuracy
- Seed Placement Error +/- 3mm
- Target dose (D90%) = 100 Gy
- Mean achieved dose (D90%) = 111 Gy

Thank You

aargent1@jh.edu



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MEDICINE

NSCLC Survival Has Greatly Improved

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

The Effect of Advances in Lung-Cancer Treatment on Population Mortality

Nadia Howlader, Ph.D., Gonçalo Forjaz, D.V.M., Meghan J. Mooradian, M.D., Rafael Meza, Ph.D., et al.

- Mortality for all lung cancer stages has greatly improved

- Precision Medicine is the driver of recent NSCLC survival gains