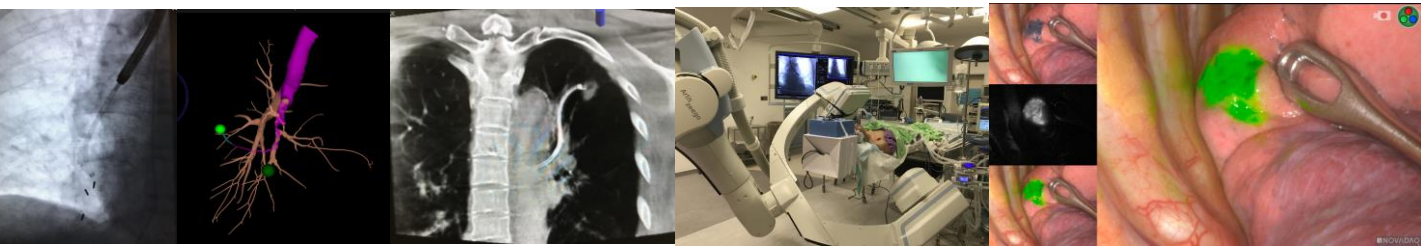

One Stop One Shop Strategy for Lung Nodules: What the Future may hold

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Disclosures

- Siemens – Research, Speaker & Travel
- Johnson & Johnson – Advisory Boards, Speaker & Travel
- Medtronic - Advisory Boards, Research (PI) , Speaker & Travel
- Karl Storz - Educational Fund, Speaker & Travel
- Stryker - Advisory Board, Speaker & Travel
- Intuitive - Advisory role, Travel
- Broncus - Advisory role, Research (Co-I), Speaker & Travel

Content

- Background
- Hybrid OR hookwire localization (iVATS)
- Hybrid OR & Electromagnetic Navigation Bronchoscopy (iENB)
  - Biopsy
  - Marking –surgical localisation
  - Hybrid Value
  - Ablation & others

REGIONAL SPOTLIGHT – ASIA:

- 51 % of the world's lung cancer cases occur in Asia.

- 21 % of cancer deaths in Asia are due to lung cancer

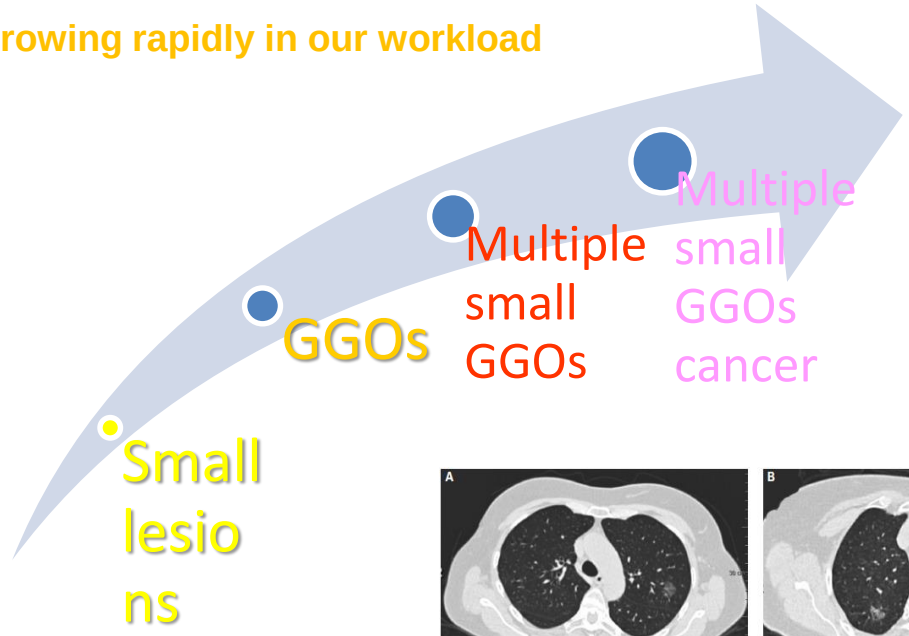
IASLC database

Lung Cancer- The Changing Trend

- Younger patients
- Non-smokers
- Earlier detection
- More patient awareness
  - Annual healthchecks
  - More liberal use of CT scan
  - Very small lesions at detection

Diagnostic & treatment challenge

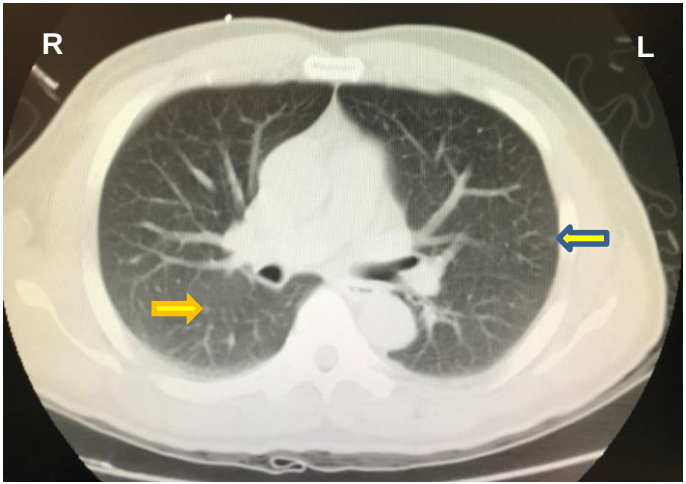
- **Growing rapidly in our workload**



Zhao Z, Situ D, Lau R, Mok T, Chen G, Ng CSH. Comparison of segmentectomy & lobectomy in stage IA adenocarcinomas. *J Thorac Oncol* 2017;12:890-6

Small Ground Glass Opacity (GGO) lung shadow

- Right lower lobe 3mm GGO



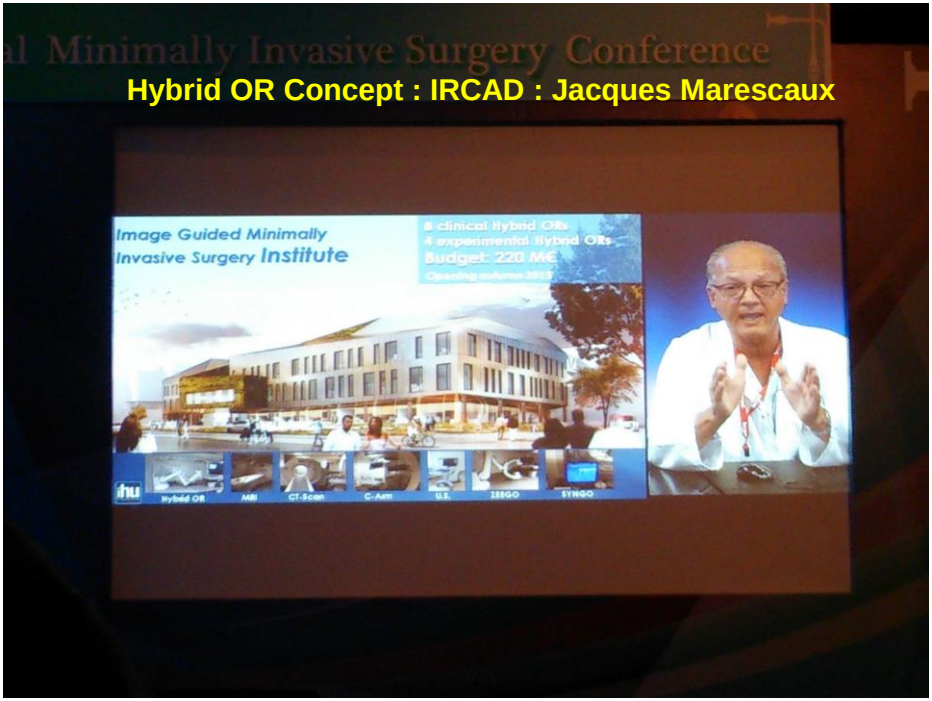
- Left upper lobe 3mm GGO

Table 1 Brief summary of pulmonary nodules localization techniques without the need for palpation

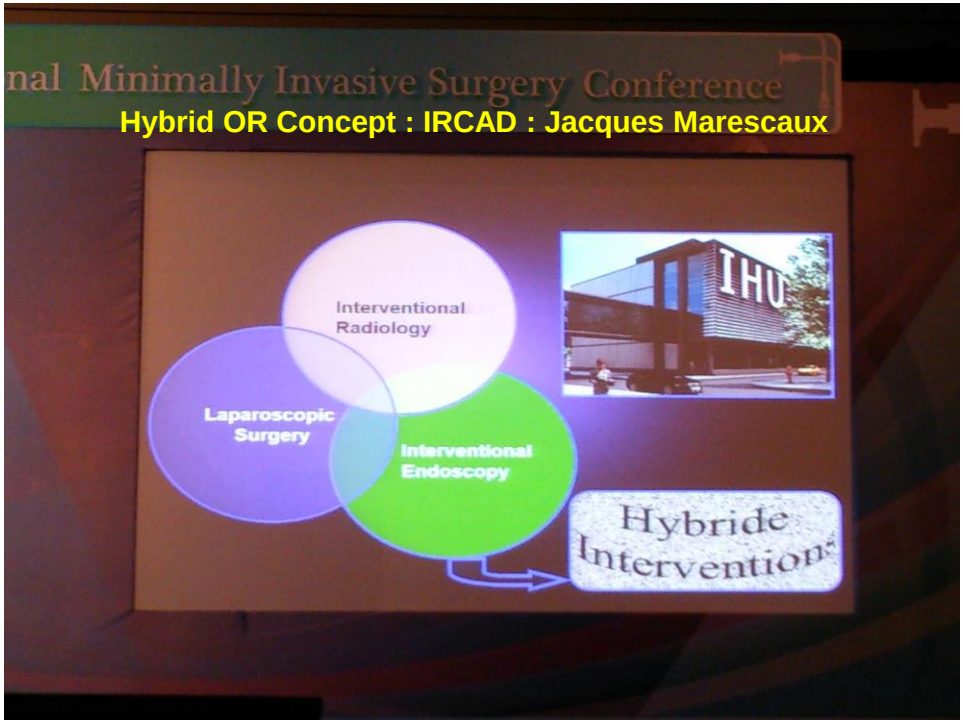
Techniques	Pulmonary Nodules Localization Techniques					n in
Hookwire	Percutaneous placement	Widely used	Puncture-associated complication; dislodgement	Apical, diaphragmatic, or mediastinal regions; multiple lesions	Real-time adjustment by DynaCT	
Metallic fiducials	Percutaneous placement/ENB	Multi-site localization	Puncture-associated complication; fiducials migration	No	Accurate placement by intraoperative ENB and/or DynaCT	
Dye marking	Percutaneous placement	Easy to perform	Puncture-associated complication; contrast medium migration	Deep and posterior nodules	Accurate placement by intraoperative ENB and/or DynaCT, ICG fluorescence thoracoscopy	
Radionuclide labelling	Percutaneous placement	Multi-site localization; also locates sentinel node	Puncture-associated complication; contrast medium migration; radiation exposure	Deep and posterior nodules	Accurate placement by intraoperative ENB and/or DynaCT	
Ultrasound	Intraoperative use	Noninvasive; detect occult nodule; helps to define pathology	No	Operator dependent; emphysema	Cross-check with DynaCT	

OR, operation room; ENB, electromagnetic navigation bronchoscopy; DynaCT, on-table cone-beam computed tomography; ICG, indocyanine green.

Zhao ZR, Lau RW, Ng CS. Hybrid OR & alternative localization techniques in conventional & SPVATS. J Thorac Dis. 2016;8(S3):319-27

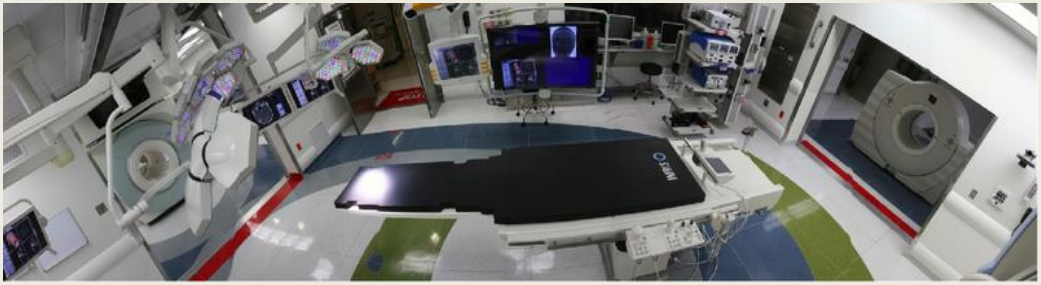


Hybrid OR Concept : IRCAD : Jacques Marescaux


nal Minimally Invasive Surgery Conference
Hybrid OR Concept : IRCAD : Jacques Marescaux
Interventional Radiology
Laparoscopic Surgery
Interventional Endoscopy
IHU
Hybride Intervention

Thoracic

Advanced Multi-modality Imaging Guided Operating Room (AMIGO)

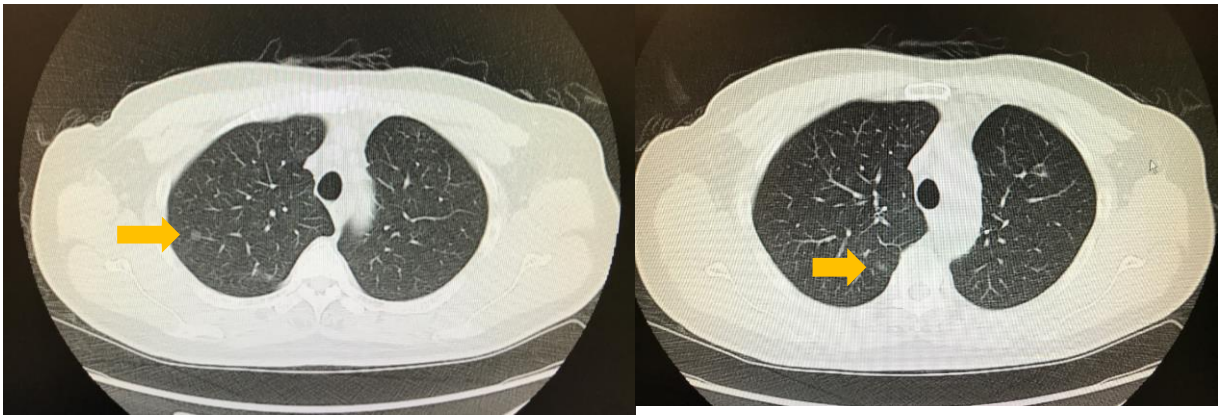


World First Image Guided VATS (iVATS) in AMIGO 2013

J Surg Oncol. 2015;112:18-25

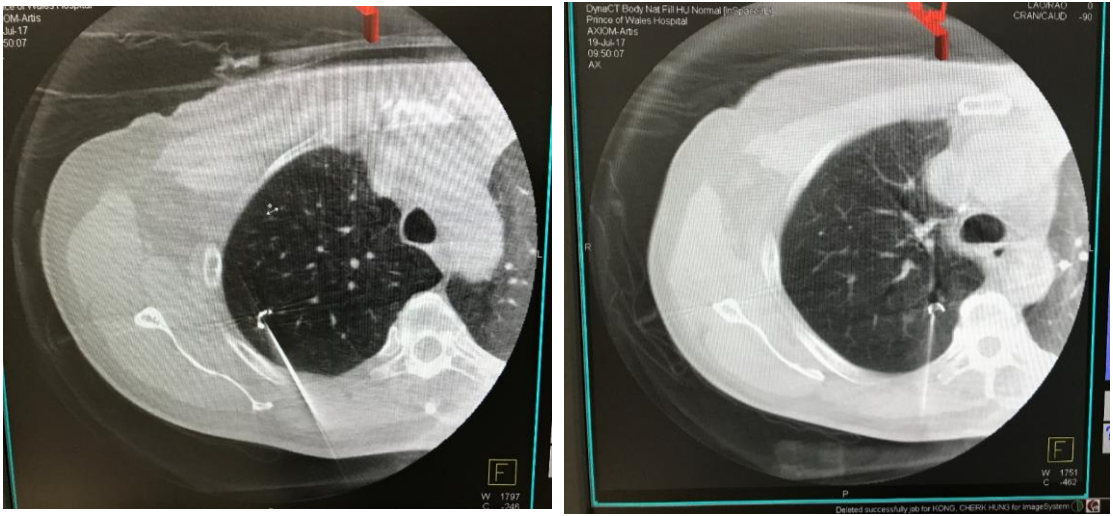
Hybrid OR- The Chinese University of Hong Kong: Artis Zeego CBCT (PURE platform) - since 2014

Hybrid OR Dual Hookwire Localization



Ng CS, et al . Hybrid DynaCT Guided Localization Single Port Lobectomy. *Chest* 2015 Mar 1;147:e76-8
Zhao ZR, Lau RW, Ng CS. Hybrid theatre & alternative localization techniques in conventional & SPVATS. *J Thorac Dis*. 2016;8(S3):319-7

Hybrid OR Dual Hookwire Localization



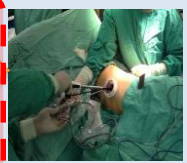
Zhao ZR, Lau RWH, **Ng CSH**. Hybrid theatre & uniportal VATS: the perfect match for lung nodule localization. *Thorac Surg Clin* 2017;27:347-5

Atypical adenomatous Hyperplasia (AAH)

Adenocarcinoma in-situ (AIS)

Radiology

CONVENTIONAL



Hookwire insertion

VATS

RISK of :

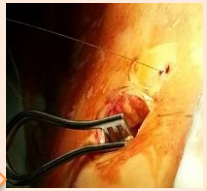
1. **PNEUMOTHORAX**
2. **DISLODGED WIRE**
3. **PROLONGED PATIENT DISCOMFORT**

HYBRID THEATRE

Artis Zeego system DynaCT

General Ward

HOOKWIRE + VATS
in the **SAME** session



Real-Time CT Image-Guided Hookwire Insertion

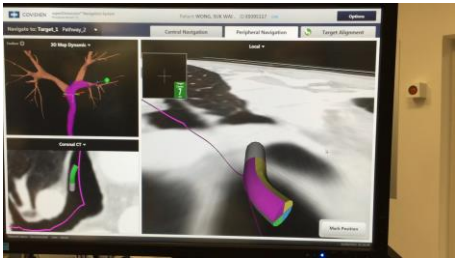
Hybrid OR hookwire localization (iVATS) versus Standard hookwire localization (S-VATS)

	iVATS	S-VATS	p value
Lung Nodule: Radiological Features			
Size (mm)	9.6 ± 4.6	9.1 ± 2.6	0.751
Distance from visceral pleura (mm)	10.1 ± 7.8	13.5 ± 10.8	0.452
Depth : Diameter ratio	1.3 ± 1.1	1.6 ± 1.4	0.632
% Soft/Ground Glass Opacity	63%	25%	0.068
Duration of 'at-risk' period (minutes)	41.2 ± 14.2	109.5 ± 53.4	**0.011**
Pneumothorax	41%	75%	0.096
Dislodged hookwire	N = 0	N = 2	**0.047**

Yu PS, Lau RW, Underwood MJ, Chu CM, Yu SCH, Ng CSH. Minimally-Invasive Sublobar Resection of Tiny Pulmonary Nodules with Real-Time Image Guidance in Hybrid OR. *Innovations* 2016;11:98-99

Yu PSY, Chu CM, Lau RWH, Underwood MJ, Yu SCH, Ng CSH. VATS for Tiny Pulmonary Nodules with Real-time Image Guidance in Hybrid Theatre: The Initial Experience. *J Thorac Dis* 2018;10:2933-9

Electromagnetic Navigation Bronchoscopy (ENB) to target lesion



- **FOB: 2.8mm working channel**
- **GA, Single Lumen Endotracheal tube size 7.5 or above**

Siemens Artis Zeego with ENB since 2015

Intra-op CBCT

iENB – CBCT in Hybrid Theatre

Ng CS, Yu SC, Lau RW et al. Hybrid DynaCT Guided Electromagnetic Navigation Bronchoscopic Biopsy. *Eur J Cardiothorac Surg* 2016;48:i87-8

Lau WH, Chow CY, Chu C, Ng CS. Hybrid OR DynaCT Real-Time Image Guided ENB Biopsy–The Initial Experience. *Respirology* 2016;21:(S3)74

Hybrid OR iENB workflow

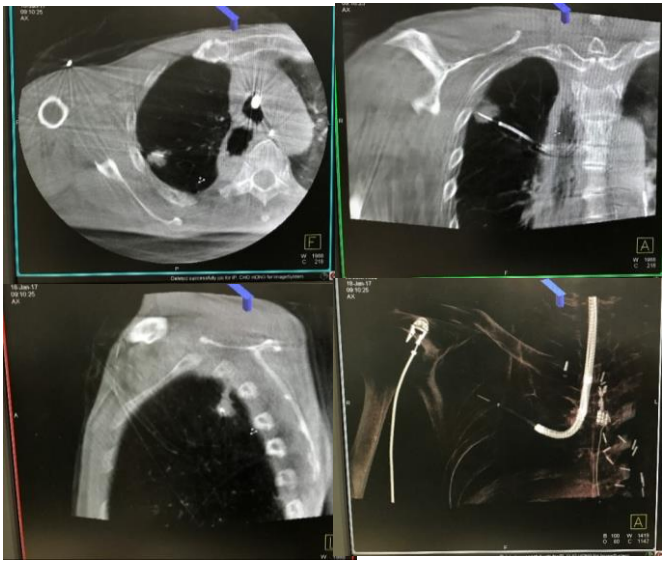
ENB Navigation

CBCT confirmation

1. Renavigate if failure
2. Guided by i-guide/fluoro/CBCT

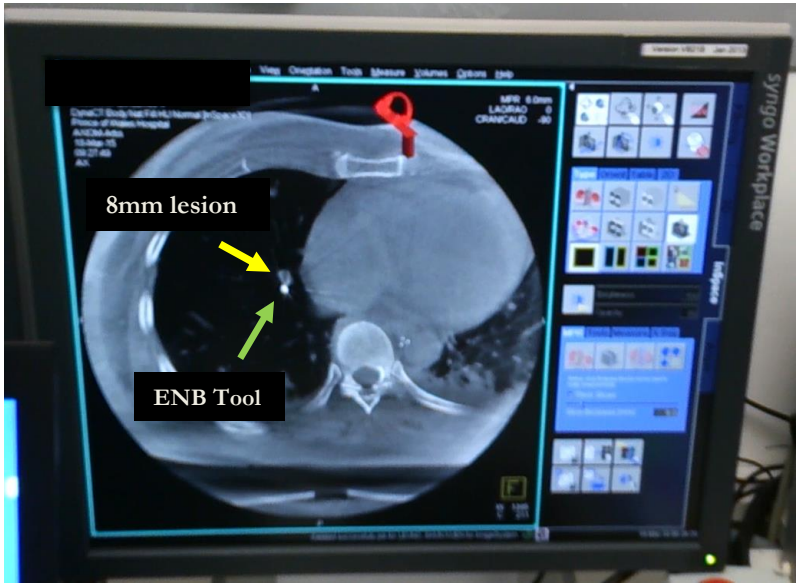
Hybrid OR iENB

- CBCT can confirm **accurate successful** ENB navigation/ biopsy



Hybrid OR iENB

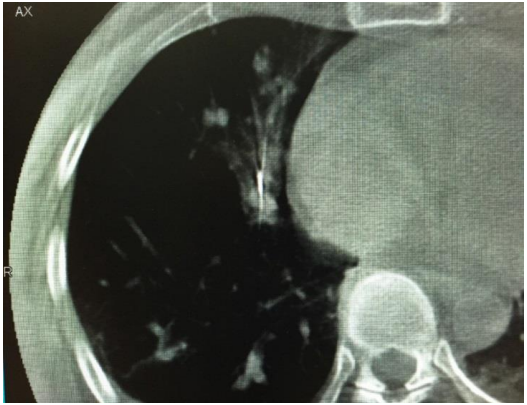
- Can also confirm **inaccurate unsuccessful** ENB navigation/ biopsy



Ng CSH, et al. *Eur J Cardiothorac Surg* 2016

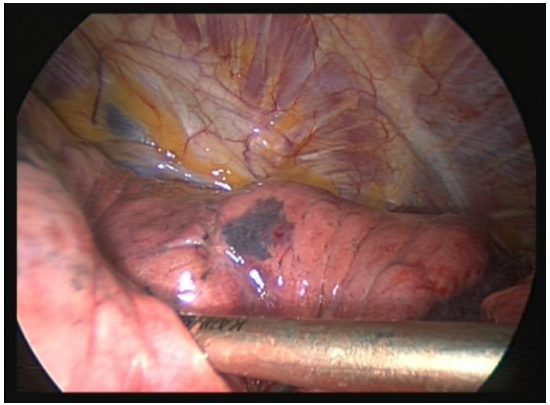
Hybrid OR iENB

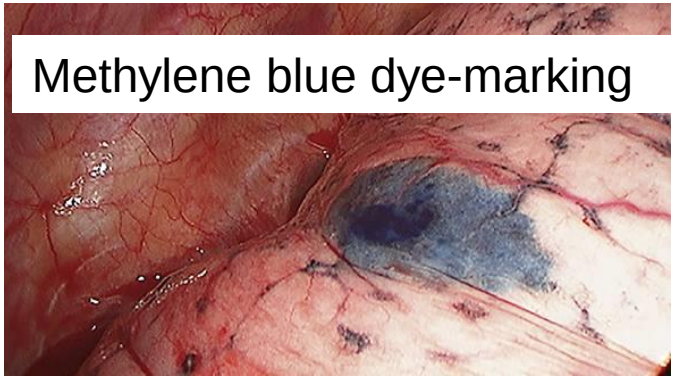
- After adjustment guided by CT scan
- Successful biopsy 8mm lesion



Ng CS, Yu SC, Lau R et al. Hybrid DynaCT Guided Electromagnetic Navigation Bronchoscopic Biopsy. *Eur J Cardiothorac Surg* 2016;48:i87-8

Hybrid OR iENB : Lung Dye Marking VATS resection

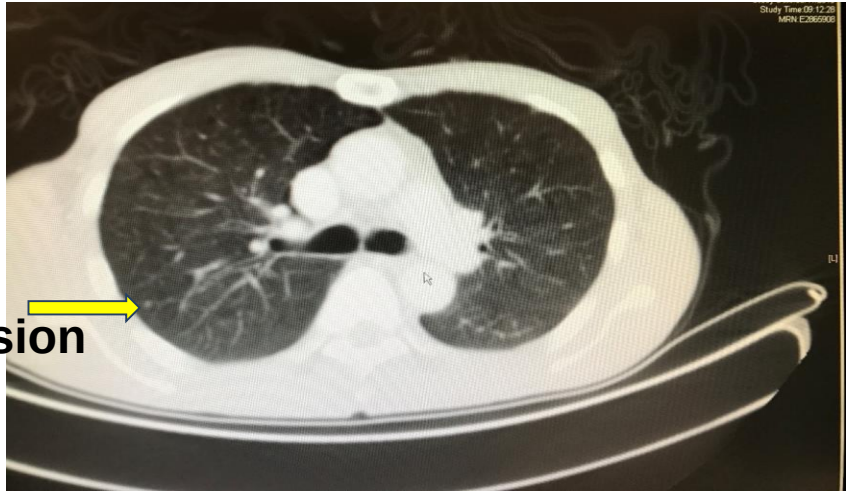




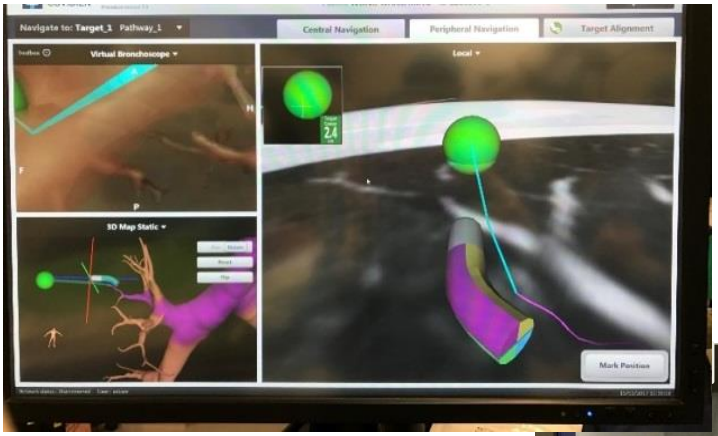
Zhao ZR, Lau RWH, Yu PSY, Ng CSH. Devising the guidelines: the techniques of pulmonary nodule localization in uniportal VATS—hybrid operating room in the future. *J Thorac Dis* 2019 Sep;11(S16):S2073-8

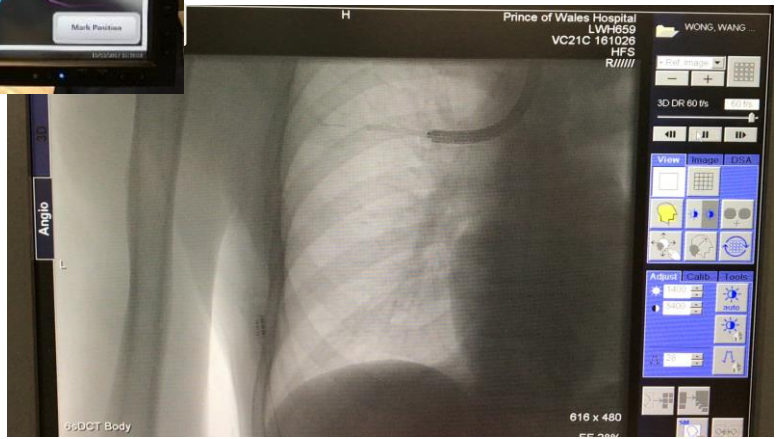
iENB Hybrid Theatre - Lung Dye Marking

2mm lung lesion

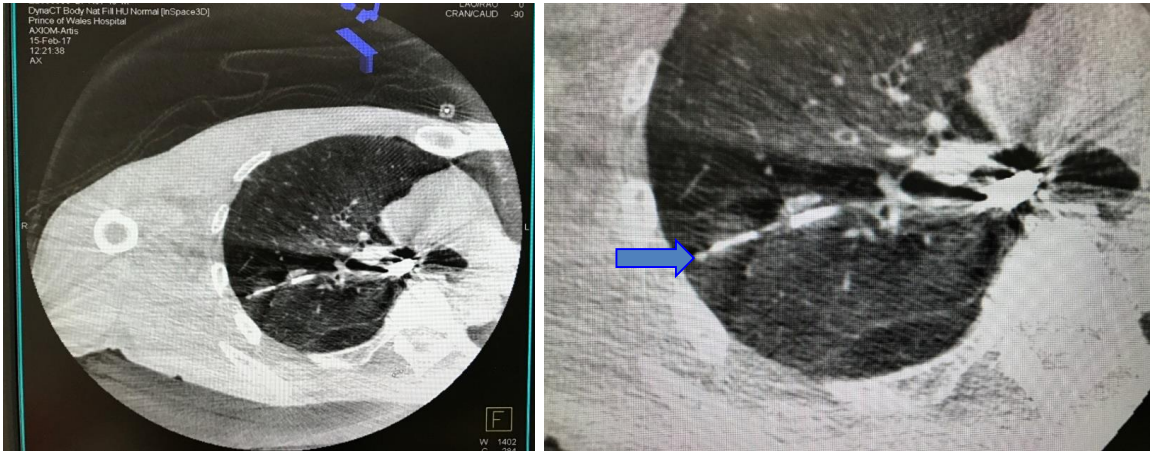


iENB Hybrid Theatre - Lung Dye Marking





iENB Hybrid Theatre - Lung Dye Marking

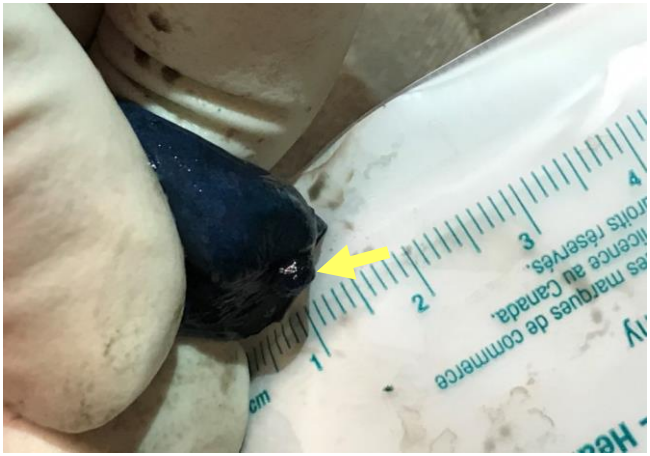


Zhao Z, Lau R, Ng CSH. Hybrid theatre and uniportal VATS: the perfect match for lung nodule localization. *Thorac Surg Clinics* 2017 Nov ;27:347-5

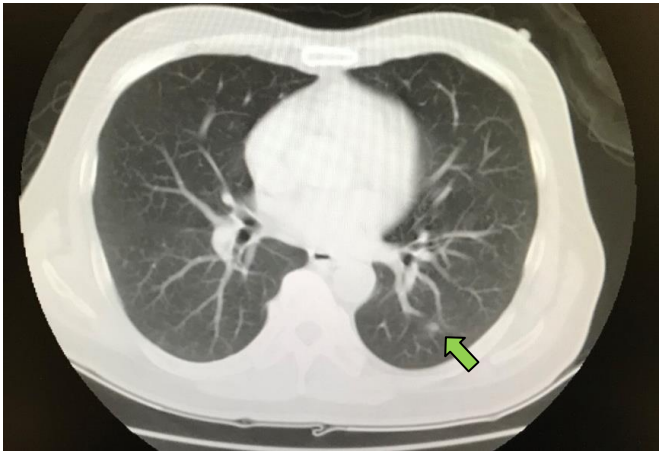
iENB Hybrid Theatre - Lung Dye Marking

Zhao Z, Lau R, Ng CSH. Hybrid theatre and uniportal VATS: the perfect match for lung nodule localization. *Thorac Surg Clinics* 2017 Nov ;27:347-5

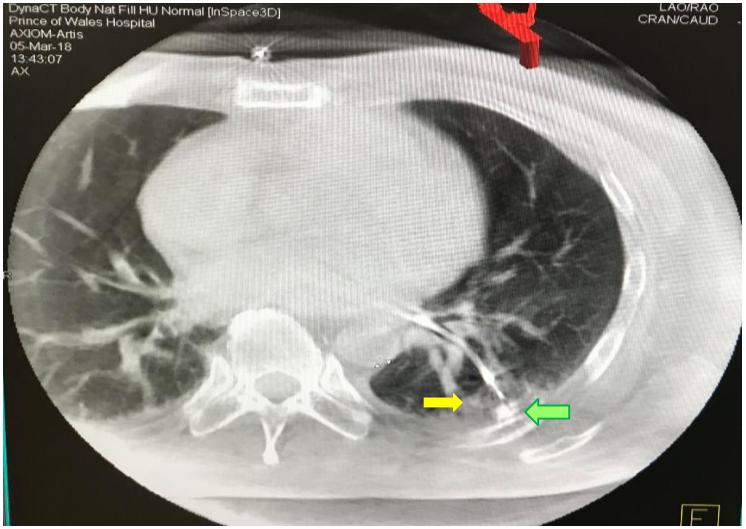
iENB Hybrid Theatre - Lung Dye Marking



Dye (version 3.0): Hybrid OR iENB triple dye *Indocyanine Green (ICG) Fluorescence* Marking- Deeper Lesions



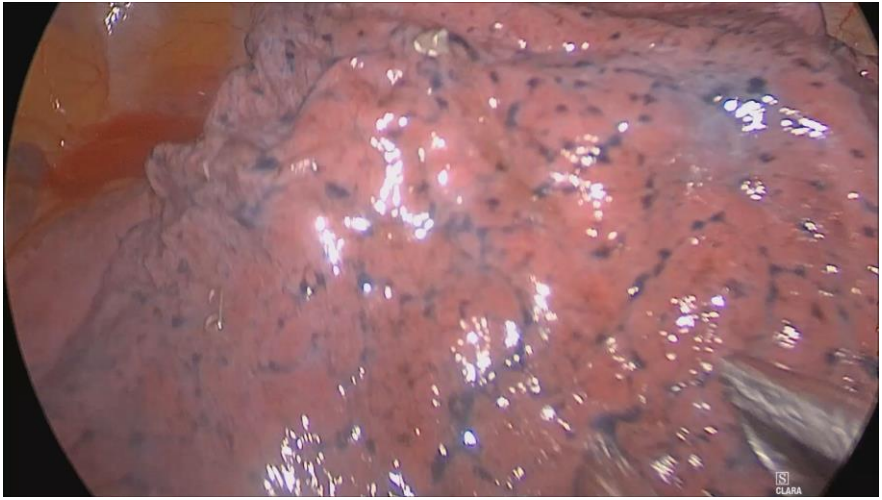
iENB Hybrid OR triple Dye *ICG* Marking 3.0



⇦ **Mix triple ICG dye Marking**

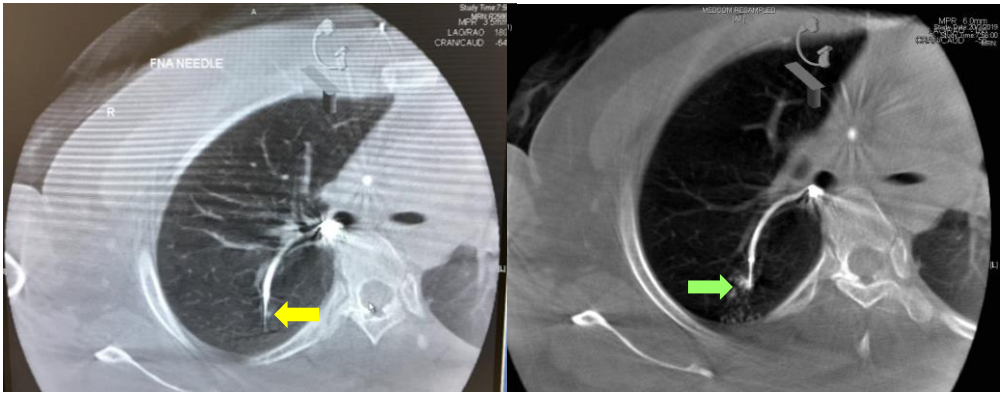
⇨ **Lung lesion**

iENB Hybrid OR triple dye *ICG* Marking 3.0 Karl Storz Camera



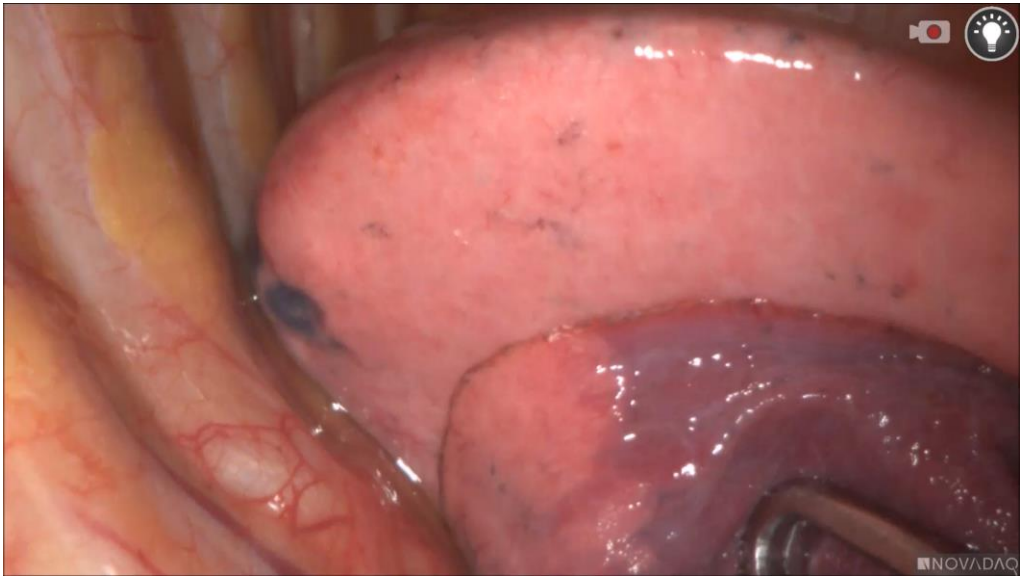
Ng CSH, Zhao Z, Long H, Lau RWH. Electromagnetic Navigation Bronchoscopy Triple Contrast Dye Marking for Lung Nodule Localization. Thorac Cardiovasc Surg. 2019 Jan 11. doi: 10.1055/s-0038-1676964

iENB Hybrid OR Triple Dye *ICG* Marking

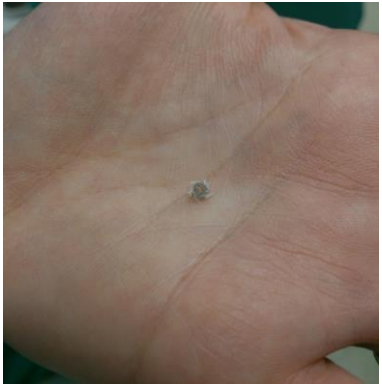


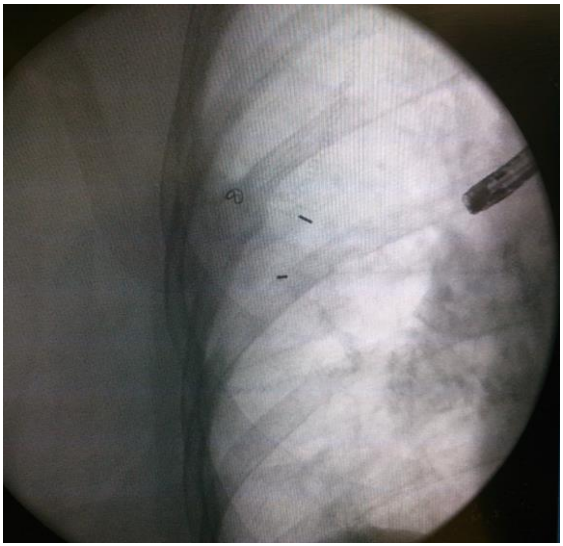
⇦ 3mm lung nodule ⇨ Triple ICG dye Marking

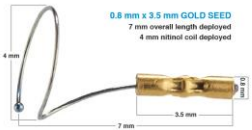
iENB Hybrid OR Triple Dye *ICG* Marking Stryker Camera



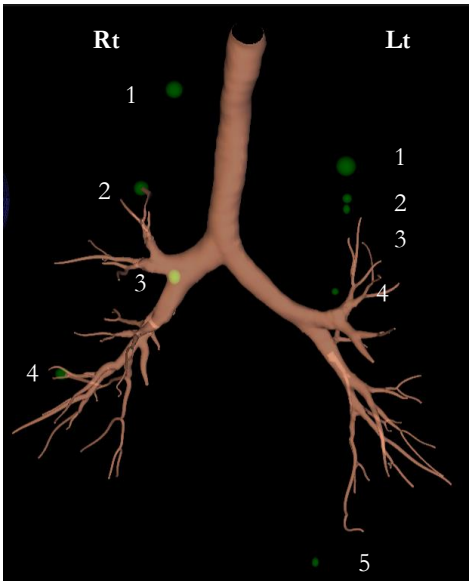
Marking of deep lesions – addition Metallic marker(s) to capture deep margin





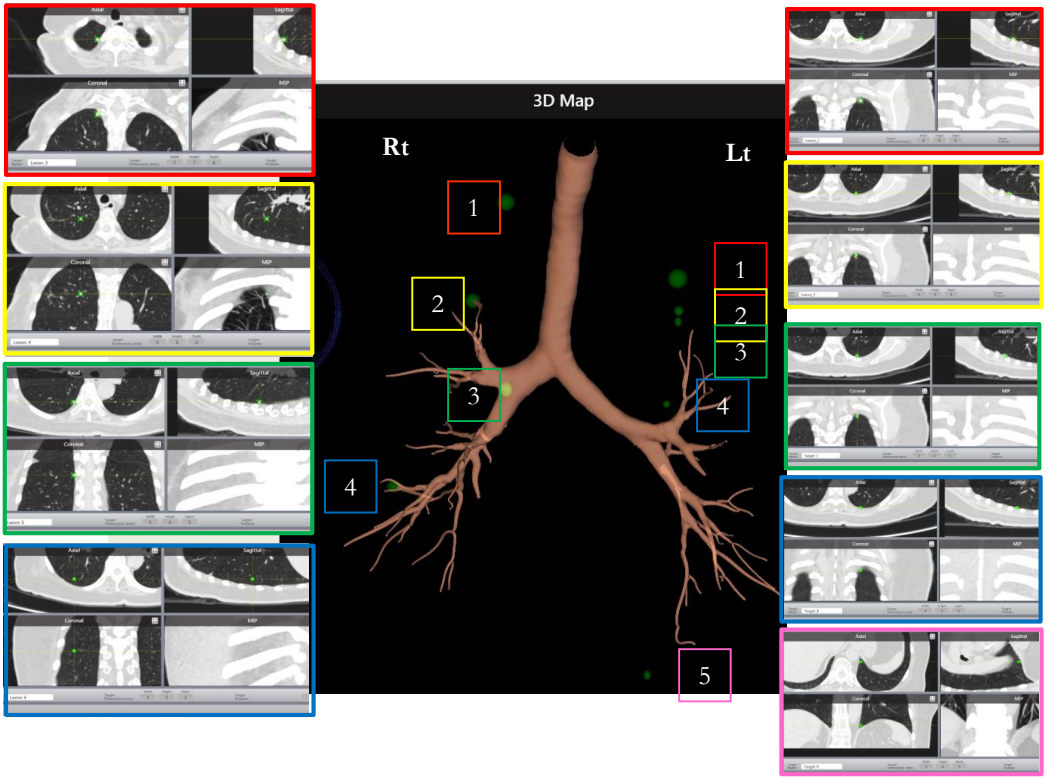


Hybrid OR Combine iENB hookwire iVATS

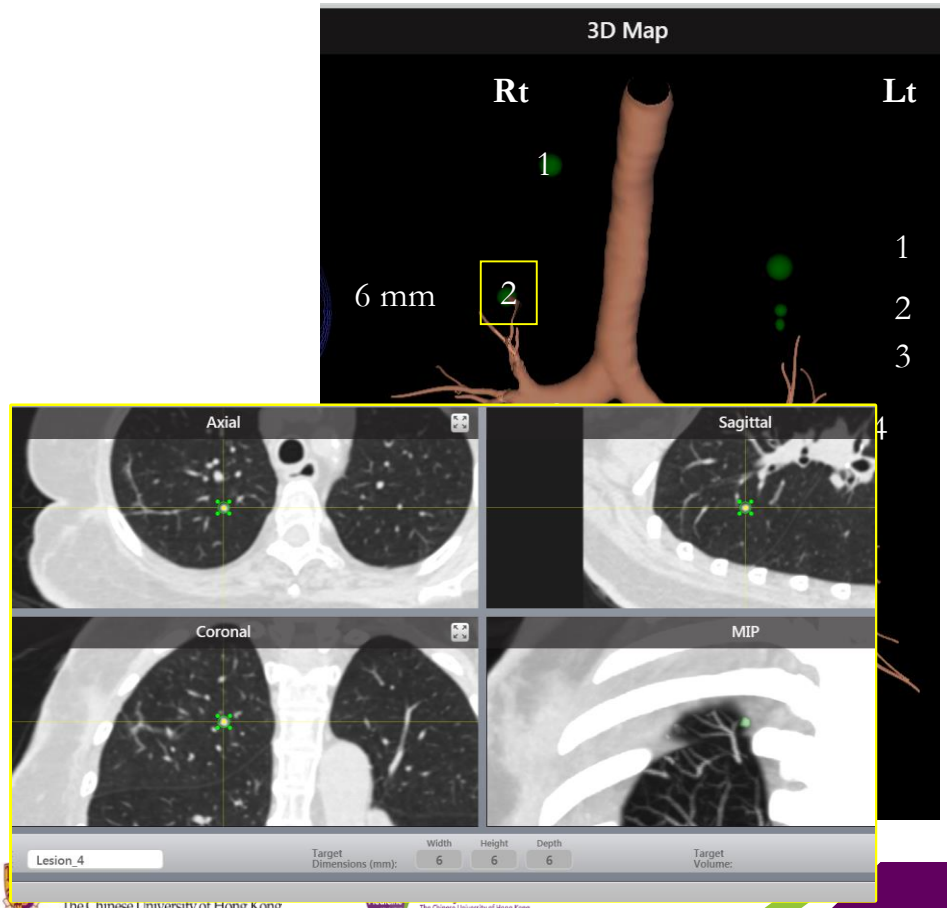


- 46 yr old female
- Hx leiomyosarcoma- Rt upper forequarter amputation
- 2 yrs later multiple tiny lung lesions (all subcentimeter)

Ng CSH et al. Hybrid OR Dyna-CT combined image-guided ENB dye marking and hookwire localization VATS metastasectomy. *Interact Cardiovasc Thorac Surg* 2018 Feb;26(2):338-40


3D Map
Rt
Lt
1
2
3
4
1
2
3
4
5

R2 Lesion



- Central, Small
- Surgically Unlocatable

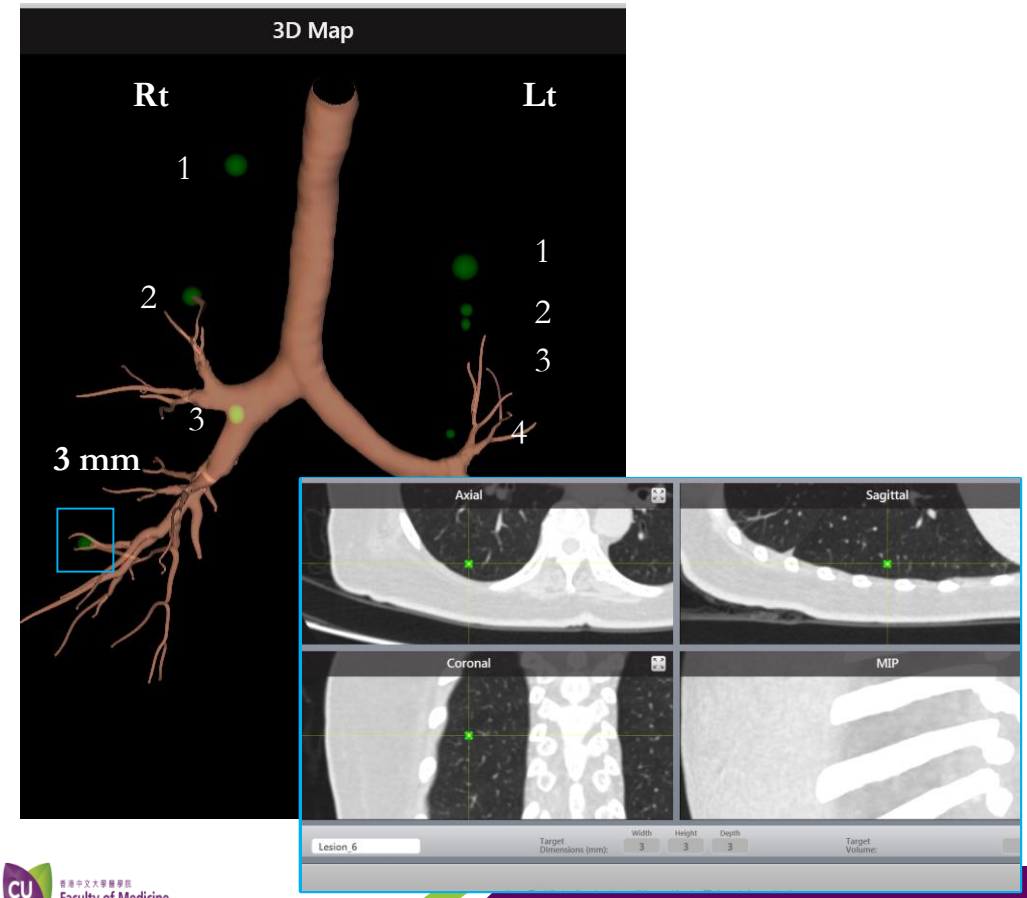
- ENB planning
  Poor airway access & may not see dye

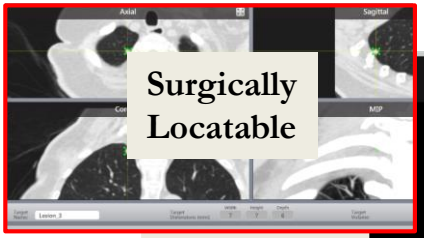
- For Hybrid OR Hookwire Localization

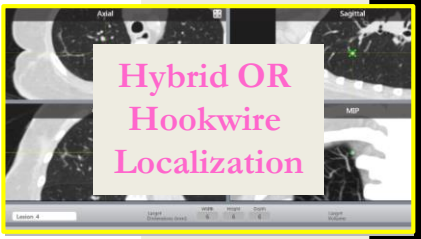
R4 Lesion

- Peripheral
- Very small
- Surgically Unlocatable

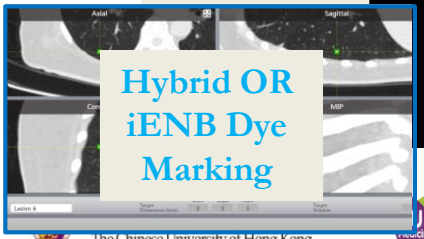
- ENB planning: *Airway adequate*
- Hybrid OR iENB dye marking

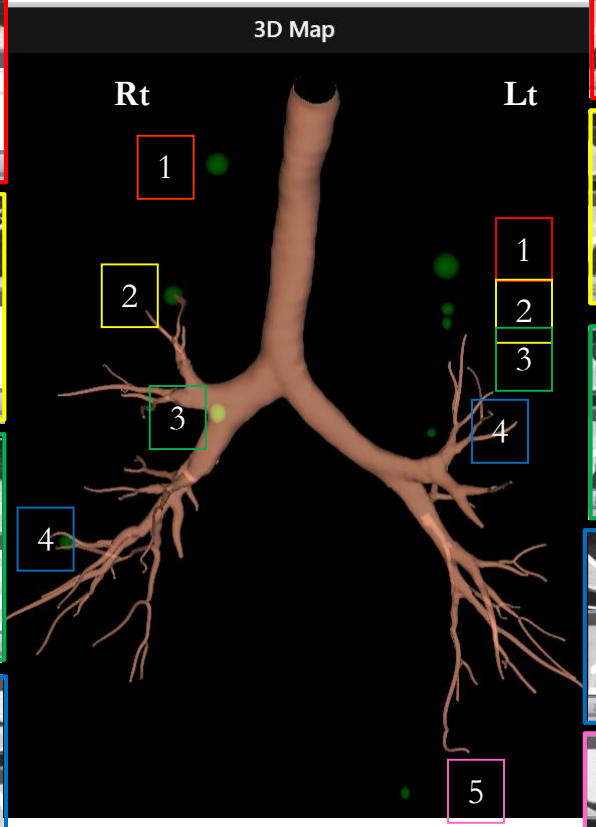



Surgically
Locatable


Hybrid OR
Hookwire
Localization


Surgically
Locatable


Hybrid OR
iENB Dye
Marking


3D Map
Rt
Lt
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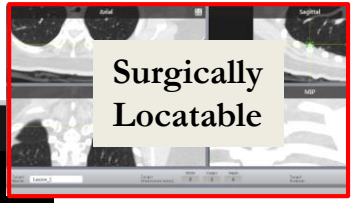
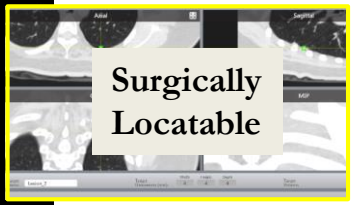
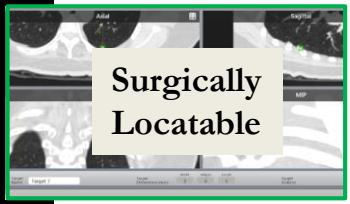
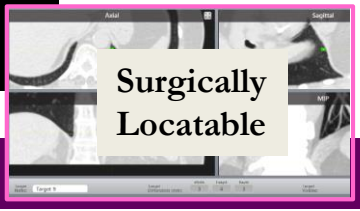

Surgically
Locatable

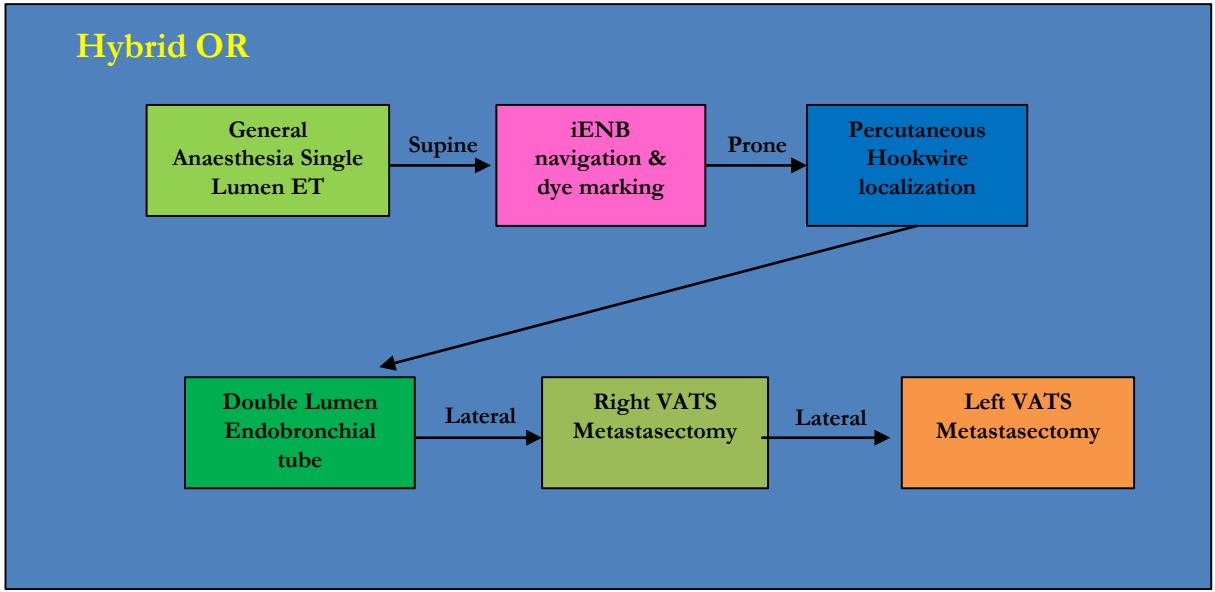

Surgically
Locatable


Surgically
Locatable

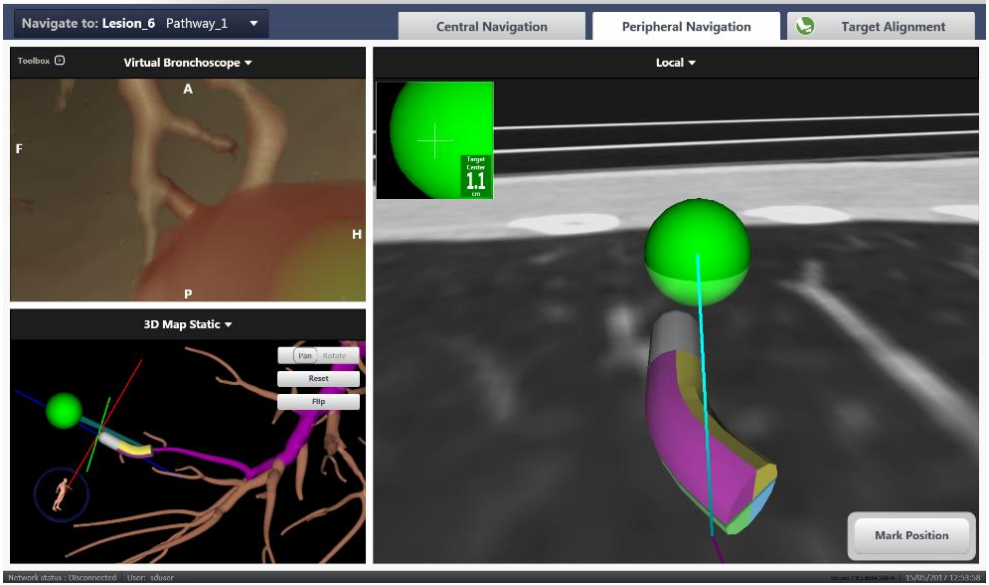

Surgically
Locatable


Surgically
Locatable

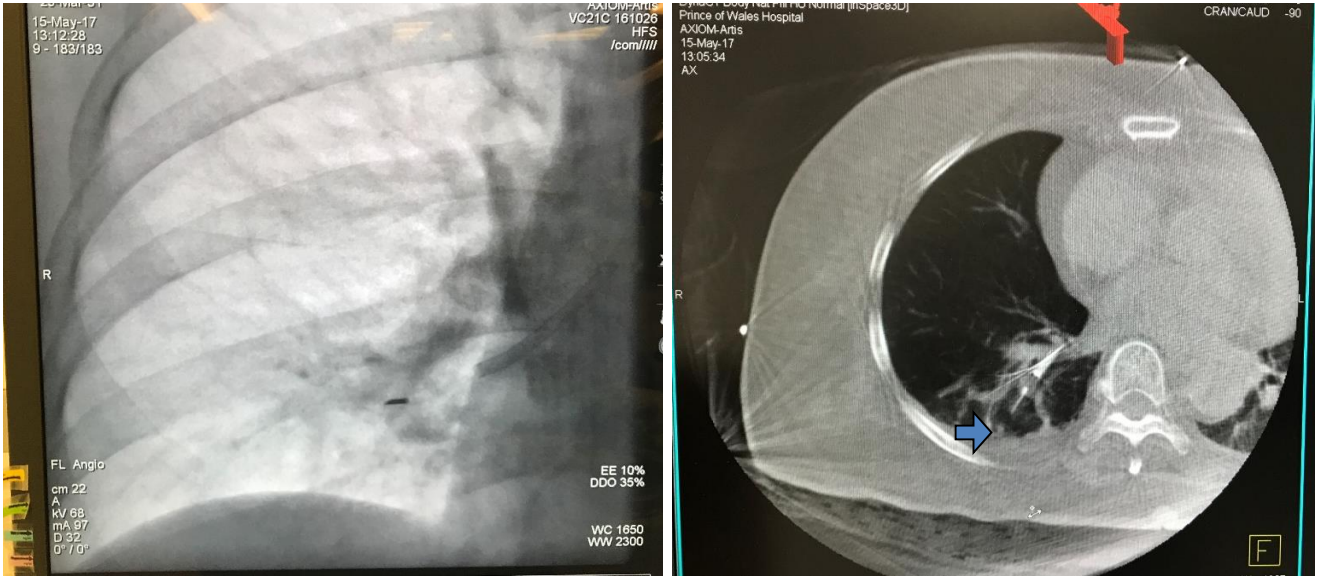
Hybrid OR iENB Dye Marking & Hookwire Localization Bilateral VATS Metastasectomy



Hybrid OR iENB Dye Marking & Hookwire Localization Bilateral VATS Metastasectomy

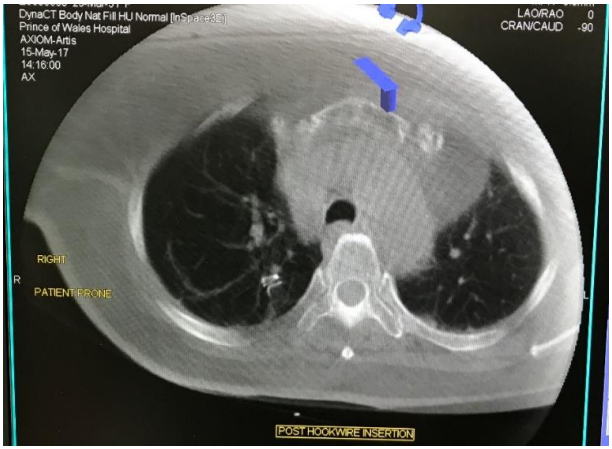


Hybrid OR iENB Dye Marking & Hookwire Localization Bilateral VATS Metastasectomy



Ng CSH et al. Hybrid OR Dyna-CT combined image-guided ENB dye marking and hookwire localization VATS metastasectomy. *Interact Cardiovasc Thorac Surg* 2018 Feb;26(2):338-40

Hybrid OR iENB Dye Marking & Hookwire Localization Bilateral VATS Metastasectomy



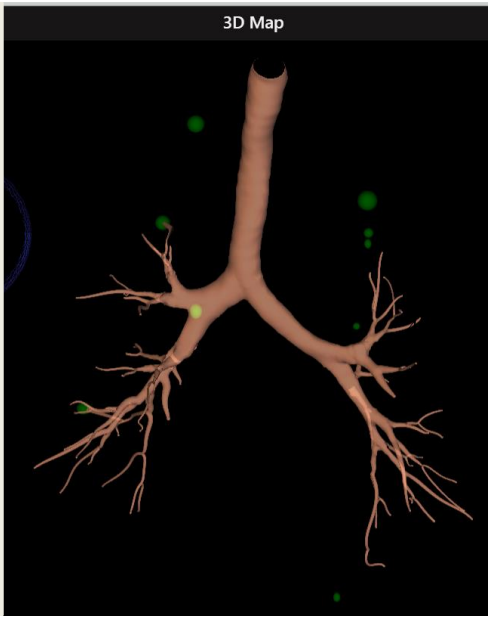
Ng CSH et al. Hybrid OR Dyna-CT combined image-guided ENB dye marking and hookwire localization VATS metastasectomy. *Interact Cardiovasc Thorac Surg* 2018 Feb;26(2):338-40


R1


R2


R3


R4

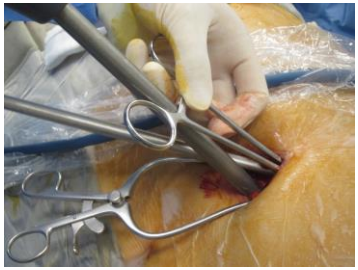

3D Map

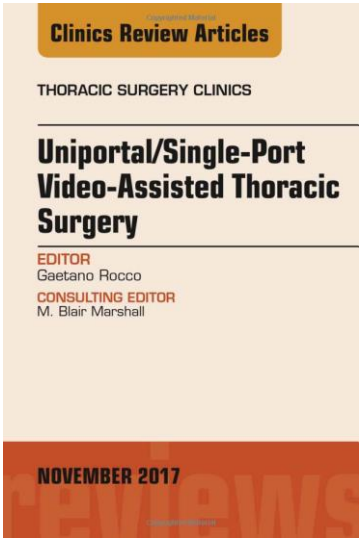

L1

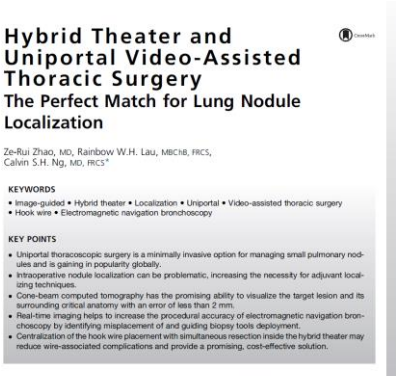

L2
L4
L3


L5

Challenge of Lesion Localization with Less & Smaller Wounds - Uniportal VATS







Hybrid Theater and Uniportal Video-Assisted Thoracic Surgery

The Perfect Match for Lung Nodule Localization

Ze-Rui Zhao, MD, Rainbow W.H. Lau, MBChB, FRCS, Calvin S.H. Ng, MD, FRCS*

KEYWORDS

- Image-guided • Hybrid theater • Localization • Uniportal • Video-assisted thoracic surgery
- Hook wire • Electromagnetic navigation bronchoscopy

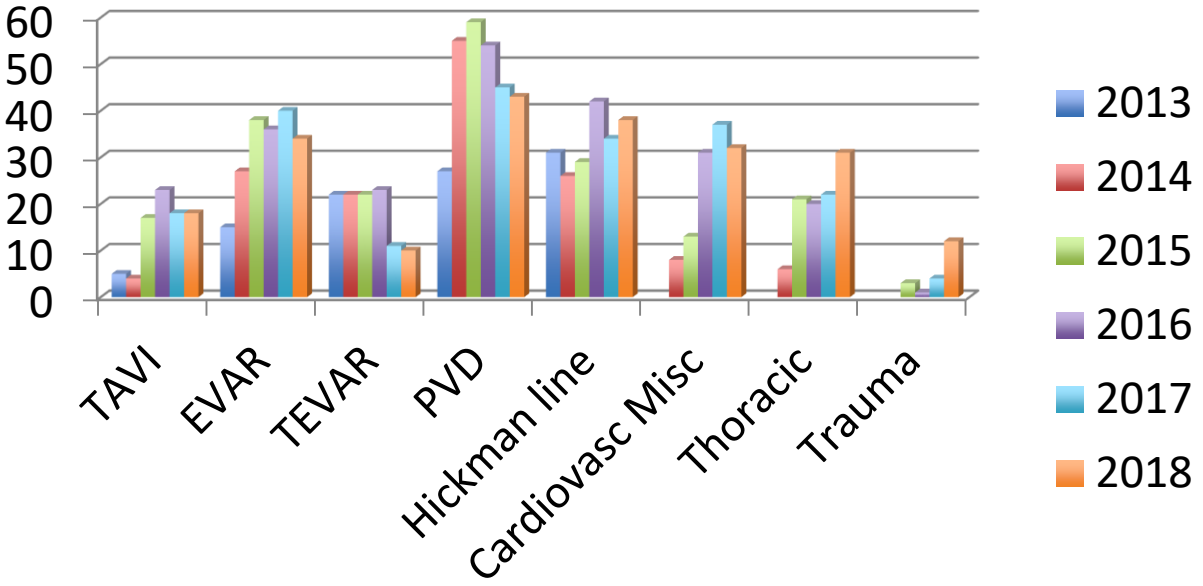
KEY POINTS

- Uniportal thoracoscopic surgery is a minimally invasive option for managing small pulmonary nodules and is gaining in popularity globally.
- Intraoperative nodule localization can be problematic, increasing the necessity for adjuvant localizing techniques.
- Cone-beam computed tomography has the promising ability to visualize the target lesion and its surrounding critical anatomy with an error of less than 2 mm.
- Real-time imaging helps to increase the procedural accuracy of electromagnetic navigation bronchoscopy by identifying misplacement of and guiding biopsy tools deployment.
- Centralization of the hook wire placement with simultaneous resection inside the hybrid theater may reduce wire-associated complications and provide a promising, cost-effective solution.

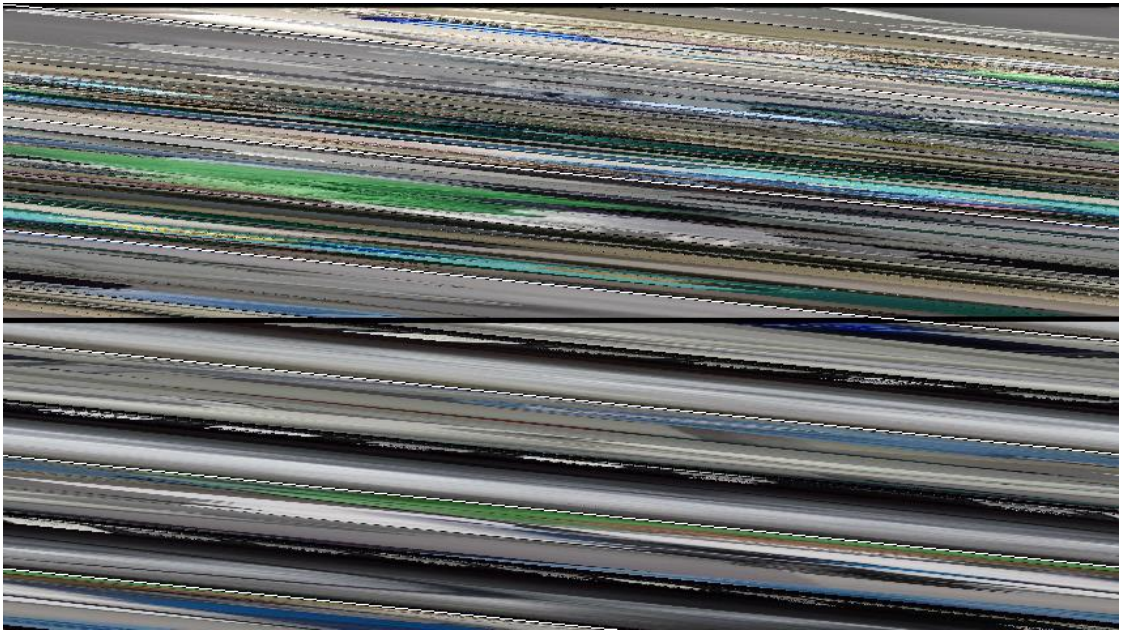
Hybrid OR & Associate Technology – Getting Best Value

- Full usage of hybrid theatre
  – management / liasing with other specialties
- Optimizing its performance
  – squeeze all the value you can get from it
- Value for one hospital or country , may not be value for another

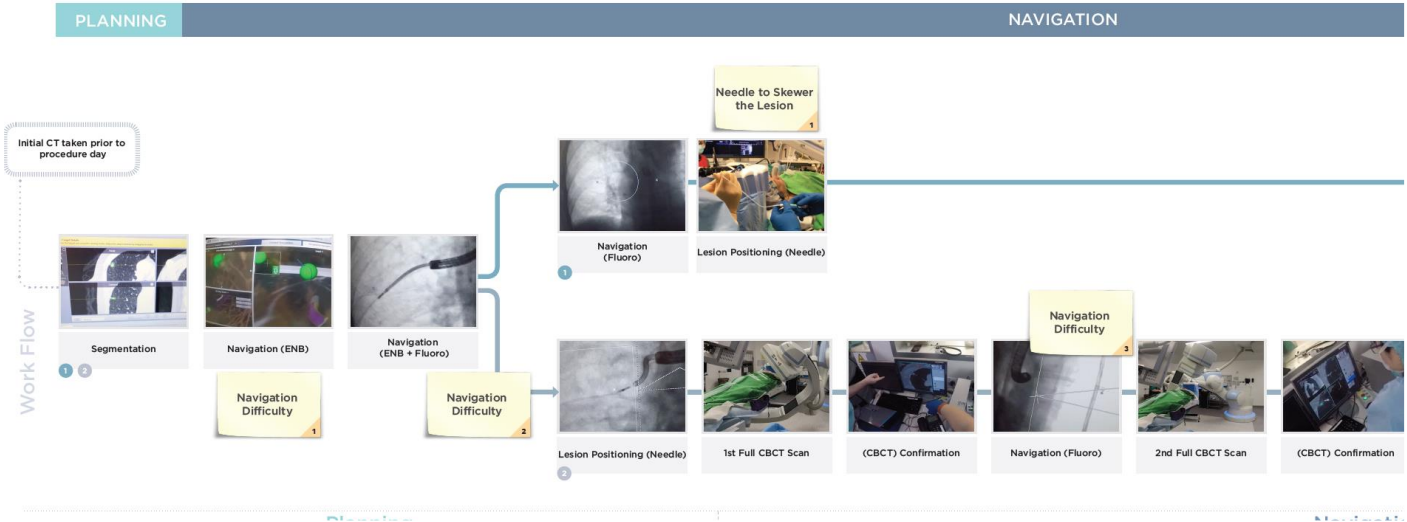
PWH Hybrid OR Throughput 2013-2018



Prince of Wales Hospital Efficiency Workflow analysis- Hybrid OR ENB procedure

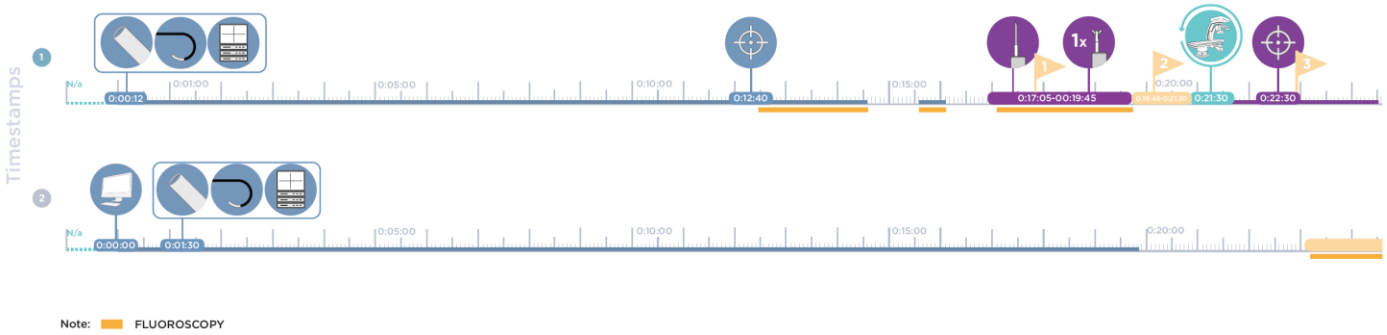


Prince of Wales Hospital Efficiency Workflow analysis- Hybrid OR ENB procedure

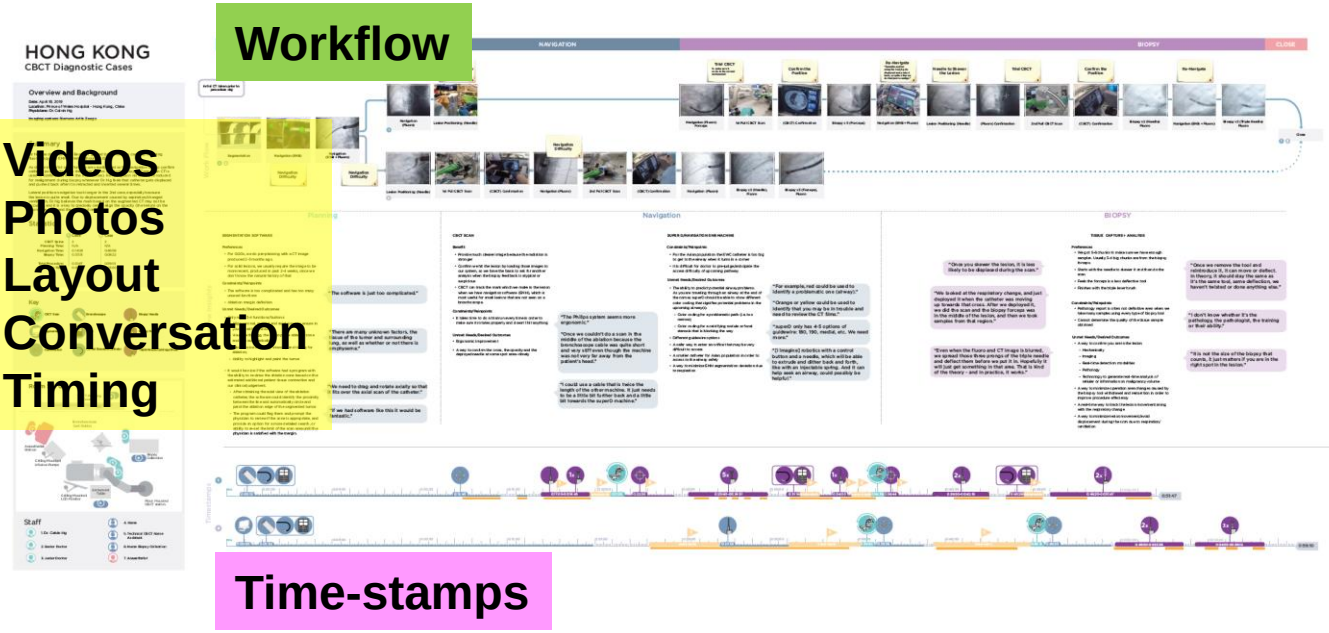


Time-stamps analysis for efficiency
Hybrid OR ENB procedure

Allowing us to look into reasons for delays , prolong procedure duration, streamline



Efficiency analysis - Hybrid OR ENB procedure



ORIGINAL INVESTIGATION

OPEN

Cone-Beam CT With Augmented Fluoroscopy Combined With Electromagnetic Navigation Bronchoscopy for Biopsy of Pulmonary Nodules

Michael A. Pritchett, DO, MPH,† Stéphanie Schampaert, PhD,‡ Joris A.H. de Groot, PhD,‡ Charles C. Schirmer, MD,§ and Imramsjah van der Bom, PhD‡*

TABLE 3. Diagnostic Performance of ENB and CBCT With Augmented Fluoroscopy

Diagnostic Performance	Diagnostic Yield (95% CI)	Diagnostic Accuracy (95% CI)*
All lesions (n = 92) (mm)	83.7% (74.8%-89.9%)	93.5% (86.5%-97.0%)
Lesions ≤ 10 (n = 19)	84.2% (62.4%-94.5%)	89.5% (68.6%-97.1%)
Lesions ≤ 20 (n = 65)	83.1% (72.2%-90.3%)	90.8% (81.3%-95.7%)
Lesions > 20 (n = 27)	96.3% (81.7%-99.8%)	100% (87.5%-100%)
Minimum sensitivity for malignancy†	91.3% (82.3%-96.0%)	
Maximum sensitivity for malignancy‡	95.5% (87.5%-98.4%)	
Minimum prevalence of malignancy‡	71.7% (61.8%-79.9%)	
Maximum prevalence of malignancy†	75.0% (65.3%-82.7%)	
Minimum negative predictive value	79.3% (61.6%-90.2%)	
Maximum negative predictive value	89.7% (73.6%-96.4%)	

*Diagnostic accuracy represents the malignant and benign lesions as well as the indeterminate lesions confirmed as benign with clinical and radiographic follow-up divided by the total number of lesions biopsied.

†Minimum sensitivity and maximum prevalence were based on the assumption that patients with uncompleted follow-up (n = 3) actually had lung cancer (ie, were false negative).

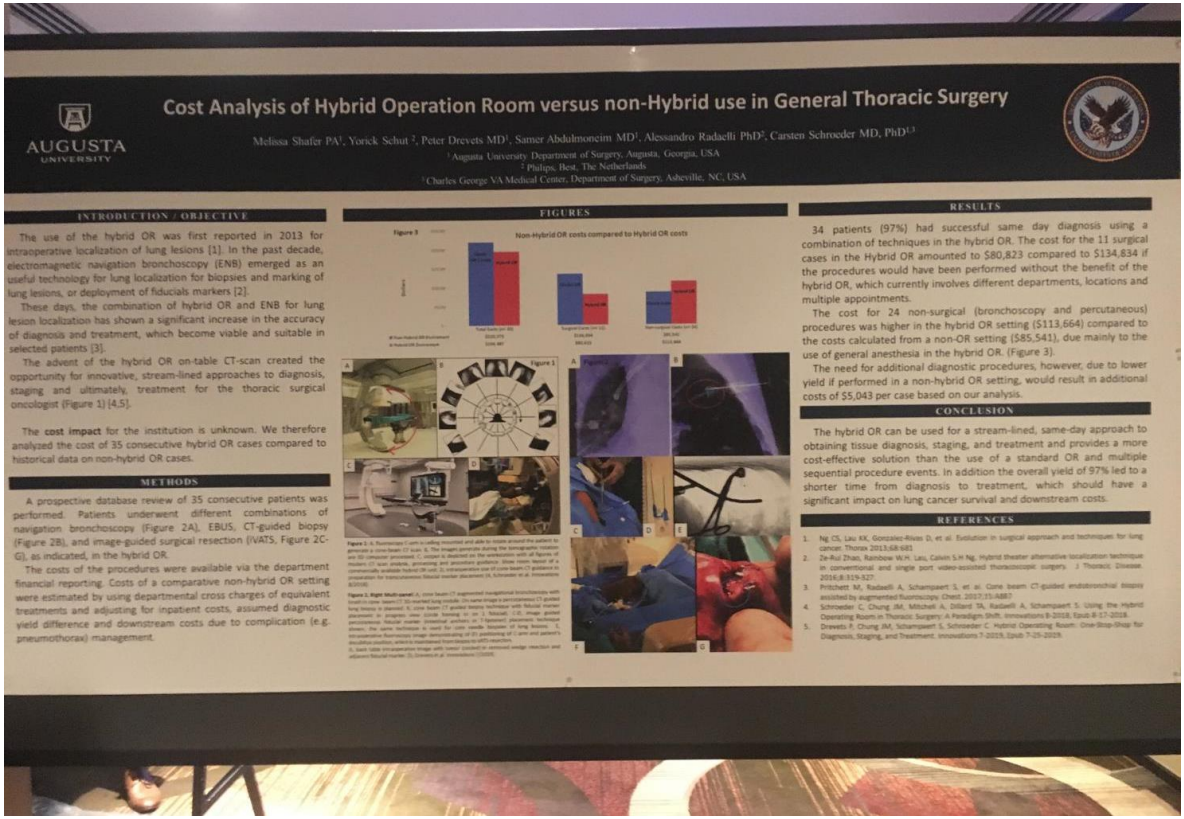
‡Minimum sensitivity and prevalence were based on the assumption that patients with uncompleted follow-up (n = 3) actually had lung cancer (ie, were false negative).

CBCT indicates cone-beam computed tomography; CI, confidence interval; ENB, electromagnetic navigation bronchoscopy.

Technology improving outcomes versus Costs

- **If you improve outcomes enough → offset cost of tech**

AATS International Thoracic Surgical Oncology Summit



Cost Analysis of Hybrid Operation Room versus non-Hybrid use in General Thoracic Surgery

Melissa Shafer PA[1], Yorick Schut [2], Peter Drevets MD[1], Samer Abdulmoneim MD[1], Alessandro Radaelli PhD[2], Carsten Schroeder MD, PhD[1,3]

[1] Augusta University Department of Surgery, Augusta, Georgia, USA
[2] Philips, Best, The Netherlands
[3] Charles George VA Medical Center, Department of Surgery, Asheville, NC, USA

INTRODUCTION / OBJECTIVE

The use of the hybrid OR was first reported in 2013 for intraoperative localization of lung lesions [1]. In the past decade, electromagnetic navigation bronchoscopy (ENB) emerged as an useful technology for lung localization for biopsies and marking of lung lesions, or deployment of fiducials markers [2].

These days, the combination of hybrid OR and ENB for lung lesion localization has shown a significant increase in the accuracy of diagnosis and treatment, which become viable and suitable in selected patients [3].

The advent of the hybrid OR on-table CT-scan created the opportunity for innovative, stream-lined approaches to diagnosis, staging and ultimately, treatment for the thoracic surgical oncologist (Figure 1) [4,5].

The **cost impact** for the institution is unknown. We therefore analyzed the cost of 35 consecutive hybrid OR cases compared to historical data on non-hybrid OR cases.

METHODS

A prospective database review of 35 consecutive patients was performed. Patients underwent different combinations of navigation bronchoscopy (Figure 2A), EBUS, CT-guided biopsy (Figure 2B), and image-guided surgical resection (iVATS, Figure 2C-G), as indicated, in the hybrid OR.

The costs of the procedures were available via the department financial reporting. Costs of a comparative non-hybrid OR setting were estimated by using departmental cross charges of equivalent treatments and adjusting for inpatient costs, assumed diagnostic yield difference and downstream costs due to complication (e.g. pneumothorax) management.

FIGURES

Figure 3

Figure 1

RESULTS

34 patients (97%) had successful same day diagnosis using a combination of techniques in the hybrid OR. The cost for the 11 surgical cases in the Hybrid OR amounted to $80,823 compared to $134,834 if the procedures would have been performed without the benefit of the hybrid OR, which currently involves different departments, locations and multiple appointments.

The cost for 24 non-surgical (bronchoscopy and percutaneous) procedures was higher in the hybrid OR setting ($113,664) compared to the costs calculated from a non-OR setting ($85,541), due mainly to the use of general anesthesia in the hybrid OR. (Figure 3).

The need for additional diagnostic procedures, however, due to lower yield if performed in a non-hybrid OR setting, would result in additional costs of $5,043 per case based on our analysis.

CONCLUSION

The hybrid OR can be used for a stream-lined, same-day approach to obtaining tissue diagnosis, staging, and treatment and provides a more cost-effective solution than the use of a standard OR and multiple sequential procedure events. In addition the overall yield of 97% led to a shorter time from diagnosis to treatment, which should have a significant impact on lung cancer survival and downstream costs.

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2. Ze-Rui Zhao, Rainbow W.H. Lau, Calvin S.H Ng. Hybrid theater alternative localization technique in conventional and single port video-assisted thoracoscopic surgery. J Thorac Dis. 2016;8:319-327.
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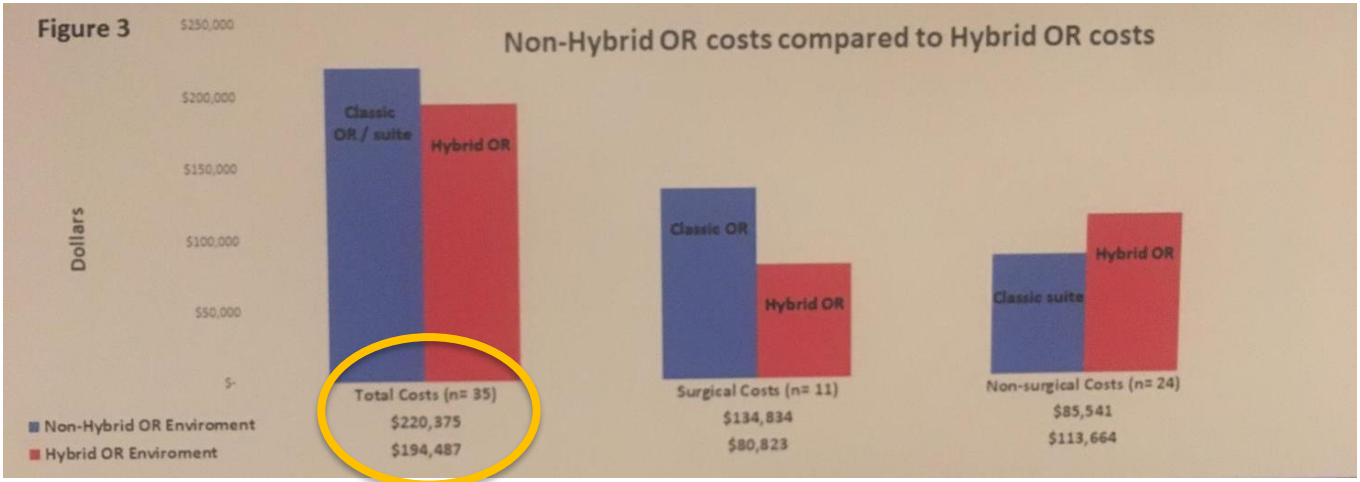
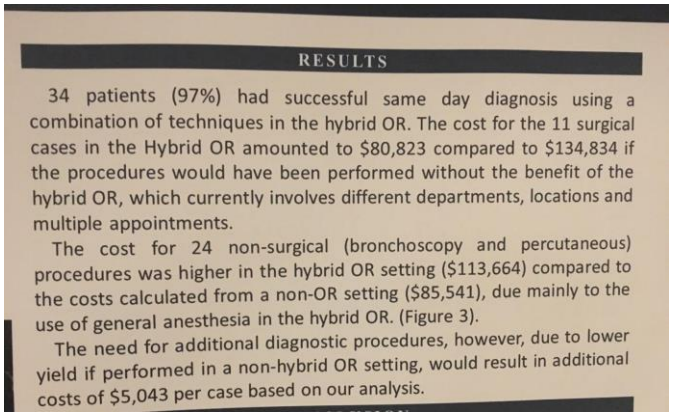
4. Schroeder C, Chung JM, Mitchell A, Dillard TA, Radaelli A, Schampaert S. Using the Hybrid Operating Room in Thoracic Surgery: A Paradigm Shift. Innovations 8-2018; Epub 8-17-2018.
5. Drevets P, Chung JM, Schampaert S, Schroeder C. Hybrid Operating Room: One-Stop-Shop for Diagnosis, Staging, and Treatment. Innovations 7-2019, Epub 7-25-2019.

Cost: Non-hybrid v. hybrid OR



Same day one-stop one-shop



RESULTS

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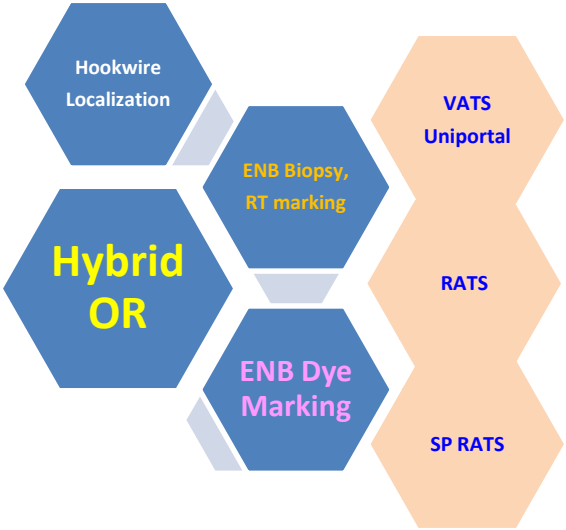
The need for additional diagnostic procedures, however, due to lower yield if performed in a non-hybrid OR setting, would result in additional costs of $5,043 per case based on our analysis.

Conclusion:

- $5000 savings per case when diagnosis and treatment is performed in the Hybrid OR preferably with a 97% same day diagnosis rate.

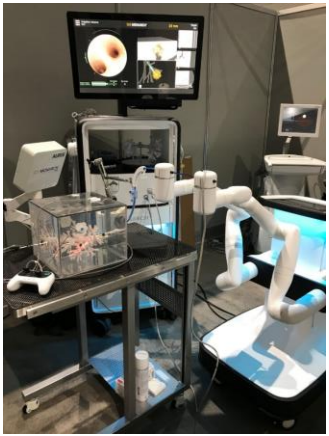
Hybrid OR: Operative Bx & Localisation

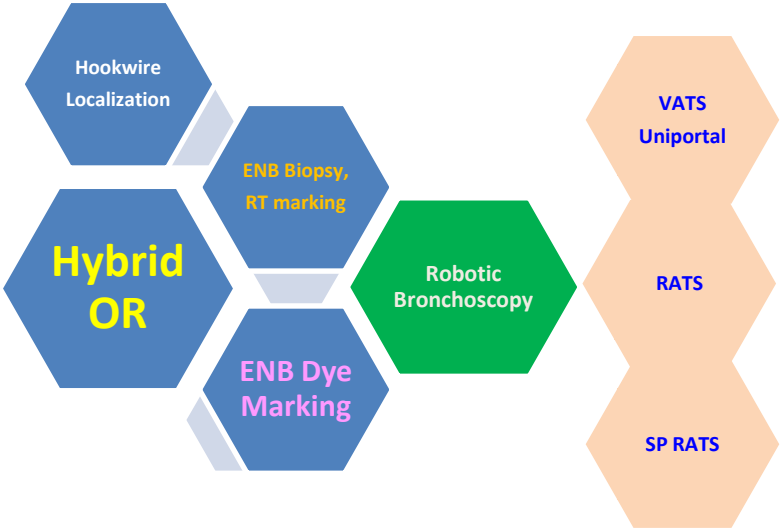


Ng CSH, He JX, Rocco G. Innovations and technologies in thoracic surgery. *Eur J Cardiothorac Surg* 2017;52:203–5.

Hybrid OR: Operative Bx & Localisation

Robotic Bronchoscopy





Ng CSH, He JX, Rocco G. Innovations and technologies in thoracic surgery. *Eur J Cardiothorac Surg* 2017;52:203–5.

“Local Therapy” Choices for Lung

- **Wedge Resection** v. SBRT v. Ablation

- Ablation conventionally

  1) **=> Percutaneous**

  => Pneumothorax / Hemothorax

  => Pulmonary-pleural Fistula

  => Limited access

  2) => Radiofrequency RF energy

  => Ablation zone small

  => Ablated zone less predictable

  3) => Less data than SBRT

Not so popular

ORIGINAL RESEARCH • VASCULAR AND INTERVENTIONAL RADIOLOGY

Radiology

Survival Rates after Thermal Ablation versus Stereotactic Radiation Therapy for Stage 1 Non–Small Cell Lung Cancer: A National Cancer Database Study

Johannes Uhlig, MD, MPH • Johannes M. Ludwig, MD • Sarah B. Goldberg, MD, MPH • Anne Chiang, MD, PhD • Justin D. Blasberg, MD • Hyun S. Kim, MD

From the Division of Interventional Radiology, Department of Radiology and Biomedical Imaging (J.U., J.M.L., H.S.K.), Division of Medical Oncology, Department of Medicine (S.B.G., A.C., H.S.K.), Division of Thoracic Surgery, Department of Surgery (J.D.B.), and Yale Cancer Center (H.S.K., S.B.G., A.C., J.D.B.), Yale School of Medicine, 330 Cedar St, New Haven, CT 06510; Department of Diagnostic and Interventional Radiology, University Medical Center Goettingen, Germany (J.U.); Department of Diagnostic and Interventional Radiology and Neuroradiology, University Hospital Essen, University of Duisburg-Essen, Essen, Germany (J.M.L.). Received April 24, 2018; revision requested June 19; revision received July 7; accepted July 20. **Address correspondence to** H.S.K. (e-mail: *kevin.kim@yale.edu*).

Conflicts of interest are listed at the end of this article.

See also the editorial by Shyn in this issue.

Radiology 2018; 289:862–870 • https://doi.org/10.1148/radiol.2018180979 • Content codes: CH IR OI

Purpose: To compare survival rates of thermal ablation and stereotactic radiation therapy (SRT) for stage 1 non-small cell lung cancer (NSCLC)

28834 patients : 1102 thermal ablation ; SRT 27732

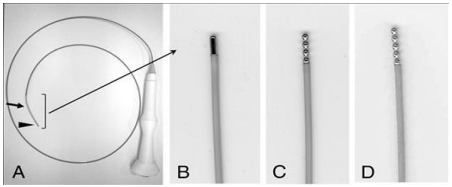
Results: This study included 28 834 patients (TA, 1102 patients; SRT, 27 732 patients). Patients treated with TA had more comorbidities (Charlson comorbidity index of 1 vs ≥2, 32.8% [362 of 1102] vs 19.7% [217 of 1102], respectively) compared with SRT (Charlson comorbidity index of 1 vs ≥2, 26.9% [7448 of 27 732] vs 15.3% [4251 of 27 732], respectively; $P < .001$) and smaller tumor size (mean tumor size, TA vs SRT: 19 mm vs 22 mm, respectively; $P < .001$). In the propensity score–matched cohort with balanced distribution of potential confounders, there was no significant difference in overall survival

Conclusion:
Regarding overall survival, thermal ablation was not inferior to stereotactic radiation therapy for primary treatment of stage 1 NSCLC

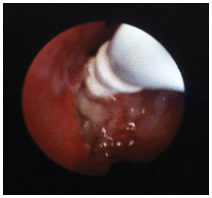
Online supplemental material is available for this article.

Bronchoscopic Catheter Based Therapy: RF/ Microwave ablation/ Cryotherapy

- RF / microwave ablation



- Cryotherapy



Zhao ZR, Lau RW, Ng CS. Catheter-based alternative treatment for early-stage lung cancer with a high-risk for morbidity. *J Thorac Dis* 2018 June;10(Suppl 16):S1864-1870 doi: 10.21037/jtd.2018.03.151

Lung Ablation:
Endobronchial route - “Game changer” ?

- Route to ablation

  => ~~Percutaneous~~ → Endobronchial

  => Pneumothorax / Hemothorax ↓ ↓

  => Pulmonary-pleural Fistula ↓ ↓ ↓

  => Limited access ↓ ?

  => ~~RF energy~~ → Microwave

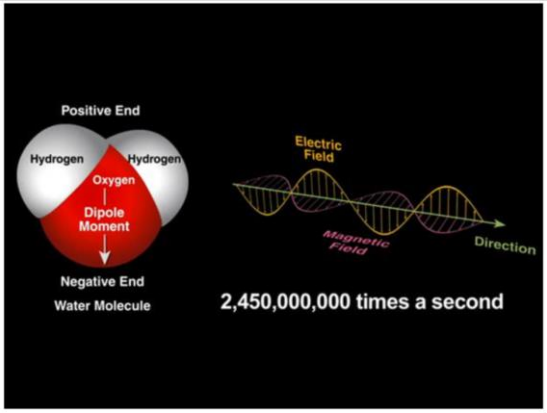
  => Ablation zone bigger

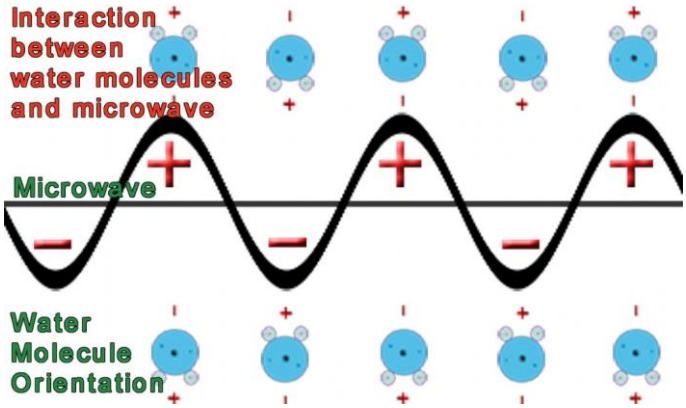
  => Ablated zone more predictable

Microwave – Game Changer

Video of ablation zones:
Left – Microwave (Neuwave) & Right – RF

Microwave Ablation

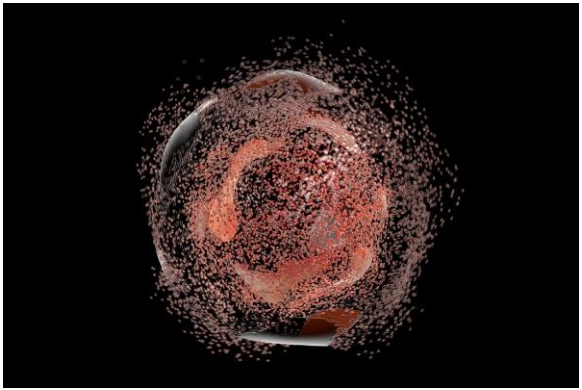


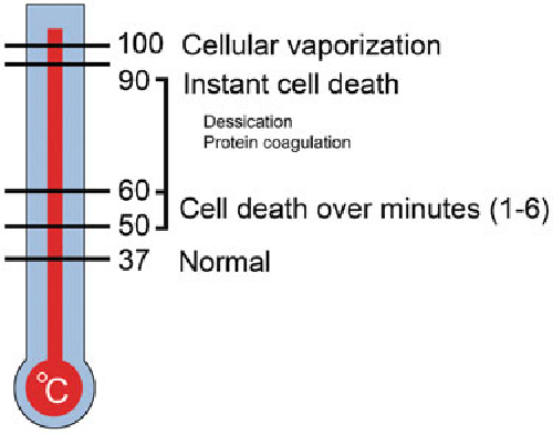


Microwave Ablation

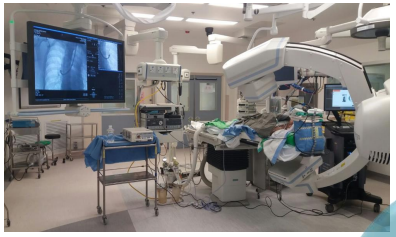
What does microwave & heat do to tissues?

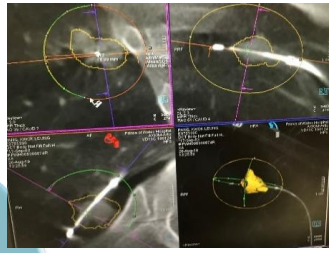
- At above 60° C all living cells, including cancer cells will die, effectively destroying the cancer

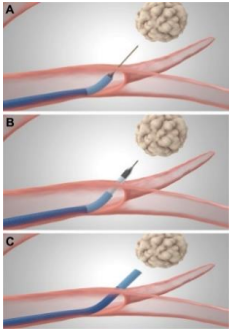


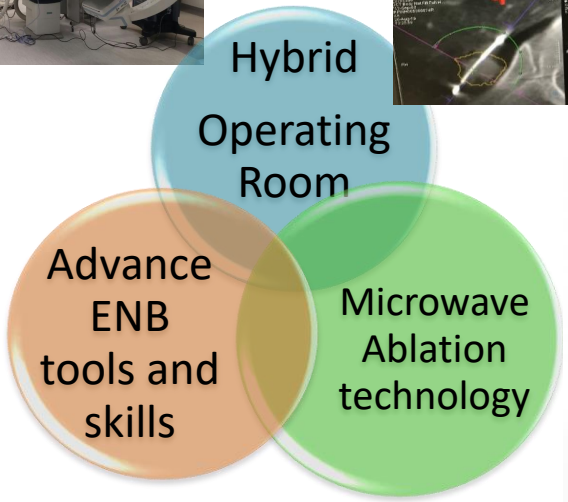


Bronchoscopic Microwave Ablation enable by Amalgamation of Technologies







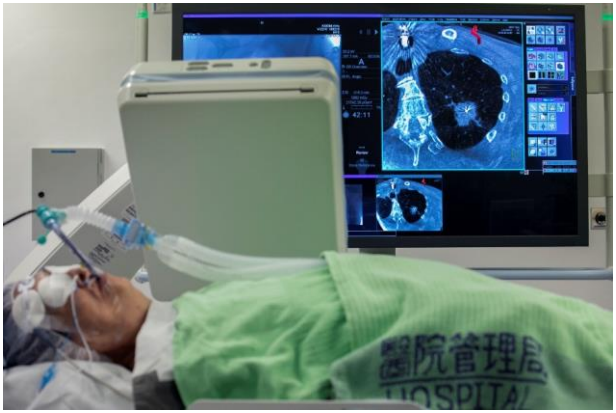


Bronchoscopic Microwave Ablation (BMA) of Lung Tumours

Step 1: Navigate to lung cancer using hybrid OR CBCT guided ENB

Bronchoscopic Microwave Ablation (BMA) of Lung Tumours

Step 2: Precise placement of MW catheter into cancer with CBCT guidance



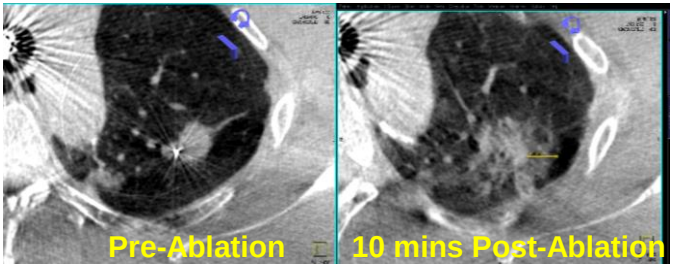
Bronchoscopic Microwave Ablation (BMA) of Lung Tumours

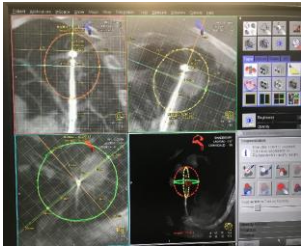
Step 3: Microwave Ablation of Cancer

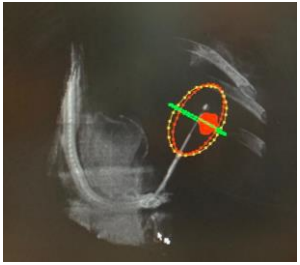
Bronchoscopic Microwave Ablation (BMA) of Lung Tumours

Step 4: Evaluation of CT images confirm adequate ablation of cancer

Our First Hybrid OR CBCT Guided bronchoscopic microwave ablation of lung cancer, March 2019





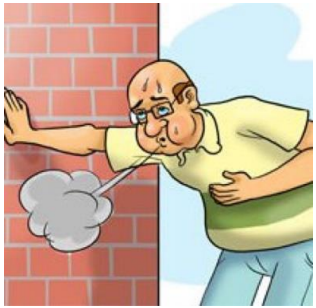


Bronchoscopic Microwave Ablation

May be offered to:

Primary lung cancer:

- not suitable to undergo surgery:
  - advanced age, major co-morbidities or limited lung function;
- decline/ not suitable for SBRT
- those who decline surgery for personal reasons

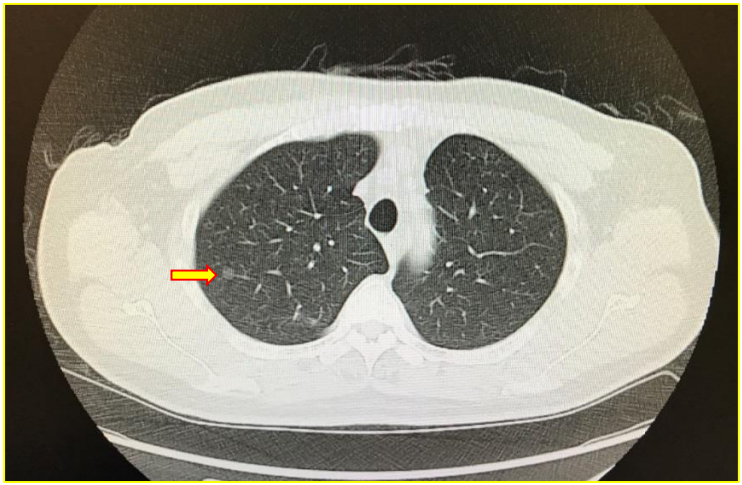


Bronchoscopic Microwave Ablation

May be offered to:

- Patients with small ground glass opacities that can be pre-cancerous or very early lung cancers

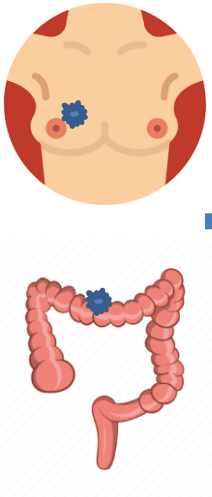
- Right upper lobe 5mm GGO

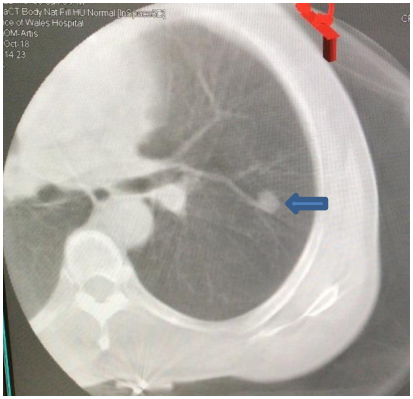


Bronchoscopic Microwave Ablation

Patients with lung metastases

Primary CA

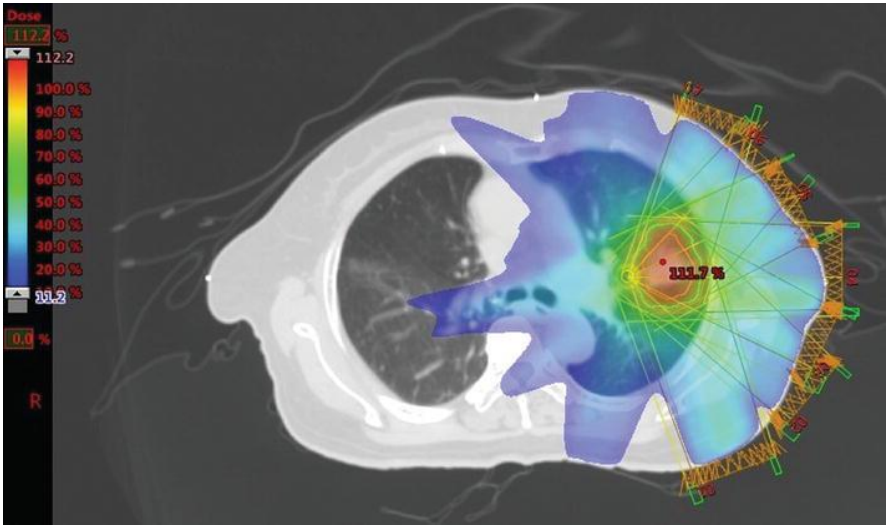




Lung metastases

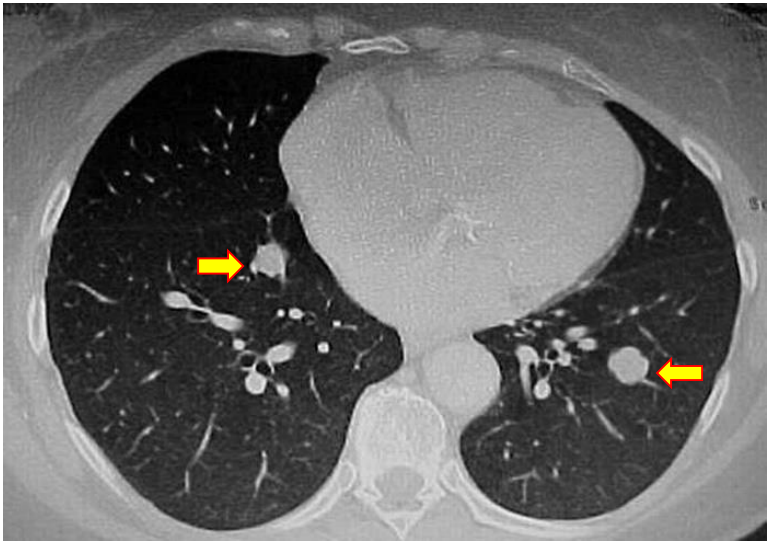
Bronchoscopic Microwave Ablation

Lung cancer patients who had previous radiotherapy to the same region of the lung



Bronchoscopic Microwave Ablation

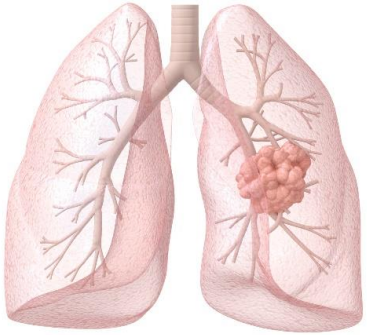
Patients with multiple or bilateral lung cancers requiring local control



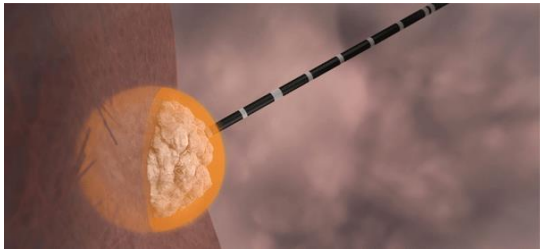
Bronchoscopic Microwave Ablation

Important to select the appropriate patients for the best outcomes:

- Lung lesion to be ablated is less than 3 cm.
- (maximum treatment zone of microwave catheter is 4.2cm)



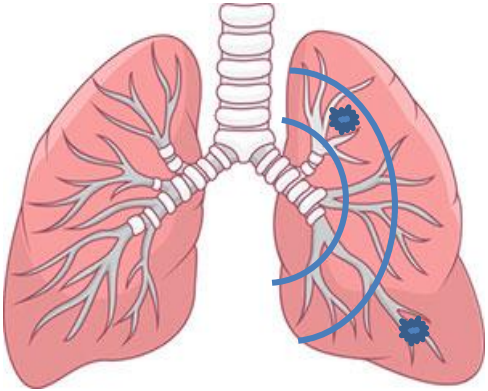
Lung cancer
Size < 3cm

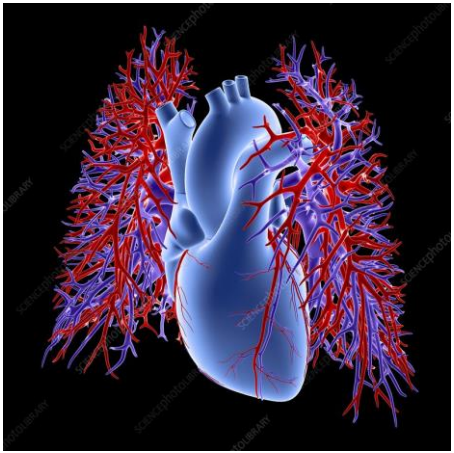


Bronchoscopic Microwave Ablation

Important to select the appropriate patients for the best outcomes:

- Lung cancer is at the outer two-thirds of the lung.
- Lung lesion is away from large pulmonary blood vessels.





Bronchoscopic Microwave Ablation (BMA)

	Conventional Surgery	BMA
Access trauma	++	-
Blood loss	++	-
Pain	++	+/-
Scars	++	-
Hospital Stay	++	+

BMA-CUHK

- March – Nov 2019; 22 patients
- Mean age 67 (range 54-87), 12 patients were female.
- Twelve (55%) had a pre-operative or intra-operative diagnosis of NSCLC or pulmonary metastases, and 10 had no definitive confirmation of cancer

- Mean size of lesion ablated 2.1 cm (range 0.8-3).
- Mean total procedure time was 132 mins (range 82-190)
- 4 cases required “double” ablation in same GA session to ensure adequate margins

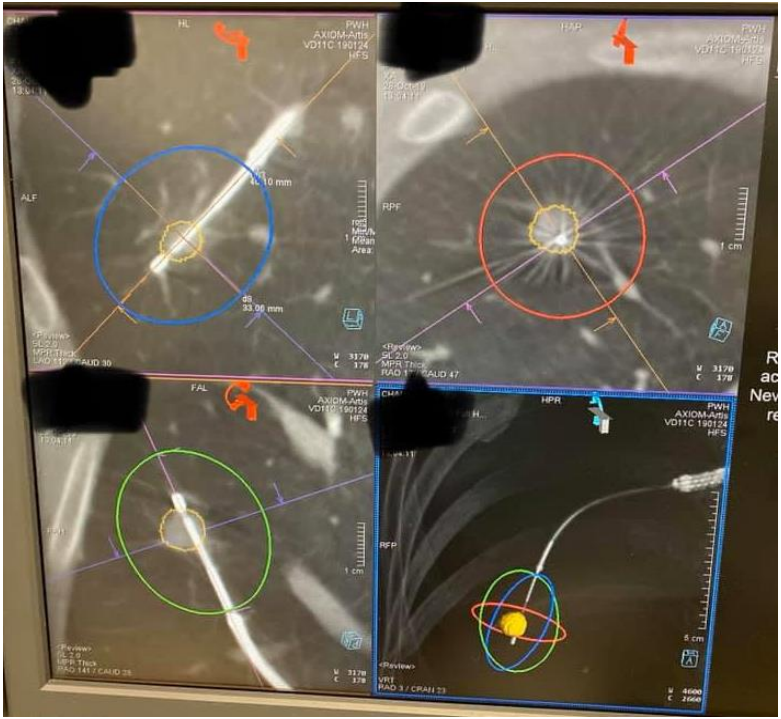
BMA-CUHK

- Mean intra-operative blood loss was 0.2 mls (range 0-2)
- 1 pneumothorax and 1 hemopneumothorax requiring chest drain insertion
- 17 patients (77%) had no pain reported during their hospital stay.

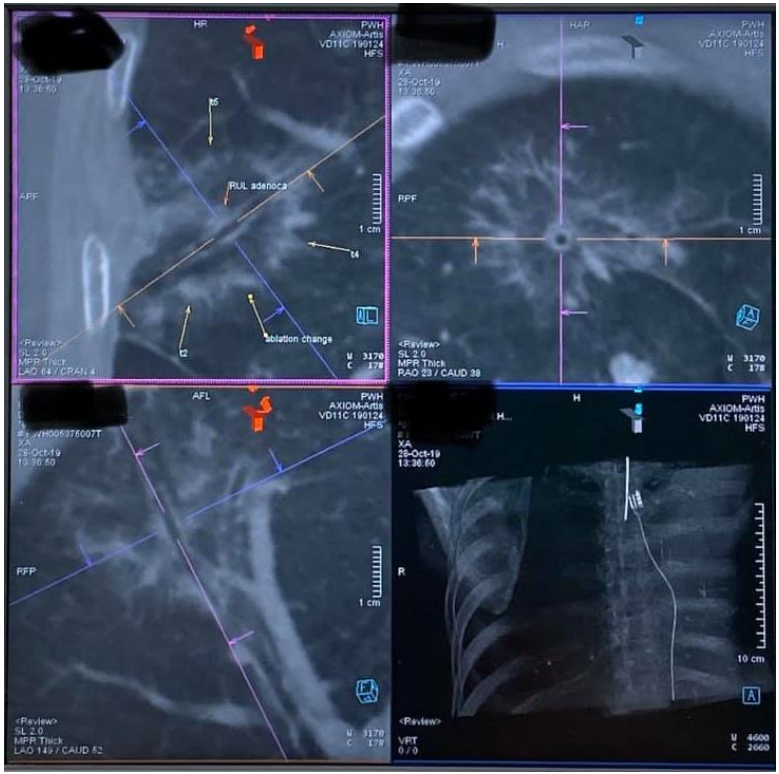
- Median hospital stay was 1 day (range 1-16).
- Mean follow-up duration was 4.8 months (range 0-8).

- There are no radiological signs of local recurrence

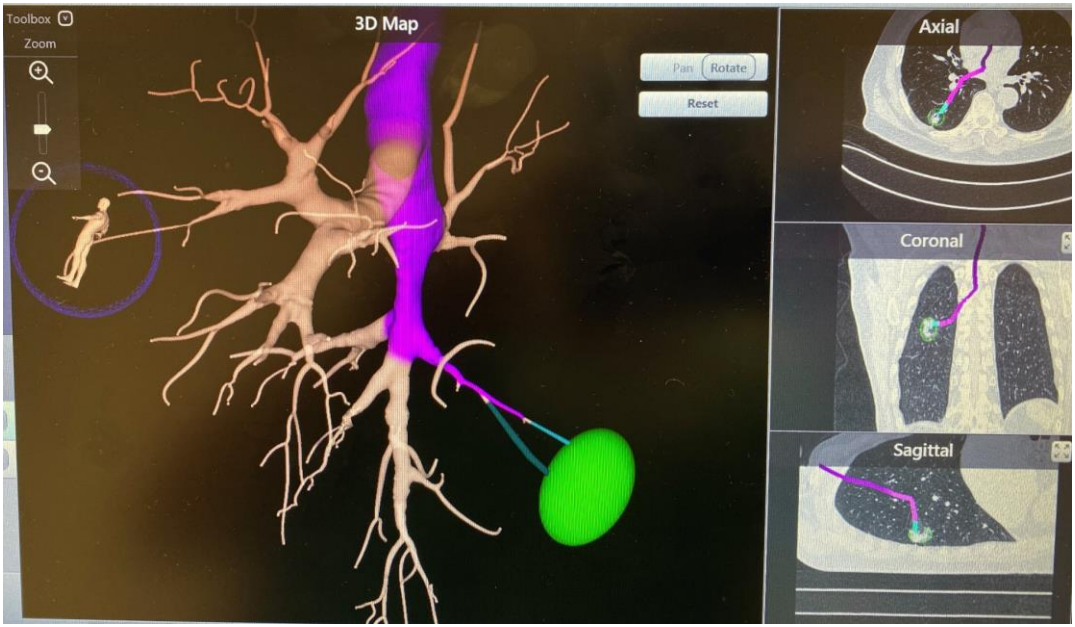
Case A: 1cm RUL adenoCA lung



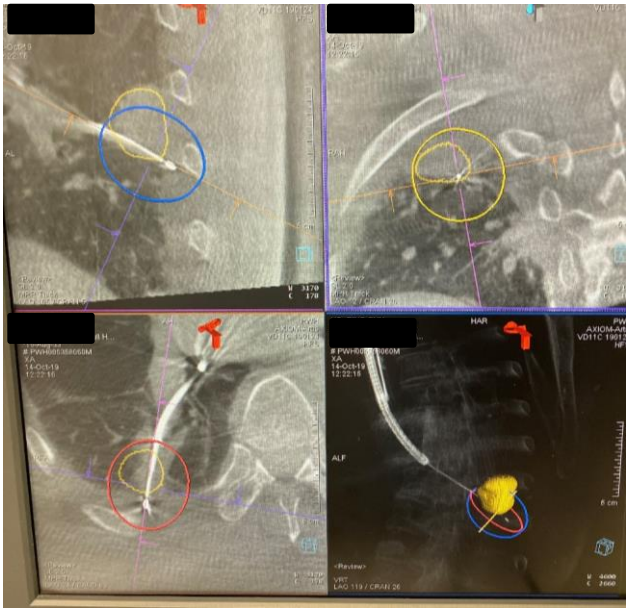
Case A: Post-ablation CBCT 20 mins- *Halo effect*

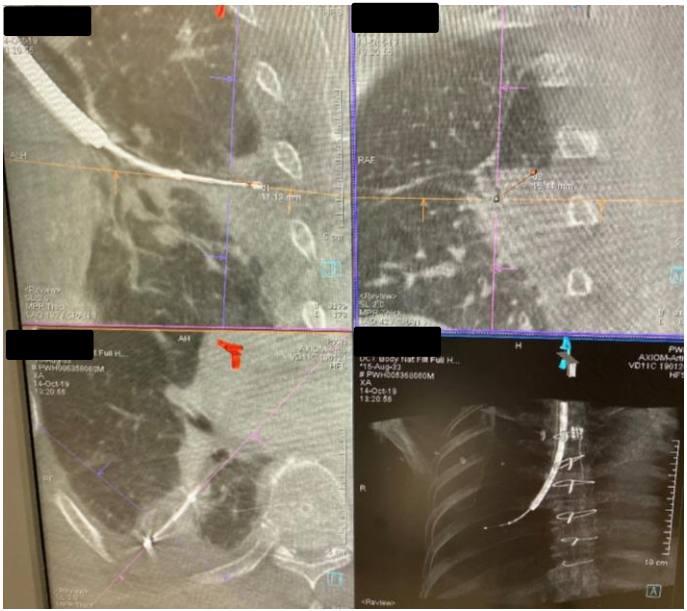


Case B: “Bracket” (Double) Ablation
RLL 3cm cancer

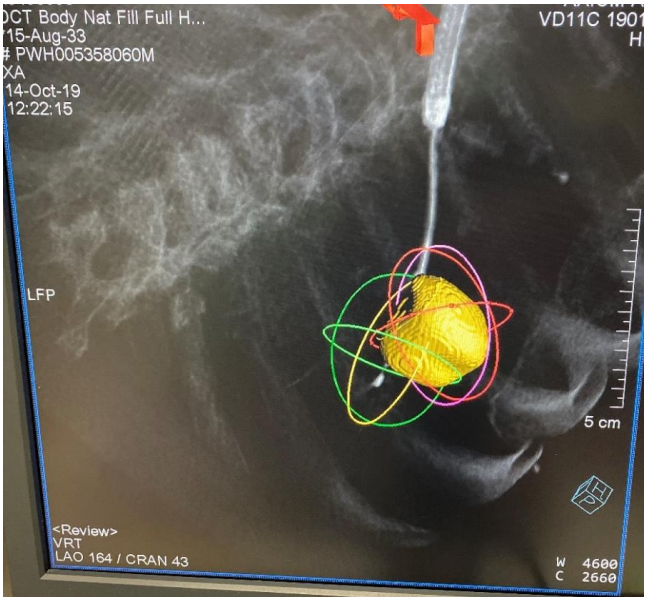


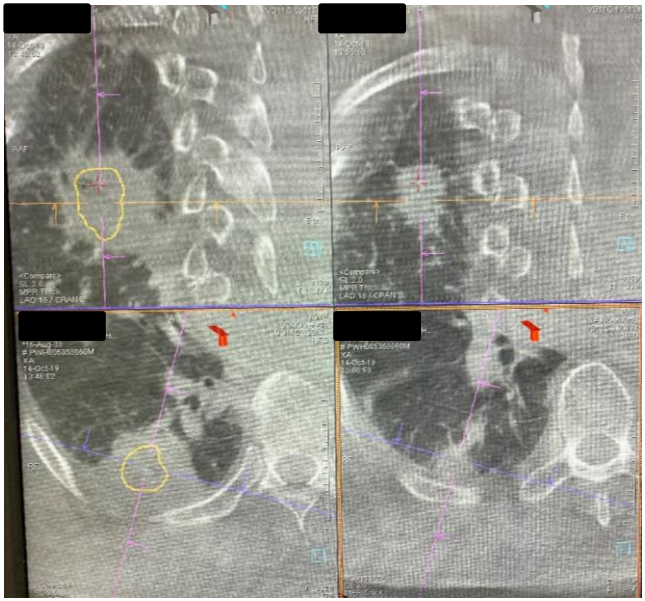
Case B: “Bracket” (Double) Ablation
RLL 3cm cancer



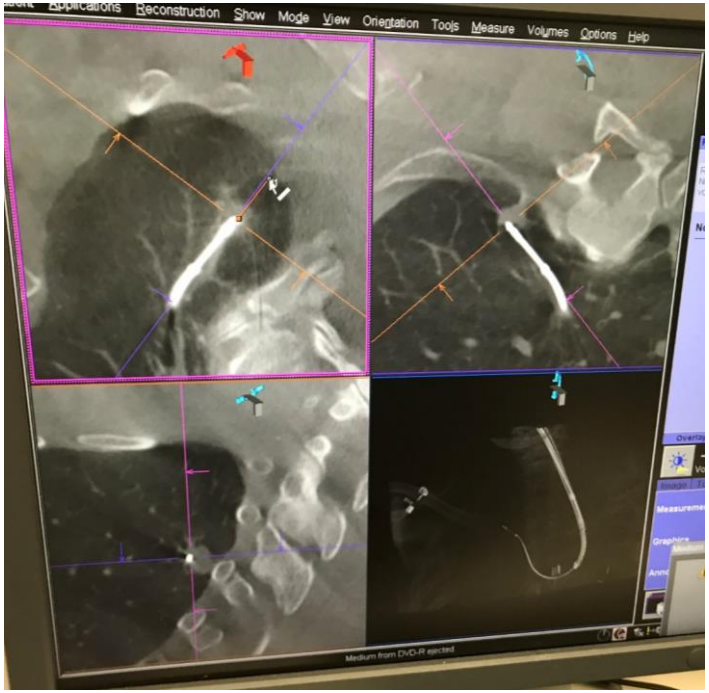


Case B: “Bracket” (Double) Ablation
RLL 3cm cancer

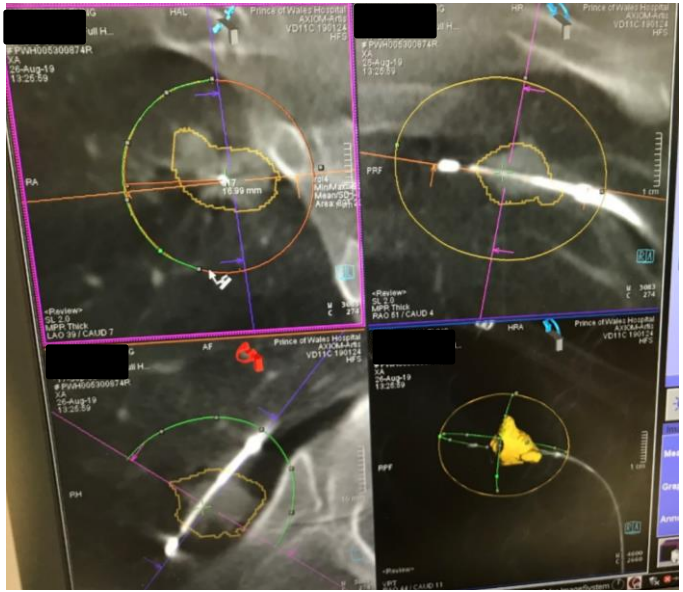


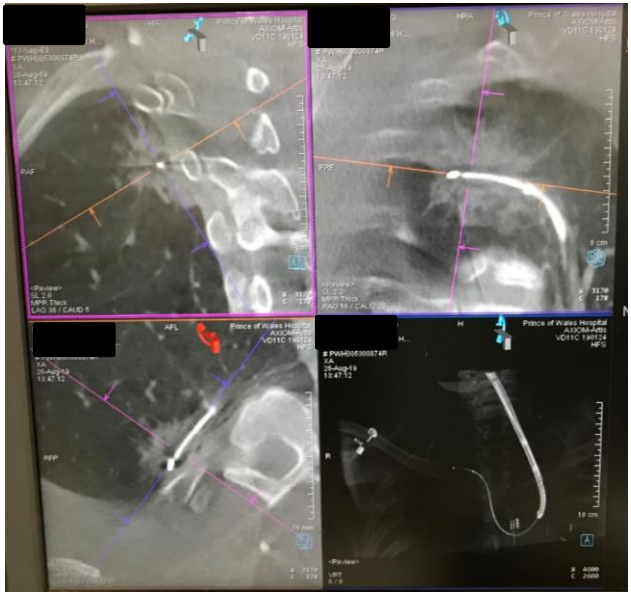


Case C: 55/M, Post Lt Pneumonectomy
RUL Bx proven SqCC 1.5cm



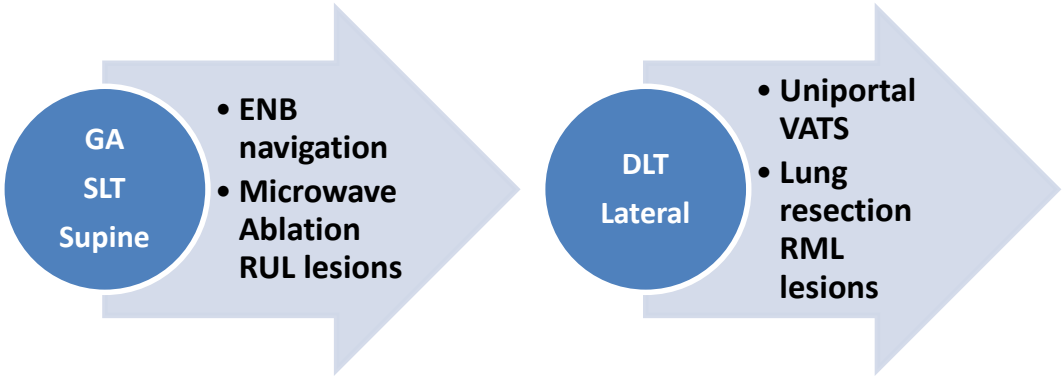
Case C: 55/M, Post Lt Pneumonectomy
RUL Bx proven SqCC 1.5cm



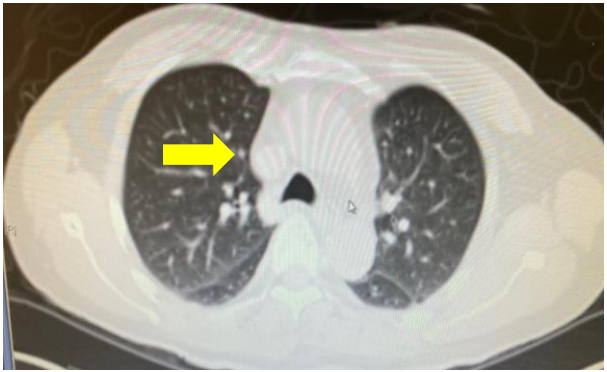


Case D: 68/M, HCC & Liver transplant, Pulmonary Mets- 2 in RUL (0.9 cm & 0.6 cm), 2 in RML (1 cm & 1.8 cm)

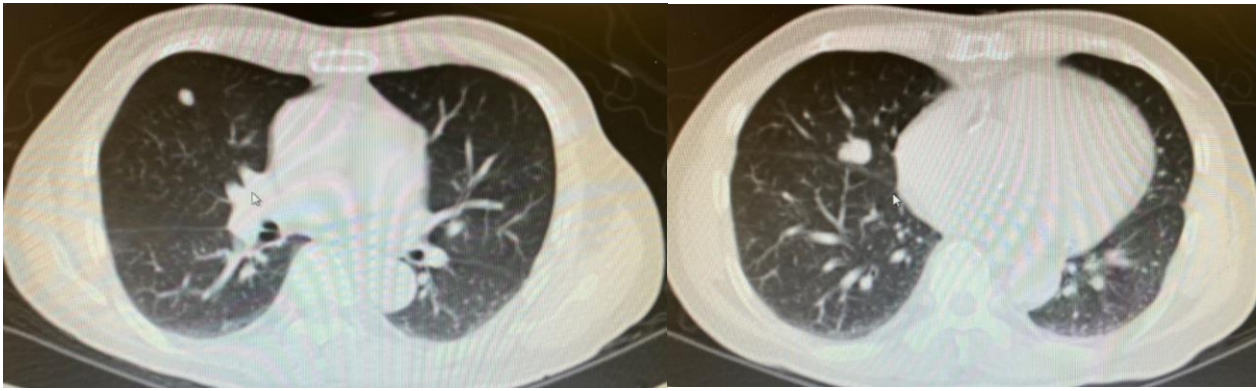
- ***Hybrid Approach in Hybrid Operating Theatre***



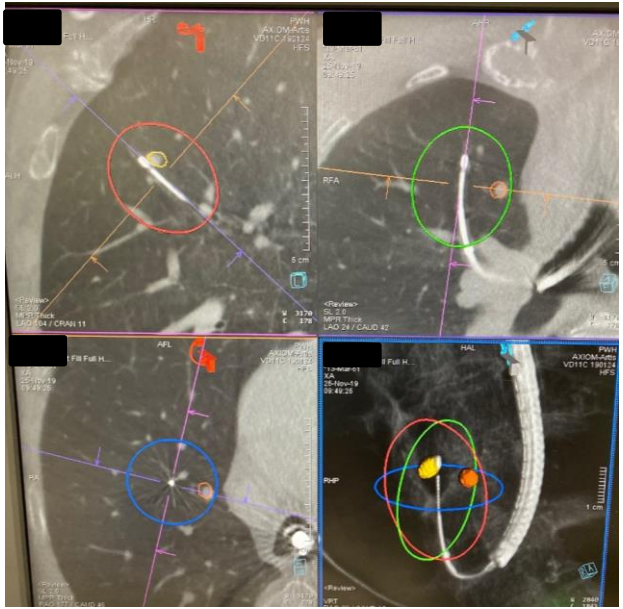
Case D: 68/M, HCC & Liver transplant, Pulmonary Mets- 2 in RUL (0.9 cm & 0.6 cm), 2 in RML (1 cm & 1.8 cm)

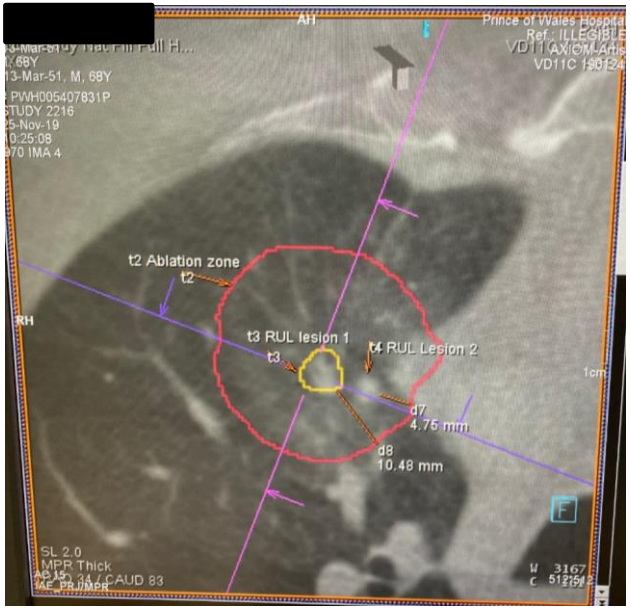


Case D: 68/M, HCC & Liver transplant, Pulmonary Mets- 2 in RUL (0.9 cm & 0.6 cm), 2 in RML (1 cm & 1.8 cm)



Case D: 68/M, HCC & Liver transplant, Pulmonary Mets- 2 in RUL (0.9 cm & 0.6 cm), 2 in RML (1 cm & 1.8 cm)



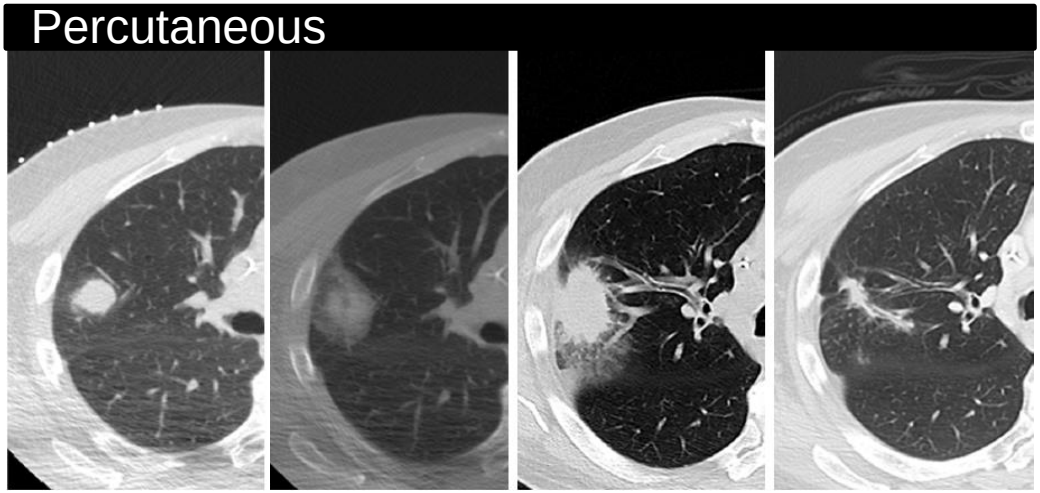


Pre-ablation predicted

CBCT 20 mins Post-ablation

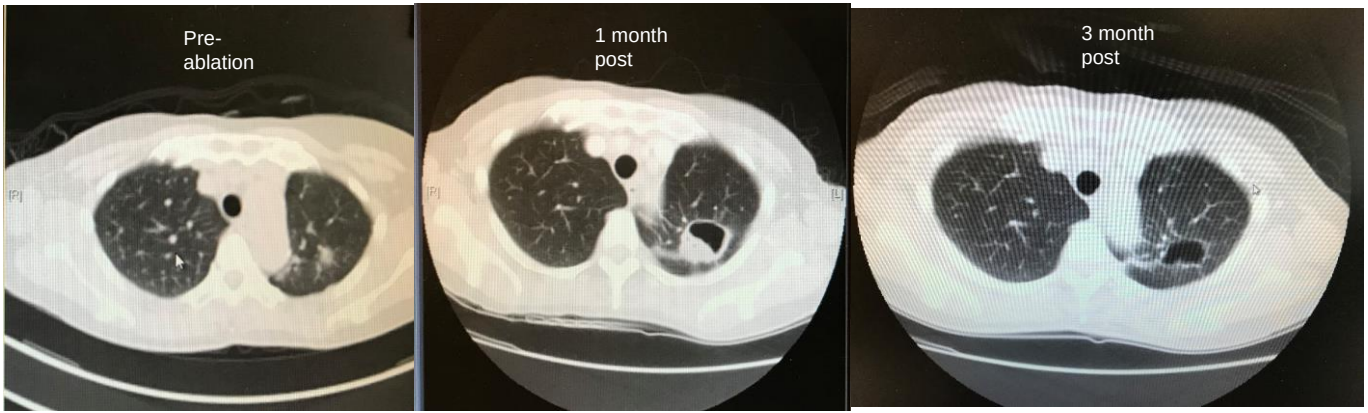
Case D: 68/M, HCC & Liver transplant, Pulmonary Mets- 2 in RUL (0.9 cm & 0.6 cm), 2 in RML (1 cm & 1.8 cm)

Expected CT findings
Post-Microwave Ablation of Lung lesion

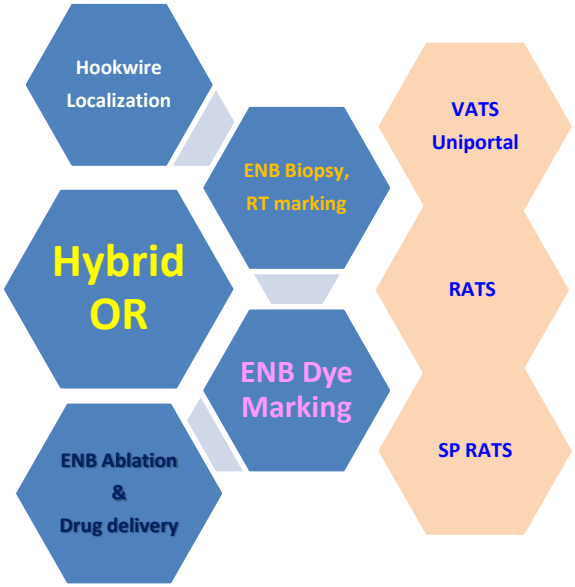


Before ablation | **1 month** | **3 months** | **6 months after ablation**

Case: Pre-ablation (left)v. 1 month Post Ablation (middle) v. 3 months Post Ablation (right)

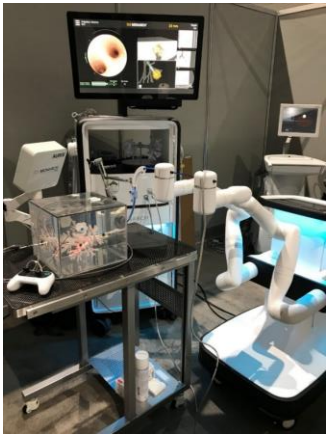


Hybrid Operating Room:

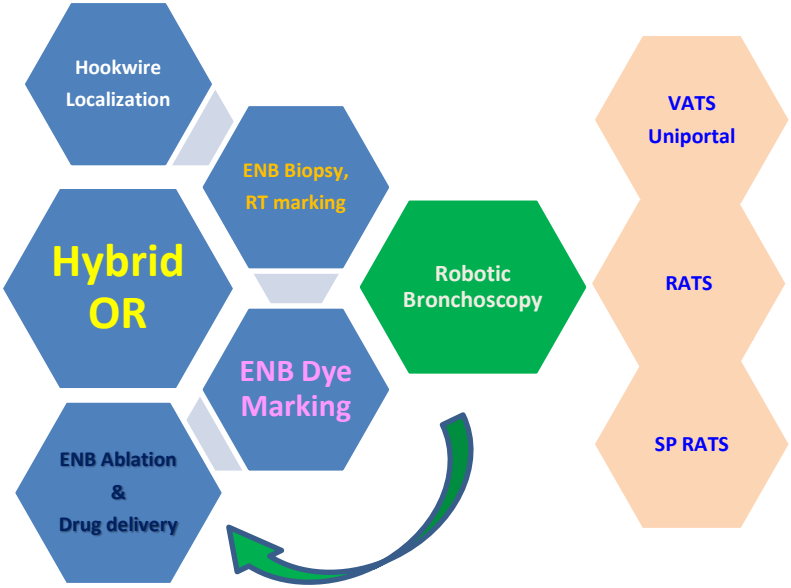


1) Ng CSH, He JX, Rocco G. Innovations and technologies in thoracic surgery. *Eur J Cardiothorac Surg* 2017;52:203–5.
2) Kwok J, Lau RW, Ng CS. Multi-Dimensional Printing in Thoracic Surgery. *J Thorac Dis* 2018;10:S756
3) Ng CSH. Recent and Future Developments in Chest Wall Reconstruction. *Semin Thorac Cardiovasc Surg* 2015;27:234-9

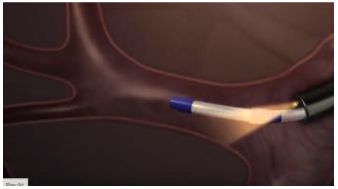
Robotic Bronchoscopy

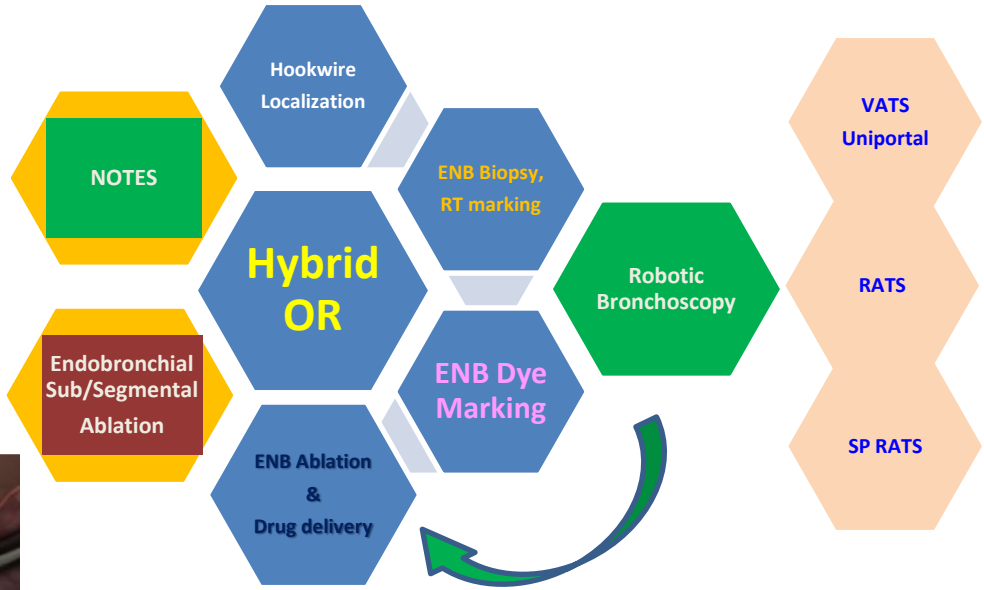


Hybrid Operating Room:



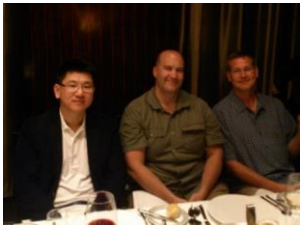
Look into the Future



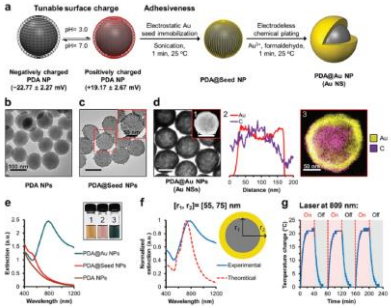


Ng CSH, Zhao ZR, Lau RWH. Tailored Therapy for Stage I Non-small Cell Lung Cancer. *J Clin Oncol* 2017 Jan;35:268-70
Li Z, Ng CSH. Future of Uniportal VATS – Emerging Technology. *Ann Cardiothorac Surg* 2016 ;5:127-32

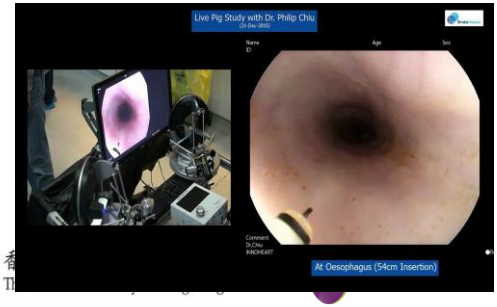
Building International Alliance



Direct Tumour Injection	•Immune – Dan Sterman , NYU Langone & Industry •Nanoparticles – CUHK
Sub/ Segmental ablation	•Energy – Bill Krimsky, Baltimore •Steam – Felix Herth, Heidelberg & Industry & CUHK
NOTES	•Robotic NOTES – CUHK & Imperial College, John Hopkins, ETH Zurich & Industry



janssen | PHARMACEUTICAL COMPANIES OF Johnson & Johnson



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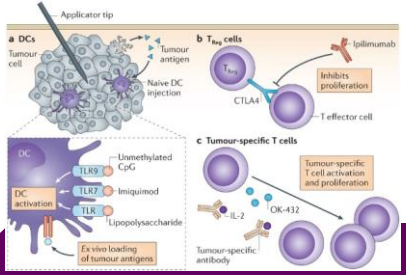

Summary: “One stop, one shop”

- Hybrid OR CBCT percutaneous & endobronchial image guidance improves our ability to diagnose & localize small lesions for surgery

- For the foreseeable future, the imaging capabilities of the hybrid room CBCT is essential for confirming:
  - accurate placement/ positioning of effector devices (eg, ablation catheters) & adequate treatment delivered

Summary: “One stop, one shop”

- “One stop, one shop” strategy for mx of small nodules could be attractive compared with the current “ multi- stop, multi shop, multi day” approach

- Continue to evolve
  - Streamlined workflow
  - Improve economy, add value
  - Decrease complexity
  - Increase tools & efficacy


"Intelligence is the ability to adapt to change."
Stephen Hawking

Prince of Wales Hospital
The Chinese University of Hong Kong

CUHK T Stone Robotics Institute
香港中文大學天石機器人研究所

Chow Yuk Ho Technology Centre for Innovative Medicine
周毓浩創新醫學技術中心
The Chinese University of Hong Kong

香港中文大學
The Chinese University of Hong Kong

香港中文大學醫學院
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