Supplementary

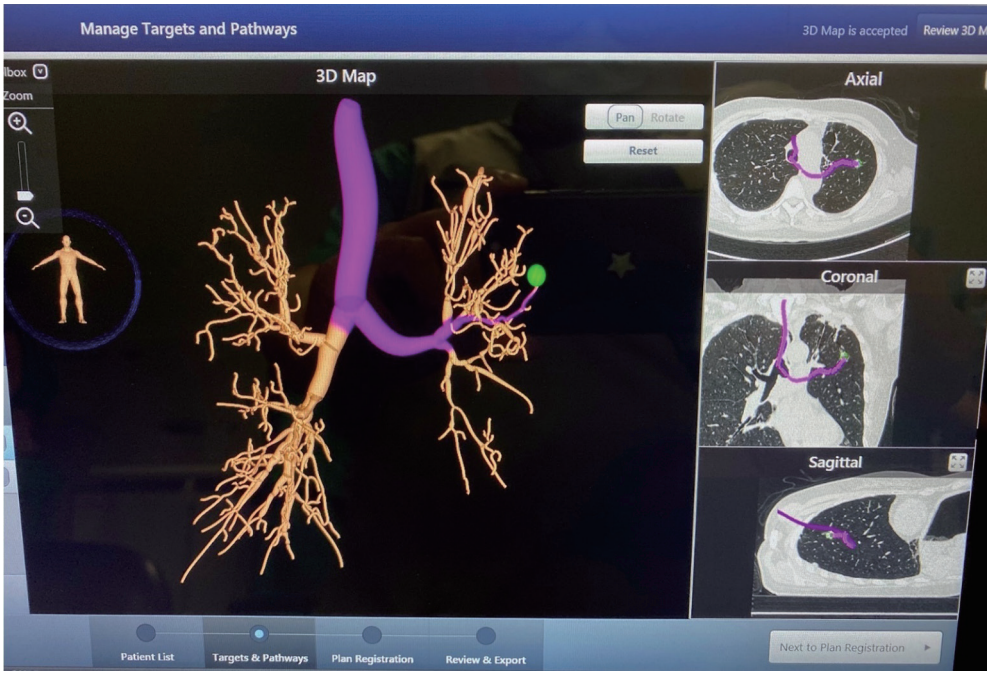

Figure S1 Figure shows the lung nodule (green ball) and the planned ENB pathway (pink route) using SuperDimension™ software.

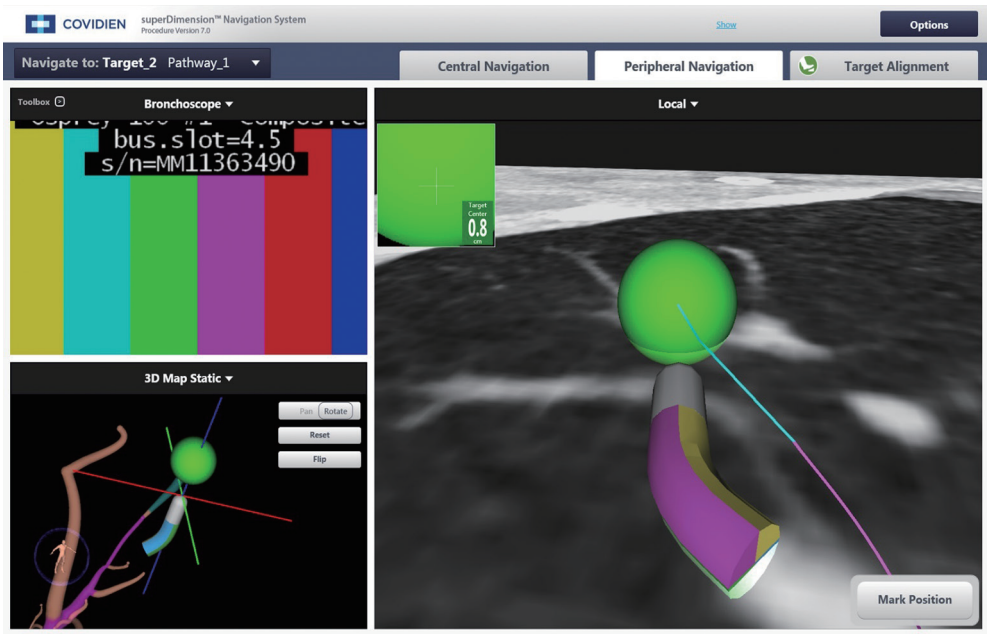

Figure S2 The right side panel shows the tip of locatable guide within 0.8cm from centre of target lesion (green ball).

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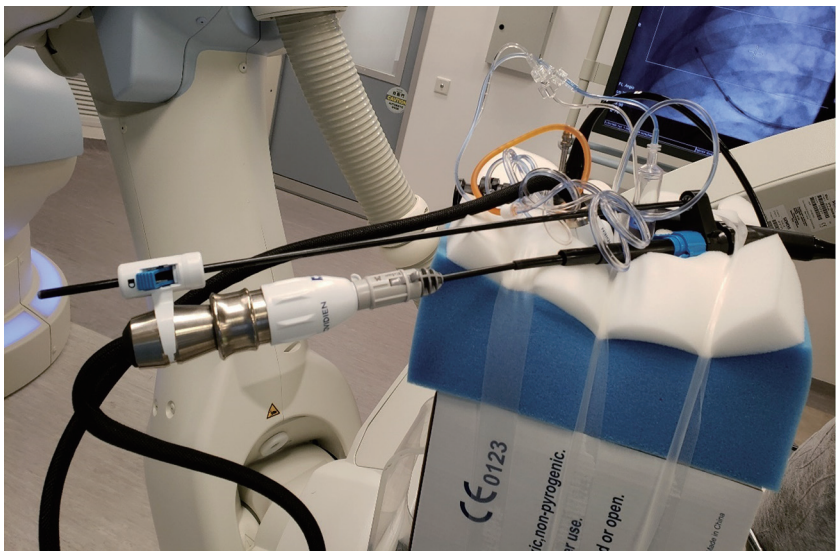

Figure S3 The microwave catheter was inserted into the extended working channel of the bronchoscope and fixed to the system with a long rod. The whole system is supported by a box and foam so that CBCT can be performed without a person holding the system.

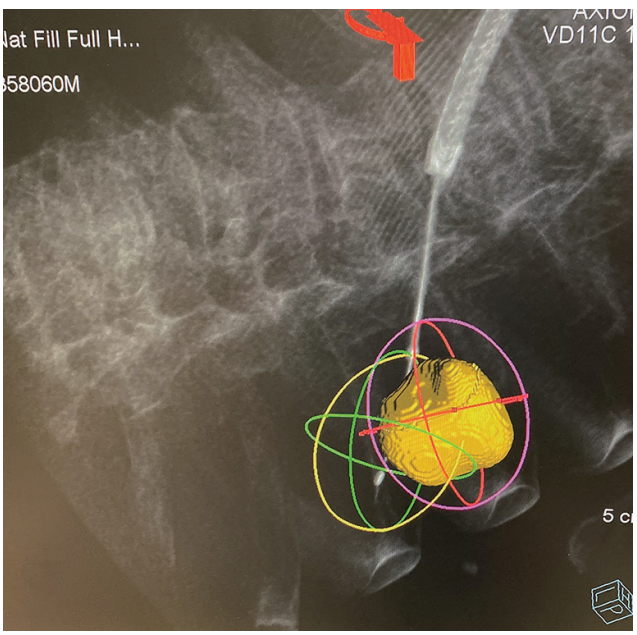

Figure S4 Figure shows a relatively large lung nodule planned for double ablation with re-navigation (bracket ablation). The two oval "cages" (yellow-green and pink-red rings) indicate the predicted ablation zones from the two ablations.

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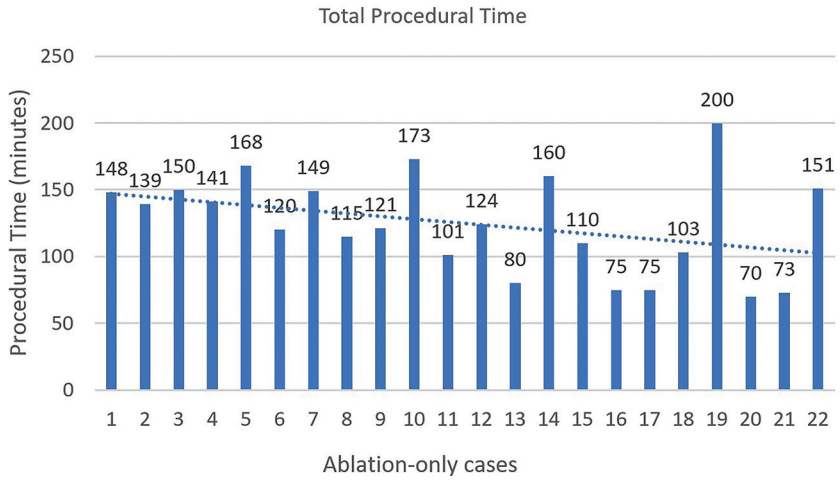

Figure S5 There was a trend towards shorter procedural time with experience.

	45 W			75 W			100 W		
A	MM:SS	B	C	MM:SS	B	C	MM:SS	B	C
1.6 cm	2:00	2.8 cm	0.6 cm						
1.9 cm	3:00	3.0 cm	0.7 cm	2:00	3.1 cm	0.8 cm			
2.2 cm	4:30	3.3 cm	0.8 cm	2:30	3.3 cm	0.9 cm			
2.5 cm	7:30	3.5 cm	0.9 cm	3:30	3.6 cm	0.9 cm	2:30	3.3 cm	0.7 cm
2.7 cm	10:00	3.6 cm	1.0 cm	4:30	3.8 cm	1.0 cm	3:00	3.5 cm	0.8 cm
2.9 cm				5:30	3.9 cm	1.1 cm	4:00	3.7 cm	0.8 cm
3.1 cm				7:00	4.0 cm	1.1 cm	5:00	3.9 cm	0.9 cm
3.3 cm				9:00	4.1 cm	1.1 cm	7:00	4.0 cm	1.0 cm
3.4 cm				10:00	4.2 cm	1.1 cm	8:30	4.1 cm	1.0 cm
3.5 cm							10:00	4.2 cm	1.0 cm

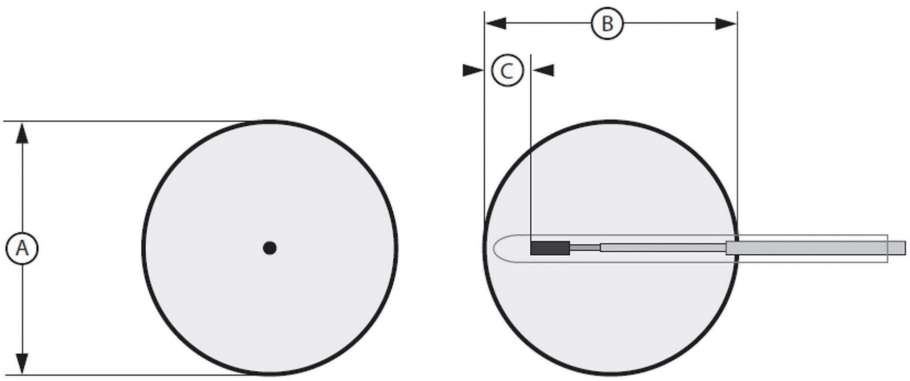

Figure S6 The upper panel shows the predicted ablation zone size provided by the manufacturer. It was developed using the ablation catheter kit in in-vivo porcine lungs. The table includes the ablation diameter (A), height (B) and distance from the tip (C) versus time for three power levels (45 watts, 75 watts and 100 watts). Time is represented as MM:SS (minutes: seconds). In the lower panel, the circular areas represent the ablation zone in cross-section, which is a spheroid shape 3-dimensionally.

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Table S1 Procedural steps for ENB microwave ablation of lung nodules in hybrid operating theatre

Step	Descriptions	CBCT
1	Supine, general anesthesia, single lumen endotracheal intubation	
2	Bronchoscopic toileting	
3	Baseline CBCT at inspiratory hold	First
(4)	Lesion marked on fluoroscopy screen with iGuide (Siemens Healthineers, Germany) and 3-dimensional segmentation	
5	Registration of patient airway, verification of correct orientation with SuperDimension™ software	
6	Navigation to target lesion with ENB and/or fluoroscopic guidance.	
(7)	Transbronchial access adjuncts may be used, for example CrossCountry™ Transbronchial Access Tool (Covidien™, Plymouth, MN, USA); Soft-tip guidewires to enter small airways at an awkward angle if necessary.	
8	FNA or CrossCountry™ needle puncture of lesion, CBCT to confirm position and adjust if necessary	Second
(9)	Biopsy of lesion if indicated	
10	Exchange needle to Emprint™ microwave ablation set	
11	CBCT to confirm desirable location of catheter. Ablation energy decided with planning of predicted margin.	Third
12	Ablation performed. Fluoroscopy obtained every 3 minutes to detect any inadvertent movement of catheter. Cooling for 10 minutes	
13	CBCT at 10 minutes post-ablation with ablation catheter in-situ. Evaluation of ablation zone coverage, contraction and margin	Fourth
(14)	If ablation zone coverage suboptimal, options: 1) Repeat CBCT 10-20 minutes later and re-evaluate 2) Re-ablate at same location 3) Re-ablate after pull-back of catheter 4) Re-ablate after re-navigation via a different route	
15	Removal of ablation catheter, EWC and bronchoscope. Bronchial toileting. Extubation.	

CBCT, bone beam computer tomography scan; ENB, electromagnetic navigation bronchoscopy; FNA, fine needle aspiration. A minimum of 4 CBCT required to complete ablation. Bracketed steps are optional. The microwave output frequency is 2.45GHz ± 5MHz, the active ablation tip is 1.8cm in length and 2mm in diameter. The system is water-cooled.

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Table S2 Clinical characteristics of patients and lung nodules

Case	Patient	Sex	Age (years)	CCI	Lobe	Histology	Maximum Nodule size (mm)	Suzuki Class	Comorbid or history
1	A	F	55	3	LLL	atypia	17	6	Previous LUL lobectomy for lung cancer
2	B	F	83	6	LUL	atypia	24	6	Previous RUL and RML lobectomy for lung cancer, COPD GOLD stage 2
3	C	F	69	4	RUL	AAH	16	3	Previous LUL lobectomy for lung cancer
4	D	F	69	5	LUL	NFM	10	2	Previous RUL lobectomy for lung cancer
5	E	M	77	8	LUL	atypia	22	3	COPD GOLD stage 2
6	A				RLL	adenoCA	27	5	(see patient A)
7	C				RML	atypia	15	3	(see patient C)
8	F	M	69	8	RUL	adenoCA	13	4	Sigmoid cancer with liver metastasis resected
9	G	M	59	8	LUL	n/a	13	cavitary	Previous anterior resection for rectal cancer
10	H	M	63	4	RUL	NFM	22	3	Previous LLL lobectomy for lung cancer
11	I	F	60	5	LUL	NFM	20	3	Previous RML lobectomy for lung cancer, poor lung function
12	J	M	77	6	LLL	atypia	14	6	COPD GOLD stage 2
13	K	M	86	8	RLL	adenoCA	29	6	Frail, history of stroke, dementia, previous thymectomy for thymoma
14	H				RLL	n/a	8	1	(see patient H)
15	L	F	85	6	LLL	NFM	18	3	Frail, Previous RLL lobectomy for lung cancer
16	M	M	68	8	RUL	n/a	7	6	Salvage liver transplant for liver cancer
17	N	M	74	8	RLL	atypia	16	3	Previous LUL and LLL sublobar resection for lung cancer
18	O	F	65	4	LUL	n/a	11	3	Previous LLL lobectomy for lung cancer
19	P	F	60	5	LLL	atypia	13	1	Previous RUL lobectomy and RML wedge resection for lung cancers
20	Q	M	82	7	RUL	adenoCA	15	6	Frail, Previous Hartmann operation for rectal cancer, with complicated post-operative course
21	R	F	65	4	LUL	atypia	14	1	Nasopharyngeal carcinoma with chemoradiation
22	G				LLL	n/a	9	6	(see patient G)
23	S	M	64	4	LUL	n/a	16	1	Previous RUL lobectomy for lung cancer
24	T	F	67	8	RUL	n/a	9	6	Colonic cancer with liver metastasis with primary and metastasis resected
25	T				RUL	n/a	11	6	(see patient T)
26	U	M	70	5	LLL	n/a	18	3	Previous RML lobectomy, LUL lobectomy, RLL and LLL wedge resection for lung cancer
27	V	F	66	4	RUL	NFM	10	6	Previous RML lobectomy and hemicolectomy for colonic cancer
28	W	F	73	6	RML	atypia	12	1	Previous right total hip replacement, moderate mitral stenosis
29	X	M	51	7	RML	Metastasis	19	6	Previous thyroidectomy for thyroid cancer (known lung metastasis)
30	Y	F	63	4	RUL	n/a	7	1	Previous LLL segmentectomy for lung cancer

CCI: Charlson Comorbidity Index. LUL, left upper lobe; RUL, right upper lobe; RML, right middle lobe; LLL, left lower lobe; RLL, right lower lobe. AdenoCA, adenocarcinoma; n/a, not available; NFM, negative for malignancy; AAH, atypical adenomatous hyperplasia. COPD, chronic obstruction pulmonary disease.

Table S3 Morphology of post-ablation CT at first month

	Value
GGO with air-bronchogram	
With solid component	4 (13.3%)
Without solid component	12 (40%)
GGO	5 (16.7%)
Cavity	5 (16.7%)
Solid/soft tissue pre-dominant	4 (13.3%)
Linear or triangular shaped scars	0

GGO, ground-glass opacity. Linear or triangular shaped scars are usually seen several months after successful ablation.

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