In response to an enquiry from the NHSScotland National Infrastructure Board

Robotic-assisted bronchoscopy (RAB) for diagnosing lung cancer

Recommendations for NHSScotland

Robotic-assisted bronchoscopy (RAB) should be available as a diagnostic biopsy option for patients with pulmonary lesions identified on computed tomography (CT) imaging that are suspected of being lung cancer. RAB should be the preferred biopsy technique for patients with small (<20mm) peripheral lesions that are not suitable for sampling using conventional techniques.

Access to RAB should be equitable and consistent across Scotland, ensuring all eligible patients have access regardless of geographic location. Successful introduction of RAB will require comprehensive training for clinicians in the safe and effective use of this technology and adequate infrastructure for the decontamination, sterilisation and ongoing quality assurance of reusable RAB bronchoscopes.

The use of RAB should be accompanied by systematic data collection and analysis to inform future decision making regarding its role within Scottish lung cancer diagnostic pathways.

NHSScotland is required to consider the Scottish Health Technologies Group (SHTG) recommendations.

What were we asked to look at?

We were asked to review the evidence on the clinical effectiveness, cost effectiveness and safety of RAB for diagnosing lung lesions suspected of being cancer.

Why is this important?

A lung nodule biopsy is needed to accurately diagnose patients with suspected lung cancer. Conventional techniques are unable to reliably biopsy peripheral pulmonary lesions or nodules <20 mm in diameter.[1] Patients with these peripheral or small nodules who cannot get a biopsy-confirmed diagnosis may experience anxiety, disease progression or unnecessary aggressive treatments. The planned introduction of lung cancer screening in Scotland from 2027 is expected to increase the number of patients needing diagnostic biopsies of small pulmonary nodules, not all of which will be suitable for conventional biopsy procedures. RAB may be an option for obtaining biopsy-confirmed diagnoses for these patients. RAB is not currently available in NHSScotland.

What was our approach?

We reviewed the published literature on the clinical effectiveness, cost effectiveness, safety and patient experience of RAB for diagnosing lung cancer. We developed an exploratory economic model to gauge the likely cost effectiveness of introducing RAB in Scotland. A patient organisation submission was obtained from the Roy Castle Lung Cancer Foundation. More information about SHTG Recommendations is available on our website.

What next?

The NHSScotland National Infrastructure Board will use our advice to inform a decision on introducing RAB for diagnosing lung cancer in adults in Scotland.

Key points from the evidence

1. Systematic reviews of RAB combined results from studies assessing different RAB platforms and did not adequately report patient characteristics or the appraisal of primary study quality. Many of the primary studies recruited small numbers of highly selected patients and few studies directly compared RAB with other diagnostic modalities.

2. A systematic review with meta-analysis (27 studies, n=2,315) reported a diagnostic yield (calculated based on intermediate criteria) of 86.6% (95% confidence interval [CI] 83.7% to 89.2%) for RAB in patients with peripheral lung nodules and a suspicion of cancer.[2] In the meta-analysis, pneumothorax occurred in 2.0% of patients having RAB (95% CI 1.3% to 2.7%).

3. A network meta-analysis (NMA; 37 studies, n=4,285) found no statistically significant differences in diagnostic yield (intermediate criteria) between RAB and CT-guided transthoracic bronchoscopy (CTTB), endobronchial ultrasound (EBUS), virtual bronchoscopic navigation (VBN) or electromagnetic navigation bronchoscopy (ENB) in patients with peripheral pulmonary lesions.[3] Only three studies (n=242) contributed data on patients undergoing RAB in these comparisons.

4. Five primary studies compared RAB using the Ion™ platform with other diagnostic modalities. The patients in each group across these five studies may be highly selective because individuals eligible for RAB may be unsuitable for the comparator diagnostic modalities because of the size or anatomical location of their pulmonary nodules.

    - A cluster randomised trial (n=411) comparing RAB with ENB in patients with peripheral pulmonary lesions found no statistically significant difference between the two modalities when diagnostic yield was calculated using strict criteria (odds ratio [OR] 1.23, 95% CI 0.73 to 2.07).[4] Pneumothorax was reported in 1.97% of patients in the RAB group and 2.88% of patients in the ENB group (OR 0.39, 95% CI 0.12 to 1.25).

    - A retrospective cohort study (n=92) comparing RAB with ENB in patients with pulmonary nodules reported a statistically significantly higher diagnostic yield (strict criteria) from RAB (89% versus 66%, p<0.001).[5] Pneumothorax was reported in 1.8% of patients in the RAB group and 2.1% of patients in the ENB group.

    - A second retrospective cohort study (n=116) comparing RAB with ENB in patients with pulmonary nodules also reported statistically significantly higher diagnostic yield (intermediate criteria) from RAB (86.1% versus 49.5%, p<0.0001).[6] No complications were reported in either group in this study.

- A retrospective cohort study (n=59) comparing RAB with VBN in patients with peripheral pulmonary nodules reported that diagnostic yield (intermediate criteria) was 90% for RAB compared with 69% for VBN (p=0.045).[7] Pneumothorax was reported in 6.9% of patients in the VBN group and no patients in the RAB group (p=0.237).

- A retrospective cohort study (n=296) comparing RAB with CTTB in patients with pulmonary nodules found no statistically significant difference in diagnostic yield between the two modalities using strict criteria (86.48% versus 89.18%, p=0.594).[8] Pneumothorax was reported in 3.38% of patients in the RAB group compared with 44.45% in the CTTB group (p<0.001).

5. A retrospective cohort study (n=162) compared the diagnostic yield (strict criteria) between the Ion™ and Monarch™ RAB platforms in patients with pulmonary lesions.[9] Diagnostic yield was statistically significantly higher with the Ion™ platform compared with the Monarch™ platform (84.2% versus 71.0%, p=0.003). There were no statistically significant differences in complication rates between the two platforms.

6. A patient organisation submission from the Roy Castle Lung Cancer Foundation reported that:

    - lung cancer can have life-limiting symptoms with serious effects on patients' physical and emotional well-being, quality of life and ability to perform daily tasks

    - there is an unmet need among patients with small peripheral pulmonary lesions that are not suitable for biopsy using conventional techniques

    - patients with lung lesions who are placed on a 'watch and wait' list, which may be for as long as 3 years, experience anxiety and may undergo unnecessary invasive treatments for lung cancer

    - patients having RAB need a general anaesthetic rather than the sedation used for a standard bronchoscopy, but some patients prefer general anaesthesia

    - RAB offers patients hope of a definitive diagnosis and improved outcomes.

7. Lung cancer incidence and mortality are approximately three times higher among people living in the most deprived areas of Scotland compared with people living in the least deprived areas.[10] Ethnicity, sex, age and smoking status were each statistically significantly associated with people having late-stage (III or IV) lung cancer at diagnosis.[11]

8. Organisational issues relating to the introduction of RAB include a recognised learning curve for clinicians, a need for training on using the RAB platforms and the need for infrastructure to manage cleaning and monitoring of reusable RAB bronchoscopes.[12-17]

9. We performed an exploratory economic analysis comparing RAB with usual care, which suggested that RAB (Ion™ platform) is expected to be cost effective. The analysis assumes that a proportion of patients who would otherwise be on a 'watch and wait' list would be able to get an earlier biopsy-confirmed diagnosis with RAB, which would lead to earlier treatment and improved 5-year survival rates. The results of our analysis were consistent across sensitivity analyses including the time horizon and the assumed proportion of patients diagnosed with early-stage lung cancer in the RAB arm of the model. A lack of comparative clinical data means our analysis should be viewed as indicative.

SHTG Council considerations

1. The Council agreed that RAB offers a high diagnostic yield and low complication rates, making it an effective and safe diagnostic option for patients. The Council felt that RAB was likely to be especially beneficial for patients with hard-to-reach lesions that are not accessible using conventional biopsy techniques. Introducing RAB would offer extra diagnostic capacity in advance of the rollout of a national lung cancer screening programme to help improve the early diagnosis of lung cancer in Scotland.

2. A clinical expert advised the Council that published studies comparing RAB with conventional biopsy techniques were likely to include two different patient populations because people with small, peripheral nodules that did not have a bronchus sign would not be considered for biopsy using conventional techniques but would be suitable for biopsy using RAB.

3. The Council acknowledged that interpreting the evidence on RAB was difficult because of variations in the definitions of diagnostic yield used across the published studies. A clinical expert advised that efforts continue to be made at an international level to agree a strict definition of diagnostic yield which would help improve consistency in definitions and reporting across future studies.

4. Council members expressed strong objections to having the economic analysis data redacted because of the need for pricing confidentiality. Members felt that this made it impossible to judge the appropriateness of the analysis and its conclusions. The Council agreed to limit the conclusion of the economic analysis to exploratory or indicative only.

5. A clinical expert and patient group representative explained to the Council that people with small (<20 mm) lung lesions were often put on a 'watch and wait' list. Patients on these lists received a CT scan after 3 months, 1 year, 2 years and would be discharged from the list after 3 years if their pulmonary nodule remained stable. If the nodule was found to be growing during this time, the patient would begin treatment with surgery or radiotherapy without a confirmed diagnosis. This causes some patients and their families a great deal of anxiety, distress and confusion.

6. The Council recognised the importance of RAB to patients who may not be able to have a timely biopsy using conventional techniques. This issue was highlighted by a presentation to Council by the Roy Castle Lung Cancer Foundation.

7. The Council observed that Scotland does not currently have a lung cancer screening programme or RAB, both of which are available in England. They acknowledged that this

leads to inequities in access to healthcare for people with a high risk of lung cancer living in different parts of the United Kingdom (UK).

8. The Council noted that a national lung cancer screening programme for Scotland is planned to begin in late 2027. The introduction of this programme is expected to generate an increase in the number of patients requiring diagnostic biopsies for small nodules suspected of being early-stage lung cancer. The Council recognised that, without RAB in place ahead of the programme's launch, services may be unable to manage the resulting demand, leading to significant delays for patients awaiting biopsy.

9. The Council acknowledged that the Ion™ RAB device is the only platform currently available for purchase in Scotland. The Council also noted that most of the published evidence on RAB related to the Ion™ platform and that the findings of studies on the Ion™ platform may not generalise to the Monarch™ or Galaxy™ platforms.

10. The Council discussed how many RAB devices would be needed across NHSScotland. It was agreed that this was not the responsibility of the Council, but that RAB devices would not be needed in every hospital. The Council flagged that a minimum caseload is likely to be required to maintain an acceptable level of expertise in using RAB.

11. The Council highlighted the value of gathering and analysing data on the use of RAB in Scotland in a way that could be shared and compared with registry data from England or Europe.

Contents

Definitions

Abbreviations used in this document are listed in *Appendix 1*.

Bronchoscopy: a procedure used to examine the airways using a thin, flexible tube with a camera (a bronchoscope) that is passed through the mouth into the lungs.[18]

Bronchus (plural bronchi): one of the major airways branching off from the trachea (windpipe) to deliver air into each lung.[19]

Bronchus sign: the presence of a bronchus leading directly to a peripheral lung lesion that is observed on a CT scan of the chest.[20]

CT-to-body divergence: the difference between where a lung lesion appears on a CT scan before the RAB procedure and where it is located during the bronchoscopy, caused by natural changes in lung position, movement, or anatomy.[16]

Diagnostic yield: the likelihood that a test or procedure will provide enough information to establish a diagnosis.[21] The definitions used in the published literature vary across studies and are described alongside the individual studies in this document.

Electromagnetic navigation bronchoscopy (ENB): a bronchoscopy technique that uses low-frequency electromagnetic fields to track the bronchoscope's position in real time, helping guide it through the airways to reach peripheral lung nodules.[4]

Lung lesion: any area of abnormal tissue in the lung, including nodules, tumours, infections or scars.[22]

Lung nodule: a small (normally <30 mm in diameter) abnormal growth in the lung. Most lung nodules (90–95%) are benign.[22, 23]

Radial endobronchial ultrasound (EBUS): a small, flexible ultrasound probe that can be passed down through a bronchoscope to provide images of the airways and surrounding tissue in the lung.[18]

Tool-in-lesion: a diagnostic criterion where the tool (such as a biopsy needle) is confirmed to be located within the lesion to be biopsied.[24]

Virtual bronchoscopic navigation (VBN): a bronchoscopy procedure that uses specialist computer software to create a virtual three-dimensional map of the airways in the lungs, helping to guide insertion of a bronchoscope to a target lesion.[18]

Introduction

Lung cancer can develop in the trachea, bronchi (main airways) or lung tissue.[25] It is the most common cancer in Scotland, with poor 5-year survival rates because people are often diagnosed with late-stage or incurable disease (63.9% present with stage III or IV cancer).[10, 26, 27] Earlier diagnosis of lung cancer significantly improves patient prognosis, with 5-year survival rates increasing from 5% among people with stage IV lung cancer to almost 65% for stage I.[25]

In 2022, the UK national screening committee recommended rolling out lung cancer screening across the four nations, targeting adults aged 55 to 74 (particularly those with a history of smoking) through risk assessment and CT imaging.[11, 28] The introduction of lung cancer screening programmes using low-dose CT imaging is expected to increase detection of small, early-stage pulmonary lesions requiring diagnostic biopsy.[12]

In England, by 2025, 31% of the eligible population had been assessed and offered screening, resulting in 75% of detected lung cancers being stage I or II.[28] In contrast, in Scotland, which currently has no lung cancer screening programme, only 28.4% of detected lung cancers were stage I or II.

Several techniques are available for diagnosing suspected lung cancer. In Scotland, current options include:

- routine CT surveillance every 3–6 months (also known as 'watch and wait')
- CTTB
- ENB
- surgical excision of lung tissue containing suspicious lesions (Dr A Marshall, Consultant Respiratory Medicine and Interventional Pulmonology, NHS Lothian. Personal communication, 27 June 2025).

The choice of diagnostic technique depends on lesion size and location, local expertise, patient risk factors and equipment availability.[9] An advantage of RAB is its ability to access and biopsy small (<20 mm) peripheral pulmonary nodules that conventional techniques cannot reliably sample.[12] RAB also enables diagnosis and staging of malignant nodules in a single procedure, which may help to reduce the time to treatment, consequently improving long-term patient outcomes.[9]

Diagnostic yield in bronchoscopy

Diagnostic yield is generically defined as the likelihood that a test or procedure will provide enough information to establish a diagnosis (see the definitions section).[21] This is calculated as the proportion of procedures that provide a diagnostic result. The published literature on RAB reports diagnostic yield based on strict or intermediate criteria.

Strict diagnostic yield is calculated as the number of malignant diagnoses plus the number of specific benign diagnoses, divided by the total number of procedures.[29] Non-specific benign findings are considered non-diagnostic regardless of any results obtained during follow-up. This allows researchers to calculate diagnostic yield at the time of the procedure without waiting for a follow-up period.

Intermediate diagnostic yield is calculated as the number of malignant diagnoses plus specific benign and non-specific benign diagnoses that are radiographically stable or resolved over 12–24 months of follow-up, divided by the total number of procedures.[29] This definition has the advantage of aligning with common clinical practice by including radiographic follow-up results for benign diagnoses, but delays calculation of diagnostic yield.

Research question

What is the clinical effectiveness, cost effectiveness and safety of RAB for diagnosing pulmonary lesions suspected of being lung cancer?

Literature search

A systematic search of secondary literature was carried out between 25 and 27 August 2025 to identify systematic reviews, health technology assessments and other evidence-based reports. The Medline, Embase and Cochrane Library databases were searched for systematic reviews and meta-analyses.

Primary literature was systematically searched between 25 and 27 August 2025 using the Medline, Embase and Cochrane Library databases. An RAB manufacturer (Intuitive Surgical) provided additional primary study references for inclusion in our evidence review. To ensure we identified all the relevant primary studies published after the literature search in the most recent systematic review (after November 2024), we repeated our search of the primary literature on 25 November 2025.

All search results were limited to English language publications. No date limits were applied.

Key websites were searched for guidelines, policy documents, clinical summaries, economic studies and ongoing trials.

Concepts used in all searches included lung cancer, lung neoplasms, robotic surgical procedures and robotic-assisted bronchoscopy. A full list of resources searched and terms used is available on request.

Health technology description

RAB is a diagnostic procedure used to examine the lungs after a suspicious lesion or nodule has been detected on a CT scan. A clinician inserts a flexible tube called a bronchoscope through the patient's mouth and uses a robotic arm and remote controller to guide the bronchoscope through the airways and to the target lesion in the lungs.[30] A camera on the end of the bronchoscope allows the clinician to view progress towards the target lesion on a display screen.[16] A biopsy of the lesion is obtained using tools passed through the bronchoscope's working channel.

There are currently three RAB platforms available on the global market (*Table 1*): the Ion™ Endoluminal RB Platform (Intuitive Surgical), the Monarch™ Platform (Auris Health) and the Galaxy™ System (Noah Health).[12] Only the Ion™ platform has regulatory approval for marketing and use in the UK. All three RAB platforms use a similar two-stage process.

- Stage 1: the planning stage, where specialist software uses data from thin-slice CT scans of the patient's lungs to plan a pathway from the central airway to the suspicious lesion.
- Stage 2: the guidance and biopsy phase, where the bronchoscope is navigated through the patient's airways to the target lesion using the pathway mapped out during the planning stage. On reaching the target lesion, biopsy samples can be taken.

The differences between the three RAB platforms are described in *Table 1*. The Ion™ platform uses proprietary shape-sensing technology to help navigate the bronchoscope through the airways; a fibre running along the length of the bronchoscope provides real-time shape and location information.[31] The Monarch™ and Galaxy™ platforms both rely on electromagnetic navigation using sensors attached to the patient's chest.[16]

The Ion™ platform uses a bronchoscope with a smaller diameter than the other two devices, meaning it can access lesions near smaller airways.[16] The camera in the Ion™ platform bronchoscope must be removed before passing biopsy tools through the working channel. This means the clinician cannot visualise the lung tissue during the biopsy. Both the Monarch™ and the Galaxy™ platforms use bronchoscopes with a built-in camera that allows visualisation throughout the procedure, including tissue biopsy.[16] The Ion™ platform uses a trackball and scroll wheel on a static platform rather than a handheld gaming controller to manoeuvre the bronchoscope. The Monarch™ platform is unique in its ability to independently move the bronchoscope sheath and inner scope.[31]

Table 1: Key characteristics of three RAB platforms[12, 16]

System feature	Ion™ Endoluminal RB Platform (Intuitive Surgical)	Monarch™ Platform (Auris Health)	Galaxy™ System (Noah Medical)
Navigation	Shape-sensing technology	Electromagnetic navigation	Electromagnetic navigation and digital tomosynthesis
Bronchoscope specifications	Catheter with removable camera	Sheath and bronchoscope with built-in camera	Bronchoscope with built-in camera
Vision during biopsy	No	Yes	Yes
Reusable scope	Yes, disposable after five uses	Yes, disposable after two uses	No
Controller	Trackball and scroll wheel on a platform	Gaming controller	Gaming controller
Catheter range of movement	180°	180° (sheath 130°)	180°
Catheter outer diameter	3.5 mm	outer sheath 6.0 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	Yes	No	Yes
Augmented fluoroscopy	No	No	Yes
Tool-in-lesion confirmation	Yes	No	Yes
Tactile feedback	No	No	No
Sensitive to metals	No	Yes	Yes
Regulatory approval	Food and Drug Administration (FDA) approved* Conformité Européenne (CE) marked	FDA approved	FDA approved

**FDA approval only requires RAB devices to have similar safety and effectiveness to existing technologies[4]*

Epidemiology

Over 85% of lung cancers are caused by smoking tobacco products, such as cigarettes and cigars.[32] Other risk factors for developing lung cancer include passive smoking, radon gas in the environment, occupational exposure (for example, asbestos or coal fumes) and pollution.

Lung cancer is the most common cancer in Scotland, with 5,391 people diagnosed with the condition in 2022, accounting for 15% of all cancer diagnoses that year.[26] This equates to an age standardised rate of 95.5 lung cancer diagnoses per 100,000 population. *Table 2* shows that, in Scotland in 2022, 20.1% of people diagnosed with lung cancer were diagnosed with stage III cancer and 43.8% of people diagnosed with lung cancer were diagnosed with stage IV cancer. *Table 2* also shows that the 5-year survival rate declines as the stage of lung cancer advances.

Table 2: Lung cancer stage at diagnosis and survival rates in Scotland 2022[26, 33]

Stage	n people diagnosed	% diagnoses	5-year survival
Stage I	1,132	21.0%	65%
Stage II	398	7.4%	40%
Stage III	1,083	20.1%	15%
Stage IV	2,359	43.8%	5%
Stage unknown	416	7.7%	–

Between 2012 and 2022 lung cancer mortality fell by 20.5%, most likely as a result of the declining prevalence of tobacco smoking.[10] Despite falling mortality, lung cancer remains the most common cause of cancer-related deaths, with 3,925 deaths from lung cancer in 2022 (24% of all cancer-related deaths that year). This high mortality reflects the high incidence of lung cancer and the relatively poor overall survival rate (43.5% at 1 year, 18.2% at 5 years).[10, 27] Estimated age-standardised 5-year mortality rates for lung cancer were 73.4 deaths per 100,000 people in 2022.[10]

Public Health Scotland (PHS) estimates that the number of people in Scotland who are living with lung cancer will increase by 59% by 2044.[34] The largest increase is expected in women and people aged 65 to 84 years.

Inequalities

In 2022, lung cancer incidence in Scotland was 3.2 times higher among people living in the most deprived areas compared with people living in the least deprived areas (168.5 versus 53.3 people diagnosed per 100,000 population).[10, 35] Similarly, mortality rates from lung cancer were 3.8 times higher for people living in the most deprived areas compared with the least deprived areas (126.7 versus 33.5 deaths per 100,000 population). These statistics likely reflect the higher prevalence of

tobacco smoking among people living in the most deprived areas (25%) compared with the least deprived areas (7%) in Scotland.[35]

A large cohort study (84,253 adults with lung cancer, of which 57,249 had their ethnicity recorded) reported differences in lung cancer epidemiology between ethnic groups.[11] The study cohort was derived from a database of over 35 million people who were registered with a general practitioner (GP) in England. Patients selected the most appropriate ethnic group when enrolling at their GP practice. The options were white, Indian, Pakistani, Bangladeshi, Chinese, other Asian, Caribbean, black African or other. These categories may not have accurately reflected participants' heritage.

Most people in the cohort identified as white (64.8% of the participants with lung cancer). The proportion of men with lung cancer was higher among patients with a Pakistani (75.4%), Bangladeshi (78.3%), Caribbean (71.6%), Indian (66.4%) or other Asian (63.6%) background compared with people with a white background (55%). The incidence of lung cancer among women was highest among those from a white (96.9 per 100,000 person years) or Chinese background (75.0 per 100,000 person years). The lowest incidence of lung cancer was in women with an Indian (27.7 per 100,000 person years), Pakistani (26.4 per 100,000 person years) or black African (23.0 per 100,000 person years) background.

Ethnicity, sex, age and smoking status were each statistically significantly associated with having a more advanced stage of lung cancer at diagnosis.[11] A higher proportion of people from Chinese, other Asian, Caribbean or black African backgrounds were diagnosed with stage IV lung cancer (range 43.8% to 48.6%) compared with other ethnic groups (range 34.0% to 38.0%). Men had a higher relative risk (RR) of being diagnosed with advanced lung cancer compared with women (RR for stage IV cancer 1.39, 95% CI 1.32 to 1.46). People aged 45 to 54 had a higher risk of being diagnosed with stage III or IV lung cancer compared with people aged over 75 years (RR 1.41, 95% CI 1.24 to 1.61 and RR 1.44, 95% CI 1.24 to 1.67, for stage III and IV respectively). Former and current smokers were more likely to be diagnosed at an advanced stage of lung cancer compared with never smokers (RR between 1.33 [95% CI 1.21 to 1.47] and 2.54 [95% CI 2.11 to 3.06]). No statistically significant association was found between socioeconomic deprivation and stage of lung cancer at diagnosis.

People in England who have a high risk of developing lung cancer have access to a national lung cancer screening programme and, in some areas, RAB is used to biopsy nodules detected by the screening programme. Neither lung cancer screening nor RAB are currently available in Scotland, leading to inequities in access to healthcare for people with a high risk of lung cancer living in different parts of the UK.

Clinical effectiveness and safety

The systematic reviews and meta-analyses combined results from studies assessing different RAB platforms (Ion™, Monarch™ and Galaxy™), making interpretation of the results more difficult. The systematic reviews and meta-analyses did not adequately report patient characteristics or the appraisal of primary study quality. Many of the primary studies recruited small numbers of highly selected patients and few studies directly compared RAB with other diagnostic modalities.

Most published studies assessed the Ion™ platform. There is only one study on the Galaxy™ RAB system, which is the newest platform on the market.

Secondary literature

A systematic review with meta-analysis (Li et al, 2025) evaluated the effectiveness of RAB for diagnosing people with pulmonary nodules and a suspicion of lung cancer.[2] Cohort studies published in English were eligible for inclusion. The diagnostic outcome definitions used by Li et al are described in *Table 3*.

Table 3: Outcome definitions used in a systematic review with meta-analysis by Li et al (2025)[2]

Outcome	Definition
Diagnostic yield at time of procedure (strict criteria)	The number of true positive diagnoses of malignant tumours plus the number of specific benign diagnoses, divided by the total number of RAB procedures
Diagnostic yield including follow-up (intermediate criteria)	The number of true positive diagnoses of malignant tumours plus the number of specific benign diagnoses plus the number of non-specific benign diagnoses confirmed as true negatives using histopathology, divided by the total number of RAB procedures
Sensitivity for malignancy	The ratio of the number of true malignancy diagnoses using RAB to the number of cases where a final malignant diagnosis was confirmed by biopsy or imaging

Twenty-seven cohort studies were included in the systematic review (n=2,315 patients with 2,463 nodules). Eleven cohort studies were prospective and 16 were retrospective. Generally, sample sizes were small, ranging from 15 to 264 patients (median 60, mean 85). Twelve studies had fewer than 50 participants and 17 had fewer than 100 participants.

No patient characteristics, such as age, sex or smoking status were provided. Seventeen studies assessed the Ion™ platform, nine studies assessed the Monarch™ platform and one study assessed the Galaxy™ platform. Mean or median nodule size ranged from 12 mm to 26 mm. Successful

navigation to the target nodule was achieved for 87.6% to 100% of patients in each study. Mean or median procedure time ranged from 36.4 minutes to 93 minutes.

Li et al assessed the quality of the primary studies using the Quality Assessment of Diagnostic Accuracy Studies version 2 (QUADAS-2) tool, but there is no description of the appraisal results or study quality in their review.

Results from the meta-analysis are presented in *Table 4*. Diagnostic yield for RAB was statistically significantly higher when intermediate criteria were used compared with strict criteria (p=0.004). After adjusting for publication bias, the diagnostic yield with strict criteria was reduced to 69.6% (95% CI 61.8% to 76.8%). Diagnostic yield was statistically significantly higher when the prevalence of malignancy in the patient population was ≥60% (p=0.02).

Sensitivity for malignancy varied significantly between RAB platforms (p=0.008), with an overall pooled estimate of 85.4% (*Table 4*). Sensitivity for malignancy across all platforms was statistically significantly higher for small nodules (<20 mm) compared with larger nodules (≥20 mm, p=0.005).

Safety outcomes are difficult to interpret because the results reported in the text of the review do not match the data presented in the associated forest plots. The safety results reported in *Table 4* are based on the main text and abstract.

Table 4: Results from a meta-analysis by Li et al (2025)[2]

Outcome	n studies (n patients)	Pooled result (95% CI)	I^2
Diagnostic yield (all platforms)			
Strict criteria	17 (1,364)	77.8% (71.8% to 83.2%)	83%
Intermediate criteria	17 (1,615)	86.6% (83.7% to 89.2%)	53%
Sensitivity for malignancy			
Overall (all platforms)	20 (990)	85.4% (83.0% to 87.7%)	48%
Monarch™ platform	7 (NR)	80.3% (75.6% to 84.6%)	46%
Ion™ platform	12 (NR)	87.6% (84.8% to 90.2%)	31%
Galaxy™ platform	1 (18)	92.9% (65.0% to 98.0%)	–
Lesions <20 mm (all platforms)	13 (NR)	86.4% (83.7% to 88.9%)	84%
Lesions ≥20 mm (all platforms)	5 (NR)	77.5% (70.5% to 83.9%)	37%
Safety outcomes (all platforms)			
Pooled complication rate	26 (2,296)	3.0% (2.3% to 3.9%)	42%
Pneumothorax	26 (2,296)	2.0% (1.3% to 2.7%)	22%
Pneumothorax requiring intervention	26 (2,296)	0.5% (0.2% to 1.0%)	19%
Bleeding*	26 (2,296)	0.1% (0% to 0.4%)	1%

** There were no bleeding events in 20 of the 26 studies reporting this outcome, which may bias the findings*
NR = not reported

Comparing diagnostic modalities

A systematic review that included a pairwise meta-analysis and NMA (Balasubramanian et al, 2024) compared the diagnostic yield and safety of CTTB, EBUS, VBN, ENB and RAB in patients with peripheral pulmonary lesions suspected of being lung cancer.[3] The systematic review methodology is clearly described, but information about the methods used in the NMA, other than it was a frequentist analysis, is not provided. They do not appear to have tested any of the assumptions underlying NMA.

Diagnostic yield was defined as the number of procedures providing a diagnostic result divided by the total number of procedures (intermediate criteria). A procedure was classed as providing a diagnostic result if it led to a definitive diagnosis of malignancy or a specific benign cause, or if a non-specific result was later confirmed during follow-up or by a second diagnostic procedure.

The review included 363 studies (n=75,842 patients with 79,519 nodules). Eighteen studies were randomised controlled trials (RCTs), 92 were prospective observational studies and 253 were retrospective observational studies. Thirty-seven studies in total (n=4,285) had a comparator group and were included in the meta-analysis and NMA. Twenty-four studies (n=2,471) included in the systematic review related to RAB, but only three studies (n=242) had a comparator group and could be included in the pairwise meta-analysis and NMA. No patient characteristics, such as age, sex or smoking status were provided. It is unclear which RAB platform was used in the primary studies.

The quality of single-arm primary studies was assessed using the QUADAS-2 tool. Comparative studies were assessed using the QUADAS-C tool. Ten out of 37 comparative studies were found to have a high risk of bias. Some had a high risk of bias because they used a broad definition of diagnostic yield or did not report the diagnostic yield criteria clearly. All other comparative studies were found to have a low risk of bias. Heterogeneity was high in the pairwise meta-analysis and NMA. The GRADE (grading of recommendations assessment, development and evaluation) approach was used to present the certainty of the evidence from the NMA.

Publication bias was reported for studies of RAB, EBUS and ENB. Meta-regression analysis suggested that the year of publication was associated with increasing diagnostic yield estimates in RAB studies over time. Balasubramanian et al speculated this could be a result of increased clinician familiarity and use of RAB in clinical practice.

In the pairwise meta-analysis, there were no statistically significant differences in diagnostic yield between CTTB and RAB (RR 1.01, 95% CI 0.92 to 1.11, p=0.86, one study, n=113) or between ENB and RAB (RR 0.89, 95% CI 0.23 to 3.47, p=0.48, I^2=49%, two studies, n=176).

Results from the NMA comparing each diagnostic modality with RAB are presented in *Table 5*. Thirty-seven comparative studies (n=4,285) contributed to the NMA, but only three studies with a total of 242 participants contributed data for comparisons with RAB. None of the diagnostic modalities assessed showed statistically significantly superior or inferior diagnostic yield compared with RAB. Evidence certainty was moderate, low or very low for all comparisons involving RAB.

Table 5: Diagnostic yield from an NMA comparing different diagnostic modalities with RAB[3]

Diagnostic modality	RR (95% CI)	GRADE
CTTB versus RAB	1.15 (0.94 to 1.40)	Moderate
EBUS versus RAB	0.97 (0.79 to 1.19)	Low
VBN versus RAB	1.05 (0.84 to 1.30)	Low
ENB versus RAB	1.03 (0.85 to 1.24)	Very low

Single-arm studies and comparative studies were included in the meta-analysis on safety outcomes. CTTB had the highest incidence of pneumothorax (16.8%, 95% CI 16.4% to 17.2%, 70 studies) and pneumothorax requiring a chest tube (1.6%, 95% CI 1.4% to 1.7%, 47 studies). Clinically significant bleeding events occurred most frequently with CTTB (5.2%, 95% CI 5.02% to 5.5%, 53 studies). In comparison, RAB had a pneumothorax incidence of 2.2% (95% CI 2.1% to 2.9%, 15 studies), pneumothorax requiring a chest tube incidence of 0.9% (95% CI 0.64% to 1.48%, 12 studies) and clinically significant bleeding incidence of 0.3% (95% CI 0.18% to 0.72%, seven studies).

Primary studies

Diagnostic yield from RAB

Four primary studies published in 2025 (after the literature search in the most recent systematic review) reported the diagnostic yield for RAB in patients with suspected lung cancer.[24, 36-38] Three studies evaluated the Ion™ platform and one study assessed the Monarch™ platform. The study characteristics and results from these studies are presented in *Table 6*.

Table 6: Summary of study characteristics and results from four primary studies measuring the diagnostic yield of RAB

	Chan et al[24]	Husta et al[38]	Brownlee et al[36]	Murgu et al[37]
Study characteristics				
RAB platform	Ion™	Ion™	Ion™	Monarch™
n patients	200	155	940	679
Mean age (SD) or median age (IQR), years	69 (62 to 74)	65.9 (12.8)	69.7 (12.1)	68.7 (10.1)
% female	70.5	56.1	51.3	55.6
% former / current smokers	49.5 / 27.5	47.7 / 19.4	53.7 / 9.14	56.1 / 21.4
% with history of cancer	39.5	–	30.4	13.0
Median nodule size, mm (IQR)	13.0 (10.9 to 16)	14.0 (11.0 to 17.0)	21.0 (13 to 33)	20.9 (range 7.0 to 63.0)
Study results				
Diagnostic yield, %	Strict criteria: 85 Intermediate criteria: 92.0 Nodules <15 mm: 86.1 Nodules <20 mm: 88.2	Strict criteria: 89 (95% CI 83.0 to 93.5)	86.1	Local pathology confirmed: 83.2 Strict criteria: 61.6 Nodules ≤20 mm: 66.7 Nodules >20 mm: 68.8
Sensitivity for malignancy, %	95.5	91.5	89.4	78.8
All adverse events, n (%)	6.0 (3.0)	11 (7.1)	45 (4.8)	26 (3.8)
Pneumothorax, n (%)	1 (0.5)	0	31 (3.3)	19 (2.8)
Bleeding events, n (%)	2 (1.0)	6 (3.9)	9 (1.0)	7 (1.0)

SD = standard deviation; IQR = inter-quartile range The prospective cohort study by Chan et al (2025) described results from patients with suspicious pulmonary nodules undergoing RAB using the Ion™ platform in the UK.[24] Two hundred patients had procedures carried out by one of three operators with no prior experience of RAB. Patients were followed up 7 and 30 days after their procedure and

at 6 months if they received a non-malignant biopsy result. The definitions of diagnostic outcomes used in this study are presented in *Table 7*.

Table 7: Outcome definitions used in the prospective cohort study by Chan et al[24]

Outcome	Definition
Diagnostic yield (strict criteria)	The number of malignant diagnoses plus the number of specific benign diagnoses, divided by the total number of RAB procedures
Diagnostic accuracy at 6-months follow-up (intermediate criteria)	The number of true positive biopsies plus the number of true negative biopsies, divided by the total number of RAB procedures
Sensitivity for malignancy	The number of true positive biopsies, divided by the number of true positive biopsies plus the number of false negative biopsies
True positive	Malignant biopsy results
True negative	Specific or non-specific benign biopsies confirmed as non-malignant after 6 months follow-up or a second diagnostic procedure
False negative	Non-malignant diagnoses (specific benign, non-specific benign or non-diagnostic) confirmed as malignant at 6 months follow-up or a second diagnostic procedure

Chan et al found that RAB was associated with a diagnostic yield of ≥85% based on strict diagnostic yield criteria and for nodules <20 mm in diameter. Diagnostic accuracy was reported as 92.0% and the prevalence of cancer in the study population was 77.8%. Median RAB procedure time was 44 minutes (interquartile range [IQR] 33 to 56 minutes), with procedure duration reducing as operators gained experience.

The procedure-related serious adverse event rate was 2.0% (four out of 200 patients). Serious adverse events were a pneumothorax that required a chest drain, a bronchial infection, sinus bradycardia and suspected embolism or cerebrovascular accident. Two patients (1%) had bleeding that required intervention, but these were not considered serious adverse events in the study.

Husta et al (2025) assessed the Ion™ RAB platform with integrated mobile cone-beam CT for diagnosing small pulmonary nodules in a prospective cohort study.[38] Participants had a single solid or semisolid lung nodule that was ≤20 mm in diameter. All patients were followed up for 30 days and anyone with a non-malignant diagnosis was followed up for 12 months. Diagnostic yield and sensitivity for malignancy definitions were the same as those presented in *Table 7*.

A total of 155 consecutive patients were enrolled in the study. Procedures were performed by 14 experienced operators. The diagnostic yield based on strict criteria was 89.0%. No patients experienced a pneumothorax. The median procedure time was 45 minutes (IQR 35 to 56.5 minutes). The overall tool-in-lesion rate was 99.4%.

A large retrospective analysis by Brownlee et al (2025) reported the diagnostic yield from 1,121 biopsies (n=940) using the Ion™ RAB platform.[36] Diagnostic yield was calculated based on categorising findings as malignant, non-malignant, atypical cells suspicious of malignancy or insufficient sampling. A benign diagnosis was assigned if there were specific benign pathologic findings, a lesion had resolved on repeat imaging or additional sampling, or if a lesion was stable after 1 year. The patient population overlaps with a previous study by the same authors that was included in the meta-analysis by Li et al.

Brownlee et all reported an overall diagnostic yield of 86.1% for RAB. In multivariate regression analyses, larger lesion size was statistically significantly associated with higher diagnostic yields (OR 1.46, 95% CI 1.15 to 1.85 and OR 1.04, 95% CI 1.02 to 1.04, for every 1 cm and 1 mm increase respectively). Sensitivity and specificity for malignant diagnoses were 89.4% and 97.8%, respectively. The overall complication rate in this study was 4.8%. In 1.9% of patients a pneumothorax needed a chest tube inserted. Infections were reported in 0.21% (n=2) of patients.

A prospective cohort study by Murgu et al (2025) evaluated diagnostic yield and safety outcomes of RAB using the Monarch™ platform in patients with peripheral lung lesions.[37] The study was sponsored by the device manufacturer (Auris Health), which was involved in the study design, data analysis and reporting. An independent steering group adjudicated outcomes.

Murgu et al assessed diagnostic yield using two approaches. First, they considered the findings reported in local pathology results following the procedure. Secondly, an independent steering group applied strict diagnostic yield criteria, defined as the proportion of patients with either a confirmed malignant diagnosis or a specific benign diagnosis, divided by the total number of patients who underwent RAB.

Participants were selected based on the size of the lesion (8 mm to 50 mm) on CT scans, which had to have been within 28 days of the bronchoscopy procedure. Patients with indwelling medical devices that might interfere with electromagnetic navigation, such as cardiac pacemakers, were excluded. Participants were followed for up to 24 months after the RAB procedure.

The study recruited 679 patients. Diagnostic yield was estimated at 83.2% using local pathology confirmation and 61.6% using strict criteria adjudicated by the independent steering group. Cancer prevalence was 64.2% at 12-month follow-up. Multivariate regression analysis found that larger lesion size, a history of chronic obstructive pulmonary disease (COPD), presence of bronchus sign or a higher preprocedural probability of malignancy were associated with higher diagnostic yields.

RAB device- or procedure-related adverse events were reported by 26 patients. Pneumothorax requiring a chest drain was reported in 2.2% (n=15) of patients. Ninety-seven patients (14.3%) reported experiencing an adverse event within 7 days of their RAB procedure and 28 (4.1%) of these events were considered serious.

Comparing RAB with other techniques

Five primary studies published in 2025 (after the literature search in the most recent systematic review) compared RAB using the Ion™ platform with other diagnostic modalities in patients with pulmonary nodules.[4-8] Three studies compared RAB with ENB.[4-6] One study compared RAB with VBN and another compared RAB with CTTB.[7, 8] All five studies are likely to have substantial selection bias because patients selected for RAB are unlikely to be eligible for any conventional comparator techniques. Since diagnostic yield is dependent on patient selection, the results of these studies should be treated with caution.

The study characteristics and results from these five studies are presented in *Table 8*.

Table 8: Summary of study characteristics and results from five primary studies comparing RAB with other diagnostic modalities

	Paez et al[4]		Abdelghani et al[5]		Trimble et al[6]		Zhang et al[7]		Fernandez-Bussy[8]	
Study characteristics										
Comparison	RAB versus ENB		RAB versus ENB		RAB versus ENB		RAB versus VBN		RAB versus CTTB	
n patients	411		92		116		59		296	
Mean age (SD) or median age (IQR), years	69.0 (61.0 to 74.0)	67.0 (59.0 to 75.0)	68.0 (62 to 75)	69.0 (64 to 74)	66.5 (9.9)	66.7 (12.2)	59.6 (10.6)	59.0 (13.0)	71.0 (65 to 77)	72.0 (65 to 78)
% female	49.8	48.1	44.3	39.6	46.5	54.9	70.0	65.5	51.4	48.6
% former smokers	47.8	45.2	81.4	81.1	–	–	13.3	13.8	78.4	77.0
% current smokers	21.7	21.2			–	–	16.7	20.7	9.46	10.8
% with history of cancer	35.0	20.2	–	–	–	–	3.3	10.3	23.0	22.3
Median nodule size, mm (IQR)	18.0 (12.0 to 28.0)	20.0 (14.0 to 29.0)	12.0 (9 to 16)	16.5 (12 to 22)	22.0 (SD 1.6)	26.0 (SD 1.4)	19.0 (13.4 to 24.3)	21.7 (18.5 to 24.7)	20.0 (13.17 to 28.0)	21.25 (13.55 to 31.0)
Study results										
Diagnostic yield, % (strict criteria)	77.8	75.5	89.0	66.0	–	–	–	–	86.48	89.18
Diagnostic yield, % (intermediate criteria)	–	–	94.6	79.0	86.1	49.5	90.0	69.0	–	–

Diagnostic yield, % (by nodule size, mm)	–	–	84.0 (≤10) 92.7 (11–20) 100 (21–30)	50.0 (≤10) 64.0 (11–20) 69.0 (21–30)	85.2 (7–20) 100 (21–30) 75.0 (>30)	31.9 (7–20) 65.0 (21–30) 70.8 (>30)	84.2 (8–20) 100 (20–30)	41.7 (8–20) 88.2 (20–30)	–	–
All adverse events, n (%)	5.0 (2.5)	12.0 (5.8)	7.0 (6.3)	5.0 (5.2)	0	0	0	2.0 (6.9)	–	–
Pneumothorax, n (%)	4.0 (1.97)	6.0 (2.88)	2.0 (1.8)	2.0 (2.1)	0	0	0	2.0 (6.9)	5.0 (3.38)	66.0 (44.45)
Bleeding events, n (%)	–	–	2.0 (1.8)	0	0	0	0	0	–	–

Paez et al (2025) conducted a cluster randomised non-inferiority trial comparing RAB (Ion™ platform) with ENB with integrated digital tomosynthesis in patients with peripheral pulmonary lesions.[4] Randomisation was clustered at the operating room level, with each operating room randomly assigned to RAB or ENB at the start of each day. Allocation was concealed in sealed opaque envelopes that were opened by operating room staff each morning. A biostatistician, who was not involved in patient care, generated the randomisation sequence. People performing the bronchoscopy procedures, patients and procedure schedulers were blinded to intervention allocation until the day of the procedure.

Diagnostic yield was defined as the proportion of procedures in which lesional tissue was acquired, where lesional tissue was defined as the presence of pathological findings that explained the pulmonary lesion and were sufficient to inform patient care. All biopsy specimens were interpreted by lung pathologists who were blinded to group assignment.

A total of 411 patients were included in the trial (203 in the RAB group and 208 in the ENB group). Diagnostic yield was higher in the RAB group compared with the ENB group, but that the difference was not statistically significant (OR 1.23, 95% CI 0.73 to 2.07). RAB had a statistically significantly higher diagnostic yield for smaller nodules compared with ENB (15 mm to 30 mm, OR 2.93, 95% CI 1.34 to 6.39). Median procedure time was shorter for ENB (32 minutes) than for RAB (37 minutes), but the clinical relevance of the difference was unclear. Seventeen complications were reported during the trial, five in the RAB group (2.5%) and 12 in the ENB group (5.8%). The difference in complication rates between groups was not statistically significant (OR 0.39, 95% CI 0.12 to 1.25).

In a retrospective cohort study, Abdelghani et al (2025) compared RAB with ENB in patients with pulmonary nodules when both procedures were guided by cone-beam CT.[5] Consecutive patients (n=185) were assigned to groups based on the scheduled date of their bronchoscopy. Between July 2020 and May 2022, all patients were assigned to ENB and between June 2022 and May 2023, all patients underwent RAB (Ion™ platform).

Diagnostic yield was assessed using two definitions. Firstly, as the presence of malignant or benign histological findings leading to a specific diagnosis at the time of bronchoscopy (strict criteria). Secondly, 12-month follow-up data were used to confirm non-specific benign findings based on a repeat biopsy or imaging (intermediate criteria). Diagnostic accuracy was calculated as the sum of true positive and true negative results divided by the total number of biopsies at the final follow-up.

A total of 92 patients (97 pulmonary nodules) underwent ENB and 93 patients (111 pulmonary nodules) underwent RAB. Median nodule size was statistically significantly smaller in the RAB group (12 mm, IQR 9 mm to 16 mm) compared with the ENB group (16.5 mm, IQR 12 mm to 22 mm, $p<0.001$). More patients in the RAB group (31.5%) underwent biopsy of multiple nodules in one procedure compared with the ENB group (10.3%). Prevalence of malignancy was 64.95% in the ENB group and 66.67% in the RAB group.

Abdelghani et al found that diagnostic yield at the time of bronchoscopy (p<0.001) and after 12-month follow-up (p=0.001) was statistically significantly greater in the RAB group compared with the ENB group. Diagnostic yield was higher for both diagnostic modalities after the addition of 12-month follow-up data.

For lesions ≤10 mm and between 11 mm and 20 mm, the diagnostic yield for RAB was statistically significantly higher than the yield for ENB (50% for ENB versus 84% for RAB, p=0.01 and 64% for ENB versus 92.7% for RAB, p<0.001, respectively). For lesions between 21 mm and 30 mm, there was no statistically significant difference in diagnostic yield between the two modalities (69.23% for ENB versus 100% for RAB, p=0.24).

The overall complication rate was similar across study groups. The most common complication was pneumothorax. Other complications included bleeding (n=2), respiratory failure (n=2) and haemodynamic instability (n=4).

Another retrospective cohort study (Trimble et al, 2024) compared RAB with ENB for biopsy of pulmonary nodules in a thoracic surgical practice.[6] Patients referred for a biopsy between January 2015 and February 2021 received ENB. Patients referred between March 2021 and June 2022 underwent RAB. All procedures were performed by a single surgeon.

Intermediate criteria diagnostic yield was defined as pathologic confirmation of either malignancy or a benign diagnosis. Biopsies with non-malignant findings were defined as true negatives if a subsequent biopsy or imaging modality confirmed the diagnosis during 2 years of follow-up. Biopsies that did not provide a definitive diagnosis were classed as non-diagnostic.

The study included 116 patients with 134 nodules (91 nodules in the ENB group and 43 nodules in the RAB group). Diagnostic yield was statistically significantly lower with ENB compared with RAB (p<0.0001). The greatest difference in diagnostic yield was observed for the smallest nodules (7–20 mm); 85.2% for RAB compared with 31.9% for ENB (p<0.0001). No complications were reported in either group of patients in this study.

A retrospective cohort study by Zhang et al (2025) explored the diagnostic efficacy and safety of RAB (Ion™ platform) compared with VBN in patients with peripheral pulmonary nodules.[7] Diagnostic yield was defined as the ratio of nodules with a diagnosis to the total number of nodules biopsied with each technique. Non-specific benign biopsy results were classed as diagnostic if there was subsequent confirmation from a second procedure or evidence of nodule improvement or resolution during 2 years of follow-up.

Fifty-nine consecutive patients were enrolled in the study; 30 underwent RAB and 29 had VBN. The method of allocation to the treatment groups was not reported. Most participants in the study were female (70% in the RAB group and 65.5% in the VBN group).

Diagnostic yield was 90% for RAB and 69% for VBN (p=0.045). Diagnostic yield was statistically significantly greater with RAB compared with VBN for nodules measuring 8–20 mm in diameter (84.2% versus 41.7%, p=0.021) but not for nodules >20 mm (p=0.505). The most common complication reported was pneumothorax, which occurred in two patients (6.9%) in the VBN group and no patients in the RAB group. No bleeding complications were reported in this study.

Fernandez-Bussy et al (2025) compared RAB (Ion™ platform) with CTTB in patients undergoing biopsy for lung nodule diagnosis and staging.[8] The retrospective cohort study used propensity score matching to balance covariates between the two groups. The matching adjusted for age, sex, body mass index (BMI), smoking status, lung cancer history and family or personal non-lung cancer history. After matching, results from 148 patients allocated to RAB and 148 to CTTB were included in the analysis.

Diagnostic yield is not clearly defined by the authors, who state that biopsy results were classed as malignant or non-diagnostic based on the American Thoracic Society criteria. Their results found no statistically significant difference in the diagnostic yield for RAB compared with CTTB (p=0.594). In both groups, a proportion of non-diagnostic biopsy results were later confirmed as malignant (13.52% in the RAB group and 10.82% in the CTTB group).

Cancer staging was performed in a separate procedure for 59.46% of patients with a malignant diagnosis in the CTTB group, a median of 21.5 days after the diagnostic CTTB procedure. All patients in the RAB group who received a malignant diagnosis had cancer staging during the initial RAB procedure.

Compared with patients undergoing CTTB, patients who underwent an RAB procedure had statistically significantly longer median procedure times (70 minutes [95% CI 59 to 83] versus 26 minutes [95% CI 20 to 34], p<0.001), shorter lengths of hospital stay (3.29 hours [95%CI 2.96 to 3.87] versus 3.87 hours [95% CI 3.42 to 4.42], p<0.001) and lower rates of hospital admissions (5.41% versus 19.59%, p<0.001).

In the CTTB group, statistically significantly more patients developed a pneumothorax visible on imaging or required hospital admission, compared with the RAB group (p<0.001). In logistic regression analysis, RAB was associated with 93% lower odds of needing a chest tube for a pneumothorax after the procedure (OR 0.07, 95% CI 0.01 to 0.23) and 77% lower odds of needing admitted to hospital (OR 0.23, 95% CI 0.10 to 0.51) compared with CTTB.

Comparing diagnostic performance of the Monarch™ and Ion™ platforms

A retrospective cohort study by McNierney et al (2025) compared the diagnostic performance of the Monarch™ and Ion™ RAB platforms at a single high-volume hospital.[9] Consecutive adults (n=365) scheduled for biopsy of a single pulmonary nodule were enrolled in the study. Patients scheduled for biopsy between November 2021 and March 2023 were assigned to the Monarch™ platform. Patients

scheduled for biopsy between April 2023 and December 2023 were allocated to the Ion™ platform. Patients in the two groups were matched based on age, sex, nodule size, nodule location and presence of bronchus sign.

Diagnostic yield was defined as all patients with peripheral pulmonary nodules who received biopsy results that established a specific benign or malignant diagnosis sufficient to inform patient care, divided by the total number of patients who underwent RAB (strict criteria).

A total of 162 patients underwent RAB using the Monarch™ platform and 203 using the Ion™ platform. Median age was 70.0 years (IQR 64.0 to 76.0) in the Monarch™ group and 68.0 years (IQR 59.0 to 75.0) in the Ion™ group. The proportion of women was 56.8% in the Monarch™ group and 50.7% in the Ion™ group. Median nodule size was 20.0 mm (IQR 14.0 mm to 32.0 mm) in the Monarch™ group and 19.0 mm (IQR 13.0 mm to 31.0 mm) in the Ion™ group.

Diagnostic yield was statistically significantly greater in the Ion™ group compared with the Monarch™ group (84.2% versus 71.0%, p=0.003). Compared with the Monarch™ platform, the Ion™ platform had a statistically significantly shorter median procedure time (37 minutes [IQR 26 to 51] versus 70 minutes [IQR 51.25 to 87], p<0.001).

There were no statistically significant differences in complication rates between the Ion™ and Monarch™ platforms. Complications were reported for 4.9% of patients in the Monarch™ group and 2.0% of patients in the Ion™ group (p=0.199). Pneumothorax occurred in 4.3% of patients in the Monarch™ group and 1.0% of patients in the Ion™ group (p=0.089). All patients with a pneumothorax in the Ion™ group (n=2) needed a chest tube compared with four out of seven patients in the Monarch™ group. No patients in either group experienced significant bleeding.

Ongoing trials

Table 9 presents seven ongoing studies on RAB. All seven studies are evaluating the Ion™ platform.

Table 9: Ongoing studies evaluating the Ion™ RAB platform

Study ID	Intervention and comparator	Study design	Countries	Estimated completion date
NCT06308120	RAB versus ENB	RCT	Three sites in China	September 2026
NCT06962436	RAB versus ultrathin bronchoscopy with VBN	Randomised non-inferiority trial	Five sites in China	December 2026
NCT07057648	RAB	Patient registry	One site in Korea	May 2027
NCT06489678	RAB with con-beam CT	RCT	One site in Switzerland	July 2027
NCT06923774	RAB	European patient registry	Four sites in France, Switzerland and the UK	October 2029
NCT06004440	RAB	International patient registry	16 sites in the US	August 2030
NCT06613412	Remote RAB	Single arm proof of concept clinical trial	One site in China	Unclear

Patient and social aspects

No published evidence was found that described patients' experiences of RAB.

A patient organisation submission was provided by the Roy Castle Lung Cancer Foundation. Their submission is based on information gathered through the charity's helpline, online forum, emails and enquiries. The full submission can be found on our website. The key points from the submission include:

- Lung cancer can have life-limiting symptoms that seriously affect patients' physical and emotional well-being, quality of life and ability to perform daily tasks.
- There is an unmet need for access to diagnostic biopsy techniques for people with small or difficult to access lesions. Patients with these lesions currently experience anxiety from being placed on 'watch and wait' lists for up to 3 years and may undergo unnecessary invasive treatments.
- Patients having RAB need a general anaesthetic rather than sedation that is used for a standard bronchoscopy. Some patients have expressed a preference for general anaesthesia because of discomfort and distress experienced during a previous bronchoscopic biopsy.
- There are fewer restrictions on areas within the lungs that RAB can biopsy. This provides patients with hope that their treatment will be appropriate and their outcomes improved because a tissue biopsy is possible, leading to a definitive diagnosis that is not based solely on radiological imaging.

Organisational issues

RAB learning curve

Three studies measured the learning curve for RAB operators using the Ion™ platform based on changes in diagnostic yield and procedure duration.[13, 14, 17]

Guarize et al (2026) conducted a retrospective analysis of the first 129 consecutive patients (147 nodules) who underwent a lung nodule biopsy using the Ion™ platform at a high-volume hospital in Milan, Italy.[17] All RAB procedures were performed by a single interventional pulmonologist with substantial experience in other bronchoscopic techniques, including ENB.

Biopsy results were classed as diagnostic if histopathology confirmed malignancy or a specific benign pathology. Indeterminate samples and benign samples that were later confirmed as malignant during surgery were classed as false negatives. Acceptable and unacceptable thresholds for diagnostic yield were set at 73% and 60%, respectively. Patient characteristics were not provided.

The median diameter of pulmonary nodules sampled was 12.9 mm (range 3.8 mm to 38.0 mm), with 19% measuring less than 10 mm in diameter. The overall diagnostic yield was 87.8% across all procedures. In the first 60 procedures, the diagnostic yield ranged from 80% to 85%. After 60 procedures, the diagnostic yield rose to 90%. Diagnostic yield was consistently above 85% after around 40 procedures.

In a subset of procedures where a single pulmonary nodule was being biopsied, the median procedure time decreased from 60 minutes to 35 minutes after 40 procedures. In multivariable regression analyses, longer procedure time was statistically significantly associated with a lower likelihood of diagnostic success (OR 0.98, 95% CI 0.965 to 0.996, p=0.014).

The second learning curve analysis (Bott et al, 2025) was conducted at a high-volume tertiary cancer centre in the United States.[13] RAB procedures were conducted by nine thoracic surgeons or interventional pulmonologists. All nine operators had no previous experience with RAB. Patients were selected for RAB based on their fitness for general anaesthesia and lesion characteristics, such close to an airway.

Biopsy samples were classed as malignant, non-malignant or insufficient. Samples that showed atypical cells but could not be further classified were considered insufficient and were considered non-diagnostic. Non-malignant lesions were considered diagnostic if the diagnosis was confirmed by an alternative sampling method, if imaging showed partial or complete resolution of the lesion at follow-up, or the lesion was stable on follow-up imaging after at least 12 months. Acceptable and unacceptable diagnostic yield thresholds were set at 73% and 60%, respectively.

In total, 442 patients (551 nodules) underwent RAB. A median of 61 lesions (IQR 60 to 63) were sampled by each operator. Median patient age was 70 years (IQR 61 to 76). Most patients (70%) were current or former smokers and 21% had a history of lung cancer. Median lesion size was 19 mm (IQR 13.3 mm to 28.0 mm), with 10% of lesions measuring less than 10 mm in diameter.

Overall diagnostic yield was 72% across all 551 lesion biopsies, ranging from 58% to 83% among the nine operators. Five out of nine operators reached the prespecified competency threshold (diagnostic yield of 73%) after 25 procedures. One operator reached the threshold after 50 procedures. The remaining three operators did not achieve competency during the study period. The median total procedure time was 52 minutes (IQR 36 to 75). The median procedure time decreased from 62 minutes for the first ten procedures to 39 minutes for procedures 41 to 50.

The final study (Bruinen et al, 2016) calculated the learning curve for RAB combined with cone-beam CT for two bronchoscopists with more than 5 years' experience using cone-beam CT-guided ENB.[14] The definition of diagnostic yield used was unclear, with the authors stating that biopsy results were classified as malignant, specific benign, non-specific benign or non-diagnostic. No patient characteristics were provided. The acceptable diagnostic yield threshold was set at 81.9% and the unacceptable diagnostic yield threshold as 69.0%.

The authors assessed the learning curve using two different scenarios. In the first scenario, they assumed that the bronchoscopists had no prior proficiency and calculated the point at which each operator achieved a predefined level of proficiency, measured by diagnostic yield. In the second scenario, they assumed that both bronchoscopists were proficient from their first RAB procedure.

One bronchoscopist performed 68 RAB procedures and the other performed 63 procedures. In the first scenario, one bronchoscopist achieved proficiency after 43 procedures, with a diagnostic yield of 83.7%, and the other achieved proficiency after 42 procedures, with a diagnostic yield of 85.7%. In the second scenario, the performance of both bronchoscopists was considered adequate for all procedures, with diagnostic yields of 80.9% and 85.7%. The authors concluded that both bronchoscopists had high success rates from their first procedure and were proficient after 42 or 43 procedures.

Considerations when introducing RAB

The Ion™ and Monarch™ RAB platforms include reusable bronchoscopes.[12, 16] This has implications for determining the number of bronchoscopes needed to maintain continuous availability of RAB procedures, accounting for those temporarily unavailable during sterilisation. Services will need to consider how and where reusable bronchoscopes will be cleaned and sterilised after use and how they will determine when a reusable bronchoscope needs replacing. For some hospitals, this may mean setting up new high-level disinfection facilities and monitoring procedures.[15]

When introducing RAB services, staff will need training on how to use the platform. Specialist training may be available from the device manufacturers.

There are three cancer networks in Scotland:

- the West of Scotland Cancer Network (WOSCAN)
- the South East Scotland Cancer Network (SCAN)
- the North Cancer Alliance (NCA).

Implementation of a national RAB programme would require a national decision on the location of the RAB platforms to ensure equitable access for all patients.

Cost effectiveness

Published literature

No published studies were found that evaluated the cost effectiveness of RAB for diagnosing pulmonary lesions.

De novo cost-effectiveness analysis

Model

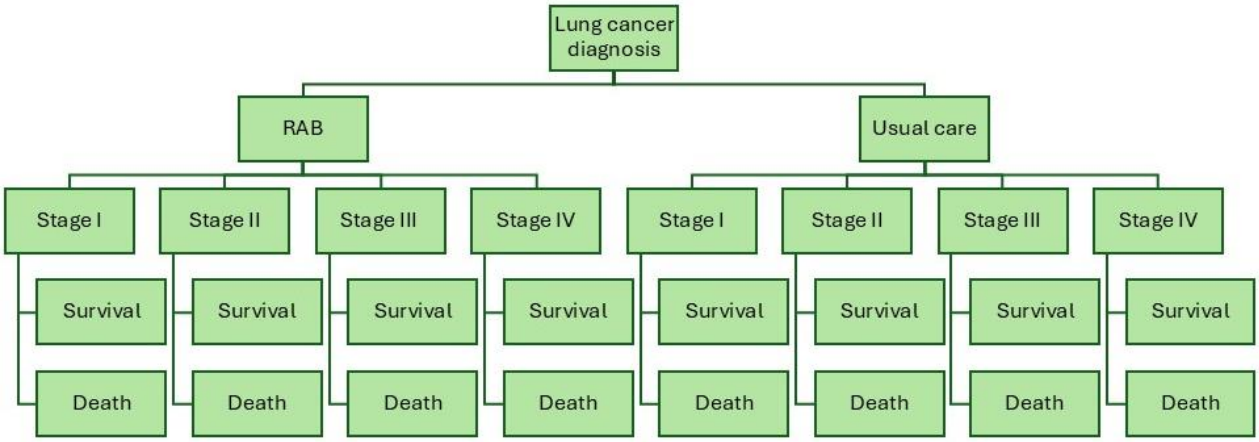
We conducted an economic analysis to explore the potential cost effectiveness of RAB for NHSScotland. A decision tree was used to model outcomes for patients needing a diagnostic biopsy for suspected lung cancer. Key modelling criteria are presented in *Table 10*.

Table 10: Key modelling criteria

Criterion	Value	Justification
Population	Number of patients diagnosed with lung cancer in Scotland in 1 year	The most relevant population estimate based on data available in Scotland
Intervention	Ion™ RAB platform	The only RAB platform currently approved for use in the UK
Comparator	Usual care – conventional bronchoscopy or regular CT scans for 'watch and wait' patients	The usual care pathway is complex, but was simplified because of a lack of available data
Analysis type	Cost-utility analysis	The reference standard for health technologies in the NHS
Time horizon	5 years	To use Scottish 5-year survival data and take into account average patient age when diagnosed
Perspective	NHS	The most relevant for NHS decision making
Model type	Decision tree	The best option for modelling outcomes based on the available data

Patients entered the decision tree model after a lung cancer diagnosis. In the model, patients in the usual care arm received conventional bronchoscopy or monitoring using a 'watch and wait' strategy with regular CT scans to monitor lung lesions. The model followed patients over a period of 5 years (time horizon) and recorded cancer-related deaths and survival. All costs were incurred on entering the model. The model's decision tree is presented in *Figure 1*.

Figure 1: Decision tree model for patients needing a diagnostic biopsy for suspected lung cancer



A list of the model input values we used is presented in *Table 11*. Some input values have been redacted to avoid disclosing confidential cost information for the Ion™ RAB platform (provided by Intuitive Surgical, November 2025).

Table 11: Decision tree model inputs

Model parameter	Value used	Data source
Utility values		
Stage I lung cancer	0.825	Ost DE, et al (2024)[39]
Stage II lung cancer	0.825	
Stage III lung cancer	0.772	
Stage IV lung cancer	0.573	
5-year survival rates		
Stage I lung cancer	65%	Cancer Research UK (2025)[33]
Stage II lung cancer	40%	
Stage III lung cancer	15%	
Stage IV lung cancer	5%	
Proportion of patients diagnosed with each stage of lung cancer (usual care arm)		
Stage I lung cancer	22.49%*	PHS (2023)[40]
Stage II lung cancer	8.05%*	
Stage III lung cancer	22.07%*	
Stage IV lung cancer	47.17%*	

Proportion of patients diagnosed with each stage of lung cancer (RAB arm)		
Stage I lung cancer	[redacted]	Assumption, based on likely reduction in 'watch and wait' list
Stage II lung cancer	[redacted]	
Stage III lung cancer	[redacted]	
Stage IV lung cancer	[redacted]	
Other patient-related inputs		
Proportion of patients having a bronchoscopy (usual care)	54%	Zhang Y, et al (2020)[41]
Proportion of patients having a bronchoscopy (RAB)	[redacted]	Assumption, based on expert advice
Proportion of patients having a repeat bronchoscopy (usual care)	[redacted]	
Proportion of patients having a repeat bronchoscopy (RAB)	[redacted]	
Proportion of patients on a 'watch and wait list' (usual care)	23%	Noonan K, et al (2015)[42]
Proportion of patients on a 'watch and wait' list (RAB)	[redacted]	Assumption, based on likely reduction in 'watch and wait' list
Cost inputs		
Cost of RAB machine (Ion™)	[redacted]	Intuitive Surgical (2025)
Annual service fee for RAB platform (Ion™)	[redacted]	
Instrument and accessories cost per RAB procedure (Ion™)	[redacted]	
Cost of a standard diagnostic bronchoscopy (usual care)	£1,313	National schedule of NHS costs 2024–2025, code DZ69A[43]
Cost of a CT scan	£142	National schedule of NHS costs 2024–2025, code RD24Z[43]

**Patients with an unknown lung cancer stage at diagnosis were distributed proportionately between the four stages*

The proportion of patients diagnosed with stage I–IV lung cancer in the usual care arm of the model was derived from PHS data.[40] A small proportion of patients in the PHS data had an unknown stage of lung cancer at diagnosis. These patients were proportionately distributed between cancer stages I to IV in our model. In the RAB arm of the model, cancer stage at diagnosis was assumed to include an increase of [redacted] for stage I and II and a decrease of [redacted] for stage III and IV lung cancer compared with patients in the usual care arm of the model. This assumption was validated by a Scottish clinical expert. If a lung cancer screening programme is introduced in Scotland, the predicted increase in the

number of patients diagnosed with stage I or II lung cancer is likely to exceed the estimates used in our model.

The 5-year survival rate for patients diagnosed with stage I–IV lung cancer in our model was based on data from Cancer Research UK.[33] The percentage of patients undergoing standard bronchoscopy or assigned to a 'watch and wait' strategy was not dependent on cancer stage at diagnosis in either arm of the model because these data were not available for Scotland.

The number of patients entering the decision tree model was set at 5,391 (the number of patients diagnosed with lung cancer in Scotland in 2022).[26] Based on advice from a Scottish clinical expert, the model assumed that three Ion™ RAB platforms would be needed in NHSScotland to provide equitable access to RAB for all eligible patients. An annual service fee for the RAB platforms was applied for 5 years in the model. The number of CT scans for patients assigned to a 'watch and wait' strategy in the model was assumed to be three over 2 years for each patient.

Results

The base case comparing RAB with usual care in patients diagnosed with lung cancer in Scotland resulted in an incremental cost-effectiveness ratio (ICER) of £10,176 per quality-adjusted life-year (QALY, *Table 12*), which indicates that RAB is likely to be cost effective. The key driver of the base-case results was the QALY gains in the RAB arm of the model from an assumed increase in 5-year patient survival based on the assumption that a greater proportion of patients would be diagnosed at an early stage of disease.

Table 12: Base case results (5-year time horizon)

Technology	Total costs (£)	Total QALYs	Incremental costs (£)	Incremental QALYs	ICER (£/QALY)
RAB	[redacted]	[redacted]	–	–	–
Usual care	[redacted]	[redacted]	[redacted]	[redacted]	£10,176

The conclusions of our economic analysis were robust across a range of sensitivity analyses. Sensitivity analyses included varying the proportion of patients diagnosed with stage I–II lung cancer in the RAB arm of the model, assuming that bronchoscopies were not repeated in the usual care arm of the model and varying the model time horizon.

Analysis limitations

The cost data for RAB in the model include only the Ion™ RAB platform, which is reasonable because it is the only one currently approved for use in the UK. Confidentiality requirements around the costs quoted by Intuitive Surgical for the Ion™ RAB platform limit the transparency of our analysis.

Our model and analysis were based on the number of patients diagnosed with lung cancer in 1 year. This approach does not account for patients who did not have a confirmed diagnosis because they had small peripheral lung lesions that are unsuitable for biopsy using conventional techniques (but that could be biopsied using RAB). Consequently, our model may underestimate the value of RAB.

Our economic analysis assumed that introducing RAB would result in a higher proportion of patients being diagnosed with lung cancer at an earlier stage, on the basis that more patients with small peripheral lung nodules would be suitable for a diagnostic biopsy using RAB. We were unable to find any published data to confirm this assumption.

Our model assumed that diagnosing patients with lung cancer at an earlier stage using RAB would translate into improved patient outcomes. In practice, treatment decisions depend on multiple factors, including patient preference, multidisciplinary team discussions and treatment capacity. Consequently, our analysis may have overestimated the clinical benefits of RAB if it does not translate into timely patient treatment and subsequent improvements in outcomes.

No cost data relating to training clinicians in the use of RAB were available. Training costs are likely to increase the overall costs associated with RAB in the short term.

Conclusion

The diagnostic yield from RAB is approximately 86% across meta-analyses and primary studies. This suggests that RAB offers a similar diagnostic yield to CTTB, the diagnostic technique with the highest reported yield for pulmonary nodules. It must be noted that the patient population likely to undergo RAB would generally not be eligible for CTTB because of the small size and location of the pulmonary nodules, which could introduce bias to comparisons of diagnostic yield.

There were no statistically significant differences in diagnostic yield when comparing RAB with ENB, VBN, EBUS or CTTB in an NMA, but the number of studies directly comparing RAB with other diagnostic modalities was limited, which reduces the certainty of this finding. More recent primary studies comparing RAB with ENB, VBN or CTTB generally reported no statistically significant differences in diagnostic yield. There is a potential risk of selection bias in studies comparing RAB with ENB, VBN, EBUS or CTTB, where patients are excluded from the conventional comparator groups because their nodules are too small or not in a location that conventional diagnostic techniques can reliably biopsy. This would result in an underestimation of the diagnostic yield of RAB.

Since most of the current published evidence is based on the Ion™ platform, the diagnostic yield reported in the literature may not generalise to other RAB platforms. The secondary literature did not provide patient characteristics for included studies and so it is possible that the diagnostic yield reported in the meta-analysis is not generalisable to the Scottish population. The primary studies

that did report patient characteristics produced similar estimates of diagnostic yield to the secondary literature, which increases our confidence in the estimates for RAB.

Diagnostic yield may be influenced by the definition used, the prevalence of cancer in the study population, lesion size and patient characteristics, such as smoking history. It is also likely that some patients were excluded from primary studies because they were not eligible for the diagnostic techniques being considered, which may have affected published diagnostic yield estimates. For example, patients would not be eligible for CTTB if they had a small peripheral lung nodule situated near major blood vessels.

Complication rates with RAB were generally low, with pneumothorax reported in approximately 2% of patients. This is substantially lower than the incidence of pneumothorax reported for CTTB.

A patient group submission described the impact of lung cancer on patients' lives and how there is a lack of diagnostic biopsy options for people with small peripheral pulmonary lesions. RAB may offer these patients a definitive diagnosis.

An exploratory economic analysis by SHTG indicated that RAB is potentially cost effective. These results should be considered indicative because of a lack of data to support the model's assumptions.

Identified research gaps

Additional studies are needed that:

- use a consistent definition of diagnostic yield
- report key patient characteristics
- directly compare RAB with other diagnostic modalities in meta-analyses
- present outcome data, including diagnostic yield and complication rates, for the Monarch™ and Galaxy™ RAB platforms
- compare diagnostic yield and complication rates across RAB platforms
- report on the cost effectiveness of RAB in routine clinical practice in a UK healthcare setting.

There is research interest in the possibility of combining diagnostic biopsy, cancer staging and surgical resection within a single RAB procedure, which would shorten the time from diagnosis to initiating treatment for patients with lung cancer.

Acknowledgements

Healthcare Improvement Scotland (HIS) development team

- Julie Calvert, Lead Health Services Researcher (quality assurance)
- Anna Donten, Health Economist (quality assurance)
- Jenny Harbour, Lead Author/Health Services Researcher
- Meryl Heggeland, Health Economist
- Paul Herbert, Health Information Scientist
- Joanna Kelly, Health Services Researcher (quality assurance)
- Mary Michael, Project Officer
- James Stewart, Programme Manager

SHTG Evidence Review Team

SHTG would like to thank the following individuals on the SHTG Evidence Review Team who provided comments on the draft review, which were considered by the HIS development team:

- Edward Clifton, Unit Head, SHTG
- Moira Cruickshank, Research Fellow, University of Aberdeen
- Kate Dion, Public Partner, Healthcare Improvement Scotland
- Claire Fernie, Public Partner, Healthcare Improvement Scotland
- Claudia Geue, Lecturer, University of Glasgow
- Moray Nairn, Programme Manager, SIGN
- Noelle O'Neill, Senior Public Health Scientist, NHS Highland

SHTG Council

SHTG would like to thank the following individuals on the SHTG Council for developing the recommendation for NHSScotland:

- Dr Julie Calvert, Lead Health Services Researcher, Healthcare Improvement Scotland
- Mr Edward Clifton, Unit Head, SHTG, Healthcare Improvement Scotland
- Ms Kate Dion, Public Partner, Healthcare Improvement Scotland
- Dr Karen Facey, Evidence-based Health Policy Consultant
- Ms Claire Fernie, Public Partner, Healthcare Improvement Scotland
- Dr Rodolfo Hernandez, Senior Research Fellow, Health Economics Research Unit, University of Aberdeen
- Ms Katie Hislop, Policy Lead, Healthcare Quality and Improvement Directorate, Scottish Government
- Mr Colin Marsland, Director of Finance, NHS Shetland

- Dr Matthew Saunders, Public Health Consultant, Public Health Scotland
- Dr Neil Smart, Council Chair, Consultant Anaesthetist, NHS Greater Glasgow and Clyde

SHTG would like to thank the following individuals who took part in the SHTG Council meeting to provide clinical and patient perspectives:

- Dr Adam Marshall, Consultant Respiratory Physician, Royal Infirmary of Edinburgh, NHS Lothian
- Ms Ann Doran, Helpline Support Nurse, Roy Castle Lung Cancer Foundation

Peer reviewers

SHTG would like to thank the following individuals who took part in the peer review and provided comments on the draft document and recommendation:

- Prof Ahsan Akram, Professor of Thoracic Oncology and Imaging, University of Edinburgh
- Dr Mohammed Asif, Consultant Thoracic Surgeon, Golden Jubilee National Hospital and Lung Cancer Lead Clinician for the West of Scotland Cancer Network
- Dr Haval Balata, Consultant Respiratory Physician, Manchester University NHS Foundation Trust
- Ms Ann Doran, Helpline Support Nurse, The Roy Castle Lung Cancer Foundation
- Ms Stephanie Fraser, Thoracic Surgeon, Guy's and St Tomas' NHS Foundation Trust
- Dr Adam Marshall, Consultant Respiratory Physician, Royal Infirmary of Edinburgh
- Mr Leighton Morris, Global Access and Economics Director for the UK and Ireland, Intuitive Surgical
- Dr Ricky Thakrar, Consultant Chest Physician, University College London Hospitals NHS Foundation Trust

Declarations of interest from all reviewers are published alongside the review on our website. All contributions from reviewers were considered by the SHTG Evidence Review Team and the SHTG Council. Reviewers had no role in authorship or editorial control and the views expressed are those of Healthcare Improvement Scotland and the SHTG Council.

Published 2026

Suggested citation: Harbour J, Heggeland M, Herbert P, Calvert J, Donten A, Kelly J, Michael M, Nicol T, Stewart J (2026). Robotic-assisted bronchoscopy (RAB) for diagnosing lung cancer. Glasgow/Edinburgh; NHS Healthcare Improvement Scotland. https://shtg.scot/our-advice/robotic-assisted-bronchoscopy-rab/.

References

1. Brock JM, Dittrich AS, Kontogianni K, Heussel CP, Klotz LV, Winter H, et al. First European experience of shape-sensing robotic-assisted bronchoscopy: learning curve analysis. Respiration. 2025;104(10):736-49.

2. Li X, Bai J, Zhou X, Wang T, Zhang Y, Hu Y. Diagnostic performance and safety for robotic-assisted bronchoscopy in pulmonary nodules: a systematic review and meta-analysis. Int J Surg. 2025;111(6):4020-32.

3. Balasubramanian P, Abia-Trujillo D, Barrios-Ruiz A, Garza-Salas A, Koratala A, Chandra NC, et al. Diagnostic yield and safety of diagnostic techniques for pulmonary lesions: systematic review, meta-analysis and network meta-analysis. Eur Resp Rev. 2024;33:240046.

4. Paez R, Lentz RJ, Duke JD, Siemann JK, Salmon C, Dahlberg GJ, et al. Robotic versus electromagnetic bronchoscopy for peripheral pulmonary lesions: a randomized trial (RELIANT). Am J Respir Crit Care Med. 2025;211(9):1644-51.

5. Abdelghani R, Espinoza D, Uribe JP, Becnel D, Herr R, Villalobos R, et al. Cone-beam computed tomography-guided shape-sensing robotic bronchoscopy vs. electromagnetic navigation bronchoscopy for pulmonary nodules. J Thorac Dis. 2024;16(9):5529-38.

6. Trimble EJ, Stewart K, Reinersman JM. Early comparison robotic bronchoscopy versus electromagnetic navigation bronchoscopy for biopsy of pulmonary nodules in a thoracic surgery practice. J Robotic Surg. 2024;18(1):149.

7. Zhang Q, Wen F, Wu X, Yang H, Li X, Luo P, et al. Shape sensing robotic assisted bronchoscopy versus virtual bronchoscopic navigation in the diagnosis of peripheral pulmonary nodules. Sci Rep. 2025;15(1):23950.

8. Fernandez-Bussy S, Funes-Ferrada R, Yu Lee-Mateus A, Vaca-Cartagena BF, Barrios-Ruiz A, Valdes-Camacho S, et al. Transforming lung cancer diagnosis: the role of robotic-assisted bronchoscopy in early detection and staging. Lung Cancer. 2025;206:108646.

9. McNierney D, Chen J, Zein JG, Vaszar L, Swanson K, Azadeh N, et al. Comparing Monarch versus Ion robotic-assisted bronchoscopy platforms: a propensity score-matched analysis. J Bronchology Interv Pulmonol. 2025;32(4):e01019.

10. Public Health Scotland. Cancer mortality annual update to 2022. 2025 [cited 2025 Oct 07]. Available from: https://publichealthscotland.scot/publications/cancer-mortality/cancer-mortality-in-scotland-annual-update-to-2022/.

11. Chen DTH, Hirst J, Coupland CAC, Liao W, Baldwin DR, Hippisley-Cox J. Ethnic disparities in lung cancer incidence and differences in diagnostic characteristics: a population-based cohort study in England. Lancet Reg Health Eur. 2025;48:101124.

12. Bhandari BS, Jain A, Sharma S, Rana G, Sabath BF. Robotic bronchoscopy: a comprehensive review. J Respir. 2024;4:128-39.

13. Bott MJ, Toumbacaris N, Tan KS, Husta BC, Medina BD, Adusumilli PS, et al. Characterizing a learning curve for robotic-assisted bronchoscopy: analysis of skills acquisition in a high-volume academic center. J Thorac Cardiovasc Surg. 2025;169(1):269-78.e6.

14. Bruinen ARC, Verhoeven RLJ, Hannink G, van der Heijden EHFM. Learning shape sensing robotic assisted bronchoscopy after mastering advanced image guided navigation bronchoscopy. Respiration. 2026 [online ahead of print].

15. Eperjesiova B, Peterson J, Sriram PS. Establishment of a robot-assisted bronchoscopy program at a veterans affairs hospital. Cureas. 2024;16(11):e74013.

16. Gomes Prado RM, Cicenia J, Almeida F. Robotic-assisted bronchoscopy: a comprehensive review of system functions and analysis of outcome data. Diagnostics. 2024;14(4):399.

17. Guarize J, Bertolaccini L, Bardoni C, Donghi SM, Spaggiari L. Characterizing the Learning Curve of ION Robotic Bronchoscopy: A CUSUM-Based Analysis of Diagnostic Yield. J Bronchology Interv Pulmonol. 2026;33(1):e1043.

18. NHS North Tees and Hartlepool NHS Foundation Trust. Bronchoscopy with virtual bronchoscopic navigation (VBN) and radial endobronchial ultrasound (EBUS). 2024 [cited 2025 Dec 02]. Available from: https://www.nth.nhs.uk/resources/bronchoscopy-with-virtual-bronchoscopic-navigation-vbn-and-radial-endobronchial-ultrasound-ebus/.

19. Encylopaedia Britannica. Bronchus. c2025 [cited 2025 Dec 02]. Available from: https://www.britannica.com/science/bronchus.

20. Radiopaedia.org. Positive bronchus sign. 2019 [cited 2025 Dec 02]. Available from: https://radiopaedia.org/articles/positive-bronchus-sign.

21. Segen's Medical Dictionary. Diagnostic yield. 2012 [cited 2026 Feb 13]. Available from: https://medical-dictionary.thefreedictionary.com/diagnostic+yield.

22. Penn Medicine. Lung nodules and lesions. c2025 [cited 2025 Dec 02]. Available from: https://www.pennmedicine.org/conditions/lung-nodules-lesions.

23. City of Hope. When to worry about lung nodules: what is a pulmonary nodule? 2021 [cited 2025 Dec 02]. Available from: https://www.cancercenter.com/community/blog/2021/05/when-to-worry-about-lung-nodules.

24. Chan LT, Lau KKW, Orton CM, Temov K, Tana A, Baboolal I, et al. Tool in lesion verification of shape-sensing robotic-assisted bronchoscopy with cone beam CT in sampling peripheral pulmonary nodules. Thorax. 2025 [online ahead of print].

25. Cancer Research UK. Lung cancer. 2022 [cited 2025 Dec 02]. Available from: https://www.cancerresearchuk.org/about-cancer/lung-cancer.

26. Public Health Scotland. Cancer incidence in Scotland to December 2022. 2024 [cited 2025 Oct 07]. Available from: https://publichealthscotland.scot/media/30606/2024-11-26_cancer-incidence-report.pdf.

27. Public Health Scotland. Cancer survival statistics: people diagnosed with cancer during 2015 to 2019. 2022 [cited 2025 Oct 07]. Available from: https://www.publichealthscotland.scot/publications/cancer-survival-statistics/cancer-survival-statistics-people-diagnosed-with-cancer-during-2015-to-2019/.

28. Healthandcare.scot. Scotland falling behind on lung cancer screening. 2025 [cited 2025 Dec 02]. Available from: https://healthandcare.scot/stories/4250/lung-cancer-screening-scotland-minto-dallas-castle-beek.

29. Sajawal M, DiRico M. Definitions matter: how should we define diagnostic yield in bronchoscopy? 2026 [cited 2026 Feb 13]. Available from: https://www.chestphysician.org/definitions-matter-how-should-we-define-diagnostic-yield-in-bronchoscopy/.

30. American Lung Association. Robotic-assisted bronchoscopy. 2024 [cited 2025 Oct 01]. Available from: https://www.lung.org/lung-health-diseases/lung-procedures-and-tests/rab.

31. Ho E, Hedstrom G, Murgu S. Robotic bronchoscopy in diagnosing lung cancer - the evidence, tips and tricks: a clinical practice review. Ann Transl Med. 2023;11(10):359.

32. NHS Inform. Lung cancer: causes. 2024 [cited 2025 Oct 07]. Available from: https://www.nhsinform.scot/illnesses-and-conditions/cancer/cancer-types-in-adults/lung-cancer/.

33. Cancer Research UK. Survival for lung cancer. 2025 [cited 2025 Dec 09]. Available from: https://www.cancerresearchuk.org/about-cancer/lung-cancer/survival.

34. Public Health Scotland. Scottish burden of disease: future prevalence and burden of tracheal, bronchus and lung cancer. 2025 [cited 2025 Oct 07]. Available from: https://www.scotpho.org.uk/media/2670/2025-06-24-scottishburdenofdisease-lungcancer.pdf.

35. Public Health Scotland. Cancer incidence in Scotland: deprivation data to December 2022. 2025 [cited 2025 Oct 08]. Available from: https://publichealthscotland.scot/media/34455/2025-08-19-cancer-incidence-deprivation-report-final.pdf.

36. Brownlee AR, Perez C, Weiser L, Yu W, Bolster D, Knabe K, et al. 1121 Shape-sensing robotic-assisted bronchoscopic biopsies: diagnostic yield and surgical implications. Ann Thorac Surg. 2025;120(5):928-36.

37. Murgu S, Chen AC, Gilbert CR, Sterman DH, Pederson D, Rafeq S, et al. A prospective, multicenter evaluation of safety and diagnostic outcomes with robotic-assisted bronchoscopy: results of the transbronchial biopsy assisted by robot guidance in the evaluation of tumors of the lung (TARGET) trial. Chest. 2025;168(2):539-55.

38. Husta BC, Cheng GZ, Batra H, Reisenauer JS, Bartek WM, Kalchiem-Dekel O, et al. Shape-sensing robotic-assisted bronchoscopy with integrated mobile cone-beam CT for small nodules: results from the prospective multicentre CONFIRM study. Thorax. 2026;81(3):267-75.

39. Ost DE, Maldonado F, Shafrin J, Kim J, Marin MA, Amos TB, et al. Economic value of bronchoscopy technologies that improves sensitivity for malignancy for peripheral pulmonary lesions. Ann Am Thorac Soc. 2024;21(12):1759-69.

40. Public Health Scotland. 2022 Cancer staging data. 2023 [cited 2025 Dec 10]. Available from: https://publichealthscotland.scot/media/23835/2023-11-28_cancerstagingdata_report_final.pdf.

41. Zhang Y, Shi L, Simoff MJ, Wagner OJ, Lavin J. Biopsy frequency and complications among lung cancer patients in the United States. Lung Cancer Manag. 2020;9(4):LMT40.

42. Noonan K, Tong KM, Laskin J, Zheng YY, Melosky B, Sun S, et al. Evaluation of a 'watch and wait' approach for chemotherapy in patient with newly diagnosed advanced non-small cell lung cancer from a diverse community population. Clin Oncol. 2015;27(9):505-13.

43. NHS England. National cost collection for the NHS 2024 [2025 Dec 09]. Available from: https://www.england.nhs.uk/costing-in-the-nhs/national-cost-collection/.

Appendix 1: Abbreviations

BMI	body mass index
CE	Conformité Européenne
CI	confidence interval
COPD	chronic obstructive pulmonary disease
CT	computed tomography
CTTB	computed tomography guided transthoracic biopsy
EBUS	endobronchial ultrasound
ENB	electromagnetic navigation bronchoscopy
FDA	Food and Drugs Administration
GP	general practitioner
GRADE	grading of recommendations assessment, development and evaluation
ICER	incremental cost-effectiveness ratio
IQR	interquartile range
mm	millimetre
NCA	North Cancer Alliance
NHS	National Health Service
NMA	network meta-analysis
NR	not reported
OR	odds ratio
PHS	Public Health Scotland
QUADAS-2	Quality Assessment of Diagnostic Accuracy Studies version 2
QUADAS-C	Quality Assessment of Diagnostic Accuracy Studies – comparative
QALY	quality-adjusted life year
RAB	robotic-assisted bronchoscopy
RCT	randomised controlled trial
RR	relative risk
SCAN	South East Scotland Cancer Network
SD	standard deviation

SHTG	Scottish Health Technologies Group
UK	United Kingdom
VBN	virtual bronchoscopic navigation
WOSCAN	West of Scotland Cancer Network