Healthcare Improvement Scotland | SHTG Advice on health technologies

SHTG Assessment
February 2025

In response to an enquiry from the Accelerated National Innovation Adoption (ANIA) partnership

Artificial intelligence-assisted clinician review of chest X-rays for suspected lung cancer

Key messages

1. We found limited or no published evidence on the clinical effectiveness, cost effectiveness, safety or patient and staff experience of artificial intelligence (AI)-assisted clinician review of chest X-rays (CXR) for patients with suspected lung cancer.

2. A 12-month service evaluation in NHS Grampian that used AI calibrated to match their pathway capacity indicated that:

   - AI-assisted clinician review of CXRs as part of a clinical pathway change can support radiology workload prioritisation (for example, the triaging of urgent suspicion of cancer scans) and reduce time to CT scanning.

   - AI-assisted clinician review of CXRs as part of a clinical pathway change may lead to quicker time to treatment and earlier identification of patients with treatable lung cancer, but the results are inconclusive.

3. Our resource impact analysis of the diagnostic pathway found that AI-assisted clinician review of CXRs incurred additional costs compared with the traditional radiology pathway, based on pathway changes as part of NHS Grampian's service evaluation.

4. Ongoing research studies in the United Kingdom (UK), due for completion in the next 12 months, are expected to contribute meaningfully to the evidence base on clinical and cost effectiveness, AI performance and patient and staff experiences. One ongoing study is being conducted in NHS Greater Glasgow and Clyde (GGC), with data expected after study completion in April 2025.

5. NHSScotland may wish to consider commissioning a national evaluation to determine how the use of diagnostic AI tools could best add value in an agreed optimised national diagnostic pathway.

6. Future contributors to the evidence base should use our Evidence Framework for collecting relevant data to guide decision making, as well as research and evaluation recommendations for the topic outlined by the National Institute for Health and Care Excellence (NICE).[1]

What were we asked to look at?

We were asked by ANIA to review the clinical and cost effectiveness evidence of AI-assisted clinician review of CXRs to detect lung cancer.

Why is this important?

Lung cancer is the most common cancer in Scotland and most people present at advanced stages of the disease which makes it more challenging to treat.[2, 3] Earlier detection of lung cancer improves patient outcomes and survival rates.[4, 5] Lung cancer was the leading cause of cancer-related death in Scotland in 2021[6] and it is expected to continue to be one of the most common cancers in Scotland.[7]

The demand for radiology diagnostic tests in NHSScotland is increasing and as of June 2024, 47.1% of people were waiting more than six weeks for their test. The range of radiological diagnostic tests used includes Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Barium Studies and non-obstetric ultrasound.[8] National shortages in the clinical workforce, which are projected to increase by 2027,[9] along with evidence of delayed treatment times,[10] highlights the need to improve diagnostic pathways for patients with lung cancer.

The Scottish Government's (SG) Cancer Strategy aims to improve cancer survival and ensure accessible, equitable and excellent care across Scotland.[11] As part of an initial three-year cancer action plan, the focus is on improving outcomes for patients with lung, neck and colorectal cancers.[12] Specific actions include the implementation of optimal lung cancer diagnostic pathways, and supporting ANIA adoption of proven technological innovations across NHSScotland, including the potential use of AI in reading CXRs for earlier diagnosis of lung cancer.[12]

What was our approach?

We reviewed the evidence on the clinical effectiveness, cost effectiveness, safety and experience (for patients and staff) for the use of AI-assisted clinician review of CXRs in patients with suspected lung cancer. We incorporated evidence from a local service evaluation in NHS Grampian.

Our review updated a previous Innovative Medical Technology Overview (IMTO) published on the Scottish Healthcare Technologies Group (SHTG) website in March 2024. Further information about how we conduct our assessments can be found on our website.

What next?

Our assessment will be shared with the ANIA Innovation Design Authority (IDA) to inform decision making on the national implementation of an AI-assisted clinician review of CXRs for patients with suspected lung cancer in Scotland.

Key points from the evidence

Clinical effectiveness

1. The evidence on the clinical effectiveness of AI-assisted clinician review of CXRs in patients with suspected lung cancer is limited in quantity and quality.

    - In their Evidence Value Assessment (EVA) and later addendum, NICE did not identify any eligible studies that explored use of AI-assisted clinician review of CXRs in adults referred from primary care with suspected lung cancer. NICE (2023) concluded that these AI tools should not be used in routine clinical practice within the NHS, except in research and evaluation contexts.[1, 13, 14]

    - A UK-based observational, retrospective, accuracy study found a high rate of false positives and low positive predictive value (PPV) for the auto lung nodule detection (ALND) AI tool. The authors concluded that the AI tool may be underperforming in a real-world context, increasing strain on the healthcare system by causing unnecessary medical intervention.[15]

2. A 12-month service evaluation from NHS Grampian assessed the introduction of AI-assisted clinician review of CXRs in patients with suspected lung cancer (Annalise Enterprise CXR), alongside additional radiology staff and more CT slots. Data from the pre-pandemic baseline (n=113) and post-implementation of AI (n=68) were compared statistically. Results suggest that the NHS Grampian changes have improved workload prioritisation for radiology staff. Other findings including reduced time to treatment and earlier detection of lung cancer were positive but were not statistically significant and therefore, results remain inconclusive.

3. A summary of the NHS Grampian results post-implementation of AI and other pathway changes is as follows:

    - All patients who needed a CT scan (n=68) received a CT scan six days more quickly following a CXR report, which was statistically significant (95% confidence interval (CI) [3.647,7.369], p<0.001).

    - For all patients requiring treatment (n=68), there was a seven day reduction in average time to treatment from the pre-pandemic baseline (mean=58 days, standard deviation (SD)=35) to post-implementation (mean=51 days, SD=20), but this was not statistically significant (95% CI [-1.62,14.418], p=0.117).

    - There was a 12 per cent increase in the number of patients diagnosed with treatable cancers from a pre-pandemic baseline of 41% (n=65/110) to 53% (n=35/67) post-implementation, but this was not statistically significant (p=0.148).

- NHS Grampian calibrated the Annalise Enterprise CXR software to match their pathway capacity and aim of identifying need for urgent CT, not presence of cancer. In doing so, the software is not being used to its maximum performance capability and may lack sensitivity. Technical performance data analysed in the evaluation indicated that:
    - for Annalise Enterprise CXR compared with clinical review, AI-assisted clinical review of CXRs can successfully prioritise patients who do not have high-risk flag(s) for lung cancer and should not receive an urgent CT (specificity=91%, NPV=99.99%), but not those who should receive an urgent CT (sensitivity=78%, PPV=3%).
    - for Annalise Enterprise CXR compared with clinician-confirmed diagnosis, AI-assisted clinical review of CXRs can successfully identify patients who do not have lung cancer (specificity=91%, NPV=100%), but not patients who are later diagnosed with lung cancer (sensitivity=82%, PPV=1%).

- Seventy-two per cent of patients (n=49/68) received their CT scan within three days after referral. Twelve per cent (n=8/68) received their CT scan on the same day as referral, as per the guidance outlined in Scotland's national optimal lung cancer diagnostic pathway.[16]

Safety

4. We found no published evidence examining the impact of AI tools on safety or harm outcomes in lung cancer diagnosis.

5. We identified one unpublished rapid review by Public Health Wales Evidence Service which evaluated the effectiveness and safety or harm outcomes associated with AI in cancer diagnosis.[17] No evidence relating to lung cancer diagnosis was identified.

Patient and social aspects

6. We did not find any published research evidence on patient or staff (clinical or non-clinical) experience of AI-assisted clinician review of CXRs in patients with suspected lung cancer.

Cost effectiveness

7. Our resource impact analysis found that AI-assisted clinician review of CXRs was cost incurring, compared with the existing radiology pathway, based on data from the NHS Grampian service evaluation.

Ongoing research

8. We found four ongoing registered studies based in the UK. Three studies are due to complete in 2025. The fourth was due for completion in 2023. Three were based in England and one in Scotland. Two of the ongoing studies are using Lunit INSIGHT CXR and two are using qXR (Qure.ai).

9. We identified three ongoing pilot studies in NHS Trusts in England, one using Annalise Enterprise CXR and the other two using qXR (Qure.ai).

10. We also identified one mixed-methods evaluation of AI implementation for chest diagnostics across 11 networks of NHS Trusts in England.

Contents

Definitions

Absolute index of inequality: measures the health impact of inequality across socio-economic groups, from the lowest to the highest. Higher values indicate greater inequalities.[18]

AI: technology that enables machines to simulate aspects of human behaviour such as learning, problem solving and decision making.[19]

Cavity: specifically in this context, a space filled with gas that can be found within a nodule or mass in the lung.[20]

CXR an X-ray image of the chest area, including the lungs, airways, heart and ribs.[21]

Computer-aided detection (CADe): software that can detect abnormalities on a CXR.[1]

Computer-aided diagnosis (CADx): software that can diagnose abnormalities on CXR.[1]

Computer-assisted triage (CAST): supports the prioritisation of medical images that require urgent review.[1]

CT: an imaging procedure that uses rotating narrow X-ray beams processed by a machine to produce cross-sectional images (or 'slices') of the body. The procedure provides more information than conventional X-rays.[22]

Disability-adjusted life years (DALY): measures both years of life lost due to premature death and years lived in poor health.[5]

Equity: fairness or justice in the way people are treated, for example by providing different levels of support to individuals or groups to achieve the same outcomes.[23]

Hilar enlargement: the hila are anatomical structures in the lung containing blood vessels, bronchi (air passages), nerves and lymph nodes (part of the immune system). Enlargement can be caused by non-cancerous and cancerous conditions.[24]

Incidence: specifically in this context, the number of new cases of primary cancer in a population over a specific time period. [25]

Kyphosis: a curvature of the spine, resulting in rounding of the upper back.[26]

Lung cancer: a type of cancer that starts as growth of abnormal cells in the windpipe, main airway or lung tissue.[27]

Lung mass: an abnormal growth on the lung, usually 3 cm or larger in diameter.[28]

Mediastinal widening: the mediastinum is the space between the lungs. When the space increases by 8 cm or more, it is considered to be mediastinal widening and can have various causes.[29]

Mortality: specifically in this context, the number of cancer-related deaths (as an underlying cause) in a population over a specific time period.[25]

Multidisciplinary team (MDT): a group of professionals from various fields who work together to decide on care and treatment plans for individual patients.[30]

Net survival: specifically in this context, the number of people who survive lung cancer, considering other potential causes of death they may have experienced if they had not been diagnosed with lung cancer.[25]

Lung nodule: a small growth in the lung, usually 3 cm or smaller in diameter.[31]

Radiologist: a healthcare professional who uses images of the body to diagnose, treat and manage various medical conditions and diseases.[32]

Relative index of inequality: extent that health outcomes are better to the least deprived areas or worst in the most deprived areas, compared with the population. Higher values indicate greater inequalities.[18]

Scoliosis: a condition involving abnormal twisting and curvature of the spine.[33]

Definitions of terms relating to diagnostic test accuracy are provided in *Appendix 2*.

Introduction

Lung cancer begins as an abnormal growth of cells in any part of the lung and can develop in the windpipe (trachea), main airway (bronchus) or lung tissue. Primary lung cancer originates in the lung, while secondary lung cancer refers to cancer that has spread (metastasised) to the lungs from another part of the body.[34] The two main types of primary lung cancer are non-small cell (the most common) and small cell (less common but spreads faster).[35] In the early stages, lung cancer often has no symptoms. As the cancer progresses, common symptoms may include:

- a persistent cough
- coughing up blood
- persistent breathlessness
- unexplained tiredness and weight loss
- pain or discomfort when breathing or coughing. [35]

When someone presents to a General Practitioner (GP) with symptoms of lung cancer, they should be referred to secondary care for an urgent suspicion of cancer (USC) CXR.[36]

In Scotland, the targets for cancer waiting times are 62 days from a USC referral to treatment and 31 days from treatment decision to treatment.[37] In 2022, shorter diagnostic and treatment targets were introduced to improve outcomes for people with lung cancer. Scotland's national optimal lung cancer diagnostic pathways recommends that people with suspected lung cancer needing urgent review should receive CT on the same day or within 72 hours of a CXR report. Diagnosis should be received by week three (day 21) following a USC referral, with treatment starting for most people by week six (day 42).[16]

Public Health Scotland (PHS) reported that between April to June 2023, 82% of 541 referrals of eligible patients with lung cancer met the 62-day standard, including a median unadjusted waiting time of 49 days from referral to diagnosis.[10]

Delays in diagnosis negatively affect lung cancer survival rates, while earlier diagnosis can improve patient outcomes (for example, earlier treatment and better survival).[4,5]

There is increasing demand for radiology diagnostic tests in NHSScotland. As of June 2024, 47.1% of people who required a diagnostic test were waiting more than six weeks (CT, MRI, Barium Studies, Non-Obstetric Ultrasound).[8] Modelling by The Royal College of Radiologists estimates that the national clinical radiology workforce shortages are projected to worsen by 2027[9] risking further delayed diagnosis and treatment.[10]

The SG Cancer Strategy 2023-2033 seeks to drive improvements in cancer survival and ensure accessible, equitable and high-quality care over the next 10 years.[11] As part of the initial three-year action plan, the focus will be on improving outcomes for patients with lung, neck and colorectal cancers.[12] Actions include the implementation of optimal lung cancer diagnostic pathways.

Additional actions include supporting ANIA in fast-tracking national adoption of proven technological innovations, such as the potential use of AI in reading CXRs for earlier diagnosis of lung cancer.

Research question

Is AI-assisted clinical review of CXRs clinically and cost effective in improving the detection of lung cancer?

Literature search

A systematic search of the primary and secondary literature, along with key websites was carried out by a Health Information Scientist between 3 and 4 January 2024 and updated in June 2024. The search for primary and secondary literature used the following databases: Medline, Embase and CINAHL. The secondary literature search aimed to identify systematic reviews, meta-analyses, health technology assessments and other evidence-based reports.

Key websites were searched for guidelines, policy documents, clinical summaries and economic studies. A web-based search for preprints, registered systematic review protocols and clinical trial protocols was conducted alongside the primary and secondary literature search. The web-based search for additional evidence was carried out by a Health Services Researcher (lead author) between December 2023 and January 2024. The search was updated in July 2024. From 3 to 4 October, references from AI software Request for Information returns to the NHSScotland National Procurement team were searched.

Concepts used in all searches included: lung cancer, chest X-ray, artificial intelligence, machine learning. Results were limited to English language publications, with no date limits applied, and adult patients (18 years and older) only with suspected lung cancer referred from primary care (aligning with the criteria for the comprehensive EVA of AI technology by NICE in 2023).[1, 14] A full list of resources searched and terms used is available on request.

Health technology description

AI software to support clinician review of CXRs and help inform the need for further investigations such as a CT scan. AI software includes computer-aided detection (CADe), computer-aided diagnosis (CADx) and computer-assisted triage (CAST). CADe and CADx are used to diagnose cancer or to detect abnormalities on a CXR. CAST is used to prioritise and triage CXRs for review by a healthcare professional.

AI-assisted clinician review of CXRs is being tested in two NHSScotland health boards. In NHS Grampian, the AI technology being evaluated is Annalise Enterprise CXR (Annalise ai, Sydney, Australia, class IIb medical device, CAST, CADe) as part of a service evaluation.

In NHS GGC, the AI technology is qXR (Qure.ai, Mumbai, India, class IIb medical device, CADe). In both use cases, the aim of the AI technology is to support the lung cancer diagnostic pathway by flagging high-risk CXRs for urgent clinical review and prioritising patients with suspected lung cancer for CT scan.[38]

Inequalities

AI-derived algorithms that are used in healthcare are often trained exclusively or largely on data from a particular group of individuals. In doing so, AI may not work as intended for the whole population and can result in existing societal inequalities being reinforced, or AI-derived algorithm being developed or 'learning' based on biases already present in medical practice.[39-41]

In their EVA of the use of AI to analyse CXRs for patients with suspected lung cancer referred from primary care, NICE identified groups that may be disadvantaged by use of AI technology.[1] High-quality CXRs may be difficult to obtain in people with conditions such as morbid obesity or scoliosis, resulting in the images being rejected by the AI software because they cannot be interpreted.[1]

An independent review on equity in medical devices by the Department of Health and Social Care (DHSC, UK Government) outlined seven recommendations to facilitate the development of bias-free AI devices, while strengthening initiatives to address equity in AI and anticipate potential future harm.[42] The DHSC recommendations of relevance to AI development are as follows:

- Recommendation 8: developers of AI devices and stakeholders should engage with diverse groups of individuals (patients, patient organisations, public) to co-design devices throughout the lifecycle of the software.
- Recommendation 9: an academy should be commissioned by the government to support an understanding of equity in AI-assisted medical devices for all stakeholders (for example, health professional training, stakeholders developing devices, clinical guideline bodies).
- Recommendation 10: stakeholders should be transparent at all stages of research and development for diversity, completeness and accuracy of data.
- Recommendation 11: stakeholders should work together to reduce bias across the device lifecycle, ensuring that best practice guidance, assurance and governance processes are followed.
- Recommendation 12: long-term resources should be provided to regulatory bodies in the UK to develop guidance to support stakeholders developing AI devices, with a view to reducing unfair biases.
- Recommendation 13: the NHS should influence the use of AI-assisted medical devices that are equitable (for example, use of a minimum standard for equity, equity as part of pre-purchase validation checks, joint responsibility with manufacturers and regulators).
- Recommendation 14: commissioners of research should prioritise diversity and inclusion (for example, research funding, support, development, appraisal).[42]

To promote equity, stakeholders involved in the development of AI devices should also consider the ten guiding principles on good machine learning practice developed by the Medicines and Healthcare products Regulatory Agency (MHRA).[43] The recently developed five key principles of regularity use of AI endorsed by the MHRA should also be considered.[44]

Focused research, throughout the lifecycle of an AI-derived algorithm, will be required to identify any limitations and demonstrate compliance with the principles of AI device development.[50, 51]

We did not identify any published information discussing potential inequalities associated the AI technologies being implemented in the two use cases in NHSScotland (Annalise Enterprise CXR or qXR).

Epidemiology

Lung cancer is the most common cancer in Scotland, and is expected to remain one of the most common cancers until 2040 and beyond.[2] In 2021, 5,476 people (2,699 men and 2,777 women) were diagnosed with lung cancer, representing 15.5% of all cancer diagnoses in Scotland and an increase of 2.9% since 2019.[2]

The biggest risk factor for developing lung cancer is smoking history. Other risk factors include occupational hazard exposure (for example, to asbestos) and a family history of lung cancer.[2] In the UK, non-small cell lung cancer (NSCLC) is the most common form of lung cancer (approximately 80% to 85%), followed by small cell lung cancer (15 to 20%).[45]

While lung cancer is expected to remain one of the most common cancers in Scotland, incidence rates are continuing to fall for women and men. There has been a faster decline in incidence for men.[2] Lung cancer has a higher incidence rate in the more deprived areas of Scotland (up to three times the risk compared with the least deprived areas), as categorised by the Scottish Index of Multiple Deprivation. The higher incidence of lung cancer in more deprived areas of Scotland does not appear to impact staging at diagnosis.[2] High incidences of lung cancer have been observed for urban areas, compared with rural areas.[46]

Incidence and mortality rates across different ethnic groups are not measured in Scotland.[54] In England, evidence suggests that lung cancer incidence rates are lower in Asian and Black ethnic groups, and in people of mixed or multiple ethnicities, compared with white ethnic groups. These findings may be related to risk factor exposure.[47] These groups refer to the ethnic categories used in the study. There are often a variety of ethnic backgrounds, experiences and socio-economic circumstances contained within these broad categories.

Most lung cancer diagnoses in Scotland occur at an advanced stage. In 2021, 46.3% of people with lung cancer in Scotland were diagnosed when their cancer was at stage IV, reflecting a trend observed since 2005.[2]

A late-stage cancer diagnosis can indicate that the cancer has spread to at least one other organ, making treatment more challenging and often resulting in palliative care.[3, 5] Emergency presentation (40-45% of cases) is the most common route of diagnosis for lung cancer in Scotland.[48]

Modelling by Cancer Research UK predicts that between 2038 and 2040, lung, breast and bowel cancer will remain the most common cancers in Scotland. The average number of diagnoses of lung cancer in Scotland is predicted to increase from 5,516 (average between 2019 and 2021) to 6,012 (between 2038 and 2040), largely due to an ageing population. The number of people diagnosed with lung cancer is predicted to increase from 2,658 (2019 to 2021) to 2,849 (2038 to 2040) for men and from 2,859 (2019 to 2021) to 3,163 (2038 to 2040) for women.[7]

Mortality and burden of disease

Lung cancer mortality remains high. In 2021, it was the leading cause of cancer-related death in Scotland, with 3,959 people dying of the disease, accounting for just under a quarter of all cancer-related deaths.[6, 11]

Disability-adjusted life years (DALYs) are a measure of years of life lost due to premature death and years lived in poor health.[5] In 2019, the overall DALY rate for lung cancer in Scotland was 1,655 per 100,000 people (women: 1,499, men: 1,820), which was higher than the UK average of 1,184.32.[49] Lung cancer had the largest rate difference in DALYs between the most and least deprived areas of Scotland (2475 DALYs per 100,000 population), followed by drug use and heart disease in 2019.[49] The highest DALY rates for lung cancer are observed in NHS GGC, NHS Fife and NHS Ayrshire and Arran. The lowest rates of lung cancer burden are seen in the Island boards – NHS Shetland, NHS Western Isles and NHS Orkney.[5]

For comparison, the disease burden for lung cancer (1,655 per 100,000 population) is substantially higher than colon and rectum cancer (226 DALYs per 100,000 population) and breast cancer (84 DALYs per 100,000 population).[18]

Survival

Between 2010 and 2014, the five-year survival rate for people diagnosed with lung cancer in Scotland, adjusted for age and other causes of death, was 12.9%. This compares with the UK rate of 13.3%. Age-standardised net survival rate reported represented a 4.6% increase compared with the period between 2000 and 2014 (8.3%).[50]

From 2015 to 2019 in Scotland, 43% of women and 36% of men were still alive one year after their lung cancer diagnosis (one year net survival). The survival rates after five years were 16% for women and 11% for men.[51]

Stage at diagnosis is an important determinant of survival for patients with lung cancer. For NSCLC, one year net survival is 95% at stage I, compared with 18.5% at stage IV. Three years after diagnosis, survival for NSCLC is 79% at stage I and 3.5% at stage IV. For small cell lung cancer (SCLC), one year net survival is 80% at stage I (52% at three years) and 16% at stage IV (2% at three years).[52]

Clinical effectiveness

We identified two published studies for our clinical effectiveness review. The two studies were also reported in our corresponding IMTO.[53]

A NICE EVA published in 2023 assessed the use of AI to analyse CXRs for patients with suspected lung cancer referred from primary care.[1, 13, 14] We identified one observational study published after the NICE EVA in 2023.[15]

The NICE EVA reviewed the evidence on AI software for analysing CXRs from patients with suspected lung cancer referred from primary care and highlighted the gaps in the evidence base. The comparator used in the EVA was CXRs interpreted by a radiology specialist without using AI software. Outcomes of interest focused on the performance of the AI software (true positives, false positives, true negatives, false negatives, sensitivity and specificity). Other outcomes included service or pathway implications (for example, time to CXR report) and health outcomes (for example, mortality).

Fourteen AI software were included in the NICE EVA:

- AI-Rad Companion Chest X-ray (class 2a medical device, CADx, Siemens Healthineers)
- Annalise CXR (class 2b medical device, CADe/CAST, Annalise ai)
- ALND (class 2a medical device, CADe, Samsung)
- ChestLink (Class 2b medical device, CADe/CAST, Oxipit)
- ChestView (class 2a medical device, CADe, Gleamer)
- Chest X-ray (class 2a medical device, CADe, Rayscape)
- ClearRead Xray (class 2a medical device, CADe, Riveraintech)
- InferRead DR Chest (class 2a medical device, CADe, Infervision)
- Lunit INSIGHT CXR (class 2a medical device, CADe, Lunit)
- Milvue Suite (class 2a medical device, CADe/CAST, Milvue)
- qXR (class 2a medical device, CADe, Qure.ai)
- Red dot (class 2a medical device, CADe/CADx, CAST, Behold.ai)
- SenseCare-Chest DR PRO (class 2b medical device, CADe, SenseTime)
- Vuno Med-Chest X-ray (class 2a medical device, CADe, VUNO).[1, 14]

Nine electronic bibliographic databases were searched. No study met the inclusion criteria. Due to an absence of any evidence, the EVA subsequently included six small retrospective studies (three Lunit INSIGHT, one Red Dot Behold.ai, one AI-Rad Companion Siemens and one prototype AI-Rad Companion Siemens). The studies had initially been excluded due to unclear populations and referral routes.

Performance outcomes (true positive, false positive, true negative, false negative, sensitivity and specificity) were only reported for three of the six studies. Sensitivity and specificity were reported for five of the studies.

There was evidence that sensitivity (77%) may be higher when radiologists used AI compared with when they did not (66%).[1, 14] No other studies reported significant differences between sensitivity and specificity for readers using AI compared with not using AI.

Of the six studies that were summarised in the EVA, none provided evidence on the clinical effectiveness of the AI software used or reported test failure rates. All six studies had methodological limitations and may not be relevant to the UK clinical context. For instance, test datasets were used to train the AI rather than data from clinical practice; only one study was conducted in the UK; and software manufacturers were involved in three of the six studies which may result in bias towards more favourable results (publication bias).[1, 14]

Concerns were raised during the production of the EVA that the literature review inclusion criteria for the assessment were too strict and that the potential benefits of AI-derived software had not been fully captured. An addendum literature review was later produced by the Cedar Health Technology Research Centre that included studies with mixed populations or an unclear referral route. The addendum review identified five retrospective cohort studies.

No outcomes relating to lung cancer were reported in the five retrospective cohort studies. Performance outcomes explored included accuracy, sensitivity, specificity, PPV, NPV, false discovery rate (false positive), false omission rate (false negative) and area under the receiver operating characteristic curve. Reporting varied across the five studies, with no study reporting results for all outcomes. AI technology sensitivity ranged from 77% to 90% across four studies, specificity ranged from 83% to 92% across four studies, false positives were 62% in one study, and NPV was 96% and 97% across two studies.

The addendum concluded that evidence gaps remain for the use of AI technologies for CXR analysis in patients with suspected lung cancer. Evidence gaps include performance (for example, technical failure rate) and health-related outcomes such as morbidity, mortality and health-related quality of life. The addendum concluded that integrating AI tools into routine clinical practice within the NHS was currently unfeasible unless in the context of research.

The NICE EVA highlighted concerns over the design of the available evidence, noting that the included studies had unclear referral routes, small sample sizes and low generalisability to UK clinical practice due to restrictive exclusion criteria (for example, excluding smaller lung nodules from AI software training). NICE also highlighted that the available evidence translated poorly to an NHS setting, where AI would be used to support clinician review of CXRs using real-world data, rather than test datasets.[1,12]

NICE recommended that any NHS centres that are using AI-assisted clinician review of CXRs in adults referred from primary care (for suspected lung cancer) should not use AI software in isolation and should evaluate their ongoing work.

Any NHS centres planning to use AI-assisted clinician review of CXRs in adults referred from primary care (for suspected lung cancer) should do so for research purposes only.

Evaluations on the use of AI supported clinical review of CXRs in adults referred from primary care (for suspected lung cancer) should collect information on the following outcomes:

- impact of AI on clinical decision making
- healthcare costs and use of resources
- impact on clinical outcomes (for example, CXR review and reporting time, time to CT referral and diagnosis)
- diagnostic accuracy in different settings and groups
- technical failure rates and rejection rates
- pathway changes required for implementation of the software
- patients and staff views.[1, 14]

A UK-based observational, retrospective, accuracy study was published after the NICE EVA and the addendum.[15] The study evaluated the performance of the ALND AI tool (a class 2a medical device, by Samsung Electronics, Suwon, South Korea) in identifying cancerous lung nodules on CXRs. The output from the AI review of the CXRs was compared with radiology reports and cancer diagnoses made by the MDT.

The authors trained the ALND software on an 'unenriched' dataset that was said to be representative of routine clinical practice, rather than using 'enriched' datasets that include a higher prevalence of cancer and may skew AI performance towards false positives.[15]

From July 2020 to February 2021, 5,722 CXRs were identified retrospectively at one UK NHS tertiary centre, acquired from 5,592 adult referrals from primary care for any indication (as reported by the study authors). Only CXRs taken in the posterior-anterior projection were included. It is not clear whether performance of the AI software was adjusted to match clinical pathway capacity of the UK NHS tertiary centre or if any other adjustments to the pathway were made. The median age of the patients included in the study was 59 years and 54% identified as female.

Ethnicity information was not available for 9.1% of cases. The ethnicity categories included 79% white or white British, 5-6% South Asian or South Asian British, 1-3% Black or Black British, 2.2% any other ethnicity and 0.9% Mixed ethnicity. [15] These groups refer to the ethnic categories used in the study. There are often a variety of ethnic backgrounds, experiences and socio-economic circumstances contained within these broad categories.

For the comparison of AI-based software alone with radiologist report alone for detecting suspicious lung nodules, the ALND software flagged 1120 potentially cancerous nodules on 17.5% of CXRs. The proportion of patients with a suspicious lung nodule correctly identified by the ALND AI software was 54.5% (sensitivity). For those without a suspicious nodule, the identification was 83.2% (specificity). The probability that patients with a suspicious lung nodule when flagged by the ALND AI software was 5.5% (PPV) and for those without a suspicious lung nodule when not flagged was 99.0% (NPV) (*Table 1*).[15]

In the comparison of AI-based software alone with MDT lung cancer diagnoses, 92 patients (1.6%) were diagnosed with lung cancer by the MDT.

The probability that the ALND AI software could correctly identify patients who have lung cancer was 60.9% (sensitivity) and who do not was 83.3% (specificity).

The probability that patients flagged by the ALND AI software had lung cancer was 5.6% (PPV) and the probability that patients not flagged did not have lung cancer was 99.2% (NPV) (*Table 1*).[15]

Table 1: Performance of the ALND AI software by comparison (AI software alone compared with radiologist report for detecting suspicious lung nodules or lung cancer diagnosis by MDT decision)[15]

	Percentage (%)			
Comparison	**Sensitivity**	**Specificity**	**PPV**	**NPV**
AI software (alone) compared with radiologist report for detecting suspicious lung nodules	54.5	83.2	5.5	99.0
AI software (alone) compared with lung cancer diagnosis by MDT decision	60.9	83.3	5.6	99.2

Performance of the ALND software is summarised as follows:

- Nine hundred and forty-three false positive cases were observed for the AI software compared with MDT decision (16.8% of cases without cancer).
- The AI software flagged normal anatomy in 69.9% of false positive cases, flagged non-cancerous pathology in 31.2% of false positive cases and technical factors in 4.8% of false positive cases.

- Thirty-four false negative cases were observed for the AI software compared with MDT decision (36.9% of cases with cancer).
- In 22 out of 34 of the false negative cases, abnormalities were later found to be visible on the CXR. [15]

The study authors highlighted that the high rate of false positives and low PPV in their study suggest that the AI tool is underperforming for its intended clinical purpose. The authors observed that the AI software misidentified normal, variant or age-related anatomy as abnormalities, leading to false positives and unnecessary reviews.

Underperformance of the AI tool in this context may result in over-investigation of patients (for example, increased CT scanning), contributing to increased physical and psychological harm for patients and increasing demands on healthcare resources.[15]

The study authors concluded that there is a need for representative clinical datasets for AI training or learning, alongside prospective studies including randomised controlled trials (RCTs). The authors emphasised the need for ongoing evaluation of AI software that are representative of clinical practice before the technology can be adopted into NHS clinical pathways.

NHS Grampian service evaluation

We were asked to conduct an independent evaluation to assess the value of AI-assisted clinical review of CXRs from patients with suspected lung cancer in NHS Grampian. The AI technology was used as part of a clinical pathway that had been adjusted (additional staffing and CT lists) to risk stratify and prioritise CXR images that are highest risk of suspected lung cancer. The adjustments were made to support quicker time from CXR to treatment and to identify treatable cancers earlier.

NHS Grampian implemented the Annalise Enterprise CXR AI module (Annalise ai) in adults over 18 years old. The AI module was trained by Annalise ai on over 820,000 CXR images from 520,014 cases (individual people) obtained from databases in Australia, Spain and the United States of America.[54] The training dataset comprised 284,649 patients (female=125,245, male=125,246, unknown=34,158), with a mean age of 65 years (SD=18).[54] Using a machine learning model, Annalise Enterprise CXR scans for 124 clinically relevant findings in each CXR image, 34 of which are deemed priority findings based on their clinical importance.[55] The AI module was used in NHS Grampian as a triaging tool. When the AI module identifies images with possible clinically relevant findings, the clinical team is informed and a rapid clinical review is carried out.[56]

A summary of our 12-month evaluation report will now be discussed.

Methods

The NHS Grampian service evaluation was a cohort study with retrospective and prospective phases.

As part of the evaluation, NHS Grampian adjusted their clinical pathway, including radiologists' job plans and staff ways of working. We do not have information on the number of staff impacted by the changes. Key adjustments to the clinical pathway included:

- radiologists were asked to report urgently the CXRs flagged as high-risk of cancer by the AI
- an additional member of administration staff was employed to support the evaluation by coordinating data collection and contacting patients identified by radiologists as at high-risk to arrange an urgent CT.
- the radiologist reviewing the chest CT scans prioritised the scans within the USC pathway
- twenty CT slots per week were protected to allow for rapid provision of scans for the USC cohort
- the number of CT scans conducted per week was low with the mean CTs delivered per week=3.63, range=0 to 7.

The changes in NHS Grampian represented a move away from a traditional chronological approach, to a risk-based approach.

Two consultant radiologists from NHS Grampian worked with the manufacturer to calibrate their software. The software was calibrated to ensure that staff had capacity to urgently report CXRs and deliver rapid CTs, while maximising the identification of lung cancer. To illustrate why this is important, if the AI software was calibrated to identify a higher number of possible lung cancers, this would have resulted in a larger number of CXRs requiring urgent reporting (that is, due to a higher number of false positives) and would have been beyond available workforce capacity.

The technology (Annalise Enterprise CXR) was deployed directly within NHS Grampian clinical management systems for storing of medical images and electronic health records. During the study, Annalise Enterprise CXR was applied to all people who received a CXR during the study period (May 2023 to April 2024), from any referral source.

For our assessment, we only included people over the age of 18 years old, who were referred from their primary care GP for a CXR, and whose CXR was flagged by Annalise Enterprise CXR as having an elevated risk of lung cancer. After 12 months, data on 68 patients with lung cancer who reached treatment stage were collected. We compared Annalise Enterprise CXR implementation data with 12 months of data from retrospective clinical review only (n=113) in 2019, chosen as a pre-coronavirus (COVID-19) baseline.

Results

Following introduction of Annalise Enterprise CXR and adjustments to the clinical pathway:

- patients in NHS Grampian received a CT scan six days more quickly following a CXR report, which was statistically significant (95% CI [3.647,7.369], p<0.001)
- there was a seven day reduction in average time to treatment from the pre-pandemic baseline (mean=58 days, SD=35) to post-implementation (mean=51 days, SD=20), but this was not statistically significant (95% CI [-1.62,14.418], p=0.117)
- ninety-five per cent of patients started treatment within 113 days from referral in the pre-pandemic baseline and 84 days post-implementation but we cannot attribute any differences observed to the implementation of AI, as other changes were also implemented alongside this in NHS Grampian
- there was a 12 per cent increase in the number of patients diagnosed with treatable cancers from a pre-pandemic baseline of 41% (n=65/110) to 53% (n=35/67) post-implementation, but this was not statistically significant (p=0.148)
- NHS Grampian calibrated the Annalise Enterprise CXR software to match their pathway capacity and aim of identifying need for urgent CT, not presence of cancer. In doing so, the software is not being used to its maximum performance capability and may lack sensitivity. Technical performance data analysed in the evaluation indicated that:
    - for Annalise Enterprise CXR compared with clinical review, AI-assisted clinical review of CXRs can successfully prioritise patients who do not have high-risk flag(s) for lung cancer and should not receive an urgent CT (specificity=91%, NPV=99.99%), but not those who should receive an urgent CT (sensitivity=78%, PPV=3%).
    - for Annalise Enterprise CXR compared with clinician-confirmed diagnosis, AI-assisted clinical review of CXRs can successfully identify patients who do not have lung cancer (specificity=91%, NPV=100%), but not patients who are later diagnosed with lung cancer (sensitivity=82%, PPV=1%).
- seventy-two per cent of patients received their CT scan within three days of referral (n=49/68). Twelve per cent received their CT scan on the day of referral (n=8/68), as per the guidance outlined in Scotland's national optimal lung cancer diagnostic pathway.[41]

The results of our 12 month evaluation are consistent with our evaluation at seven months, as reported in our IMTO.[53]

The extent to which the findings from the NHS Grampian service evaluation can be applied to other settings and health boards in NHSScotland remains uncertain. Multiple changes to the clinical pathway were made at the same time as the AI technology was introduced, making it difficult to ascertain the individual effect of each change on the study outcomes. Our full report for the NHS Grampian service evaluation at 12 months is available on request.

Safety

We found one unpublished rapid review conducted by Public Health Wales Evidence Service.[17] The review highlighted that of 28 studies evaluating established AI models (seven focused on lung cancer), none reported the impact of AI tools on safety or harm outcomes. The review emphasised the importance of gathering evidence on the impact of AI on patient safety.

Patient and social aspects

AI supported clinician review of CXRs in patients with suspected lung cancer

We did not find any published evidence on patient or staff (clinical or non-clinical) experiences of AI supported clinician review of CXRs in patients with suspected lung cancer.

AI use in healthcare

We found a report based on an online survey commissioned by the Health Foundation that explored the views of NHS staff and members of the public on use of AI in healthcare.[57] The survey included 1,292 NHS staff members and 7,201 representative members of the public (by age, gender, ethnicity and socio-economic group referenced to the 2021 UK census data).

Data were collected between June and July 2024. In the NHS staff sample there were at least 125 staff across five occupational groupings (medical and dental, nursing and midwifery, scientific and technical, allied health professionals, and administrative and clerical).[57]

In relation to views of the benefits of using AI in healthcare, the survey found that:

- fifty-four per cent of members of the public and 76% of NHS staff were supportive of the use of AI for patient care
- sixty-one per cent of members of the public and 81% of NHS staff were supportive of use of AI for administrative purposes
- fifty-seven per cent of NHS staff were looking forward to AI being used in their role, but this differed across clinical roles.[57]

For views on considerations and challenges of using AI in healthcare, the survey found that:

- seventeen per cent of members of the public and 10% of NHS staff thought that use of AI would make quality of care worse
- fifty-three per cent of members of the public and 65% of NHS staff were concerned that use of AI technologies makes staff feel more distant from patients or clinicians
- twenty-eight per cent of members of the public and 26% of NHS staff were concerned about AI decisions being inaccurate and leading to wrong decisions

- overall, members of the public were more supportive of use of AI in clinical decision making if the results are checked by NHS staff compared with results not being checked
- overall, members of the public between 16 and 64 years old would like to be told when AI is used as part of their healthcare (for example, to help diagnose an illness) and this was particularly important for people aged 65 years and older (16 to 64 years=69%, 65 years and over=82%).[57]

The Health Foundation concluded that on balance, there was a receptive environment for the use of AI in healthcare across members of the public and NHS staff. There were underlying concerns about the use of AI in healthcare, relating contact time between patients and clinicians, decision making accuracy, transparency and the potential for uneven impact of AI across different clinical roles.[57]

Cost effectiveness

Published evidence

We did not identify any published cost effectiveness evidence.

Resource impact analysis

We conducted a resource impact analysis to estimate the effects of introducing AI supported clinical review of CXRs by a radiologist or reporting radiographer using Annalise Enterprise CXR ('AI-enabled pathway'), as implemented in the NHS Grampian service evaluation. The comparator is clinical review of CXRs by a radiologist or reporting radiographer only ('traditional pathway').

The AI-enabled pathway could provide value to the NHS if system efficiencies from streamlining the existing care pathway through the addition of the AI component, plus associated changes to the pathway, lead to changes in cancer stage at diagnosis for lung cancer patients. If lung cancer is diagnosed at an earlier stage this could lead to improvements in patient-centred outcomes such as survival and health-related quality of life. Diagnosis of lung cancer at an earlier stage may also have implications for treatment costs.

As data from the NHS Grampian service evaluation for cancer stage at diagnosis and time to treatment initiation were inconclusive, our resource impact analysis focuses on the period from GP referral for a CXR due to a USC to treatment initiation. We were able to explore the costs of additional resources used in the introduction of the AI-enabled pathway for the NHS Grampian service evaluation and where these were offset, for instance reductions in GP time for arranging CT scans.

The introduction of Annalise Enterprise CXR into the diagnostic pathway in NHS Grampian occurred alongside increased healthcare resource, including:

- additional CXR out-of-hours reporting
- CT slots per week that have been protected to allow for quicker time to CT for patients on this pathway
- an additional member of administration staff being employed to request urgent CT scans for people with an ongoing suspicion of cancer following a CXR, inform patients of their urgent CT scan and coordinate data collection.

Population

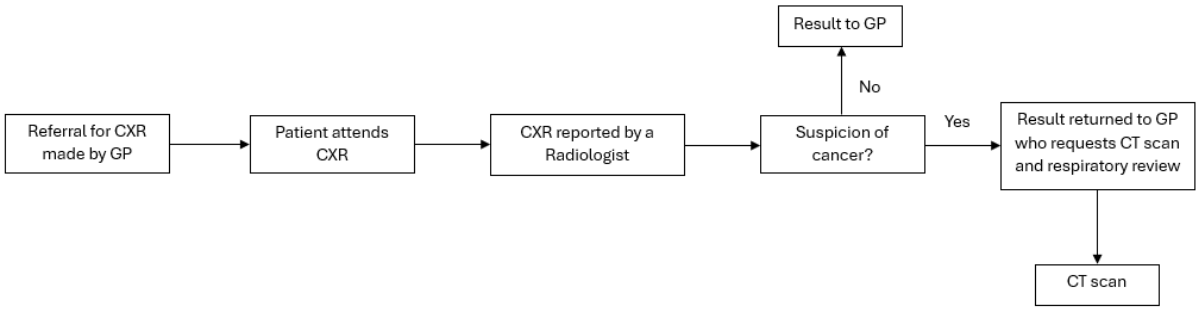
The population for this economic evaluation is patients referred for a CXR by their GP due to USC.

Diagnostic pathways

A representation of the traditional diagnostic pathway from GP referral to CT scan is provided in *Figure 1.*

Patients enter the diagnostic pathway following a referral from their GP for a CXR. After the patient has attended their CXR appointment, a radiologist or reporting radiographer reviews the patient's CXR alongside other patients' CXRs in a chronological order from the date the CXR was taken. If there is a suspicion of cancer, the CXR report is returned to the patient's GP who requests a CT scan and respiratory review. If there is no suspicion of cancer, the CXR report is returned to the patient's GP and no further action is taken.

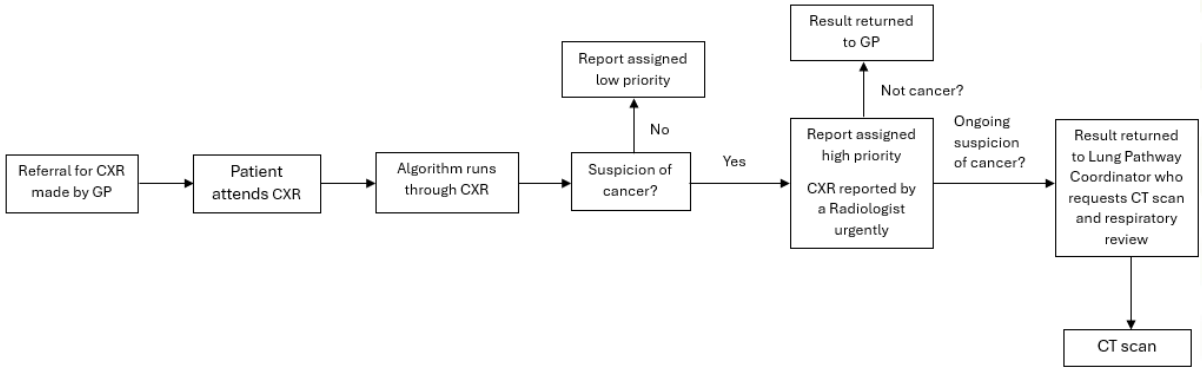
Figure 1: Traditional diagnostic pathway



A representation of the AI-enabled pathway from initial GP referral to CT scan is provided in *Figure 2.*

The pathway differs from the traditional pathway. Prior to the CXR being reported by a radiologist or reporting radiographer, the Annalise Enterprise CXR software assesses the CXR for signs of cancer, assigning it either a low or high priority for review. A radiologist or reporting radiographer then reviews the patients CXR alongside other patients' CXRs in an order consistent with the priority assigned by the software. If after radiologist review there is a suspicion of cancer, a lung pathway coordinator requests a CT scan and respiratory review. If there is no suspicion of cancer, the report is returned the patient's GP and no further action is taken.

Figure 2: AI-enabled diagnostic pathway

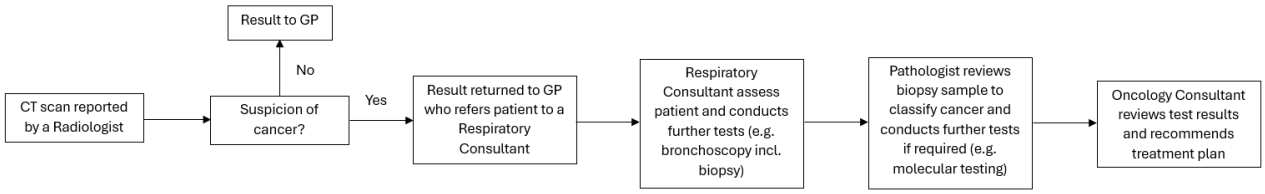


The diagnostic pathway from CT scan to treatment initiation for both the traditional and AI-enabled pathway is unchanged (*Figure 3*).

Following review of the CT scan by a radiologist or reporting radiographer, if there is no suspicion of cancer, a report is returned to the patient's GP and no further action is taken.

If signs of cancer are detected, a report is returned to the GP who refers the patient for an appointment with a respiratory consultant. The respiratory consultant then assesses the patient and conducts further tests (for example, bronchoscopy, including biopsy). Samples from these tests are then reviewed by a pathologist who classifies the patient's cancer and performs further tests if required (for example, molecular testing). The results of these diagnostic images and tests are then reviewed by a consultant oncologist who recommends a treatment plan for the patient.

Figure 3: Diagnostic pathway between CT scan and treatment initiation



Perspective, time horizon and discount rate

The resource impact analysis was conducted from the perspective of NHS Scotland. Given the relatively short time period over which patients progress from referral to diagnosis and treatment initiation (if applicable), no discount rate was applied to costs.

Identification, measurement, and valuation of healthcare resources

The identification and measurement of healthcare resources was based on a combination of engagement with clinical experts working within the diagnostic pathway before and after the implementation of AI-enabled pathway, relevant guidelines and a NICE EVA.[14, 58, 59]

The valuation of resources, in monetary terms, was based on a combination of costs published in a NICE EVA and other unit costs from the Personal and Social Services Research Unit and NHS England.[14, 30, 60]

GP appointments/referrals

GPs are involved at multiple stages in the diagnostic pathway described in *Figures 1 to 3*.

All patients enter the pathway following an appointment with their GP who refers them for a CXR. In the traditional pathway, after a patient's CXR has been reviewed by a radiologist or reporting radiographer, a report returned to their GP. If there is a suspicion of cancer, the GP will request a face-to-face appointment with the patient to communicate the findings of the report and the requirement for a CT scan.

In the AI-enabled pathway, if there is a suspicion of cancer, the hospital's lung pathway coordinator requests the CT scan and communicates this to the patient. In both pathways, if there is no suspicion of cancer on the CXR scan, the report is filed in the patient's medical record. The patient is encouraged to contact their GP practice to discuss the findings in the report via telephone.

After a patient's CT scan has been reviewed by a radiologist or reporting radiographer and a report returned to their GP, the GP will request a face-to-face appointment with the patient to communicate the findings of report. If the report highlights that there is a suspicion of cancer, the GP will refer the patient for an appointment with a respiratory consultant for further examination. If there is no suspicion of cancer, the report is filed in the patient's medical record and management of the patient is continued through primary care. The cost of GP resource use is shown in *Table 4*.

Table 4: Cost of GP resource use

GP costs	Cost
GP appointment (face-to-face, suspicion of cancer traditional pathway only)	£49[60]
GP appointment (telephone, no suspicion of cancer)	£9.40[61]

Diagnostic imaging

The costs for the different types of imaging used in the diagnostic pathways are provided in *Table 5.*

Table 5: Cost of diagnostic imaging resource use

Type of diagnostic imaging	National average unit cost[62]
Plain film	£74
CT scan of two areas, with contrast	£405

Annalise Enterprise CXR

The total cost of introducing Annalise Enterprise CXR was based on published pricing data in our IMTO provided to NHS Grampian by Annalise AI Limited shown in *Table 6*.[53]

Pricing for Annalise Enterprise CXR consists of a one-off implementation fee and an annual subscription fee. The annual subscription fee varied depending on the volume of CXRs analysed. The implementation fee covers installation, integration into the existing radiology information system, and staff training. Ongoing subscription costs are renewable on an annual basis, with fees covering software licensing, annual maintenance, support services and updates. Acquisition costs for the Annalise Enterprise CXR software that could be published (that is, that are not commercial in confidence) were only available from a NICE EVA and so these were used for the resource impact model.[14]

Table 6: Cost of Annalise Enterprise CXR

Software acquisition			
Technology name (Company name)	**Implementation fee**	**Annual subscription**	**Total first year cost**
Annalise Enterprise CXR (Annalise AI Limited)	Not available		£66,200[14]
Additional resources co-occurring with introduction of software			
Resource	**Total annual costs**		**Source**
Lung pathway coordinator	£35,000		NHS Grampian[53]
Additional CXR out-of-hours reporting by radiologist	£113,954		
Additional CT lists	£69,680		

Hospital-based non-radiological healthcare staff

Non-radiological hospital-based healthcare staff are involved at multiple stages in the diagnostic pathway described in *Figures 1 to 3.*

The cost of hospital-based healthcare professional time and the cost of procedures undertaken by these healthcare professionals was taken from the National Schedule of NHS Costs 2023 (*Table 7*).

If a review of a patient's CT scan by a radiologist or reporting radiographer indicates findings that suggest lung cancer, the patient's GP will refer the patient to a respiratory consultant for assessment. The respiratory consultant assesses the patient and, depending on the location of suspected tumour, perform a variety of diagnostic procedures.

For example, if a central tumour is suspected, bronchoscopy (a test to look at the inside of the breathing tubes) and biopsy (collection of tissue samples) for analysis may be performed. If a peripheral tumour is suspected, a percutaneous fine needle aspiration biopsy (a test where a sample of lung tissue is collected by passing a needle into the lung) may be performed.

After these diagnostic procedures are performed, tissue samples collected are analysed by pathology to classify the patient's cancer. The results of these diagnostic images and tests are then reviewed by a consultant oncologist who recommends a treatment plan for the patient.

The cost of hospital-based radiological staff input is included in the costs of different types of diagnostic imaging reported above.

Table 7: Cost of hospital-based healthcare professionals and associated procedures

Department	Hospital-based healthcare staff		National average unit cost[62]
Respiratory Medicine	Consultant-led, Non-Admitted Face-to-Face Attendance, First		£265
Medical Oncology	Consultant-led, Non-Admitted Face-to-Face Attendance, First		£305
Clinical Oncology	Consultant-led, Non-Admitted Face-to-Face Attendance, First		£234
Multidisciplinary teams	Cancer multidisciplinary team meeting		£313
	Hospital-based diagnostic procedures		
Respiratory medicine	Diagnostic Bronchoscopy, 19 years and older		£68
	Proxy for percutaneous fine needle aspiration	Intermediate Thoracic Procedures, 19 years	£606

		and older, with complexity and comorbidity score 0-2	
Direct access Pathology	Cytology		£1
	Histopathology and Histology		£195

Long-term patient outcomes

We reported in an evidence synthesis in 2019 that it is not possible to reach conclusions on the association between cancer outcomes and time intervals to diagnosis and treatment. We were unable to reach a conclusion due to a lack of standardisation around how time intervals are specified and compared, the range of outcomes examined and confounding variables in the evidence base.[63]

We ran a similar evidence synthesis in October 2024 which looked at studies published between June 2019 and October 2024 and was restricted to lung cancer. The search returned 30 results.

Following screening, we identified one relevant systematic review by Zhang et al (2022) that concluded that although current evidence suggests that people with lung cancer experience diagnosis and treatment delays, the association between times to diagnosis and treatment and patient outcomes is not established.[64]

Due to a lack of evidence, we are not able to include costs associated with patient outcomes beyond treatment initiation in the resource analysis.

Analytics and assumptions

A list of assumptions made in the generation of resource impact analysis results is shown in *Table 8.* A full list of model parameters is available in *Appendix 3*.

Table 8: Assumptions used in resource impact analysis

Assumption	Description
Type of communication with patients following CXR report	In the traditional pathway, a patient's CXR is reviewed by a radiologist or reporting radiographer and a report returned to the patient's GP. If there is a suspicion of cancer, the GP will request a face-to-face appointment with the patient to communicate the findings of the report and the requirement for a CT scan.

Assumption	Description
	If there is no suspicion of cancer on the CXR scan, the report is filed in the patient's medical record. The patient is encouraged to contact their GP practice to discuss the findings in the report via telephone. In the AI-enabled pathway, if there is a suspicion of cancer on the CXR, a hospital-based lung pathway coordinator will request the CT scan.
Type of GP appointment following CT report	After a patient's CT scan has been reviewed by a radiologist or reporting radiographer and a report returned to their GP, the GP will request a face-to-face appointment with the patient to communicate the findings of the report.
% of patients referred for a CT scan following CXR report	The percentage of patients referred for a CT scan following radiologist or reporting radiographer review of their CXR is assumed to be equal across the traditional and AI-enabled pathways.
% of patients requiring further investigations following CT report	The percentage of patients requiring further investigations following radiologist or reporting radiographer review of their CT scan is assumed to be equal across the traditional and AI-enabled pathways.

Results

The aggregated resource impact analysis results are shown in *Table 9.* The results of the analysis show that the introduction of an AI-enabled pathway, as implemented in NHS Grampian, is associated with an additional cost of £274,790 compared with the traditional pathway without AI. The incremental cost was equivalent to an additional cost per patient of £3.59. The disaggregated results are shown in *Appendix 4*.

Table 9: Aggregated resource impact analysis results

Pathway	Total costs	Incremental costs	Per patient total costs	Per patient incremental costs
Traditional	£10,426,249	-	£136.16	-
AI-enabled	£10,701,040	£274,790	£139.74	£3.59

The incremental additional cost associated with the AI-enabled pathway was driven by the cost of the AI software (implementation fee and annual subscription) and additional staff resource co-occurring with the introduction of AI software (lung pathway coordinator, additional CXR reporting

and additional CT lists). These additional costs were only partially offset by reductions in costs associated with GP-led coordination of CT scans.

We were not able to consider potential changes in patient outcomes that could be achieved through reductions in time to treatment initiation which numerically improved in the NHS Grampian service evaluation due to a lack of evidence.

The NHS Grampian service evaluation did not capture long-term patient outcomes and evidence for extrapolating changes in time to treatment in lung cancer were also not available.

Ongoing research

We identified four ongoing clinical trials based in the UK (*Table 10*), with target recruitment ranging from 33 to 150,000 The primary and secondary outcomes from the ongoing studies are presented in *Appendix 5*.

Table 10: UK-based ongoing clinical trials on the use of AI supported clinical review of CXRs from patients with suspected lung cancer

Trial ID	Study title and description	AI tool	Estimated completion
NCT05489471 Country: UK (England) Target recruitment: 20,000	A study to assess the impact of an AI system on CXR reporting. A prospective study aiming to assess the impact of AI on assessing abnormalities on CXR, sensitivity for detection of lesions, impact on reported confidence and the impact of AI on turnaround times and patient pathway from CXR to CT.	Lunit INSIGHT CXR	given as July 2023[a]
ISRCTN78987039 Country: UK (England) Target recruitment: 150,000	Impact of immediate AI-enabled patient triage to chest CT on the lung cancer pathway. A multi-centre prospective RCT aiming to assess clinical effectiveness of AI for reading and worklist prioritisation on time to diagnosis of lung cancer and time to CT from CXR.	qXR (Qure.ai)	March 2025
NCT06044454 Country: UK (Scotland)	Radiograph Accelerated Detection and Identification of Cancer in the Lung (RADICAL). A prospective clinical effectiveness study across three sites in NHS GGC to assess the	qXR (Qure.ai)	April 2025

Trial ID	Study title and description	AI tool	Estimated completion
Target recruitment: 60,000	clinical effectiveness of qXR to prioritise patients with suspected lung cancer for follow-up CT.		
NCT06075836 Country: UK (England) Target recruitment: 33	AI-Assisted Detection of CXRs (AID-CXR). A retrospective validation study (observational - cohort) aiming to assess the use of AI for diagnostic accuracy, speed and confidence of healthcare professionals in inpatient and emergency departments.	Lunit INSIGHT CXR	June 2025[b]

[a]*the trial is registered as 'not yet recruiting'. No further update on progress in the registry as of January 2025.*

[b]*the trial is registered as 'active, not recruiting'. No further update on progress in the registry as of January 2025.*

We identified three pilot studies and one mixed-methods evaluation (*Table 11*). The three pilot studies are being conducted in one NHS trust each, while the mixed-methods evaluation covers 11 networks of NHS Trusts.

Table 11: UK-based (England) ongoing pilot studies and mixed-methods evaluation on the use of AI supported clinician review of CXRs from patients with suspected lung cancer

NHS Trust or region	Study description	Pilot study website	AI tool
NHS Epsom and St Helier Trust (ESHT)	Use AI to achieve standard lung cancer timelines for diagnosis and facilitate same day CT appointments	https://annalise.ai/case-study/accelerating-lung-cancer-care-in-south-west-london-with-decision-support-ai/	Annalise Enterprise CXR
Frimley Health NHS Foundation Trust[a]	Use AI to support the efficient triaging and prioritisation of patients with lung cancer	https://www.qure.ai/news_press_coverages/early-findings-of-ai-study-at-frimley-health-nhs-foundation-trust-show-99-7-accuracy-in-triaging-chest-x-rays-as-normal	qXR Qure.ai
NHS Greater Manchester Cancer Alliance	Use AI to aid clinical decision making and provide earlier diagnosis for symptomatic lung	J50065_GMCA_Annual_Report_V3.pdf (gmcancer.org.uk)	qXR Qure.ai

NHS Trust or region	Study description	Pilot study website	AI tool
	cancer, quicker results and speed up the pathway		
11 networks of NHS Trusts	Two phase evaluation of AI implementation for chest diagnostics, as part of the AI Development Fund (AIDF)	https://fundingawards.nihr.ac.uk/award/NIHR167339	Not specified

[a]*previously identified in our published IMTO.*

Early results from the six-month pilot of Annalise Enterprise CXR based in NHS ESHT show that a significantly higher proportion of patients are receiving same day CT or CT within 72 hours. The final results for the six-month pilot in NHS ESHT were due to be presented at the end of 2023 but do not appear to be available publicly. For the ongoing pilot of qXR (Qure.ai) in Frimley Health NHS Foundation Trust, early results show a 99.7% accuracy of the AI software in triaging CXRs as 'normal' (*Table 5*).

The mixed-methods evaluation is being conducted by the National Institute for Health and Care Research Rapid Evaluation Team, to support the work of the AIDF.[65] NHS England announced the AIDF in 2023, which is funding 12 imaging networks across England (64 Trusts) to prioritise use of AI to support earlier diagnosis of lung cancer.[66]

The evaluation of the work associated with the AIDF is being conducted in two phases. The first phase aims to explore factors influencing implementation, as well as identifying settings and sources for a further evaluation phase, or any long-term evaluations. Key research questions that will be addressed include cost effectiveness, patient and staff perspectives, as well as impacts of AI on CXRs and CTs in terms of inequalities, diversity and inclusion. The authors of the AIDF evaluation outline that the evaluation is ongoing.[65]

Conclusion

There is currently no published evidence to support the clinical and cost effectiveness of using AI-assisted clinician review of CXRs to improve the detection of lung cancer.

There is local service evaluation data from NHS Grampian suggesting that using AI-assisted review of CXRs alongside changes to the clinical pathway, may help prioritise work for clinical staff by assisting in triaging scans that do not require urgent CT referral. The data shows that for AI-assisted review of CXRs compared with the reference standard of clinician review of CXRs (identification of suspicious scans), specificity is between 83.2% and 91%. NPV is between 99.0% and 99.9%. AI-assisted clinician review of CXRs and clinical pathway changes may also lead to quicker time to treatment and earlier identification of patients with treatable lung cancer but the results are inconclusive.

The range of variables that must be taken into account in the assessment of any diagnostic use of AI has been demonstrated in this review. AI performance may vary across different AI software, will depend on the variable data sets used to train the AI, and will depend on how the software is applied in clinical settings.

For example, AI software performance may be adjusted to suit local clinical capacity and staff expertise. These variations described make it difficult to draw firm conclusions from the available data.

Our resource impact analysis of the diagnostic pathway found that AI supported clinician review of CXRs may be cost incurring, compared with the traditional diagnostic pathway. Additional software and staff costs (as implemented within NHS Grampian) were only partially offset by a reduction in staff time elsewhere in the pathway. The model did not account for resource consequences beyond treatment initiation due to the absence of outcome and effectiveness data. We did not identify any published cost or cost effectiveness studies. Our analysis appears to be the first attempt at estimating the resource impact of this type of technology within the healthcare sector.

Ongoing studies will contribute to the evidence base in 2025 for clinical effectiveness, cost effectiveness, AI performance and experience (patients and staff) for AI-assisted clinician review of CXRs in suspected lung cancer. Further evidence will be required to support decision making on the use of AI alongside clinical review of CXRs to support earlier detection of lung cancer in Scotland.

Identified research gaps

The service evaluation conducted in NHS Grampian was a positive addition to the evidence base, by describing the impact of AI-assisted clinical reviews of CXRs on clinical outcomes, healthcare costs and resource, software performance and the associated pathway changes required as suggested by NICE.[1, 14] Full and verified results for the RADICAL pragmatic mixed-methods study in NHS GGC will not be available until after the study conclusion in April 2025.

Overall, the research gaps remain in the evidence base as set out by NICE.[1, 14] Further research and evaluation are needed to inform future decision making, focusing on the following outcomes:

- impact of AI on clinical decision making
- healthcare costs and resource use
- impact on clinical outcomes (for example, CXR review and reporting time, time to CT referral and diagnosis)
- diagnostic accuracy in different settings and groups (for example, younger non-smoking women, people with asthma or chronic obstructive pulmonary disease and people with a family history of lung cancer)
- technical failure rates and rejection rates
- pathway changes required for software implementation

- patient and staff views.

Future research and evaluation of AI software should also include developing training datasets that are representative of clinical practice or the local population where the software will be used.[13] Recommended frameworks for the ethical development and reporting of AI studies should also be followed to promote equity, transparency and reduce future harm.[42-51] Contributors to the future evidence base should consider using our Evidence Framework to collect relevant data that can guide decision making.

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Appendix 1: abbreviations

AI	artificial intelligence
AID-CXR	AI-Assisted Detection of CXRs
AIDF	Artificial Intelligence Diagnostics Fund
ALND	auto lung nodule detection
ANIA	accelerated national innovation adoption
CADe	computer-aided detection
CADx	computer-aided diagnosis
CAST	computer-assisted triage
CI	confidence interval
COVID	coronavirus disease
CT	computed tomography
CXR	chest X-ray
DALY	disability-adjusted life years
DHSC	Department of Health and Social Care
ESHT	Epsom and St Helier Trust
EVA	early value assessment
GGC	Greater Glasgow and Clyde
GP	general practitioner
IDA	Innovation Design Authority
IMTO	innovative medical technology overview
MDT	multidisplinary team
MHRA	Medicines and Healthcare products Regulatory Agency
MRI	Magnetic Resonance Imaging
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
NPV	Negative Predictive Value
NSCLC	non-small cell lung cancer
PHS	Public Health Scotland

PPV	positive predictive value
RADICAL	radiograph accelerated detection and identification of cancer
RCT	randomised controlled trial
SCLC	small cell lung cancer
SD	standard deviation
SG	Scottish Government
SHTG	Scottish Health Technologies Group
UK	United Kingdom
USC	urgent suspicion of cancer

Appendix 2: definitions of diagnostic accuracy terms

NPV: the probability that, given a negative test result, a person does not have the disease.[67]

PPV: the probability that, given a positive test result, a person does not have disease.[67]

Sensitivity: the probability that a person having a disease will be correctly identified by a clinical test. This is the number of true positive results divided by the total number with the disease.[68]

Specificity: the probability that a person not having a disease will be correctly identified by a clinical test. The is the number of true negative results divided by the total number of those without the disease.[68]

Appendix 3: model parameters

Clinical parameters		
Description	Traditional	AI-enabled
	Value	
Population size[a]	76,576	
% of patients referred for CT scan following CXR report[a]	0.27%	0.27%
% of patients requiring further investigations following CT scans[a]	54.62%	

[a] *Data source = SHTG evaluation of NHS Grampian dataset.*

Cost of healthcare resource parameters	
Resource	Unit Cost
Annalise Enterprise CXR	£66,250[14]
Lung pathway coordinator[b]	£35,000
Additional CXR out-of-hours reporting by radiologist[b]	£113,954
Additional CT lists[b]	£69,680
GP appointment face-to-face (initial)	£49[60]
CXR	£74[62]
GP appointment face-to-face follow-up (due to suspicious finding on CXR)	£49[60]
GP appointment telephone follow-up (no suspicious finding on CXR)	£9.40[61]
CT	£405[62]
GP appointment face-to-face follow-up (regardless of CT finding)	£49[60]
Respiratory consultant face-to-face appointment	£265[62]
Bronchoscopy (including biopsy)	£685[62]
Percutaneous fine needle aspiration (including biopsy)	£606[62]
Cytology	£1[62]

Cost of healthcare resource parameters	
Resource	**Unit Cost**
Histopathology and histology	£195[62]
Clinical oncology consultant face-to-face	£234[62]
Medical oncology consultant face-to-face	£305[62]
Multidisciplinary team meeting	£313[62]

[b] *Data source = NHS Grampian.*

Appendix 4: Disaggregated resource impact analysis results

Resource		Pathway					
		Traditional		AI-enabled		Incremental	
		Quantity	Cost (£)	Quantity	Cost (£)	Quantity	Cost (£)
AI software	Annalise Enterprise CXR	NA		NA	66,250	NA	66,250
Extra resources added to NHS Grampian diagnostic pathway	Lung pathway coordinator				35,000		35,000
	Additional CXR out-of-hours reporting by radiologist				113,954		113,954
	Additional CT lists				69,680		69,680
GP	Face-to-face initial appointment	76,576	3,752,224	76,576	3,752,224	-	-
Diagnostic imaging	CXR	76,576	5,666,624	76,576	5,666,624	-	-
GP	Face-to-face follow-up due to	206	10,094	0	0	-206.00	-10,094

Resource		Pathway					
		Traditional		AI-enabled		Incremental	
		Quantity	Cost (£)	Quantity	Cost (£)	Quantity	Cost (£)
	suspicious finding on CXR						
	Telephone call follow-up as no suspicious finding on CXR	76,370	717,878	76,370	717,878	-	-
Diagnostic imaging	CT	206	83,430	206	83,430	-	-
GP	Face-to-face follow-up to discuss CT (regardless of findings)	206	5,513	206	5,513.19	-	-
Respiratory medicine	Consultant-led appointment (face-to-face)	113	29,816	112.51	29,816.22	-	-
Outpatient procedures	Diagnostic bronchoscopy	113	77,072	112.51	77,072.13	-	-
Direct access pathology	Cytology	113	112	112.51	112.51	-	-
	Histopathology and histology	113	21,940	112.51	21,940.24	-	-

Resource		Pathway					
		Traditional		AI-enabled		Incremental	
		Quantity	Cost (£)	Quantity	Cost (£)	Quantity	Cost (£)
Multidisciplinary teams	Cancer multidisciplinary team meeting	113	35,217	112.51	35,216.90	-	-
Clinical oncology	Consultant-led appointment (face-to-face)	113	26,328	112.51	35,216.90	-	-
	Total		10,426,250		10,701,040		274,790
	Average per patient		136.16		139.74		3.59

Appendix 5: Outcomes from UK-based ongoing studies

Trial ID	UK country	AI tool	Primary outcome(s)	Secondary outcome(s)
NCT05489471	England	Lunit INSIGHT CXR	Radiologist performance review: improve radiologist performance by AI flagged missed findings (percentage error rate).	■ number of nodules and cancers detected by AI only (percentage of overall number of detected nodules and tumours) ■ time from CXR to CT scan for suspected cancer using AI generated worklists compared with pre-AI ■ time from CXR to CXR report in AI worklist compared with pre-AI
NCT06044454	Scotland	qXR (Qure.ai)	Time to 'decision to recommend CT' or decision not to undertake CT for CXR acquired with USC (CXR to CXR report).	■ time from CXR to CXR report ■ time to diagnosis ■ time to treatment initiation ■ number of hospital visits during screening pathway ■ hospitalisation within six and 12 months of CXR scan ■ percentage of CXRs not identified by qXR as suspected lung cancer that the radiologist refers for CT (USC) ■ percentage of non-USC that are referred for CT with detection of lung cancer ■ percentage of CXRs reported by qXR where features have not been correctly identified that

Trial ID	UK country	AI tool	Primary outcome(s)	Secondary outcome(s)
				would have resulted in a different course of investigation, diagnosis or treatment ■ model performance (sensitivity, specificity, positive and negative predictive values) ■ health economic evaluation (per patient healthcare utilisation costs to model cost benefits of qXR, including implementation of supported reporting of normal CXR) ■ qualitative evaluation to assess acceptability and barriers to scale-up and implementation.
ISRCTN78987039	England	qXR (Qure.ai)	Difference in time from CXR to diagnosis (days) of lung cancer for people with have CXRs with AI support and are prioritised for urgent review. The comparator are CXRs that have an AI read but are not prioritised for urgent review. Difference in time from CXR to CT (days) of lung cancer for people with have CXRs with AI support and are prioritised for urgent review. The comparator are CXRs that have an AI read but are not prioritised for urgent review.	■ time to first outpatient appointment ■ time to treatment ■ agreement between AI and human readers (normal/abnormal scans) ■ number of urgent lung cancer referrals ■ incidence of lung cancer ■ stage of lung cancer at diagnosis ■ cost effectiveness of AI support at time of CXR and prioritisation for urgent review (costs per patient diagnosed, per percentage increase in early-stage diagnosis, possibly per quality-adjusted life years but dependent on published studies)

Trial ID	UK country	AI tool	Primary outcome(s)	Secondary outcome(s)
				■ the protocol references staff interviews as part of a larger work programme, but no further information is provided.
NCT06075836	England	Lunit INSIGHT CXR	Performance of AI algorithm (compared with the reference standard): ■ sensitivity ■ specificity ■ area under the receiver operating characteristic curve. Performance of readers with and without AI support: ■ sensitivity ■ specificity ■ area under the receiver operating characteristic curve. Reader speed with and without AI support.	■ none are reported.