LUNG CANCER
POLICY NETWORK
An initiative of the Lung Ambition Alliance

Lung cancer screening: learning from implementation

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Addendum

This report was originally published in August 2022. It was updated in January 2024 to correct some information in *Case study 6* (page 22). No other changes were made at this time.

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Foreword

This report marks the launch of the Lung Cancer Policy Network, which aims to elevate lung cancer as a policy priority worldwide. The initial focus of the Network is to support the implementation of low-dose computed tomography (LDCT) screening programmes. We draw on expertise and experience from lung cancer screening implementation around the world to outline how specific challenges have been addressed in practice in different countries, in the hope of providing useful guidance for implementation elsewhere.

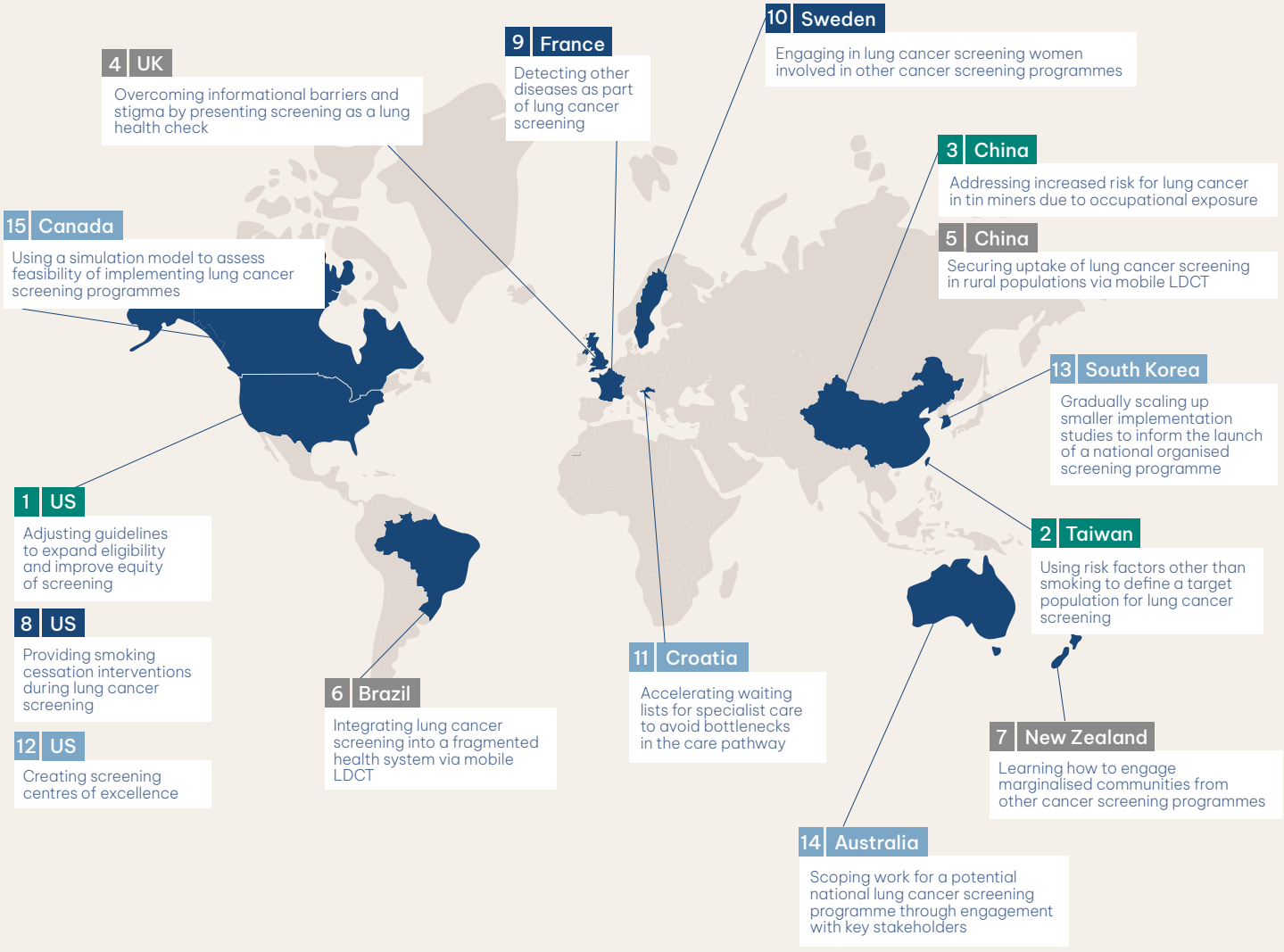
Despite the strong evidence base for targeted LDCT screening, government investment in implementation to date has been far from optimal. More than three decades of research and evidence have laid the foundations on which national, regional and local screening programmes can be developed. Screening programmes have already been established in some countries, notably the US and a small number of countries in Europe and Asia, but they are currently the exception rather than the norm. The lessons learnt from implemented LDCT lung cancer screening programmes provide an enhanced understanding of how to refine and optimise the approach to screening, ensuring it is contextually relevant and tailored to each country's specific population and health system needs.

We hope this report supports policymakers and the wider cancer community in advancing the implementation of LDCT screening for lung cancer. Now that we have evidence of the benefits of screening, it is time to accelerate its implementation to tackle lung cancer. We can bring real change to lung cancer detection, diagnosis and treatment, and ensure that more people diagnosed with lung cancer survive. It is our hope that the findings contained in this report can provide a blueprint for governments and other institutions to build their own screening programmes.

The Lung Cancer Policy Network

Map of case studies

The report showcases examples of case studies of lung cancer screening programmes drawn from around the world. Each case study is linked to one of the four lessons from implementation discussed in detail in the report.



Lesson 1

Tailor eligibility criteria for screening to reach those at highest risk of lung cancer

Lesson 2

Develop targeted outreach to address potential barriers to participation in lung cancer screening

Lesson 3

Amplify the impact of lung cancer screening by integrating it into other public health initiatives

Lesson 4

Ensure the full integration of lung cancer screening into health systems

LDCT: low-dose computed tomography.
Case studies included in this report are individual examples from across the world and are by no means exhaustive.

Executive summary

Lung cancer is currently the leading cause of cancer-related deaths in the world, but this does not have to be the case. Targeted lung cancer screening using low-dose computed tomography (LDCT) has the potential to shift the detection of lung cancer to earlier stages when prognosis is considerably better. As a result, targeted screening offers the opportunity to significantly improve the survival rates, and quality of life, of people diagnosed with lung cancer.

Progress in lung cancer survival has been slow owing to complex factors, such as overlap in symptoms with other common respiratory infections, late-stage presentation, and misconceptions towards lung cancer and people diagnosed with lung cancer. A more proactive approach is needed to prioritise LDCT screening in national and international public health strategies and national cancer plans. This could help ensure that more people are able to access timely care, and survive lung cancer.

Several decades of implementation research have provided important lessons that can help pave the way for successful implementation of LDCT screening:

- **Tailoring eligibility criteria for screening to local contexts is essential to reach individuals at highest risk of lung cancer.** Clinical trials have often focused LDCT screening on people who smoke and people who used to smoke. While smoking is a major risk factor for lung cancer, other risk factors are also significant. National screening guidelines and eligibility criteria should be flexible and reactive to new evidence, to ensure that populations at the highest risk of lung cancer are captured in screening programmes.
- **Targeted outreach is needed to ensure lung cancer screening programmes do not exacerbate existing inequalities in lung cancer.** There are existing inequalities, in terms of access to lung cancer care and care outcomes, which need to be addressed when implementing a screening programme. Securing participation from people who are at a high risk of lung cancer is fundamental. Targeted interventions that include positive messaging and shared decision-making can help tackle some of these barriers and secure attendance from populations that may experience difficulty in accessing or engaging in screening programmes.
- **The success of lung cancer screening can be further amplified by combining it with other public health initiatives, such as smoking cessation.** Smoking cessation results in better clinical outcomes for people who participate in screening and improves lung cancer survival rates. LDCT can also offer the opportunity to detect other common diseases, further increasing its efficiency and cost-effectiveness.

➜ **Screening programmes need to be fully built into lung cancer care pathways and existing health system governance.** Strong coordination and investment is required across the entire lung cancer care pathway, with a clear understanding of workforce and capacity needs, and careful planning.

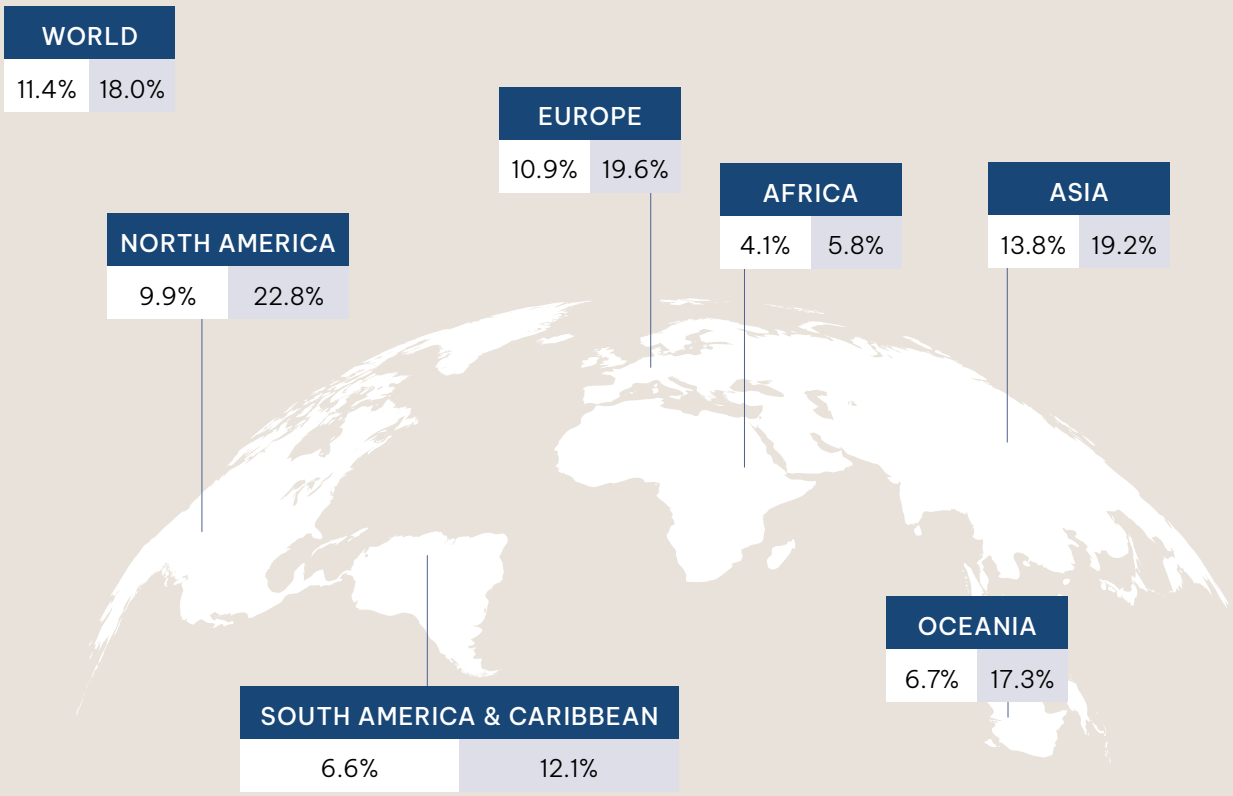
We already have a firm foundation from which large-scale national LDCT screening programmes can be developed. We need to build political will to raise lung cancer up on the policy agenda and make progress in lung cancer screening a central pillar of cancer control strategies globally. By acting now, governments have a unique opportunity to reduce the toll of lung cancer on their populations.

Four key lessons from lung cancer screening implementation

Lung cancer screening: an introduction

The global impact of lung cancer is considerable. In 2020, more than 2.2 million people were diagnosed with lung cancer.[1] It incurs the greatest economic burden of all cancers in terms of lives lost, impaired quality of life and productivity losses owing to premature mortality.[2-4] It also accounts for around one fifth of all cancer deaths worldwide (*Figure 1*) – more than breast and colorectal cancers combined.[1] The incidence and mortality of lung cancer are inequitably distributed across the population, with particular groups at an increased risk of developing lung cancer and of a poor prognosis.[5 6]

Figure 1. The global and regional public health burden of lung cancer[1]

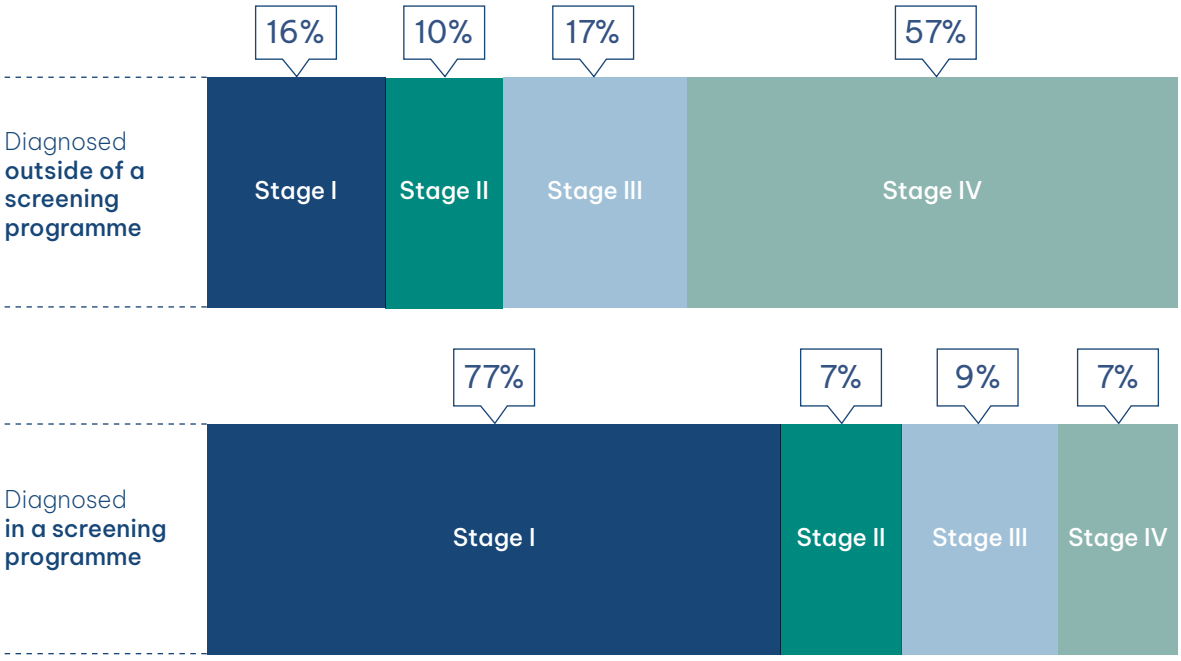


LEGEND	New cases of lung cancer as a percentage of total cancer cases	Deaths from lung cancer as a percentage of total cancer deaths

Data by region reported by the World Health Organization's Global Cancer Observatory (GLOBOCAN, 2020)

Progress in survival in lung cancer has been slow, largely due to the impact of late-stage presentation. More than 40% of people with lung cancer are diagnosed at stage IV, when the five-year survival rate is less than 10%; approximately 20% of people are diagnosed at stage I, when five-year survival is considerably higher (68–92%) (*Figure 2*).[7,8] Among the many reasons for late presentation is that symptoms of lung cancer are often overlooked because of their similarity with common respiratory infections, such as bronchitis, and more recently COVID-19.[9,10] Owing to the link between smoking and lung cancer, stigma also acts as a powerful barrier to people receiving appropriate and timely care. Stigma can affect the way that health professionals engage with individuals and influence how comfortable a person feels accessing healthcare.[11]

Figure 2. Stages of lung cancer diagnosed inside and outside of a screening programme[12]



Data from Sands *et al* (2021).

Early detection plays a crucial role in reducing the mortality burden of lung cancer by increasing the number of people who can benefit from treatments such as surgery. Curative surgery is only effective if the cancer is detected and treated early.[13] Early detection can transform lung cancer from a fatal to a treatable disease for many people, dramatically improving their quality of life. Detecting lung cancer at an earlier stage could also markedly reduce its economic and public health burden.[14,15]

We are at a critical juncture in the implementation of lung cancer screening. The COVID-19 pandemic has had a particularly damaging impact on lung cancer outcomes, exacerbating the risk of late presentation.[10 16] At the same time, the pace of implementation of large-scale lung cancer screening programmes has been too slow. Despite over three decades of research, clinical trials and other evidence demonstrating the benefits of lung cancer screening with low-dose computed tomography (LDCT),[17] many policymakers have shown hesitancy towards committing to national screening programmes. The stage of implementation varies considerably around the world; some countries have either formally committed to setting up nationwide programmes targeting high-risk individuals or are at different stages of implementation pilots; others have not yet embarked on this process.[18-25] A more proactive approach is needed to ensure LDCT screening is prioritised in national and international early cancer detection strategies, and built into national cancer plans.

Implementing large-scale screening programmes is, invariably, complex. Screening includes an end-to-end pathway: it starts with identifying people at high risk of lung cancer who are eligible for screening, leading to referral for timely diagnosis and treatment.[26] To be successful, this pathway must be fully integrated into all facets of the health system – governance, workforce planning with care coordination, data and infrastructure.[27] This requires careful consideration of health system characteristics within each setting, as well as local epidemiology and cultural norms (*Box 1*).

The knowledge gained from the implementation of large-scale organised lung cancer screening programmes and pilots around the globe can be used to guide new programmes. Informed by experts from the global lung cancer community, this report presents four key lessons focused on strategies that can be embedded into screening programmes to ensure implementation is tailored to national contexts and optimised for success.

Box 1. Why screening and why LDCT?

Why do we perform screening in high-risk populations?
Effective screening has the potential to reduce poor outcomes from a disease by detecting it earlier (secondary prevention). As such, screening is an essential component of early detection; it involves testing healthy individuals to identify cancers before symptoms appear.[28]

Why are we advocating for LDCT screening for lung cancer?
There is widespread evidence that LDCT is a safe and effective screening tool for lung cancer in high-risk individuals. Multiple large-scale randomised controlled trials have shown that targeted lung cancer screening with LDCT among people who smoke or used to smoke heavily can reduce mortality by nearly one quarter, by shifting lung cancer detection to an earlier stage (*Figure 2* and *Appendix*).[29-31] The benefits significantly outweigh potential risks associated with screening: LDCT screening shows a negligible risk from radiation exposure, and false positives are low if screening is performed to high quality standards.[12]

Lessons learnt from implementation of lung cancer screening programmes

Lesson one

Tailor eligibility criteria for screening to reach those at highest risk of lung cancer

Lesson two

Develop targeted outreach to address potential barriers to participation in lung cancer screening

Lesson three

Amplify the impact of lung cancer screening by integrating it into other public health initiatives

Lesson four

Ensure the full integration of lung cancer screening into health systems

Lesson one

Tailor eligibility criteria for screening to reach those at highest risk of lung cancer

Context

The ultimate aim of lung cancer screening programmes is to reduce mortality through earlier detection. To achieve this, screening programmes need to capture those at highest risk of lung cancer who are most likely to benefit. This requires defining the target population based on current evidence of known risk factors in each region. Defining appropriate and adaptable screening eligibility criteria is a critical first step for any screening programme. Most clinical trials performed to date have focused LDCT screening on people within a certain age bracket who smoke heavily and people who used to smoke heavily (*Box 2*).[32] While smoking is a major risk factor for lung cancer, there is growing recognition of the importance of other factors as well.

Box 2. Terms related to smoking used in this report

- **People who smoke or used to smoke heavily:** definitions for this can vary, but it is often measured by using a minimum number of packs of cigarettes smoked per day multiplied by the number of years a person has smoked (pack-years); for those who no longer smoke, it is this amount within a minimum number of years since quitting.[33 34]
- **People who do not smoke:** people who do not currently smoke but who have smoked at least 100 cigarettes in their lifetime, perhaps intermittently or for a short period of time, and not recently.[35]
- **People who have never smoked:** people who have smoked between 0 and 100 cigarettes during their lifetime and do not currently smoke.[35]

What have we learnt from implementation so far?

Screening programmes have adapted eligibility criteria originally used in randomised controlled trials to the local epidemiology of their population. Adapting eligibility criteria ensures that groups of people at high risk of lung cancer who might otherwise not have been captured using smoking status and age are offered screening.[36 37] Moreover, it should reduce the risk of screening programmes inadvertently perpetuating existing inequities in lung cancer.[36]

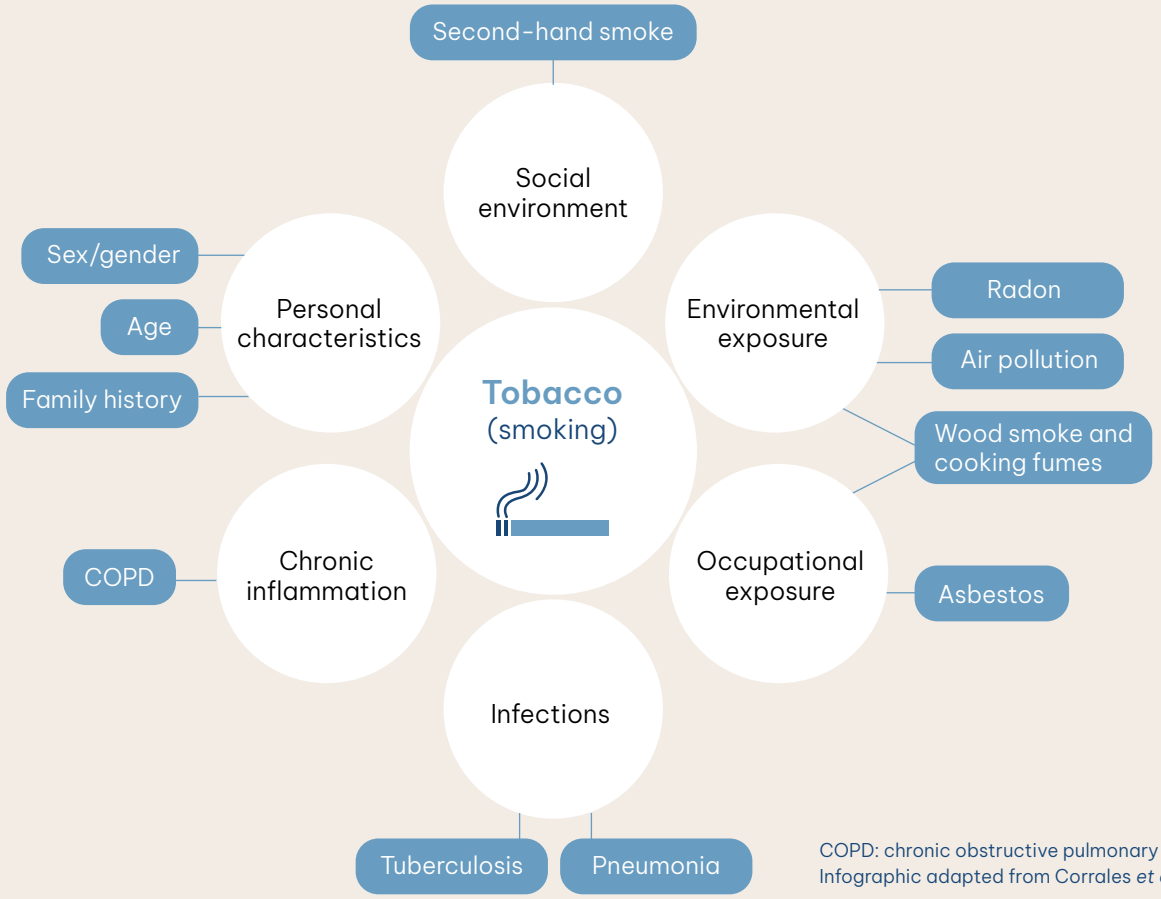
National screening guidelines should be flexible and react to new evidence to ensure that the populations at highest risk of lung cancer are captured. Flexibility is required so that these populations continue to be targeted for enrolment during both the pilot phase and long-term implementation (*Case study 1*). Additionally, protocols based on evidence from implementation in certain geographies (e.g. the US or Europe) are often not appropriate for populations elsewhere (e.g. Asia), reinforcing the need for country-specific guidelines.[38-41]

Case study 1. US: adjusting guidelines to expand eligibility and improve equity of screening

In 2013, the US Preventive Services Task Force recommended lung cancer screening for people aged 55–80 with a 30 pack-year smoking history (e.g. people who smoked one pack of cigarettes a day for the past 30 years, or two packs a day for the past 15 years).[42] Eligible participants either had to be currently smoking or had to have stopped smoking within the past 15 years. In 2021, the task force modified its guidelines by lowering the age for screening eligibility to 50 and number of pack-years to 20. The new guidelines aim to include more women and racial or ethnic minority groups, especially African Americans, as previous research indicated the 2013 guidelines may have exacerbated existing inequalities in lung cancer diagnosis and outcomes.[43-45]

Expanding eligibility criteria beyond smoking status can help capture more people at high risk of lung cancer. While tobacco use and older age remain the major and best-documented risk factors for lung cancer,[46] other risk factors include air pollution, exposure to occupation-related carcinogens, and genetic predisposition (*Figure 3*).[47] Several studies have demonstrated the benefits of targeting screening to people with previous occupational exposure to asbestos.[48-50] Also, given the rising prevalence of lung cancer among people who have never smoked,[51-53] many countries are actively investigating how to approach LDCT screening in this population, as they may be at high risk of developing lung cancer owing to other risk factors[54-56] (*Case studies 2* and *3*).

Figure 3. Examples of common risk factors for lung cancer[47 57]



COPD: chronic obstructive pulmonary disease.
Infographic adapted from Corrales *et al* (2020).

Case study 2. Taiwan: using risk factors other than smoking to define a target population for lung cancer screening

In Taiwan, lung cancer is the leading cause of cancer mortality and an estimated 53% of cases occur in people who have never smoked.[53] The Taiwan Lung Cancer Screening for Never Smoker Trial (TALENT) was designed to inform a strategy for screening in people who have never smoked and to ensure all people at high risk of lung cancer could benefit from a national LDCT programme. Between 2015 and 2019 the study recruited 12,011 participants aged 55–75 who had one of the following risks: a family history of lung cancer; exposure to passive smoking or long-term exposure to cooking fumes; dormant or active tuberculosis infection; or chronic obstructive pulmonary disease. Of those found to have lung cancer, in 96.5% of cases it was detected at early stages. The prevalence of lung cancer was higher in participants with a family history (3.3%) compared with those without (2%).[58] Based on these findings, Taiwan started to implement a national LDCT screening programme from 1 July 2022, in which both people who smoke heavily and people who do not smoke but have a family history of lung cancer would be eligible to participate.[58] Other countries in Asia are also investigating how to identify populations for screening who have never smoked but are at high risk of lung cancer.[59 60]

Case study 3. China: addressing increased risk of lung cancer in tin miners due to occupational exposure

Yunnan province in China has the largest tin mining industry in the world.[61] Since the 1970s, studies targeted a population of tin miners in Geiju city for lung cancer screening using chest X-ray and sputum testing.[61,62] At the time, this population had the highest rates of male lung cancer mortality in the country.[63] In 2014, the same population was targeted as part of the Lung Cancer Screening Program in Rural China (LungSPRC), a government-sponsored national LDCT screening programme.[62] Both men and women were invited for annual LDCT screening if they had a history of working in the mining industry; smoking history and age were also considered. The programme found that tin miners had high levels of lung cancer compared with those who did not work in mining. After five years of screening, the proportion of participants diagnosed with stage I lung cancer increased from 37.5% to 75%.[62] A similar programme also targeted rural populations exposed to occupational carcinogens at the Dagang oil field (Tianjin) for LDCT screening.[40]

To ensure that screening is targeted to those at highest risk of lung cancer, risk prediction models should be taken into account when developing population-specific eligibility criteria. Risk prediction models are powerful tools that can be adapted to ensure that screening is targeted to people at highest risk of lung cancer in a specific population. For example, they can be applied to primary care databases to identify candidates for screening who might have been missed by considering only smoking status and age.[64,65] The models can incorporate multiple important risk factors, such as family history of cancer or pneumonia, occupational exposure (e.g. to asbestos), race and ethnicity, as well as underlying conditions that may increase a person's risk of lung cancer (*Table 1*).[66,67] When applying risk prediction models, it is important to consider how they might be embedded into lung cancer screening programmes, including which resources are required to ensure their successful uptake by healthcare professionals.[32]

Table 1. Examples of risk prediction models used in lung cancer screening[12 64 67]

Risk factors	Examples of risk prediction models that may be used to calculate eligibility for screening						
	Etzel[68]	LLP_{v3}[69]	Wang[70]	$PLCO_{m2012}$[37]	LCRAT/ LCDRAT[71 72]	Spitz[73]	TNSF-SQ[74]
Target population	African Americans (US)	General population (UK)	General population (China)	People who have ever smoked (global)	People who have ever smoked (global)	People who currently smoke, used to smoke or never smoked (global)	Women who have never smoked (Taiwan)
Age and/or sex		⊕	⊕	⊕	⊕		⊕
Smoking status	⊕	⊕		⊕	⊕	⊕	
Smoking history	⊕	⊕	⊕	⊕	⊕	⊕	
Race/ethnicity	⊕			⊕	⊕		
Education*			⊕	⊕	⊕		⊕
Body mass index			⊕	⊕	⊕		⊕
Personal history of COPD	⊕	⊕	⊕	⊕	⊕	⊕	⊕
Personal history of pneumonia		⊕	⊕				
Family history of lung cancer		⊕		⊕	⊕	⊕	⊕
Occupational exposure e.g. to asbestos	⊕	⊕	⊕			⊕	
Second-hand smoke						⊕	
Other types of exposure e.g. to dust, hay fever (pollen), cooking fumes	⊕		⊕			⊕	

Risk factors can be combined to calculate an individual's risk 'score' for lung cancer

Table adapted from Kauczor *et al* (2020), Toumazis *et al* (2020) and Sands *et al* (2021). Please note this list is not exhaustive and other risk factors may be included in the risk models presented.

COPD: chronic obstructive pulmonary disease; LLP: Liverpool Lung Project cancer risk stratification model; LCRAT, lung cancer risk assessment tool; LCDRAT: lung cancer death risk assessment tool; $PLCO_{m2012}$: Prostate, Lung, Colorectal, and Ovarian Cancer Screening Trial Model 2012; TNSF-SQ: Taiwanese Never Smoker Female lung cancer risk model and Simplified Questionnaire.

* Education is often used as an indicator of socioeconomic position.[57]

Finally, many programmes are exploring the use of biomarkers to further improve targeting. Currently, many biomarkers drawn from blood samples are being investigated in the context of lung cancer screening, but no definitive biomarker has been identified as yet.[75] In the future, biomarkers could be used to identify people most likely to have lung cancer to determine or supplement the population eligible for screening.[76] Biomarkers offer the potential to improve the impact of screening as they may be able to identify people with a high risk of lung cancer without simultaneous risk for other causes of death related to age and smoking.[76-78] Their use may also optimise the impact of screening on detection, increase the efficiency of screening, reduce the number of false positives, and help to differentiate benign and malignant lung nodules.[79]

What does this mean for future screening programmes?

- ➜ Eligibility criteria for screening should be tailored to local contexts and adapted where appropriate to ensure greater equity in recruitment for lung cancer screening programmes.
- ➜ Risk prediction models should be used when developing population-specific eligibility criteria.
- ➜ Regions that have a high rate of lung cancer among people who have never smoked should explore the feasibility of expanding eligibility criteria beyond age and smoking status to capture high-risk populations more effectively.
- ➜ Lung cancer screening protocols should be revised and adapted as evidence on the role of biomarkers evolves.

Lesson two

Develop targeted outreach to address potential barriers to participation in lung cancer screening

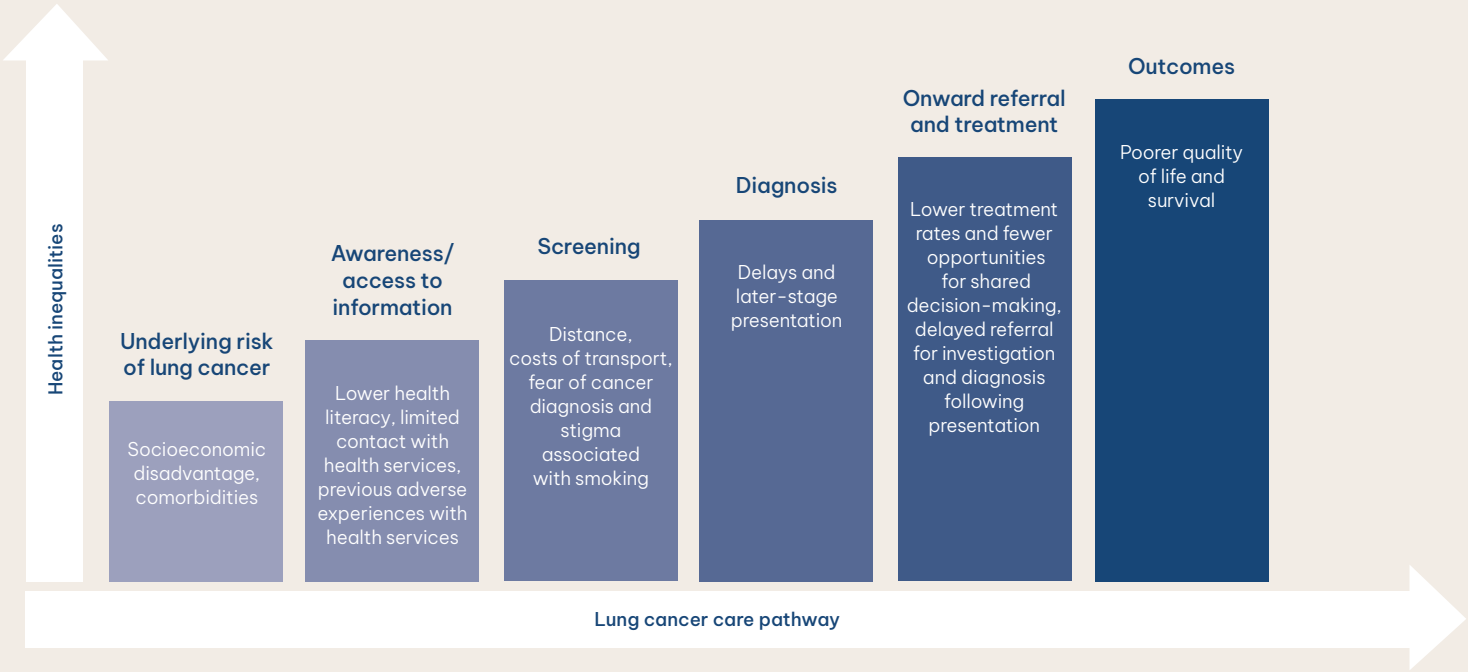
Context

The risk of developing lung cancer and of late presentation is much greater among people in lower socioeconomic groups,[80] yet these groups are less likely to participate in cancer screening and are more likely to have poorer survival.[5 81-83] The reasons behind this are complex and vary between populations.[84 85] Barriers to participation can be informational (e.g. limited understanding about the importance of early detection), physical and financial (e.g. distance from screening sites and costs of transport), as well as cultural or psychological.[86] Of particular importance is the persistent misperception of lung cancer as a disease that only affects people who smoke, which can inadvertently lead to the stigmatisation of individuals eligible to participate in screening programmes.[67]

What have we learnt from implementation so far?

Screening programmes need to include targeted efforts to secure participation from populations that are at a high risk of lung cancer. Engaging populations at risk of lung cancer in screening is a particular challenge,[87] and they often experience cumulative inequalities across the entire lung cancer care pathway (*Figure 4*). This has led some countries to actively engage in consultations with marginalised communities or other populations at highest risk to understand how they can better design screening programmes to be safe and effective, while encouraging attendance.[88 89]

Figure 4. Cumulative inequalities across the lung cancer care pathway[27]



Positively framing screening and using shared decision-making can help engage people who would benefit from lung cancer screening. Targeted interventions can help overcome informational and logistic barriers to screening and reduce social inequalities in lung cancer.[90] One example of a successful screening model is the Targeted Lung Health Check pilots in England, with high uptake among groups with the highest levels of deprivation (*Case study 4*).[91] The programme is purposely framed as a 'lung health check' to avoid stigmatisation associated with lung cancer, and information about the screening process and benefits is provided to participants at every stage. The programme also focuses on fostering informed choice from participants, using a shared decision-making model, a widely studied approach.[67 92]
In Canada, researchers partnered with people living with lung cancer to co-design an e-learning module for healthcare providers to promote equitable access to screening.[88] The module included videos and case studies from various stakeholders (such as people living with lung cancer, healthcare providers and policymakers) based on lived experiences.[88]

Case study 4. UK: overcoming informational barriers and stigma by presenting screening as a lung health check

The Targeted Lung Health Check (TLHC) programme is a community-based lung cancer screening pilot service initially offered in 23 metropolitan areas across England.[93 94] The first cities to adopt TLHCs were Liverpool and Manchester, where additional interventions were introduced to reduce barriers to participation for those at high risk and in more socioeconomically deprived areas of the city.[82 91] In Manchester, the programme was framed as a one-stop 'lung health check' rather than 'cancer screening'.[82 95] People aged 55–74 who had smoked or were currently smoking and were registered at one of the 14 participating general practice clinics across the city were invited to have a lung health check at convenient community venues.[96] Mobile computed tomography (CT) scanners were located next to shopping centres, to minimise transport costs and increase accessibility.[97] Participants were provided with information at each stage of the pilot so that they felt informed and supported in their decision.[93] The majority of lung cancers detected were early stage (stage I or II) and the majority of attendees were from the most deprived population quintile in the city.[91] There are now plans to expand the pilot to a further 20 locations across the UK by 2024-25.

Appropriate service design can help secure attendance from more people in lower socioeconomic groups. Using mobile screening units, for example, can help address physical, logistical and financial barriers to screening, such as by reducing transport costs for participants and the need to take significant time off work to participate.[97] Mobile screening models are being explored to secure uptake in countries including England, the US, Canada, Switzerland, Japan, Brazil and China[22 98–101] (*Case studies 5* and *6*).

Case study 5. China: securing uptake of lung cancer screening in rural populations via mobile LDCT

Despite widely publicised lung cancer screening campaigns in China, many people report that they are unaware of free screening programmes or are reluctant to participate if attendance is inconvenient, including for follow-up consultations.[40 102] To address this challenge, one implementation study in a predominantly rural area in western China sought to explore the feasibility and effectiveness of mobile LDCT lung cancer screening with remote interpretation of scans.[100] Overall, 8,073 residents responded to the invitation and were offered either mobile or hospital-based LDCT screening in Mianzhu city, Sichuan province. Both groups had a larger representation of women than men, and more than 75% of participants had never smoked. Rural residents with a positive screening result were referred to lung cancer specialists following guidelines from the National Comprehensive Cancer Network (NCCN).[103] The lung cancer detection rate in mobile LDCT screening participants was significantly higher than that in the hospital group. As Mianzhu city is representative of rural populations in western China, this model is being expanded via pilots in three other cities (Longquan, Ganzi and Guangan).

Case study 6. Brazil: integrating lung cancer screening into a fragmented health system via mobile LDCT

In Brazil, a coordinated approach to lung cancer screening is essential, as health assistance is fragmented across the country and has resulted in significant health inequalities.[104-106] The benefits of LDCT screening were illustrated in the Second Brazilian Early Lung Cancer Screening Trial (BRELT2). Of the 74 people found to have lung cancer, 70% were diagnosed at stage I or II.[107] However, there are still many barriers to overcome before an organised screening programme can be implemented nationwide, including inequitable access to screening equipment between public and private healthcare.

Two mobile screening projects provide examples of how these barriers are being addressed. The municipal health office in Barretos (São Paulo) partnered with the local cancer hospital to pilot delivery of a smoking cessation intervention and mobile LDCT screening in the community, with 19 teams established in primary healthcare centres.[99] Screening data were shared via an online platform, and a direct line of communication was established between the participating clinics and a multidisciplinary team to discuss individual cases for diagnosis and treatment. Another mobile LDCT screening programme has increased coverage and access to lung cancer screening; originally set up by the Brazilian lung cancer network ProPulmão in the greater metropolitan area of São Paulo, the programme has recently been expanded to three municipalities in remote areas of the Northeastern Region.[108]

Successful targeted engagement approaches from other cancer screening programmes can offer valuable lessons. In some countries, community health workers have been effectively engaged in enabling outreach to the target population. For example, the Wise Up to Cancer community health programme in the UK works with community pharmacies to increase awareness of cancer symptoms and boost participation in national screening programmes for breast, bowel and cervical cancers.[109] Working closely with community leaders has also been shown to help engage people at risk of cancer from communities who face marginalisation. In New Zealand, the uptake of breast cancer screening was increased among Māori women by working with community leaders as well as improving community education strategies and access to screening via mobile units[110] (*Case study 7*).

Case study 7. New Zealand: learning from other cancer screening programmes how to engage marginalised communities

Inequalities in breast cancer diagnosis and outcomes have long been reported in New Zealand, with Māori women 21% more likely to be diagnosed with cancer than non-Māori women.[110 111] The Te Whānau ā Apanui Community Health Service, which provides primary healthcare to a rural and predominantly Māori community, aimed to increase participation rates in breast cancer screening via greater community engagement. The service provided information about breast cancer screening and encouraged participation by promoting it at local community events where women were present. It also engaged members of the community to advocate for breast cancer screening. As a result, participation among Māori women increased from less than 45% in 2003 to approximately 98% in both 2005 and 2007. The success of the programme was attributed to using existing structures and engagement strategies that were embedded in established methods of communication in this community, rather than creating new approaches.[110]

Similar strategies were used in the development of a Māori lung cancer screening pilot programme, the Te Oranga Pūkahukahu: Lung Health Check.[112] As the first of its kind in New Zealand, it has been co-designed with Māori stakeholders to understand how a national lung cancer screening programme could be implemented to reduce inequalities. An implementation trial began in 2021 to compare two different methods of inviting 550 Māori men and women in Auckland for LDCT screening.[113]

There is particular interest in taking a gender-based approach to lung cancer screening for women. Lung cancer rates and mortality in women have risen significantly in the past 40 years.[114] Some evidence suggests that lung cancer develops differently in women compared with men; women are more at risk of lung cancer but, paradoxically, it is less fatal in women.[115] Previous randomised controlled trials (Dutch-Belgian lung cancer screening trial (NELSON) and the German Lung Cancer Screening Intervention trial (LUSI)) have suggested that screening may be more effective in women as lung cancer in women tends to progress more slowly,[29 116] thereby increasing the likelihood of catching it at an early stage.[37] Some pilots and feasibility studies are looking at the effectiveness of different strategies to increase awareness of lung cancer screening among eligible women, in order to create scalable community-based interventions.[117-119]

What does this mean for future screening programmes?

- Lung cancer screening programmes need to be designed to proactively engage at-risk individuals, especially populations which experience disadvantage and marginalisation. This will enable the programmes to address inequalities in access to screening and ensure they do not exacerbate the existing inequities observed in lung cancer.
- The design of screening programmes, and the approaches they use to engage people, must be appropriate for the local population and consider potential barriers to screening. This should include ensuring the language used to talk about screening and lung cancer is appropriate and addresses potential fears or misunderstanding; locating screening centres close to the communities they serve; and involving key community and healthcare professionals to engage targeted populations.
- Lung cancer screening programme leads can look to local qualitative research and findings from other cancer screening programmes when planning how best to engage different communities within their target population. Programmes should be designed in close consultation with the communities they intend to serve.
- Considering a gender-based approach in screening and targeting women may be necessary as lung cancer prevalence is increasing in women. For interventions and screening programmes to be successful, we need to understand the evolution of lung cancer prevalence in women as well as their perceptions of screening, and tailor interventions appropriately.

Lesson three

Amplify the impact of lung cancer screening by integrating it into other public health initiatives

Context

Smoking cessation is recognised as an integral part of lung cancer screening programmes, and pairing the two amplifies the success and cost-effectiveness of both programmes.[34 67 120 121] Smoking cessation results in better clinical outcomes for people who participate in screening and improves lung cancer survival rates.[122] Screening with LDCT can also offer an opportunity to detect other diseases that are prevalent in similar high-risk groups, such as chronic obstructive pulmonary disease (COPD) and cardiovascular disease (CVD). Combining screening programmes would potentially enable governments to create economies of scale in ensuring earlier detection of both lung cancer and other diseases.

What have we learnt from implementation so far?

Lung cancer screening programmes need to be complementary to anti-tobacco and smoking cessation interventions. The Wilson and Jungner principles, which outline the criteria to inform decisions about whether a screening programme should be implemented, state that all primary preventive strategies should be implemented before screening is considered.[123] Smoking prevention and cessation is currently viewed as the most effective way to reduce mortality in lung cancer.[57 124] However, a person remains at high risk of lung cancer for up to 25 years after stopping smoking.[34] Screening is therefore needed to enable the early detection of lung cancer in people at high risk on account of their smoking history. Communicating the combined value of these approaches is important in terms of policy and public awareness. In practice, lung cancer screening may offer a 'teachable moment' in which people who currently smoke can be encouraged to stop,[124] and provide an opportunity to deliver smoking cessation for high-risk individuals (*Case study 8*).

Case study 8. US: providing smoking cessation interventions during lung cancer screening

The US Preventive Services Task Force national health guidelines for lung cancer screening recommend that people who smoke should also receive smoking cessation support during screening.[42] Professional bodies, such as the American Thoracic Society and the American College of Chest Physicians, have issued recommendations for developing comprehensive lung cancer screening, but it was previously reported that sites varied in their readiness to deliver smoking cessation.[125 126] The American Thoracic Society now has a whole section dedicated to smoking cessation resources in its implementation guide for lung cancer screening.[127] Interventions such as telephone-based support have also been shown to be effective.[128] A pilot in which people who currently smoke and were eligible for lung cancer screening were offered telephone-based counselling, found a quit rate of 17.4% in the intervention group compared with 4.3% in the group that did not receive counselling.[128] Based on the success of combining these two services, the National Cancer Institute sponsored the Smoking Cessation at Lung Examination (SCALE) collaboration to conduct research on lung cancer screening and smoking cessation in people who smoke, and will share best practices for measuring feasibility, cost and other implementation outcomes.[129]

LDCT screening may also offer the opportunity for earlier detection of other common diseases. As well as early lung cancer detection, LDCT could offer the additional benefit of enabling the early detection of common comorbidities found in people who smoke, such as COPD and CVD[130 131] (*Case study 9*). As an example, in the US the structured reporting tool used in most lung cancer screening programmes (Lung-RADS) requires the reporting of findings beyond lung cancer.[132] This opportunity should thus be considered of strategic importance to governments, as non-communicable diseases (NCDs), which include COPD and CVD, are expected to increase by 17% by 2030, and reducing their global burden is a recognised priority for economic and social sustainability (the United Nations Sustainable Development Goal 3.4).[133]

Case study 9. France: detecting other diseases as part of lung cancer screening

Some types of biomarkers are released into the blood in early-stage lung cancer and can be detected before a tumour is visible on a CT scan.[134] Drawing on earlier research,[135] a national research consortium in France sought to evaluate whether a biomarker for chronic obstructive pulmonary disease (COPD) could aid the selection of a population at high risk of lung cancer for screening.[134] A total of 614 people with COPD (aged 55–74) who currently smoked or had recently quit smoking were invited to take part in the Circulating Tumor Cells in Lung Cancer Screening project (AIR).[136] Over three years, participants underwent annual LDCT screening with blood tests. While the study concluded that using biomarkers as a standalone tool for lung cancer screening was not feasible, the incidence of lung cancer detected in participants each year was high (2.8%). Additionally, 4% were found to have other types of cancer and 53% had cardiovascular disease, further demonstrating the utility of combining screening programmes to target people at high risk of lung cancer.[130]

Engaging people who are already enrolled in another screening programme can help maximise reach and efficiency – but this requires careful planning. Lung cancer screening can be combined with other screening programmes to maximise cost-effectiveness and efficiency.[131] For example, women already taking part in mammography screening may be easier to engage in other cancer screening tests, including for lung cancer[137] (*Case study 10*). Combining these programmes requires joint protocols and ensuring individuals are appropriately referred to multidisciplinary care pathways for each cancer detected.

Case study 10. Sweden: engaging in lung cancer screening women involved in other cancer screening programmes

In recent years, the rate of lung cancer in women has been steadily increasing in Sweden.[138] The Regional Cancer Centre Stockholm Gotland was commissioned to assess whether targeted screening can be a cost-effective way to detect lung cancer at an early stage.[139] [140] As part of this research project, a lung cancer screening pilot has been designed to target women eligible for breast cancer screening in an area of Stockholm. Around 1,000 women aged 55–74 will be given questionnaires on their smoking habits and asked about their interest in receiving support to quit. Based on their smoking history, eligible participants will then be invited to LDCT screening. The pilot is planned to start in late 2022 and will run over two years.[141] If successful, it will be used to inform the development of a national organised LDCT screening programme, in which men would also be eligible to participate.[140]

What does this mean for future screening programmes?

- Smoking cessation support should be fully embedded in lung cancer screening programmes to amplify the success of both, as well as increasing efficiency and cost-effectiveness.
- Countries should explore the feasibility of offering lung cancer screening to people attending other cancer screening programmes. This may offer some economies of scale by using common recruitment databases and engagement strategies, data management software or coordination centres. It may also help strengthen population-wide messages about the importance of early detection.
- Countries should make early detection of cancer a central pillar of comprehensive lung and CVD plans, and recognise the opportunities afforded by combined approaches to early detection.
- To enable detection of other NCDs through LDCT screening, an integrated approach is needed from detection to treatment, ensuring individuals are channelled to the appropriate care pathway based on findings.

Lesson four

Ensure the full integration of lung cancer screening into health systems

Context

To be most effective, screening programmes must be integrated into lung cancer care pathways to ensure clear processes for the ongoing management and care of lung cancer, with adequate staff, technical capacity and high-quality standardised care. They also need to be fully integrated into a health system's existing governance frameworks, information systems, funding flows, and workforce and facility infrastructure. This requires a comprehensive approach to planning, recognising that each national context has its own healthcare structure.

What have we learnt from implementation so far?

Screening should be built into lung cancer care pathways. Implementing a successful screening programme requires strong coordination and understanding of the lung cancer care pathway, with workforce and capacity planning to avoid bottlenecks and delays in diagnosis and treatment (*Case study 11*). In the US, the GO2 Foundation for Lung Cancer developed a national framework of excellence in lung cancer and formed a nationwide network dedicated to responsible lung cancer screening.[142] Collecting and sharing data from screening centres enables evaluation of the screening programme as well as identification of barriers to implementation, so they can be addressed (*Case study 12*).[143] Building screening into lung cancer care pathways also requires robust quality assurance frameworks, which set standards for healthcare professionals (nurses, radiologists), software and data management, communications, reporting and follow-up care.

Case study 11. Croatia: accelerating waiting lists for specialist care to avoid bottlenecks in the care pathway

In 2020, Croatia became the first country in Europe to implement an organised, nationwide lung cancer screening programme, which includes a system that fast-tracks people with suspected disease, including lung cancer. This system aims to address the issues caused by fragmented and sometimes underutilised primary care in the country. There are six specialist lung cancer nodule clinics in Croatia participating in the programme, which is financed by the national health insurance fund.[119 144] In the first year, 4,000 people underwent LDCT screening and 11% were referred for follow-up.[119] The fast-tracking system requires that people invited to screening are offered access to specialist care within three days of referral, and that treatment must be initiated within one month. Assessments demonstrated that these fast-track referral pathways work well and that people referred to specialists using the priority list often do have a serious disease.[145]

Case study 12. US: creating screening centres of excellence

The GO2 Foundation for Lung Cancer Screening Centers of Excellence (SCOE) is a network of around 800 screening centres committed to high-quality screening practices.[146] It facilitates knowledge sharing, enabling centres to tailor programme strategies to address common barriers to uptake and adherence, and support readiness for anticipated rapid growth in patient volumes.[143] Some of the barriers to screening implementation that the SCOE has encountered are a lack of insurance provider referral, lack of awareness among target groups, and internal workflow challenges. These barriers guide future focus for the SCOE network. For example, they highlight the need to build capacity to deliver resource-intensive individual outreach, required to maintain high rates of screening adherence and enable more effective screening practices. A network-wide approach can also help to identify best practice. The SCOE requires facilities to be accredited in lung cancer screening by the American College of Radiology,[147] which conducts regular audits to ensure facilities meet its accreditation criteria. These cover data entry into a national quality registry, technical specifications of the imaging programme and training of facility staff.

Appropriate management of pulmonary nodules is integral to the success of LDCT screening for lung cancer. Lung nodules are detected not only in lung cancer screening programmes – they are also frequently detected incidentally during routine chest CT scans.[148 149] In both instances, it is crucial to have clear protocols in place to correctly identify potentially malignant lung nodules and ensure appropriate follow-up care to reduce false positives (*Case study 13*),

especially in individuals who may have been deemed low risk.[148 150] LDCT and lung nodule management programmes can be complementary and could be rolled out together as part of early detection programmes.[150] These programmes should ideally involve a multidisciplinary team consisting of radiation oncologists, medical oncologists, thoracic surgeons and pulmonologists.[149]

Case study 13. South Korea: gradually scaling up smaller implementation studies to inform the launch of a national organised screening programme

Since its launch in 2002, the Korean National Cancer Screening Programme has been providing cancer screening for stomach, liver, colorectal, breast and cervical cancers.[151 152] In 2019, its reach was expanded to lung cancer screening via LDCT. However, one challenge in South Korea was the large number of false positive scans resulting from the high burden of tuberculosis.[153] In a small-scale pilot study of 256 participants in 2016–17, 11.7% were diagnosed with pulmonary tuberculosis via LDCT lung cancer screening, yet the number of cases of lung cancer detected was lower than expected.[154] Findings from this study were used to modify the protocol for the larger national Korean Lung Cancer Screening pilot (K-LUCAS).[153-155] This pilot also built on earlier research to evaluate how a computer-aided detection (CADe) system could be used as a means of quality control in the national programme.[156] In 2019 and 2020, around 23% of the eligible population in the country (690,000 people) had been screened in the national programme,[151] and the sensitivity of screening was recently reported to have improved when using CADe.[157] Additionally, a new implementation study was announced to investigate how to expand selection criteria to include people who have never smoked.[59]

Planning screening programmes requires a comprehensive approach, from recruitment all the way to evaluation and monitoring of outcomes. Screening programmes are much more than just the screening process itself. They require a thorough investment in appropriate information systems, pathway design, communication and engagement, and workforce. The main considerations for their design have been outlined in the recently updated guidelines on cancer screening from the World Health Organization[85] and should be an essential starting point when setting up lung cancer screening (*Figure 5*). Several countries have also developed comprehensive frameworks to assess feasibility for implementation of screening, which can be emulated elsewhere (*Case studies 14* and *15*).

Figure 5. Key considerations for the design of a lung cancer screening programme

Case study 14. Australia: scoping work for a potential national lung cancer screening programme through engagement with key stakeholders

In 2019, Cancer Australia led an enquiry into the prospects of a potential national lung cancer screening programme, exploring the best national and international evidence for lung cancer screening in the consideration of how a lung cancer screening programme could be effectively delivered in Australia. In partnership with the Australian Government Department of Health, Cancer Australia is taking a collaborative approach to engage and work with key stakeholders. This provides the opportunity for stakeholders to contribute to the early design of a potential national lung cancer screening programme. The potential programme will comprise an LDCT scan every two years in high-risk individuals. The consultation will build on the policy settings defined in the lung cancer screening enquiry report,[23] and will explore how existing systems and funding models could be leveraged to support nationwide lung cancer screening. This scoping work also considers the communication, information and technology requirements of a potential programme.

Case study 15. Canada: using a simulation model to assess feasibility of implementing lung cancer screening programmes

The Canadian Partnership Against Cancer (CPAC) produced a readiness assessment toolkit, which can be useful when evaluating capacity for screening programmes.[167] Building on existing expertise from other cancer screening programmes, the toolkit can be used by decision-makers in cancer agencies and programmes. CPAC also developed the OncoSim model, a free, web-based simulation tool that evaluates cancer control strategies to better understand their impact and value.[168] The model projects that over a 20-year time frame, lung cancer screening with LDCT will detect 8,000–17,000 more lung cancer cases at stage I, leading to 6,000–14,000 fewer cases of stage IV lung cancer and 5,000–13,000 fewer deaths from lung cancer across Canada.[22] The model can also assess the impact of smoking cessation programmes and evaluate lung cancer screening strategies and new treatment options.

What does this mean for future screening programmes?

- Planning for the implementation of lung cancer screening requires a comprehensive approach, with input from all relevant professionals representing the entire lung cancer pathway to ensure professional buy-in and training.
- Investment in high-quality multidisciplinary lung cancer care pathways is needed to ensure the success of lung cancer screening programmes. Governments need to assess potential gaps and bottlenecks in existing pathways so that people with suspected lung cancer can be rapidly referred to comprehensive diagnosis and care.
- Lung cancer screening programmes need to be agile to adapt to the health system within which they operate. They should be fully integrated into all facets of existing health systems, harnessing and maximising existing infrastructure and technologies to enhance their effectiveness.

Putting the lessons from lung cancer screening implementation into practice

We are at a pivotal moment to progress lung cancer screening as a central pillar of cancer control strategies. The evidence base supporting implementation is clear. Several decades of research have laid the foundation on which large-scale national LDCT screening programmes can be developed. This report draws on the wealth of experience and learning from implementation around the world to outline how specific challenges have been addressed in practice. These lessons can provide an enhanced understanding of how to refine and optimise the approach to lung cancer screening based on specific national contexts – ensuring programmes achieve optimal effectiveness, efficiency and impact.

Now is the time to build the political will needed to raise lung cancer up on the policy agenda. A necessary first step is to tackle misconceptions about lung cancer head on. Significant stigma and misinformation about lung cancer screening remain among the general public, including politicians and healthcare workers, often contributing to misconceptions about its value.[11 169 170] Efforts are needed to improve understanding of lung cancer screening and its complementary benefits to smoking cessation,[171] and proactively address the issue of stigma through awareness campaigns.[172] Evidence-based continuing professional development is also needed to engage family physicians and other primary care providers in screening efforts.

Governments should consider how to promote a broader appreciation for the importance of early detection in lung cancer. This could potentially involve working with advocacy groups to change attitudes towards lung cancer and convey a sense of hope: treatment options exist, particularly if lung cancer is detected early, and screening is a doorway to this early detection.

The lessons presented in this report speak to the possibility of ensuring feasible, resource-efficient and effective implementation of lung cancer screening programmes. We have indisputable evidence that lung cancer screening works. It offers a tangible opportunity for governments to dramatically shift the detection of lung cancer to earlier stages, and to address its global impact, reducing its burden on people and society. It is time to drive forward implementation and bring real change to lung cancer detection, diagnosis, treatment and survival for the benefit of all.

Four key lessons from lung cancer screening implementation

Appendix

Randomised controlled trial evidence for lung cancer screening

Country	Randomised controlled trial
 BELGIUM & THE NETHERLANDS	Dutch-Belgian lung cancer screening trial (Nederlands-Leuvens Longkanker Screenings Onderzoek; NELSON)[29]
 DENMARK	Danish Lung Cancer Screening Trial (DLCST)[173]
 GERMANY	Lung Cancer Screening Intervention (LUSI)[116]
 ITALY	Detection And screening of early lung cancer with Novel imaging TEchnology (DANTE)[174]
	Italian Lung Cancer Screening Trial (ITALUNG)[175]
	Multicentric Italian Lung Detection trial (MILD)[12,31]
 UK	UK Lung Cancer Screening Trial (UKLS)[176]
 US	National Lung Screening Trial (NLST)[30]

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