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Review

Challenges in Implementing Lung Cancer Screening and Early Detection in Low-and Middle-Income Countries: Between Evidence and Real-World Constraints.

Défis liés à la mise en œuvre du dépistage et de la détection précoce du cancer du poumon dans les pays à revenu faible et intermédiaire: entre données probantes et contraintes de terrain.

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ABSTRACT

Lung cancer remains the leading cause of cancer-related mortality worldwide, with an increasing burden disproportionately affecting low- and middle-income countries (LMICs). Landmark randomised controlled trials, conducted primarily in high-income countries, have demonstrated that low-dose computed tomography (LDCT) screening significantly reduces lung cancer mortality among high-risk individuals. However, translating these findings into effective and sustainable screening programmes in LMICs remains challenging because of systemic, infrastructural, economic, and workforce-related constraints. This article reviews the current evidence on lung cancer screening and early detection, examines the major barriers to implementing LDCT screening programmes in LMICs, and discusses strategies tailored to local contexts. Particular attention is given to differences in epidemiology, health system capacity, resource availability, and socioeconomic conditions that may influence the feasibility and effectiveness of screening programmes. Bridging the gap between scientific evidence and clinical implementation will require context-specific policies, strengthened health systems, sustainable financing, international collaboration, and the generation of high-quality evidence relevant to LMIC settings.

KEYWORDS: Lung cancer screening; low-dose computed tomography; low- and middle-income countries; health economics.

RESUME

Le cancer du poumon demeure la première cause de mortalité par cancer dans le monde, avec un fardeau croissant touchant de manière disproportionnée les pays à revenu faible et intermédiaire (PRFI). Des essais contrôlés randomisés de référence, menés principalement dans des pays à revenu élevé, ont démontré que le dépistage par tomodensitométrie à faible dose (LDCT) réduit significativement la mortalité par cancer du poumon chez les personnes à haut risque. Cependant, la traduction de ces résultats en programmes de dépistage efficaces et durables dans les PRFI demeure un défi, en raison de contraintes systémiques, infrastructurelles, économiques et liées aux ressources humaines en santé.

Cet article passe en revue les données actuelles concernant le dépistage et la détection précoce du cancer du poumon, examine les principaux obstacles à la mise en œuvre de programmes de dépistage par LDCT dans les PRFI, et propose des stratégies adaptées aux contextes locaux. Une attention particulière est portée aux différences en matière d'épidémiologie, de capacité des systèmes de santé, de disponibilité des ressources et de conditions socioéconomiques, susceptibles d'influencer la faisabilité et l'efficacité des programmes de dépistage. Combler l'écart entre les données

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scientifiques et leur mise en œuvre clinique nécessitera des politiques adaptées au contexte, un renforcement des systèmes de santé, un financement durable, une collaboration internationale, ainsi que la production de données probantes de haute qualité pertinentes pour les contextes des PRFI.
Mots-clés : Dépistage du cancer du poumon ; tomodensitométrie à faible dose ; pays à revenu faible et intermédiaire; économie de la santé.

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Introduction

Lung cancer continues to represent a major global public health challenge and remains the principal cause of cancer-related mortality worldwide. **According to the latest GLOBOCAN 2024 estimates, approximately 2.6 million new lung cancer cases and 1.9 million deaths occurred worldwide, corresponding to 12.8% of all newly diagnosed cancers and 19.1% of cancer-related deaths [1].** Although several high-income countries (HICs) have experienced a decline in age-standardised incidence and mortality, the worldwide burden of lung cancer is expected to increase further. Population ageing and demographic expansion, together with persistent exposure to tobacco, environmental pollutants, and other carcinogenic factors, are likely to contribute substantially to this trend, particularly in low- and middle-income countries (LMICs), where the greatest future increase is anticipated [1].

Among Among currently available early-detection strategies, low-dose computed tomography (LDCT) is the only screening approach for which a reduction in lung cancer mortality has been convincingly demonstrated. **The National Lung Screening Trial (NLST) and the NELSON trial provided the principal evidence supporting this benefit [2,3]. The National Lung Screening Trial (NLST) demonstrated a 20.0% relative reduction in lung-cancer mortality with low-dose computed tomography (LDCT) compared with chest radiography [1]. In the NELSON trial, LDCT screening was associated with a 24% reduction in lung-cancer mortality among men at 10 years of follow-up. Among women, the estimated reduction was larger, but the subgroup was smaller and the confidence interval included no effect; therefore, this finding should be interpreted cautiously [2].** These findings contributed to recommendations from the International Association for the Study of Lung Cancer (IASLC), the American Cancer Society (ACS), and other professional organisations advocating risk-based LDCT screening in appropriately selected high-risk populations [4-6].

Despite this established evidence base, access to organised LDCT screening remains predominantly concentrated in HICs. This discrepancy is particularly concerning because many LMICs are expected to experience the largest future increase in lung cancer incidence and mortality. In these settings, limitations in imaging infrastructure, financial resources, trained personnel, healthcare organisation, and diagnostic pathways can substantially compromise the feasibility of conventional screening models. Therefore, simply reproducing programmes designed for high-resource healthcare systems is unlikely to provide an effective or sustainable solution.

This article examines the current evidence supporting LDCT screening and analyses the principal barriers to its implementation in LMICs. **It distinguishes three related but different approaches: screening refers to testing asymptomatic people in a defined target population; early diagnosis aims to identify cancer promptly in people who have symptoms; and case finding refers to the targeted identification of possible disease during routine healthcare encounters. This review considers both screening and early-detection approaches, while recognising that they require different eligibility criteria, pathways, resources, and evaluation measures.** Particular attention is given to infrastructure, human resources, economic constraints, healthcare organisation, and equity. Finally, potential strategies for developing locally appropriate, sustainable, and equitable approaches to lung cancer early detection are discussed.

Review methodology

This narrative review draws on relevant published evidence on lung cancer screening and early diagnosis, including randomised controlled trials, observational studies, and international clinical guidelines. Evidence was selected based on its relevance to the review objectives and its clinical significance.

Evidence supporting lung cancer screening

The scientific rationale for LDCT screening is largely based on the NLST and NELSON trials, subsequently reinforced by systematic reviews and meta-analyses demonstrating a reduction in lung cancer mortality among appropriately selected individuals [2,3,7]. In the NLST, low-dose computed tomography (LDCT) screening was associated with a 20.0% relative reduction in lung-cancer mortality compared with chest radiography, whereas the NELSON trial reported a 24% reduction among men at 10 years compared with no screening [2,3]. These relative reductions were observed in selected high-risk trial populations and should not be assumed to be directly transferable to all healthcare settings. The effectiveness of screening in routine practice depends on appropriate risk-based eligibility, screening uptake and adherence to repeat examinations, accurate image interpretation, timely diagnostic evaluation, and access to effective treatment. On the basis of this evidence, the US Preventive Services Task Force (USPSTF) and the IASLC recommend regular LDCT screening in populations considered to be at sufficiently high risk of developing lung cancer [8,9].

An important evolution in screening methodology has been the transition from selection based exclusively on age and smoking history toward more individualised risk assessment. Prediction tools such as the Prostate, Lung, Colorectal and Ovarian Cancer Screening Trial 2012 model (PLCOm2012), the Liverpool Lung Project (LLP) model, and the Bach model can improve identification of individuals whose absolute risk of lung cancer is sufficiently high to justify screening [10,11].

However, the evidence underpinning these models and most existing screening strategies has been generated predominantly in HICs with relatively mature healthcare infrastructures [12]. Their performance and clinical utility cannot therefore be assumed to be equivalent in LMICs. Differences in tobacco exposure, occupational and environmental hazards, biomass fuel exposure, air pollution, tuberculosis (TB) epidemiology, and potentially tumour characteristics may substantially modify baseline risk and the diagnostic consequences of screening [6]. Local or regional validation should precede routine use of risk-prediction models, and their performance should be assessed for calibration, discrimination, feasibility, and equity.

Consequently, implementation in resource-constrained settings requires more than the simple transfer of recommendations developed elsewhere. The underlying risk profile, healthcare capacity, diagnostic infrastructure, and economic context of each setting must be taken into consideration.

Structural barriers in low- and middle-income countries and human resource

The availability of CT infrastructure constitutes one of the fundamental prerequisites for implementing an LDCT screening programme. In many LMICs, access to CT remains inadequate, with particularly pronounced shortages in several sub-Saharan African countries and substantial geographic inequalities in South Asia, where imaging facilities are frequently concentrated in major urban and tertiary-care institutions [13,14]. Moreover, the mere presence of CT equipment does not necessarily translate into effective screening capacity. Equipment maintenance problems, unstable electricity supplies, inadequate Picture Archiving and Communication System (PACS) infrastructure, and the absence of validated LDCT acquisition protocols can all compromise programme quality. Existing data suggest that fewer than 15% of institutions have dedicated LDCT protocols and that functional PACS systems allowing remote reporting are available in fewer than 20% of institutions [15].
The diagnostic process is further weakened by poorly coordinated referral systems. Patients with suspicious findings may encounter multiple delays between screening, specialist assessment, tissue diagnosis, staging, and treatment. Median diagnostic intervals have been reported to reach 126 days in LMICs, compared with approximately 42 days in HICs [16]. Furthermore, national, population-based screening programmes remain uncommon, and existing initiatives are generally pilot projects operating on a limited scale, often within tertiary-care institutions [1,3].

Human-resource limitations represent another major obstacle. High-quality LDCT screening requires radiologists capable of recognising and characterising pulmonary nodules and applying structured reporting systems such as the Lung Imaging Reporting and Data System (Lung-RADS). Such expertise is unevenly distributed and remains particularly limited in several sub-Saharan African settings, where the number of radiologists relative to the population is critically low [17]. Training opportunities are also constrained by differences in radiology curricula, limited thoracic-imaging subspecialisation, and restricted access to advanced educational resources [18].

The shortage extends beyond radiologists. Multidisciplinary teams (MDTs), which are central to the interpretation of suspicious lesions and coordination of subsequent cancer management, are still uncommon outside specialised centres in many LMICs [19]. In parallel, inadequate knowledge among primary care professionals regarding individual lung cancer risk, eligibility criteria, and the potential benefits and limitations of LDCT may substantially reduce appropriate referral and screening uptake [20]. Where the infrastructure to investigate abnormal results and

provide timely treatment is not available, strengthening symptom awareness, referral, and early diagnosis may be a more immediate priority than initiating population-based screening.

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Health system, economic, and implementation challenges

The establishment of an effective LDCT screening programme entails considerably more than the acquisition of CT scanners. Sustainable implementation requires investment in imaging infrastructure, equipment maintenance, trained personnel, quality-control mechanisms, reporting systems, PACS, data management, and diagnostic and therapeutic pathways. Although published incremental cost-effectiveness ratios (ICERs) differ substantially according to the healthcare system and assumptions used, their applicability to LMICs remains uncertain. In countries where healthcare expenditure is already constrained, the recurrent costs associated with population-based screening may make large-scale implementation difficult to sustain [21,22]. Three economic questions must be distinguished. Cost-effectiveness assesses the additional cost relative to the health gained compared with an alternative strategy. Affordability asks whether the health system can finance and sustain the intervention within its available resources. Budget impact estimates the total financial consequences of introducing the programme over a defined period. A programme may appear cost-effective in an economic model yet remain unaffordable at national scale.

In LMICs, economic evaluation should use country-specific estimates rather than directly extrapolating results from HICs. Relevant inputs include the size of the eligible population, expected participation, the number and frequency of scans, repeat imaging for indeterminate nodules, diagnostic procedures, pathology, treatment, follow-up, and programme administration. Where local data permit, studies should report the incremental cost per life-year or quality-adjusted life-year gained, alongside uncertainty analyses and the total annual and multi-year budget impact. The number of scans required per person screened, per cancer detected, and per death averted may help policymakers understand resource implications, but these measures must be calculated from local data rather than assumed. These financial considerations must also be interpreted in the context of competing health priorities. Many LMICs simultaneously face substantial burdens from communicable and non-communicable diseases. TB remains a major cause of morbidity and mortality in several regions, alongside HIV, malaria, and major maternal and child health needs [13,21-23]. Consequently, decisions concerning lung cancer screening cannot be based solely on the efficacy of LDCT. They should incorporate country-specific health technology assessments, economic modelling, and explicit consideration of opportunity costs [24,25].

Financial barriers can also operate at the individual level. In healthcare systems characterised by substantial out-of-pocket (OOP) expenditure and limited public reimbursement, the cost associated with screening and subsequent diagnostic procedures may disproportionately exclude socially and economically vulnerable populations [22]. Such inequalities may be amplified by fragmented healthcare systems and inefficient referral mechanisms, which increase the risk of delayed diagnosis and loss to follow-up [26]. Economic assessments should therefore consider not only the costs borne by health services but also travel, time away from work, diagnostic expenses, and whether the programme could widen existing inequalities.

Operational capacity is equally important. Screening programmes require reliable cancer registries and health information systems to identify eligible populations, monitor participation, evaluate outcomes, and generate evidence regarding programme effectiveness. These systems remain insufficiently developed in many LMICs, thereby limiting both programme monitoring and the ability to inform future policy decisions [6].

Risk prediction represents an additional challenge. Models such as PLCOm2012 and LLP were developed and validated primarily in high-income populations. Their use in LMICs should therefore be preceded by appropriate local or regional validation, particularly because factors such as TB-related lung damage, biomass exposure, ambient air pollution, and differences in smoking behaviour may modify individual risk profiles [13,27].

The success of a screening programme also depends on awareness. Limited knowledge among both healthcare professionals and the general population may result in low participation or inappropriate referrals. Primary care physicians, in particular, may have insufficient familiarity with current LDCT recommendations and eligibility criteria, representing a potentially important missed opportunity for early detection [28].

Finally, detection itself does not guarantee improved outcomes. Patients with abnormal screening results must be rapidly incorporated into an organised diagnostic pathway. Delays in additional imaging, specialist assessment, biopsy, staging, or treatment can substantially diminish the clinical benefit expected from earlier detection. Efficient coordination between screening services, diagnostic facilities, multidisciplinary teams, and oncology services is therefore essential [29].

Tobacco control and the wider public-health strategy

Tobacco exposure remains the principal modifiable risk factor for lung cancer and should be central to national lung cancer control strategies. LDCT screening is a secondary-prevention intervention for selected high-risk individuals; it does not prevent cancer development and must not be considered a substitute for primary prevention. Comprehensive tobacco-control measures including taxation, smoke-free policies, restrictions on tobacco advertising and promotion, health warnings, prevention of tobacco initiation, and access to smoking-cessation support remain essential. Smoking cessation should be integrated into screening pathways for current smokers. A negative LDCT result does not eliminate future lung cancer risk and should never be interpreted as reassurance that continued smoking is safe. Lung cancer screening should therefore complement, rather than displace, tobacco control, smoking cessation, and measures to reduce relevant occupational and environmental exposures.

Potential adaptive and context-specific strategies

The experience of HICs provides an important evidence base but should not be interpreted as a universal blueprint for LMICs. Screening strategies need to be adapted to local epidemiology, available resources, healthcare organisation, and population characteristics. A pragmatic approach should therefore prioritise interventions capable of generating the greatest health benefit within the constraints of each healthcare system.

Universal population-based LDCT screening is unlikely to be immediately achievable in most LMICs. A more realistic strategy may involve concentrating resources on individuals with the highest estimated risk. Risk-stratified approaches based on locally validated prediction models could improve efficiency by incorporating regional determinants of lung cancer risk, including previous TB-related lung damage and exposure to biomass smoke [30]. Where capacity for LDCT screening is insufficient, priority should be given to tobacco control, recognition of symptoms, timely diagnostic assessment, and reliable access to treatment.

Digital technologies may also partially compensate for shortages in specialist expertise. Artificial intelligence (AI) and computer-aided detection (CAD) systems have the potential to assist in identifying pulmonary nodules and facilitate remote interpretation through teleradiology. Nevertheless, algorithms developed predominantly from HIC populations should not be introduced without appropriate validation in the populations in which they will ultimately be used. Differences in disease prevalence, imaging characteristics, comorbidities, and technical acquisition parameters may influence their diagnostic performance [31].

Another potentially efficient approach is to build lung cancer early-detection activities onto existing healthcare programmes. Integration with established TB and non-communicable disease (NCD) services could allow countries to use existing infrastructure, patient pathways, and healthcare personnel rather than creating entirely parallel systems. Although evidence supporting integrated models remains limited, this approach may be particularly relevant in settings where standalone cancer screening programmes would be difficult to finance or maintain [32].

Implementation should ideally proceed through carefully designed pilot programmes before broader expansion. Pilot projects can identify weaknesses in referral pathways, assess screening participation, measure diagnostic delays, and determine whether available treatment capacity is sufficient to manage screen-detected disease [33]. Evaluation should include uptake, scan quality, false-positive and indeterminate findings, subsequent investigations, complications, stage at diagnosis, access to treatment, loss to follow-up, equity, and costs. Scale-up should be conditional on evidence of feasibility, acceptable harms, sustainable financing, and a functioning pathway to definitive treatment.

The mortality reductions observed in the NLST and NELSON trials were achieved within highly organised screening systems. This observation is important: the effectiveness of screening depends not only on the imaging technology itself but also on the quality of the entire care pathway surrounding it. International organisations such as the IASLC and the International Agency for Research on Cancer (IARC), together with regional implementation networks, can contribute technical expertise, education, training, and capacity-building support to LMICs [4].

Ethical and equity considerations

Equity should be considered a central principle rather than a secondary objective of lung cancer screening in LMICs. If screening is introduced without addressing existing inequalities in healthcare access, it may disproportionately benefit urban, affluent, and well-informed populations while leaving those at greatest risk insufficiently served.

Targeted outreach and culturally appropriate communication are therefore necessary to ensure that individuals at high risk are aware of screening opportunities and understand their potential benefits and limitations. Smoking cessation interventions should be incorporated whenever possible, while participation rates should be monitored across socioeconomic and geographic groups to identify inequitable access [34].

Overdiagnosis and false-positive findings remain important potential harms of LDCT screening. Standardised nodule-management pathways and multidisciplinary assessment are consequently essential to reduce unnecessary investigations and invasive procedures [4]. Screening discussions should also incorporate shared decision-making, ensuring that individuals receive balanced information about potential mortality benefits, false-positive results, radiation exposure, overdiagnosis, and downstream diagnostic procedures. Such communication should be adapted to local language, cultural context, and health-literacy levels [35].

Importantly, LDCT screening should not be introduced in populations where abnormalities cannot be adequately investigated or where patients with confirmed cancer cannot access appropriate treatment. Screening without sufficient diagnostic and therapeutic capacity risks detecting disease without providing a realistic opportunity to improve outcomes. Consequently, programmes should focus initially on populations at sufficiently high risk and be implemented only when the healthcare system can support the subsequent stages of care [4,36].

Future perspectives

The long-term development of lung cancer screening in LMICs will depend on the generation of evidence that reflects local realities rather than relying exclusively on data derived from HICs. Implementation research should therefore become an integral component of pilot and early-stage screening initiatives. Frameworks such as the Consolidated Framework for Implementation Research (CFIR) and the Reach, Effectiveness, Adoption, Implementation, and Maintenance (RE-AIM) framework can provide structured approaches for assessing feasibility, programme performance, scalability, and long-term sustainability [37,38].

Prospective studies embedded within pilot programmes should use clearly defined and standardised outcome measures. These should include screening participation, adherence to recommended screening intervals, time from abnormal CT findings to definitive diagnosis, stage distribution at diagnosis, time to treatment initiation, and ultimately lung cancer-specific mortality. Harmonisation of data collection and reporting would facilitate comparison between countries and programmes, promote transfer of successful implementation strategies, and provide a stronger evidence base for decisions regarding national scale-up [4].

Emerging blood-based technologies may eventually complement imaging-based screening. Circulating tumour DNA (ctDNA), DNA methylation patterns, circulating microRNAs (miRNAs), and multi-cancer early-detection assays are among the approaches currently being investigated [39,40]. Their potential role in LMICs is particularly attractive because blood-based testing could, in principle, provide additional risk stratification or diagnostic information in settings where imaging capacity is limited. Nevertheless, their clinical value, cost-effectiveness, and applicability to LMIC populations require prospective validation before they can be incorporated into routine screening strategies.

Ultimately, sustainable progress will require coordinated international and national investment. Collaboration involving the IASLC, the World Health Organization (WHO), the Union for International Cancer Control (UICC), and regional partners could facilitate technical assistance, workforce development, and implementation research. Investment should extend beyond CT equipment to include pathology services, cancer registries, health-information systems, quality assurance, professional training, and integrated referral pathways [4].

The central challenge for LMICs is therefore not simply to reproduce screening programmes developed in HICs, but to design models of early lung cancer detection that are epidemiologically appropriate, economically realistic, operationally feasible, and equitable. Such an approach offers the greatest opportunity to translate the mortality benefit demonstrated in controlled LDCT trials into meaningful population-level gains in countries where the future burden of lung cancer is expected to be greatest.

Conclusion

LDCT screening reduces lung-cancer mortality in appropriately selected high-risk populations. However, these findings arose in organised trial settings and cannot automatically be translated into effective programmes in resource-constrained health systems. Implementation decisions in LMICs should distinguish clinical efficacy from local feasibility, cost-effectiveness, affordability, budget impact, equity, and the capacity to complete diagnosis and treatment. The potential harms of screening including false-positive findings, overdiagnosis, cumulative radiation exposure, indeterminate nodules, and psychological distress must be considered and monitored. Tobacco control and smoking cessation must remain central to lung cancer prevention and should never be displaced by screening. A context-sensitive approach should prioritise primary prevention and timely early diagnosis, and consider targeted LDCT pilot programmes only where local evidence, quality assurance, sustainable financing, and access to definitive treatment support responsible implementations.

Conflict of interest statement

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