Challenges in lung cancer screening: a review of implemented programs

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Abstract: Lung cancer screening (LCS) with annual low-dose computed tomography has been shown to have a mortality benefit in high-risk individuals. After publication of the National Lung Screening Trial in 2011, the United States Preventive Services Task Force recommended LCS in 2013, and Medicare began to cover it in 2015. The body of literature supporting LCS continues to grow; most recently the Dutch-Belgian LCS trial reaffirmed the substantial long-term reductions in mortality. Despite this, the rate of enrollment remains extremely low due to challenges at the patient, provider, and medical system levels. Several prominent organizations, including the American Association for Thoracic Surgery and the American Thoracic Society, have provided guidelines to develop a robust LCS program. The primary tenets include a structured referral network, multidisciplinary collaboration, comprehensive patient coordination and follow-up, standardized reporting and patient data management, and quality assurance. Numerous institutions in a variety of settings have used these guidelines and employed strategies of their own to improve the success of their respective LCS programs. This review outlines the challenges that currently exist, summarizes the principles of effective LCS, and details the experiences of several existing LCS programs in a variety of healthcare settings.

Keywords: Lung cancer screening (LCS); challenges; implemented programs

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Introduction

Lung cancer is the most common cause of cancer-related death in the world, and smoking is the most prevalent risk factor (1). Although the prevalence of smoking has declined over the last few decades, a staggering 37% of adults in the United States are current or former smokers (2). Despite the knowledge of increased risk in this population, at the time of diagnosis, lung cancer is often already in an advanced stage with 5-year survival as low as 15% (3-5). In the early 1970s, the National Cancer Institute sponsored several large scale studies to evaluate the utility of using chest X-ray film and sputum cytology for lung cancer screening (LCS), however, these studies failed to demonstrate any reduction in mortality (6,7).

In 2011, the National Lung Screening Trial (NLST), a multicenter randomized controlled trial, established that screening with annual low dose chest computed tomography (LDCT) provided a 20% relative mortality reduction in individuals at high-risk for developing lung cancer (8). In addition, a 6.7% reduction in all-cause mortality was demonstrated by the NSLT, the highest seen across all cancer screening modalities (8,9). The number needed to screen with LDCT to prevent one death from lung cancer is 320 (10). For comparison, the number needed to screen to prevent one death from breast or colon cancer is 1,904.
and 1,250 respectively (11,12).

Given this evidence, in 2013, the US Preventative Services Task Force recommended screening for high-risk individuals, using the NLST criteria, with the addition of expanding the upper age limit to 80 years (13). Several professional societies such as the National Comprehensive Cancer Network (NCCN), and American Association for Thoracic Surgery (AATS), and American Thoracic Society (ATS) have all published similar guidelines (14,15). In 2015, the Centers for Medicare and Medicaid Services (CMS) began covering LDCT LCS imaging, with the caveat that several requirements were met, such as smoking cessation counseling and participation in a national registry. Providing additional support to these guidelines, the recent publication of the NELSON trial (Dutch-Belgian LCS trial) reaffirmed the benefits of LCS, demonstrating a 24% and 33% mortality reduction in men and women respectively over a 10-year follow-up period (16).

Despite the convincing benefits of LCS in high-risk patients, only 3.9% of eligible patients in the United States are successfully enrolled into a screening program (17). Several groups have used anecdotal, retrospective, and mixed methods data to identify the barriers to LCS (18). LCS programs have generally not yet had the same success as the cost-effective, population-based screening programs for breast, cervical, and colorectal cancer (19). This review outlines the challenges that currently exist, summarizes the principles of effective LCS, and details the experiences of several programs in a variety of healthcare settings.

Challenges in LCS

Regardless of the convincing evidence supporting annual LDCT scans for high-risk patients, there continues to be a discordance in enrollment (17). Due to the complex nature of LCS, the list of potential barriers are several-fold. Challenges can be categorized into issues at the patient, provider, and system level (20).

Patients themselves are often unaware of LCS, or choose not to be screened due to fear of a cancer diagnosis or concerns about cost. Using semi-structured interviews, Simmons et al. discovered a substantial number of high-risk individuals had never heard of LDCT LCS, nor had a healthcare provider mention the concept of screening to them (21). Participants also noted fear of a cancer diagnosis, as well as concerns of costs and insurance coverage for LCS. These findings were supported by a recent qualitative analysis examining a high-risk population of diverse and low income outpatients, who reported an insufficient understanding of the purpose of LCS, and desired personalized information that focused on the benefits and harms of enrolling (22).

Unique to LCS, eligibility is based on high-risk behavior, namely long-term heavy smoking, differing from colon and breast cancer screening which is primarily based on age. In this context, the perceived stigma associated with high-risk smoking behavior may lead to decreased patient engagement and participation in LCS (23,24). Additionally, high-risk smoking behavior is more prevalent in lower socioeconomic tiers (25). These individuals have fewer financial and transportation resources, opportunities to take time off from work, and less social support to aid in facilitating preventative care and LCS (26).

Primary care physicians (PCP) serve as the first line of contact in addressing preventative care measures and identifying individuals who may qualify for LCS. However, known barriers at the provider level include limited knowledge regarding eligibility and the considerable time involved in discussing the LCS process with patients (21). In addition, there continue to be fractions of PCPs who still question the benefits of the NLST trial given the high false positive rate (27). PCPs also face a lack of national endorsement by national organizations such as the American Association of Family Practitioners (AAFP) (28). The AAFP has concluded that the current evidence on LCS is insufficient to recommend for or against LCS with LDCT in high-risk individuals based on age and smoking history (29). Attempts to improve physician awareness have included focused provider outreach and education by LCS program champions, however, the efficacy of this effort is unclear (30,31).

At the system level, a robust infrastructure is needed to seamlessly integrate several specialties and ancillary resources. This may entail comprehensive cancer centers, as discussed previously, or implementing sound referral policies and establishing a network of providers that remain in close communication to follow-up and manage positive findings. Additionally, LCS is resource intensive requiring considerable ancillary personnel and equipment. For instance, the number of CT scanners can impact a health system’s scalability and ability to effectively screen patients (20). In this context, it is also important to note that insurance coverage of LCS requires American College of Radiology (ACR) CT accreditation. An LCS program must receive a passing score in several areas of evaluation including: personnel qualifications, quality control/
quality assurance, and image quality (32). Additionally, accreditation requires the use of Lung-RADS or a similar structured reporting and management system. Accreditation should provide patients and referring providers assurance and standardization in the receipt of high quality screening and recommendations for appropriate follow-up care (33).

Furthermore, some health system challenges stem from disparities in health policy. For instance, LCS is not often prioritized by health systems as it is not recognized by national healthcare performance metrics. The CMS implemented Merit-Based Incentive Payment System (MIPS) program compensates health systems based on performance in a variety of quality measures (34). As a component of the program’s preventative care initiative, screening rates for colon, breast, and cervical cancer are factored into a health system’s performance. However, LCS has not yet been recognized as a preventative care measure by the MIPS program. This impedes health systems from making LCS as high of a priority as other cancer screening programs.

### Defining the ideal LCS program

Several groups have offered perspective and expert opinion of a high quality LCS program, often through a variety of descriptors ranging from pillars to key components of success (20,31,35-38). The Thoracic Oncology Assembly of the American College of Chest Physicians (AACP) and the American Thoracic Society (ATS) identified several core components of an effective LCS program using evidence-based reviews and expert opinion outlined in an issued policy statement (35). Common themes include structured referral network, multidisciplinary collaboration, comprehensive patient coordination and follow-up, standardized reporting and patient data management system, and implementation of quality assurance measures (Table 1).

<table>
<thead>
<tr>
<th>Components of an effective lung cancer screening program</th>
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<tr>
<td>Structured referral network</td>
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<tr>
<td>Multidisciplinary collaboration</td>
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<tr>
<td>Comprehensive patient coordination and follow-up</td>
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<tr>
<td>Standardized reporting and patient data management</td>
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<td>Quality assurance</td>
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</table>

A strong referral network is critical to the viability of an LCS program. The onus of identifying eligible patients primarily falls on the shoulders of PCP, as a component of preventative patient care. Thus, the ideal LCS program has a strong investment from the primary care community and offers policies and logistical support to facilitate the referral practices of PCPs (31). A number of educational resources have been developed and can be disseminated to providers to promote adherence to the national screening guidelines. Increased PCP education regarding the benefits of LCS, insurance coverage guidelines, and shared decision making process may lead to increased referrals into an LCS program (30).

A multidisciplinary presence is integral to the success of an LCS program (38). Typically, representation is needed from primary care, pulmonary medicine, medical oncology, thoracic surgery, radiology, pathology, smoking cessation counselors, and nurse coordinators. Often representatives from most of these groups will convene at routinely scheduled tumor board or lung nodule meetings. Given the importance of multidisciplinary collaboration in implementing an effective screening program, comprehensive LCS centers afford the opportunity to deliver shared decision making, imaging, interpretation, and management within a single venue for a patient (30). Thereby providing patients a “one-stop shop” to facilitate LCS in a convenient manner. A caveat to the aforementioned comprehensive cancer center is the significant resources and infrastructure needed to create and maintain such a program.

Due to the inherent invasive nature of thoracic surgery, the specialty is often the last to be consulted and involved in guiding care for a nodule discovered on a screening LDCT scan. However, it is imperative that thoracic surgeons are involved early, as their expertise and management of positive findings on an LDCT can optimize the delivery of care for a patient (5). Moreover, excessive and unnecessary use of diagnostic resources and interventional procedures can be avoided when a multidisciplinary team is in place to investigate and manage nodules discovered on a LDCT (39). For example, a patient with a lung nodule that is highly suspicious for lung cancer may prefer diagnostic wedge resection followed by lobectomy, rather than percutaneous biopsy with the possibility of a false negative result.

In terms of patient coordination and follow-up, a patient navigator (often a mid-level provider in the department of radiology, medicine, pulmonology, or surgery) is essential to the success of a program (31,40). They are responsible for ensuring referring providers adhere to recommendations
stated in the radiology report, assisting patient referral to the appropriate specialty and provider from the clinical management team, and coordinating annual follow-up for negative scans.

A standardized reporting system is a vital component to the efficacy of an LCS program. Radiology reports for LDCT should communicate pertinent positive and negative findings, as well as incorporate management algorithms (35). The most commonly used structured reporting system is the American College of Radiology Lung CT Screening Reporting and Data System (Lung-RADS). It is recommended that at least 90% of LDCT scans performed within an LCS program be reported using a structured system in order to minimize variation in the management of nodules and permit the opportunity for consistent and uniform care (35,41).

Lastly, a robust quality improvement program is not only a requirement by the CMS, but an imperative asset to ensure reliability and effectiveness of a screening program. The ATS/AACP recommend review of an LCS program’s screening data and adherence to the components discussed above on an annual basis by an oversight body to determine the level of compliance and areas of deficiency (35). Collected screening data should include outcomes of testing (complications and number of cancer diagnoses), tumor characteristics, and treatment patterns (35). Furthermore, as a quality metric, it is recommended at least 90% of screened individuals should meet USPSTF eligibility guidelines (35).

### Experiences in implementing LCS programs

Several groups have established LCS programs in a variety of health care systems and socioeconomic settings in recent years. These published efforts offer invaluable information including points of success, challenges, and pitfalls that may be avoided in the future by others attempting to implement an LCS program of their own. Many of the programs reiterate the policies and suggestions put forth by the AACP/ATS previously discussed. A brief summary of selected studies is presented in Table 2.

Gaps in patient and provider knowledge regarding LCS were challenges encountered by several programs in a variety of settings ranging from the Veterans Affairs (VA) health system to community and academic institutions (32,42-45). Batlle and colleagues encouraged new LCS programs to invest in strategic marketing campaigns to promote awareness of its existence and the inherent benefits (32). Suggested cost-effective opportunities included grand rounds, patient educational seminars, social media outreach, and in-person visits with local physician practices. In addition, the latter facilitates the development of a robust physician referral network among PCP. In the aforementioned implemented program, one-third of the patients enrolled into LCS were directed through non-physician sources including newspapers, magazine advertisements, radio commercials, social media, and word of mouth (32). Simmerman et al. described the development of a Cancer Community Awareness & Access Research Education program to promulgate the concept of LCS to minorities and underserved populations (46). In addition to patient directed campaigns, continued provider medical education is paramount as well. Previous qualitative studies have documented a clear gap in LCS guidelines and reimbursement knowledge (47). A recently established community LCS program discovered 22.4% (80/357) of the patients it had screened through referral were ineligible per NCCN and USPSTF guidelines (48). Similar findings were mirrored in LCS programs implemented in academic health systems as well (43,45).

Coordinating care for patients with positive findings on LDCT was another commonly encountered challenge (32,45,49). Solutions encouraged by several programs included hiring nurse navigators and advanced practice nurses (APN) to direct patients to the appropriate clinicians and imaging, as well as ensuring appropriate follow-up given screening should be done on an annual basis (32,44,50). Nurse navigators have been described as the foundation of specialized LCS programs, as they are responsible for patient counseling, organizing clinical results, and mediating patient-physician interactions (51). One of the successful LCS programs implemented a toll free number for coordinators to address patient inquiries (43). Besides the logistical advantages of advanced nurse practitioners, there may be an economic benefit as well. Gilbert and colleagues examined the economic impact of a nurse practitioner directed LCS program, discovering increased revenue for their Thoracic Surgery and Interventional Pulmonary divisions primarily generated from newly identified diseases and the subsequent evaluations, procedures, and surgeries (52).

A strong multidisciplinary presence within an LCS program’s leadership is imperative and emphasized by several of the implemented programs (32,49,53,54). Leadership responsibility includes the development of a self-sustaining infrastructure with protocols in place to limit inconsistencies in patient care. Within a VA health system, a review of several LCS participating sites revealed
### Table 2 Overview of recently implemented lung cancer screening programs

<table>
<thead>
<tr>
<th>Reference</th>
<th>Health system type</th>
<th>Study period (months)</th>
<th>Number of patients screened</th>
<th>Lung Cancer detection rate, n (%)</th>
<th>Challenges identified</th>
<th>Notable features of program</th>
<th>Key takeaways/recommendations</th>
</tr>
</thead>
</table>
| Okerke et al., VA 2016 (42) | VA                | 12                    | 1,832                       | 55 (3%)                         | ● Misconception of screening benefits by smokers  
● Inadequate lung cancer screening counseling by providers | ● Smoking exposure is more prevalent in veterans than in general population  
● Clinical reminder integrated into EMR to prompt PCPs to assess patients' eligibility for lung cancer screening | ● Electronic aids can assist patient selection  
● Establish patient advocacy and outreach to promote LCS awareness  
● Implementation of an LCS program in the veteran population can be very effective given the known high-risk smoking patterns of this population |
| Miller et al., Community 2016 (48) | Community        | 18                    | 357                         | 8 (2.2%)                        | ● Screening ineligible patients  
● 22.4% (80/357) of the patients screened were ineligible per NCCN and USPSTF guidelines | ● Focused screening centers were established for patients living in rural areas  
● Spot audits were performed to maintain internal consistency among interpreting radiologists | ● Ensure standardized ordering practices are in place to ensure accuracy in eligibility for LCS  
● Consider utilizing electronic aids to guide PCP ordering practices  
● Invest in physician LCS education |
| Lanni et al., Academic 2015 (45) | Academic | 12                    | 1,065                       | 20 (1.6%)                       | ● Coordinating care for those with positive findings  
● Variability in ordering practices  
● Resource allocation given increased throughput | ● Dedicated Lung Nodule Clinic (directed by a group of pulmonary physicians)  
● Multidisciplinary team  
● Standardized intake and test protocols | ● Given increased utilization of CT machines for LCS, it is important to identify the specific machines that will be available for LDCT imaging for screening  
● Standardize test ordering protocols, intake process from appointment center, registration, and follow-up  
● Robust information technology infrastructure is needed to ensure information is properly documented |
| Simmerman et al., Community 2017 (48) | Community       | 24                    | 264                         | 8 (3%)                          | ● Enrolling minorities/underserved populations  
● Patients unaware of the existence of LCS | ● Development of a Cancer Community Awareness & Access Research Education program to improve cancer outcomes for the underserved | ● Use community based approaches and advocates to deliver education focused on cancer screening for minorities and medically underserved populations to promote awareness |
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<th>Key takeaways/recommendations</th>
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| Kinsinger et al., 2017 (50) | VA                | 24                    | 2,106                      | 31 (1.5%)                       | • Difficult to implement an electronic LCS tool given limited detailed information on pack-year smoking history and quit date  
  • Patient concerns for screening include: exposure to radiation, need for screening, psychological distress, and effort needed for examinations  
  • Increased workload for pulmonary and radiology services | • A developed LCS Implementation Guide was in place for staff and patients at all sites participating in screening  
  • Physician leaders were assigned to each screening location  
  • Full time, salary supported LCS clinical coordinators  
  • Strong support from facility leadership, clinical champions | • Research is needed in the development and design of decision aids for providers  
  • Staff dedicated to patient coordination and follow-up  
  • Involve PCPs in decision making for incidental findings to promote appropriate management  
  • Assign physician leaders to each medical center comprising a LCS program |
| Guichet et al., Community 2017 (9) | Community         | 21                    | 889                        | 2 (0.7%)                        | • The socioeconomic burdens for the underserved population limit patient adherence to follow up recommendations and referrals to specialists | • Targeted minority, socioeconomically disadvantaged, high-risk population  
  • Grant funding permitted coverage of all expenses involved in launching LCS program, community outreach, LDCT exams, and transportation for patients | • Lung cancer screening in a minority and socioeconomically disadvantaged population is feasible, however, the cancer profile may be different than previously published studies with less diverse study populations |
| Ahmed et al., Academic 2018 (49) | Academic          | 16                    | 272                        | 6 (2.2%)                        | • Ensuring patients receive appropriate follow-up and scheduling of subsequent screening examinations | • In order for a physician to order a LDCT screening exam, several questions assessing eligibility must be answered before order is executed in electronic medical record | • Multidisciplinary team is necessary to ensure appropriate patient selection and maximum benefit from screening  
  • Establish a screening coordinator to facilitate communication of screening results with ordering providers, ensuring all results are reviewed, arranging referral for consultation or further imaging |
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<tr>
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<tbody>
<tr>
<td>Patel et al., 2016 (44)</td>
<td>Community</td>
<td>13</td>
<td>150</td>
<td>1 (0.7%)</td>
<td>• Documentation of detailed smoking history</td>
<td>• Self-referral of high-risk patients allowed to facilitate increased access</td>
<td>• Outcomes monitoring</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td>• Limited radiology staff services to interpret increased volume of CT scans</td>
<td>• Multidisciplinary Thoracic Oncology Clinic in place</td>
<td>• Standardized structured reporting</td>
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<td></td>
<td></td>
<td>• Lack of coverage for LCS by some insurance carriers. Self-pay for LDCT was</td>
<td>• Structured intake questionnaire by centralized scheduler</td>
<td>• Smoking cessation counseling</td>
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<td></td>
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<td>approximately $199</td>
<td>• Within 5 d of LDCT, an advanced practice nurse (APN) will contact patient to discuss</td>
<td>• Multidisciplinary team</td>
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<td></td>
<td></td>
<td>results and schedule appropriate follow-up</td>
<td>• Advanced practice nurse for coordination, and insurance preauthorization and verification</td>
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<td>• Implemented an internal lung reporting and data system (L-RADS) for reporting results</td>
<td>• LDCT protocol and dose optimization</td>
</tr>
<tr>
<td>Mckee et al., 2013 (43)</td>
<td>Academic</td>
<td>10</td>
<td>500</td>
<td>3 (0.6%)</td>
<td>• Lack of universal reimbursement for LCS**</td>
<td>• Extensive local continuing medical education campaign (physician to physician</td>
<td>• A decentralized and informed patient referral network</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Lack of provider experience with LCS</td>
<td>discussions at referring PCP practices, grand rounds to raise awareness)</td>
<td>• Collaboration with local PCP networks</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>• Radiology equipment logistics (managing increased throughput from added LCS</td>
<td>• Toll free number for patient inquiries</td>
<td>• Standardized reporting</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td>program)</td>
<td>• Patients are contacted by patient navigator within 3 weeks of LDCT exam to answer</td>
<td>• Dedicated patient management system</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td>questions, schedule follow-up, and conduct a patient satisfaction survey</td>
<td>• Multidisciplinary coordination</td>
</tr>
<tr>
<td>Battle et al., 2018 (32)</td>
<td>Community</td>
<td>22</td>
<td>1241</td>
<td>19 (1.5%)</td>
<td>• Patient attrition</td>
<td>• Strong multidisciplinary team planning</td>
<td>• Launch a marketing campaign targeting both patients and physicians</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>• Large number of patients screened not meeting USPSTF eligibility</td>
<td>• Two nurses hired as patient navigators to verify eligibility and refer patients to</td>
<td>• The program director should establish a clear vision for the LCS program and set a</td>
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<td></td>
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<td></td>
<td>appropriate provider for nodule management</td>
<td>realistic timeline for implementation</td>
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<td></td>
<td></td>
<td></td>
<td>• Robust quality improvement strategies to facilitate continuous clinical and diagnostic improvements</td>
<td></td>
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</table>

VA, veterans affairs; LCS, lung cancer screening; EMR, electronic medical record; PCP, primary care physician. **, studies were performed prior to CMS approval of LDCT for Lung Cancer Screening in 2015.
inconsistencies in patient selection and the utilization of quality audits (55). The complexity of implementing an LCS program within an institution comprised of multiple medical centers is largely attributable to inherent variations in medical practice. In this context, it is vital for program leadership to assign physician leaders at each participating site within a program to distribute and enforce polices regarding patient selection, physician referral, imaging protocols, shared decision making, smoking cessation services, and management of positive findings on LDCT (50). Additionally, an increase in LCS uptake will naturally lead to increased workload on staff and resources (44,50). As the throughput for LCS increases for any given program, it is essential for the leadership team to manage resource allocation and make additions if needed.

The prevalence of smoking is known to be higher amongst minorities and those that are socioeconomically disadvantaged (56). A responsible and effective LCS program will allocate resources to assist this vulnerable population. Guichet et al. reported their experience in targeting underserved populations, revealing socioeconomic burdens as a barrier to patient adherence to recommendations and referrals to specialists (9). LCS programs should focus on community outreach and social services for these individuals to promote LCS awareness and to clarify the commonly misconceived notion that screening will be an expensive burden (21,46).

The future of LCS

With the ubiquitous nature of technology in patient care, a natural progression is the implementation of electronic aids to assist physician decision making (48). Ahmed and colleagues described the utilization of an electronic questionnaire that must be completed by a provider wishing to order a LDCT as an attempt to enforce appropriate screening (49). Others have incorporated computerized clinical reminders for physicians regarding patient current or recent smoking (57). However, there remain challenges in capturing detailed smoking history (pack-years and years since quitting) within the electronic medical record for these aids to be beneficial for LCS (50). Electronic aids are undoubtedly innovative and promising, however, little is known regarding their feasibility, scalability, and efficacy.

Another opportunity to improve LCS is broadening the points of referral. Currently, identifying eligible high-risk individuals for LCS is dependent on PCPs. An interesting concept may be expanding the responsibility of LCS enrollment to specialties beyond primary care. Emergency Departments (ED) have emerged as an important community resource for implementing preventative healthcare services (58). Further, ED patients smoke at rates far in excess of the national average, as high as 48% (59). Accordingly, the ED would appear to be an ideal platform to capture many high-risk smokers that would benefit from LDCT LCS. Furthermore, an important aspect of utilizing the ED as a resource for enrollment is the large volume of socioeconomically disadvantaged, racial and ethnic minorities who seek care in the ED (60). Often the ED is the only point of interaction with the healthcare system for these individuals. In this context, the ED has long been identified as an important public health platform for assessing patients’ smoking status, offering brief advice to quit, and referring patients to smoking cessation programs (58,59). However, there is limited information regarding the ED’s ability to identify and refer eligible patients for LCS (61).

Conclusions

Regardless of the convincing evidence supporting LDCT screening for high-risk patients, there continues to be a discrepancy in enrollment not seen in other cancer screening programs. Undoubtedly, there are a variety of challenges for patients, providers, and medical systems. However, many of these challenges can be overcome through a concerted effort from providers and healthcare leadership. Depending on the healthcare system and resources available, there are certainly unique considerations that must be made when implementing an LCS program. However, the general core principles have been outlined in this review.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/ccts-20-47). MR reports personal fees from Intuitive Surgical outside the submitted work. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related
to the accuracy or integrity of any part of the work are appropriately investigated and resolved. No patients were directly involved in this review, accordingly informed consent was not needed.

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