ORIGINAL ARTICLE

Early detection of lung cancer in a population at high risk due to occupation and smoking

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Received 15 August 2018
Revised 10 September 2018
Accepted 23 September 2018
Published Online First 10 November 2018

ABSTRACT

Objective The US National Comprehensive Cancer Network (NCCN) recommends two pathways for eligibility for Early Lung Cancer Detection (ELCD) programmes. Option 2 includes individuals with occupational exposures to lung carcinogens, in combination with a lesser requirement on smoking. Our objective was to determine if this algorithm resulted in a similar prevalence of lung cancer as has been found using smoking risk alone, and if so to present an approach for lung cancer screening in high-risk worker populations.

Methods We enrolled 1260 former workers meeting NCCN criteria, with modifications to account for occupational exposures in an ELCD programme.

Results At baseline, 1.6% had a lung cancer diagnosed, a rate similar to the National Lung Cancer Screening Trial (NLST). Among NLST participants, 59% were current smokers at the time of baseline scan or had quit smoking fewer than 15 years prior to baseline; all had a minimum of 30 pack-years of smoking. Among our population, only 24.5% were current smokers and 40.1% of our participants had smoked fewer than 30 pack-years; only 43.5% would meet entry criteria for the NLST. The most likely explanation for the high prevalence of screen-detected lung cancers in the face of a reduced risk from smoking is the addition of occupational risk factors for lung cancer.

Conclusion Occupational exposures to lung carcinogens should be incorporated into criteria used for ELCD programmes, using the algorithm developed by NCCN or with an individualised risk assessment; current risk assessment tools can be modified to incorporate occupational risk.

Key messages

What is already known about this subject?
- Early detection of lung cancer with low-dose CT has been shown to reduce mortality.
- Many individuals have been exposed to known lung carcinogens in their work, but current enrolment criteria recommended by professional organisations in the USA rarely include occupational risk.

What are the new findings?
- Using criteria that include occupational risk we detected a baseline rate of lung cancer equivalent to that found in the US National Lung Screening Trial, although less than half the cohort met smoking criteria used in that trial.
- This study validates lung cancer screening entry criteria recommended by the National Comprehensive Cancer Network.

How might this impact on policy or clinical practice in the foreseeable future?
- Risk calculators need to be modified to include occupational exposures in the algorithms.
- Early Lung Cancer Detection programs should specifically include individuals at high risk from occupational exposures.

INTRODUCTION

Lung cancer is a leading cause of cancer death worldwide. Five-year survival is 19% for all lung cancers and 55% for localised tumours; average 5-year survival for advanced cases with metastases is only 4.5%.

In 2011, the National Lung Screening Trial (NLST) demonstrated a 20% reduction in mortality attributable to three annual screenings using low-dose CT (LDCT).[1] Subsequently, the Preventive Services Task Force of the United States Public Health Service recommended lung cancer screening, as have other professional organisations provided that it is undertaken as a structured programme in centres with considerable expertise in lung cancer care, although not all agreed with the recommendation.[2] Discussion continues about defining appropriate risk for screening, frequency of screening, overdiagnosis of lung cancer and evaluation of non-nodule incidental findings. In Europe, recommendations on screening are awaiting the results of the NELSON trial and pooled analyses across screening trials[3–5]; ongoing trials are providing information on screening frequency, nodule management and potential for overdiagnosis.

Most guidelines for lung cancer screening do not include assessment of occupational risk, although this risk is incorporated in the National Comprehensive Cancer Network (NCCN) lung cancer screening guidelines[6] and risk models from Cronin and the Liverpool Lung Project (LLP).[7 8] Here, we present results of a lung cancer screening programme in workers at high risk for lung cancer due to a combination of occupational exposures and smoking.

METHODS AND MATERIALS

Medical programme

The study population is a subset of participants in the Building Trades National Medical Screening

► http://dx.doi.org/10.1136/oemed-2018-105464

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To cite: Welch LS, Dement JM, Cranford K, *et al*. *Occup Environ Med* 2019;**76**:137–142.

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Program (BTMed). BTMed is funded by the Department of Energy (DOE) to provide medical screening examinations to construction trades workers previously employed at DOE atomic weapons facilities, to determine if these workers have a significant risk of occupational illness.

BTMed collects a detailed history of occupational exposure followed by an examination by providers who adhere to a detailed protocol.[9–12] As of 31 December 2016, a total of 21 488 workers had completed at least one examination. The information from these screenings is then used to identify participants for the Early Lung Cancer Detection Program (ELCD) programme. These workers are at significantly increased risk for lung cancer mortality (43% higher than the general population),[13] and have an elevated risk of obstructive lung disease.[14]

Early Lung Cancer Detection program

In 2011, BTMed began LDCT screening as a pilot at one screening location, and over the next 3 years started programmes in three other cities, partnering with centres that adhere to the Lung Cancer Alliance framework for lung cancer screening[15] and follow ACR guidelines for LDCT administration.[16] Radiologists were asked to use a template, report non-nodule findings including interstitial lung disease and other findings in the neck, mediastinum, adrenal, kidneys and abdomen, and to use a simple scoring of mild/moderate/severe for coronary calcification and emphysema.

For this analysis, we include workers who had participated in a BTMed screening through 30 September 2016 and were invited to participate in lung cancer screening. The BTMed ELCD programme adheres to the NCCN lung cancer screening guidelines for screening eligibility[6]; with the addition of a requirement of 5 years of work in the construction industry or 5 years of work in a job with exposures to asbestos, silica, beryllium, chromium, radiation or welding. Screening was additionally offered to workers with chest radiographic findings consistent with asbestosis without regard to smoking history or years of construction work, and to workers with chronic obstructive pulmonary disease (COPD) or pleural plaque even if they had worked fewer than 5 years as defined above due to the recognised risk from these clinical findings.[17 18]

Prior to 2014, we used the NCCN (V.2012) algorithm to guide use of repeat LDCT and diagnostic evaluations.[6] In 2014, we adopted ACR-LungRADS[19] and reclassified all nodules using the LungRADS algorithm. We classified each scan as either negative for nodules (LungRADS 1 and 2) or as having indeterminate (needing a repeat scan in 6 months, Lung RADS 3) or suspicious nodules (a scan in 3 months or immediate referral for consultation LungRADS 4). Not every radiologist used the template provided; for this analysis, we have assumed that if a non-nodule finding was not reported it was not present.

Radiation dose was measured as dose length product (DLP). We used the conversion factor of 0.014 to estimate effective dose in mSv, as recommended.[20]

Physical and psychosocial status was measured at each scan with V.2 of the standard SF-12 questionnaire (SF12 V.2)[21] and Physical Component Summary Scores and the Mental Component Summary Scores generated using QualityMetric Health Outcomes Scoring Software V.5.0 (V.5.0.6163.22119).

All participants who were not diagnosed with lung cancer and who continued to meet age requirements were asked to return for annual LDCT examinations. All smokers were referred to smoking cessation programmes and sent information on additional tools with their results.

Table 1 Demographic and clinical characteristics Early Lung Cancer Detection (ELCD) participants and non-participants and comparison with all Building Trades Medical Screening (BTMed) participants

		ELCD programme invited (n=4399)	
Characteristic	All BTMed participants (n=21 488)*	ELCD participants (n=1290)	ELCD non-participants (n=3109)
Mean age (SD)	62.4 (12.5)	65.2 (6.8)	59.9 (8.6)†
Male sex (N, %)	19 986 (93.0)	1228 (95.2)	2936 (94.4)
Race/ethnicity (N, %)‡			
White	18 504 (86.1)	1183 (91.7)	2761 (88.8)†
Black or African-American	2118 (9.9)	76 (5.9)	264 (8.5)
Other	536 (2.5)	18 (1.4)	52 (1.7)
Unknown or missing	330 (1.5)	13 (1.0)	32 (1.0)
Spirometry, mean (SD)			
% predicted FEV_1	84.8 (21.1)	84.2 (19.0)	81.8 (19.0)†
COPD prevalence (N, %)§	3129 (15.3)	205 (15.9)	618 (20.3)†
Chest X-ray B-reader prevalence (N, %)			
Parenchymal changes (profusion ≥1/0)	831 (4.0)	78 (6.1)	129 (4.4)†
Pleural changes¶	3079 (14.8)	285 (22.1)	387 (12.7)†
Cigarette smoking status at examination (N, %)			
Current smoker	3589 (16.7)	317 (24.6)	1135 (36.5)†
Past smoker	9896 (46.1)	936 (72.6)	1838 (59.1)
Never smoker	7618 (35.5)	37 (2.9)	114 (3.7)
Smoking unknown	385 (1.8)	0 (0.0)**	22 (0.7)
Mean cigarette pack-years (SD)	20.1 (25.6)	36.0 (21.9)	38.8 (24.6)†
Mean body mass index (SD)	29.8 (5.4)	29.6 (5.4)	29.9 (5.3)
Years of DOE site work, mean (SD)	8.8 (9.9)	12.1 (11.4)	8.9 (9.5)†
Years of construction work, mean (SD)	22.4 (13.9)	26.0 (12.0)	24.5 (11.8)†

*Data for BTMed participants are based on their most current examination. Number and percent values are based workers with data for each measure. A total of 1153 workers lacked sufficient data to estimate pack-years of cigarette smoking.
†Data variable for participants statistically difference ($p<0.05$) based on a χ^2 test of general association for categorical variables, Pearson χ^2 test for proportions and analysis of variance or Wilcoxon rank-sum tests for continuous variables as appropriate.
‡Some categorical variables may not add to 100% due to rounding.
§COPD was defined as a FEV_1/FVC ratio below the Lower Limit of Normal using the prediction equations of Hankinson *et al*[44] without use of bronchodilation. Results shown for all spirometry meeting American Thoracic Society criteria.
¶B-reader notations of findings of unilateral or bilateral pleural thickening consistent with pneumoconiosis.
**Smoking status updated at ELCD programme enrolment.
DOE, Department of Energy; FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity.

The study was funded under cooperative agreement DEFC01-06EH06004 with the US DOE. Welch occasionally testifies as an expert witness for workers with asbestos-related diseases; the remaining authors have no competing interests.

RESULTS

Study population

Since the inception of the ELCD programme, we periodically invited workers eligible for lung cancer screening from the larger population of BTMed participants. Between 2011 and 2016, 4399 individuals were invited. Of these 1290 (29%) received a baseline LDCT screening. Table 1 shows demographics of the both the ELCD enrolled population and those invited but not yet participating. ELCD participants were somewhat older, had

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Table 2 Early Lung Cancer Detection (ELCD) scan results and lung cancers detected by scan type

Outcome measure	All ELCD scans	Baseline scan and required follow-up scans*	First annual scan and required follow-up scans*	All other annual scans and required follow-up scans*
No of low-dose CT scans performed				
Baseline low-dose CT scans	1290	1290		
Follow-up low-dose CT scans	356	236	57	63
Annual low-dose CT scans†	1659	–	898	761
Individuals with Indeterminate nodules‡	194	154	30	18
Individuals with suspicious nodules†	117	76	20	23
Individuals diagnosed with lung cancer§				
Non-small cell lung cancers				
Stage I	17	13	2	2
Stage II	3	2	0	1
Stage III	0	0	0	0
Stage IV	6	5	0	1
Small cell lung cancers				
Limited	2	1	0	1
Extensive	2	0	2	0
Individuals referred for follow-up other than potential lung cancer*	614	506	161	96
Estimated radiation absorbed dose per scan, measured as dose length product (DLP) (mGy cm)¶				
DLP mean	96.8			
DLP (SD)	41.0			
DLP range	0.5–843.0			

*Counts of indeterminate nodules, suspicious nodules and referrals for immediate follow-up will not add to the total as workers can have events for multiple scans.
†Suspicious nodules—non-calcified nodules that are highly suspicious for malignancy and require immediate follow-up. Individuals are referred to outside specialists.
‡Indeterminate nodules—non-calcified nodules that are not obviously benign nor highly suspicious. Individuals are offered a follow-up low-dose CT scan at 3 or 6 months.
§One worker with a suspicious nodule was still being evaluated at the time of these analyses.
¶DLP values were missing for 91 ELCD scans.

more radiological findings, smoked more and worked longer in both construction and at DOE sites than all BTMed participants. Those invited but not participating were younger than participants, a greater proportion were black or African-American and were more likely to be current smokers with higher mean cigarette mean pack-years, a higher prevalence of COPD and a lower mean percent predicted forced expiratory volume in 1 s. On average, non-participants had worked fewer years in construction and on DOE sites.

Lung cancer detection

In 1290 participants with at least a baseline scan, 194 were found to have indeterminate nodules and 117 had suspicious nodules; 24.1% needed a follow-up CT prior to next annual visit. Four participants have been diagnosed with small cell lung cancer (SCLC); two classified as limited and two as extensive. Twenty-six cases of non-SCLC (NSCLC) were detected by LDCT: 17 were stage I, 3 were stage II and 6 were stage IV. Two additional cancers developed between rounds of screening.

Table 2 shows detection of nodules and lung cancers on LDCT by screening round. A cancer was attributed to the baseline scan if a nodule was detected at baseline and subsequently diagnosed as cancer. The detection rate of NSCLC was 1.6% on baseline scan and 0.2% on annual scan. At the annual rescreenings, 5.5% had a suspicious or indeterminate nodule finding. Six NSCLC cases and three SCLC cases were detected during annual screening rounds after baseline. Of these, five NSCLC cases were diagnosed at stage I or II. The distribution of pathological diagnoses is comparable to the NLST andInternational Early Lung Cancer Action Program (IELCAP)[22 23]; our cases of adenocarcinoma sum to 57%, while the NLST reported 54.7% and the other cell types are also similar.

Radiation dose

Radiation dose per LDCT as measured in DLP is also shown by screening site in table 2. DLP per CT scan administered ranged from 0.5 to 843.0 mGy cm. The average was 96.8, which converts to an average effective radiation dose of approximately 1.36 mSv (SD=0.57 mSv).

Non-nodule findings

Of the 1290 participants with at least one LDCT, 1229 (95.2) had one or more non-nodule findings reported by the radiologist. Table 3 shows a breakdown of conditions reported for all scans performed: 38.6% of scans showed some form of COPD or emphysema; 25% had moderate or severe coronary calcification. Two cancers in organs other than the lung were identified, one oesophageal and one kidney.

Adverse consequences

Table 4 shows Short Form 12 (SF-12) score for ELCD participants with negative scans compared with ELCD participants with an indeterminate or suspicious nodule. There are no significant differences in scores between baseline and follow-up, nor between participants with and without a nodule.

Two participants who had lung surgery for evaluation of a nodule turned out not to have cancer; however, both had a significant diagnosis, one with bronchiolitis obliterans and marked pleural fibrosis and the other with a fungal mass. Two participants died within 2 weeks of lung cancer surgery. One, with a lobectomy for stage 1 minimally invasive adenocarcinoma, had a pulmonary embolism and thrombocytopenia postoperatively which was eventually attributed to an undiagnosed coagulation disorder; he died 12 days postoperatively. A second

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Table 3 Prevalence of non-nodule findings at baseline CT

Incidental finding	Prevalence of findings (N, %)
COPD/emphysema	498 (38.6)
Emphysema severity	
Mild	321 (24.9)
Moderate	83 (6.4)
Severe	30 (2.3)
Not classified	856 (66.4)
Interstitial lung disease	331 (25.7)
Pleural disease	263 (20.4)
Cardiovascular disease	936 (72.6)
Cardiac calcification severity	
Mild	561 (43.5)
Moderate	214 (16.6)
Severe	107 (8.3)
Not classified	408 (31.6)
Thyroid abnormality	28 (2.7)
Neck and mediastinal abnormalities	531 (41.2)
Breast abnormalities	17 (1.3)
Abdominal abnormalities	257 (19.9)
Adrenal abnormalities	38 (3.0)
Kidney abnormalities	107 (8.3)
Bone abnormalities	221 (17.1)
Other cancers	2 (0.2)
Other abnormalities	270 (20.9)

participant died of pneumonia 10 days after lobectomy for an adenocarcinoma.

DISCUSSION

Here, we report on screen-detected lung cancers among individuals enrolled using the group 2 criteria developed by the NCCN, with modifications as described above to account for occupational exposures. Although only 43.5% of our ELCD participants would have met the entry criteria set by the NLST, we detected lung cancers at baseline at a rate similar to the NLST.

Importance of occupational risk factors

The International Agency for Research on Cancer lists 13 agents with high likelihood of causing lung cancer: ionising radiation, asbestos, silica, nickel, cadmium, chromium, beryllium, arsenic, diesel exhaust, soot, bis(chloromethyl) ether, coal tar pitch and sulfur mustard. Many of the workers in the cohort presented here have had exposure to the first 10 agents, with exposure varying by occupation and years worked; 95% of workers reported some exposure to asbestos and silica. Our knowledge about the risk for lung cancer with exposure to these agents is variable, with the most research available on asbestos. There is a dose–response relationship between exposure to asbestos and the risk of lung cancer.[17 24] Workers with asbestosis have a two to fourfold higher risk of lung cancer than asbestos exposed workers without asbestosis.[17 25] Studies also suggest that there is a more than additive interaction between asbestos and cigarette smoking; it is not yet established if this interaction exists for other lung carcinogens as well.

BTMed participants overall experienced substantial exposure to many of these lung carcinogens, with an average of 26 years in the construction industry, of which an average of 12 years was at a DOE atomic weapons facility. Overall 17% have radiographic evidence of asbestos-related disease, and a twofold risk of obstructive lung disease compared with US national statistics.[14]

The NCCN algorithm for lung cancer screening includes occupational exposure to lung carcinogens as one of the factors that can be used in identifying high-risk individuals, but NCCN does not specifically define occupational exposure. The lung cancer risk model developed by Bach (http://nomograms.mskcc.org/Lung/Screening.aspx) incorporates occupation with 5 years of work in specific occupations. Combining these data sources, we estimated that the risk from 5 years of exposure in the construction industry to a range of lung carcinogens is at least as high as the risk from a family history of lung cancer or a diagnosis of COPD.[26]

McKee *et al*[27] have previously reported on the validity of the NCCN group 2 criteria for lung cancer screening, demonstrating that the same rate of cancer was detected among the individuals screened who met group 2 criteria as those meeting the group 1 criteria. While that population included individuals who were eligible due to family history of lung cancer or a diagnosis of COPD as well as individuals with occupational risk, occupational risk was an entry criterion for all workers in our population.

Seven LDCT screening programmes among asbestos exposed workers were summarised in a meta-analysis[28] with an overall rate of lung cancer detection at baseline of 1.1%, similar to what we report here. The Asbestos Review Programme in Western Australia offered LDCT to workers who had a minimum of 3 months asbestos exposure. The prevalence of lung cancer was 0.77% even though only 62.8% of the cohort were ever-smokers, and the mean tobacco history was 17.1 pack-years.[29] These reports support our recommendation for ELCD programmes s in populations with lung cancer risk from occupations.

Our participants volunteered for an initial medical examination and then volunteered for lung cancer screening. Studying volunteers can lead to participation bias, but we do not think that bias applies, since each participant met the risk criteria for lung cancer

Table 4 SF-12 scores at baseline and annual follow-up

	Normal baseline scan (n=739)			Indeterminate or suspicious nodule on baseline scan (n=119)		
SF-12 summary measure	Mean	SD	95% CI for Mean diff	Mean	SD	95% CI for Mean diff
SF-12 Physical Health Score						
Baseline	43.94	11.07		43.70	12.00	
Annual follow-up	43.07	11.39		44.34	10.30	
Difference (follow-up—baseline)	−0.87*	6.49	−1.34 to −0.40	0.64	7.63	−0.74 to −2.03
SF-12 Mental Health Score						
Baseline	55.05	9.23		55.42	9.49	
Annual follow-up	54.93	9.12		55.63	7.78	
Difference (follow-up—baseline)	−0.11	6.61	−0.59 to −0.36	0.21	7.16	−1.09 to −1.51

*Significant difference in baseline and first annual follow summary scores ($p<0.05$) using a paired t-test.

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screening. The staging and distribution of pathology is comparable to the NLST and IELCAP,[22 23] and the rate of screen-detected cancers at baseline is comparable to the NLST baseline and also to what was reported in the recent study from the Veterans Administration (1.5%).[30] However, we detected fewer cancers at the first annual screen than would have been expected; future risk models will need to determine if biannual screening is sufficient in individuals enrolled due to occupational risk.

As described above, only 43.5% of our cohort would have met the entry criteria for the NLST. The most likely explanation for the high prevalence of screen-detected lung cancers in the face of a reduced risk from smoking is the addition of occupational risk factors for lung cancer. In this context, it is important to note that occupational exposure to vapours, gas, dust and fumes (VGDF) has been identified as a significant risk factor for COPD generally and in this population specifically,[14] and some of the identified exposures to VGDF are also lung carcinogens, such as asbestos, silica and welding.

Although it is recognised that occupational exposures contribute to a substantial fraction of lung cancer deaths,[31] and that in some cases the risk is more than additive to that of cigarette smoking, only two predictive models for assessing individual lung cancer risk take occupational exposure into account,[7 8] and those include a history of asbestos exposure but not other occupational risks. The model described by Cronin identifies a group exposed to a substantial amount of asbestos with the criteria of work in occupations known to have asbestos exposure for at least 5 years and with the start of work at least 15 years prior to screening. The LLP model presented by Marcus simply asks: 'Can you recall any job or activity in which you were exposed to asbestos?' A validation of the LLP model determined that a history of asbestos exposure increased the lung cancer risk beyond that of smoking; for example, the 5-year risk for lung cancer in a man with a 45-year history of smoking rose from 4.8% to 8.6% with the addition of asbestos exposure.[32]

Using a synthesis of systematic reviews and expert consensus, a working group developed an estimation of the relative risk of lung cancer with 10 years of exposure to occupational lung carcinogens alone and in combination with tobacco and recommended lung cancer screening when combined risk is 30-fold over background. They identified several agents where that risk occurred at a smoking history between 20 and 30 pack-years.[33] A similar model incorporating asbestos exposure was developed using the Canadian Cancer Risk Management Model Lung Cancer microsimulation model. To translate these risks into an algorithm for enrolling individuals in lung cancer screening, a standard and validated assessment of occupational exposure to lung carcinogens is needed; one could be modelled on the exposure assessment and detailed epidemiology developed for the Standardised Exposure Assessment for Pooled Analysis of Case Control Lung Cancer Studies.[34]

Smoking cessation

Smoking cessation in combination with lung cancer screening is very effective in reducing lung cancer mortality; 7 years of smoking abstinence reduced lung cancer-specific mortality at a magnitude comparable with LDCT screening.[35] Although concern has been expressed that lung cancer screening might provide smokers with permission to continue to smoke, a systematic review concluded that LDCT screening in itself does not influence smoking behaviours while positive results on the scan were associated with increased smoking abstinence.[36] At their baseline scan 24.6% of our participants were current smokers; however, the prevalence of current smokers fell to 20.5% among workers completing annual scans. Although our LDCT screening centres offered comprehensive smoking cessation programmes, over 50% of our participants who quit smoking reported they did so 'cold turkey' without the benefit of medication or counselling.

Non-nodule findings

A high proportion of our participants had other diseases detected on the LDCT. Other investigators have expressed a concern that the evaluation of incidental findings may lead to excessive medical care and inappropriate diagnoses. In our population, with a high rate of COPD and a significant risk for cardiovascular disease,[37] we believe that reporting these other findings may result in increased attention to existing diseases or risk factors. Radiologist detected emphysema on CT confers an independent increased risk of lung cancer[38]; detection of emphysema may be useful in refining screening frequency[39] and may encourage smoking cessation in these workers.

Critics of lung cancer screening describe indeterminate and suspicious nodules as 'false positives,' leading to a low positive predictive value of a nodule. We identified 28 lung cancers out of 311 suspicious or indeterminate nodules (9%) and 28 lung cancers out of 117 suspicious nodules (24%). Other investigators have reported that the positive predictive value for indeterminate and suspicious nodules has improved as criteria for evaluation of small nodules and ground glass nodules has evolved.[27]

We did not find adverse impacts on either physical or mental health SF 12 scores comparing participants who were found to have a nodule and those who were nodule free. These findings are largely consistent with the international literature on lung cancer screening in high-risk populations.[40 41]

Adverse events

Two participants underwent surgery for benign disease, a rate of 10%. In the NLST across all screening rounds, 24% of surgical procedures in the LDCT group resulted in benign disease; two other trials reported 34% and 35%.[42 43] Although our sample size is small, it is likely that our partnership with centres of excellence and the advances in diagnostic techniques such as endoscopic bronchoscopy with ultrasound and fine needle aspiration have allowed more careful targeting of nodules for resection. We had two deaths within 14 days of lung cancer surgery, a much higher rate than that found in the larger studies. With two cases we cannot conclude that our programme has an excess risk for mortality; we continue to carefully monitor the care provided by our partners.

Radiation risk

To detect the 30 cases of lung cancer reported here our population received 3305 LDCTs; more than 100 per case detected. Individual DLP ranged from 0.5 to 843.0 mGy cm per scan. (Some patients had received a full dose CT in error, accounting for the few very high doses.) Conversion of DLP to effective radiation dose can be approximated on the population level, and the average effective dose of approximately 1.36 mSv was within the range of what is considered acceptable minimum dose,[16 20] and slightly below the average reported in the NLST. The wide range of doses reported reflects what is obtained in a community screening programme, even when the radiology groups adhered to the American College of Radiology (ACR) standard practice parameters.

CONCLUSIONS

We recommend that occupational exposures be incorporated into criteria used for ELCD programs, either using the algorithm

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developed by NCCN or with an individualised risk assessment. Current risk assessment tools can be modified to incorporate occupational risk.

We have demonstrated that it is feasible to identify and recruit individuals at high risk for lung cancer from occupational exposures into an ELCD program, and to provide screenings that meets national guidelines by using a central coordination centre working with screening centres around the country.

Acknowledgements Jeffrey Peeke at the University of Tennessee, Sandra Starnes at the University of Cincinnati, Sudakhar Pipravath at the University of Washington and Harold Hobbs at Doctor's Hospital in Augusta GA interpreted or supervised the interpretation of the CT scans. Scott Hass at Zenith-American maintained the data management system used to generate the analytical data set and Anna Chen at Zenith-American directed the overall clinical operations.

Contributors LSW was involved in designing the study, supervising data collection, participating in the data analysis and writing the manuscript. JMD was involved in designing the study, performed the data analysis and assisted in writing the manuscript. KC collected the study data. JS collected the study data. PSQ provided overall study coordination and assisted in writing the manuscript. DKM facilitated and/or conducted the follow-up medical evaluations and assisted in writing the manuscript. KR was involved in designing the study participated in the data analysis and assisted in writing the manuscript.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests LSW occasionally testifies as an expert witness for workers with asbestos-related diseases.

Patient consent Not required.

Ethics approval All study procedures and materials were reviewed and approved by the Central DOE Institutional Review Board and the CPWR Institutional Review Board.

Provenance and peer review Not commissioned; externally peer reviewed.

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