The Role of CT Scanning in Pneumoconiosis Screening

Commissioned Paper

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BACKGROUND

The purpose of screening is to identify diseases early in their course, before an individual would ordinarily seek medical care and when existing interventions may favorably affect disease outcome (1). Screening tests should be acceptable to those at risk for disease; have reasonable cost, effectively separate those with and without disease; and be sufficiently standardized to be performed with accuracy, consistency, and reproducibility. For pneumoconiosis screening, chest radiographs are acceptable, widely available and relatively inexpensive. However, the insensitivity of chest films for detection of early or moderate pneumoconioses limits their efficacy in screening. The ILO classification system, developed initially for epidemiologic purposes, is limited for purposes of clinical screening and diagnosis by high intra- and interobserver variability. Further, chest radiography is widely recognized as an ineffective tool for detection of airways abnormalities such as emphysema from dust exposure.

Within the past 20 years, newer imaging techniques such as conventional and high-resolution computerized tomography (HRCT) have enhanced visualization of the lung. Kreel and Raithel were pioneers in the use of CT to evaluate asbestosis and silicosis, with several papers from the 1970s documenting the enhanced ability of CT to show pleural plaques, subpleural parenchymal abnormalities, parenchymal bands, and micronodules in exposed workers with normal chest radiographs (2, 3). A further advance in the mid-1980's was the use of thin section, high resolution CT (thin collimation slices performed with a small field of view and reconstructed with a high spatial frequency algorithm) with both supine and prone images to more precisely characterize the extent and type of parenchymal disease (4-6). These techniques have improved the detection of early pathological changes and increased sensitivity and specificity in detecting occupational pleural and parenchymal abnormalities.

There is an increasing body of literature aimed at standardizing interpretation and validating the usefulness of HRCT in screening and surveillance for pneumoconioses. Our purpose in this working paper is to review the published literature on the role of CT in pneumoconiosis screening, assess the current state-of-the-art regarding standardized technique and scoring of CTs, comment on directions in the use of high-resolution lung imaging, and outline future research needs.

METHODS

After performing a MEDLINE literature search using the OVID search engine, we identified 762 peer-reviewed articles published between 1966 and 2003 using the exploded Medical Subject Heading terms asbestosis, silicosis, and coal workers pneumoconiosis. From these we selected all English-language papers using thin-section (? 3 mm) CT to evaluate populations of patients with asbestos, silica, or coal mine dust exposure. We included only those articles examining nonmalignant respiratory sequelae of these exposures. We systematically reviewed the findings of these papers under the following headings: (1) sensitivity of CT vs. CXR for pneumoconioses; (2) CT findings and lung function abnormalities; (3) correlation between CT findings and histopathology; and (4) CT scanning and disease progression. We initially summarized the data under multiple separate headers in tables (including details of CT technique used in each study, study design, specific occupations, smoking histories, and particular

physiologic parameters), but later collapsed several of these categories for ease of presentation.

RESULTS

Technical differences in CT scanning between studies.

We found some variability in the technical approach to CT scanning in all of the articles reviewed. These technical differences probably affect generalization of findings, especially in earlier studies. About half the studies obtained contiguous 5-10 mm images in addition to HRCT images. In patients with asbestos exposure, the use of contiguous scans increased the likelihood of detection of pleural plaques. Scanning in the prone position is standard in almost all studies, and many also included supine imaging. Supine CT scans do not enhance sensitivity for asbestosis when prone scans are available (7). Scan collimation ranged from 1-2 mm but most recent studies have used 1 mm collimation. The number and spacing of scans has varied widely, but there is general agreement that at least 5 HRCT scans are usually obtained. In suspected asbestosis, several studies have tailored the scan acquisition to the expected site of disease, with scans being obtained only through the bases in the prone position to optimize depiction of the posterior subpleural lung. In a study of the CT dose required to detect asbestosis, it was found that a CT exposure of less than 200 mAs impaired detection of short lines (8).

Sensitivity of chest radiograph vs. CT scan.

Table 1 contains summary findings from major articles regarding the sensitivity of CT vs. chest radiograph in the recognition of asbestosis, silicosis, and coal workers pneumoconiosis (CWP). CT was generally found to be more sensitive in detecting early dust diseases of all types, particularly in workers with normal or 0/1 profusion chest films. However, this finding was not uniform. Investigations by Bergin and Remy-Jardin describe a significant number of chest films positive for simple silicosis that were negative on CT scan (9, 10). Poor concordance between chest film and HRCT in the early stages of silicosis was also found by Talini et al. (11). Friedman found that HRCT showed fewer parenchymal and pleural abnormalities in an asbestos-exposed population with chest radiograph B-readings showing interstitial and pleural changes (12). Of note, reader agreement (interobserver variability) is consistently higher for CT than for B-readings of chest radiographs for all pneumoconioses, even in the absence of a standardized scoring system.

In the majority of studies on silicosis and coal workers pneumoconiosis, CT was more sensitive and specific than chest film in the early detection of parenchymal opacities. In workers with normal chest radiographs, HRCT shows pneumoconiosis in 23-27% of cases. Additionally, CT was found to be better in the detection of coalescent and conglomerate opacities compared to plain film, and CT has been recommended in patients with simple silicosis on radiograph who may have conglomerate disease amenable to additional therapy (e.g., treatment for tuberculosis) or requiring more frequent medical follow-up and assessment for progression (10). CT is also superior to chest radiograph in the detection of emphysema and other airway effects of dust exposure, which are often also associated with cigarette smoking.

For asbestos-related pleural disease, several papers have demonstrated that CT is more sensitive and more specific than chest radiograph. Extrapleural fat on the chest films leads to over-diagnosis of pleural disease (particularly on oblique radiographs), while posterior plaques are not usually visible on chest radiograph (13). In patients with normal lung parenchyma by chest film, HRCT will show lung fibrosis in 13-54% of cases, depending on the population being screened. When the chest radiograph shows abnormal lung parenchyma, CT will confirm abnormality in 67-97% of cases. CT scoring is associated with less inter-observer variation than

chest radiograph scoring.

CT findings vs. pulmonary function abnormalities. Table 2 contains information on the relationships between CT findings and lung function abnormalities in workers exposed to fibrogenic dusts. Most of these studies obtained complete pulmonary function tests on dust-exposed workers, including lung volumes, spirometry and diffusion capacity for carbon monoxide (DLCO). Several articles also evaluated exercise physiology in the context of CT findings.

A number of studies have shown that in silica or coalmine dust-exposed patients with obstructive lung disease, CT defines the presence of emphysema not evident on chest radiograph. CT findings are much better predictors of lung function abnormalities than are B-readings of chest films, particularly in the evaluation of emphysema associated with many of the functional abnormalities found in silicosis. Ooi et al. found that complicated silicosis on HRCT is an independent predictor of airflow obstruction and that HRCT mean lung attenuation is associated with restrictive physiology in silicotics (14).

The presence of asbestosis on CT is associated with decreased lung volumes, even in those with normal lung parenchyma by chest radiograph (15). The presence of diffuse pleural thickening on CT is usually associated with restriction (16). The extent of pleural plaque on CT is not usually associated with significant restriction once the extent of underlying parenchymal disease is accounted for.

Quantitative measurements derived from the CT density histogram have attracted increased interest as indices of the severity of parenchymal lung diseases (17-19). In patients with pneumoconiosis, primarily asbestosis, there have been several studies evaluating the relationship between quantitative CT-based measures of parenchymal abnormality and physiologic impairment (17, 20, 21). CT-determined lung density and other quantitative measures are correlated with decreased lung volumes and diffusion capacity.

CT findings vs. lung histopathology. An obvious limitation to the use of CT as a screening tool is the absence of a gold standard for verifying the accuracy of CT findings. The gold standard for interpretation of imaging studies would ideally be morphology of the lung parenchyma obtained via necropsy or surgical biopsy. There are few published articles on the relationship between lung histologic findings in association with abnormalities on high resolution CT scans in individuals with pneumoconioses (Table 3). Several of these studies are limited by lack of quantitative information on severity and extent of CT abnormalities compared to histologic severity of disease. However, studies generally show that findings on HRCT reflect the pathologic description of pneumoconioses, and provide insights into the specific relationships between radiologic and pathologic findings. Limited data suggests that HRCT is less sensitive than biopsy in the detection of pneumoconiosis.

CT as a tool to monitor disease progression. In the context of screening, the utility of CT as a tool to identify workers at risk for disease progression has important implications, as such workers would in most cases be well-served by changing to low exposure jobs if they are still exposed. For those workers with disease who are no longer exposed, the application of CT as a screening tool for progression would, if reliable, provide a valuable clinical tool. Table 4 summarizes the few available studies addressing this issue. These studies suggest that CT findings of early pneumoconiosis usually progress over time, particularly in workers with high cumulative dust exposures. The appropriate interval for follow-up of such abnormalities probably depends on the severity of exposure, but is likely 2-4 years.

DISCUSSION

Knowledge Gaps

While there is an expanding literature regarding

the utility of CT scanning as a screening tool for pneumoconioses, there are notable remaining gaps in knowledge that must be addressed before this technique can be recommended for widespread use. Major questions persist regarding (1) validity of CT screening (based on lung histology, physiology, and natural history of disease); (2) clinical management of both work-related and incidental CT findings; and (3) standardization of CT technique and scoring systems.

The utility of HRCT as a screening tool depends heavily on the populations targeted. The yield of CT screening probably varies depending on cumulative exposure dose, job description (e.g., underground coal mine work at the face), and latency since first exposure. Likewise, the appropriate interval for surveillance of high risk populations remains unclear. Further investigation of high-risk cohorts with carefully characterized exposure parameters is needed to address questions of efficacy and frequency of screening with this modality.

A number of studies show poor concordance between chest radiograph and HRCT in early stages of pneumoconioses. This discrepancy is partially attributable to overdiagnosis of pleural or parenchymal abnormalities on the chest radiograph. Extrapleural fat deposits commonly simulate pleural thickening on the chest radiograph, while changes of smoking-related respiratory bronchiolitis may simulate interstitial parenchymal abnormality. Additional explanations for the discordance between chest radiograph and CT include inadequate CT sampling or other technical issues or variability in reader interpretation due in part to the lack of an HRCT standardized scoring system. Despite the absence of a gold standard for diagnosing pneumoconiosis, it is likely that CT is more accurate in the early detection of parenchymal lung disease than the chest radiograph. This assumption is supported by the improved concordance between readers for HRCT compared to ILO chest radiograph scoring; the better correlation between HRCT findings and pulmonary function parameters suggests that HRCT is more accurate than chest radiograph. Additional studies assessing the correlation between imaging findings and lung pathology are required before a definitive answer will emerge.

With the increased sensitivity of HRCT, algorithms for appropriate clinical management of imaging findings need to be developed. It is probably reasonable to suggest that all interstitial findings of pneumoconiosis should prompt referral for further evaluation such as pulmonary function testing, risk communication, and interval surveillance. Pleural CT abnormalities suggesting previous asbestos exposure should prompt counseling regarding increased risk for other sequelae of asbestos exposure, minimizing further exposure, and smoking cessation if appropriate. Questions remain as to whether early findings of a pneumoconiosis should prompt removal of a worker from further exposure so as to decrease risk for disease progression. As seen in studies of high risk populations screened for lung cancer, a high prevalence of incidental findings is to be expected if contiguous CT imaging is performed. Noncalcified nodules were found in 111 of 602 asbestos workers screened by CT in a study by Tiitola et al. (22). A more limited HRCT sampling technique should lead to detection of fewer nodules, but would also lead to concern regarding missed lung cancers. These issues will need to be considered before HRCT is likely to gain widespread use as a screening tool.

A number of efforts to standardize the technical approaches and classification of CT for pneumoconioses have been proposed (23-25). The system described by Kraus et al, has been applied in over 2000 CT studies, with excellent intra and interobserver variance (70 to 90%). Their recommendations for standardized protocols for occupational lung disease surveillance using CT include:

- Examination from lung apex to base
- 1 mm slice thickness, 10 mm distance between slices
- Examination in supine position at

maximum inspiration
• 2 sections in prone position, slice thickness 1-2 mm
• Technical data: >130 kV; 180-300 mAs; high or ultra-high resolution kernel; scan time, 2 sec preferably <1 sec
• Window parameters: In lung window, W = 1500-2000HU; C = -300 to -500 HU; additional soft tissue window W= 200-500 HU; C = 40-10 HU
• Obligatory documentation on film or disk
• Internal quality control with obligatory B-reader evaluation
• Extended evaluation when malignant lesion suspected (spiral CT, additional slices)

Our only recommended changes to this protocol would be to perform the entire scan in prone position and to reduce the CT exposure parameters to 100 mAs or less.

In addition to standardizing image acquisition techniques, it is important to the science of occupational lung disease that imaging experts agree to standard methods for CT interpretation. Various standardized protocols for recording the presence and extent of abnormalities have been proposed, but none has gained widespread acceptance or endorsement. Descriptions of the CT findings in pneumoconiosis are reasonably standardized but scoring of the extent of these findings will require a standardized system of visual estimation. Whatever scoring system is adopted should be reasonably simple and associated with low inter-observer variation even in non-expert hands.

Barriers to the use of HRCT screening for pneumoconioses

There are a number of current barriers to the use of CT scanning as a screening tool for pneumoconioses. The six-fold higher cost of CT (high resolution images with interpretation, Medicare rate = $468) compared to chest radiographs (PA and lateral with interpretation and B-reading, Medicare rate = $76) is an obvious consideration. Some may question whether screening CT scans would be a windfall for owners and operators of CT scanners, for radiologists who interpret them, and for clinicians to whom many more patients are likely to be referred for medical management and follow-up. It is likely that the "downstream" evaluation of both screening-detected pneumoconiosis as well as incidental findings such as indeterminate lung nodules will add to the costs of health care. To justify the higher cost of CT, populations with a relatively high pre-test probability of disease should be selected for screening.

An additional consideration is the increased radiation dose associated with CT (1000-2000 mRads) compared to chest radiograph (5-10 mRads). Modern multi-channel scanners should allow substantial decrease in the effective CT dose. Scanning at selected non-contiguous slice intervals is associated with a lower effective dose than contiguous CT acquisition. Low dose thin section CT screening protocols are currently being used for lung cancer screening, and should also be considered for further investigation of dust diseases.

A major issue is geographic and financial access to CT scanning services. Unlike chest radiographs, there is limited availability of mobile CT units that would enable convenient, high quality and accessible service to miners and other workers at risk for dust diseases who often live and work in rural areas at long distances from medical centers. Likewise, the importance of assuring standardized approaches to imaging techniques and interpretation by trained and certified readers cannot be over-stated.

In the United States, there remains a paucity of comprehensive, confidential medical screening and surveillance programs available to workers. Rather than expanding to include costly and poorly accessible imaging techniques, would workers be better served if we focused on improving medical surveillance programs in other ways? For example, perhaps chest radiograph screening programs such as the "Miner's Choice" program

should be extended to include surface coal miners and metal/nonmetal miners at risk for silicosis who are not currently served by federally-funded and sponsored efforts. Perhaps expanding the use of more sensitive tests of lung function (e.g., spirometry, diffusion capacity and/or exercise physiology) as well as detailed histories using validated respiratory symptom questionnaires would better improve early disease detection in workers at risk for dust diseases of the lung. Indeed, one approach to improved screening might be to eliminate the chest radiograph as a primary screening tool to be replaced by some combination of questionnaire, functional assessment, and CT.

The field of occupational lung disease is characterized by an intense and often adversarial legal environment. While the ILO system for standardizing chest radiographs arose with the intent of improving epidemiologic investigations, the system has been widely used in the assessment of workers for purposes of compensation and benefits eligibility. It is likely that the addition of CT scan findings to the criteria for defining pneumoconiosis would lead to the same contentiousness within the legal and regulatory environments that exists currently for chest radiograph interpretations. Moreover, earlier disease detection, likely with less impairment than is seen with abnormal chest films, may have the effect of labeling asymptomatic workers for early lay-offs and other risks for loss of employment and insurability. Alternatively, CT may be of benefit if it is normal or if it shows another cause for symptoms or functional impairment that require other approaches to medical management.

Need for further targeted research and demonstration projects

Despite significant knowledge gaps and barriers, our review suggests that HRCT scans are more sensitive and specific in the early detection of fibrosis and emphysema associated with dust exposures than chest radiographs. Table 5 summarizes the advantages of CT scans in the context of pneumoconiosis screening and diagnosis.

While we cannot recommend routine CT screening for all at-risk worker populations, there probably is a role for CT in the screening of some high risk worker populations, e.g., in those with adequate exposure dose and latency who have normal or equivocal chest radiographic findings, particularly if these individual exhibit functional abnormalities and/or unexplained respiratory symptoms In workers exposed to silica and/or coal mine dust who have evidence of simple pneumoconiosis, HRCT appears to have a role in screening for conglomerate masses that may require further medical management. HRCT should also be considered in those with lung function abnormalities, particularly obstructive defects that are poorly demonstrated on plain film.

Further research and demonstration projects are needed in order to better validate the use of HRCT as a screening and surveillance tool in these settings. CT images need to be correlated with histopathologic findings for all interstitial and airway lung diseases, including those caused by inhalation of inorganic dusts. Multi-center, federally funded research studies using standardized low dose CT scanning protocols and scoring systems are essential. Additional longitudinal studies will be necessary to determine the natural history of these lung diseases as reflected by changes on CT. Finally, it will be important to develop computer-based methods for quantitative imaging of the lung to identify disease early, to follow disease progression over time, and to evaluate results of therapeutic interventions.

Table 1: Sensitivity of CT vs CXR in diagnosis of pneumoconiosis

Reference	Reference Summary	
Bergin 1986 (9)	Disease	Silicosis
	Mean Exposure	30 years
	Population	58 workers, 90% current or former smokers
	CT Scoring System	ILO system
	CXR vs CT # Abnormal	6 vs 12 normal 30 vs 13 simple 22 vs 33 complicated
	Conclusions	CXR is superior to CT in early detection of silicosis. Recommend CT in workers with simple silicosis on CXR to identify treatable conditions and severe disease.
Akira 1989 (26)	Disease	CWP, silicosis, talcosis, graphite and welders lung
	Mean Exposure	NA
	Population	61 silicosis; 12 CWP; 6 welders lung; 6 graphite; 5 talcosis on CXR
	CT Scoring System	2 independent readers
	CXR vs CT # Abnormal	NA
	Conclusions	Focal dust emphysema and low attenuation areas more commonly found with p opacities. CXR p opacities show on HRCT as binary branching opacities and small areas of low attenuation with central dot, not as distinct rounded opacities.
Remy-Jardin 1990 (10)	Disease	CWP
	Mean Exposure	23 years
	Population	170 coal dust exposed workers; 86 miners with CXR CWP and 84 miners without CWP CXR
	CT Scoring System	Micronodules (< 7mm); Nodules (8-20 mm); Progressive Massive Fibrosis (PMF) >20 mm; emphysema honeycombing, LN
	CXR vs CT # Abnormal	0/48 (CXR) vs 11/48 (23%) with abnormal HRCT. In 72 with normal HRCT 36 (50%) had abnormal CXR.
	Conclusions	CT better than CXR for silicosis, emphysema, necrosis, cavitation.

Table 1: Sensitivity of CT vs CXR in diagnosis of pneumoconiosis (continued)

Reference	Reference Summary	
Begin 1991 (27)	Disease	Silicosis
	Mean Exposure	29 years
	Population	49 workers referred to compensation board; 2 normal Controls
	CT Scoring System	ILO system; 3 independent chest MD readers
	CXR vs CT # Abnormal	32 vs 22 normal, 6 vs 1 indeterminate, 10 vs 19 simple, 3 vs 9 confluent.
	Conclusions	13 (27%) abnormal by CT alone. HRCT better than comparison of conventional CT (CCT) (added 10% new cases). Better reader agreement for CT than CXR. CT more sensitive than CXR for opacities & confluence.
Begin 1993 (28)	Disease	Asbestosis
	Mean Exposure	22 years
	Population	N= 61 Referral for evaluation for asbestos related disease
	CT Scoring System	Similar to ILO 5 readers
	CXR vs CT # Abnormal	27% (CXR) vs 39% (HRCT)
	Conclusions	Reader agreement was higher for CT than for CXR. CT is more sensitive and specific.
Gamsu 1995 (29,30)	Disease	Asbestosis
	Mean Exposure	52.5 years
	Population	N=30 HRCT and histologic material available
	CT Scoring System	4-point scale of extent and severity 6 features
	CXR vs CT # Abnormal	Asbestosis present in 10/14 patients with CXR $\leq$0/1, and in all 11 of those with CXR $\geq$1/0.
	Conclusions	NA

Table 1: Sensitivity of CT vs CXR in diagnosis of pneumoconiosis (continued)

Reference	Reference Summary	
Friedman 1988 (12)	Disease	Asbestosis, pleural disease
	Mean Exposure	> 1 year
	Population	N=60 Chest radiograph showing pleural disease
	CT Scoring System	Presence or absence of lines, bands, subpleural curvilinear lines, honeycombing
	CXR vs CT # Abnormal	CXR: 23 (38%) had asbestosis; 38 (63%) had pleural disease. CT: 21 (35%) had asbestosis (2 without pleural disease); 31 (52%) had pleural disease.
	Conclusions	Selection bias?
Aberle 1988 (4,5)	Disease	Asbestosis, pleural disease
	Mean Exposure	21 years exposure 37 years mean latency
	Population	N=100 Disagreement over presence of asbestosis or pleural disease on CXR
	CT Scoring System	Type, location, thickness of pleural disease. Parenchymal abnormality scored as low, medium or high probability of asbestosis. Thickened lines, subpleural density, and parenchymal bands were major contributors to CT diagnosis.
	CXR vs CT # Abnormal	CT high probability in 39/45 with clinical asbestosis, in 20/55 who did not meet clinical criteria, and in 28/65 with normal CXR. Pleural disease present in 93/100 (minimal in 29).
	Conclusions	CT more sensitive than CXR for pleural and parenchymal disease; it is appropriate criteria for minimal disease.
Ameille 1993 (13)	Disease	Asbestos pleural disease
	Mean Exposure	NA
	Population	23 workers with pleural disease on oblique CXR
	CT Scoring System	Comparison of PA and oblique CXR with HRCT diagnosis of pleural plaque.
	CXR vs CT # Abnormal	CXR: 6/23 (PA radiographs) 23/23 (oblique radiographs) HRCT: 3/23
	Conclusions	Pleural disease absent on CT in 2 of 6 in whom it was diagnosed on PA CXR and in 17 of 23 in whom it was diagnosed on oblique radiographs. Extrapleural fat simulates pleural disease, particularly on oblique radiographs.

Table 1: Sensitivity of CT vs CXR in diagnosis of pneumoconiosis (continued)

Reference	Reference Summary	
Oksa 1994 (31)	Disease	Asbestos pleural disease and asbestosis
	Mean Exposure	≥15 years
	Population	21
	CT Scoring System	Evaluation of CT findings in asbestosis
	CXR vs CT # Abnormal	CXR: 5 abnormal CT: 27 abnormal
	Conclusions	CT should be performed in those with normal CXR and functional impairment.
Gevenois 1998 (32)	Disease	Asbestos-related diseases
	Mean Exposure	≥10 years
	Population	159 exposed, with normal CXR
	CT Scoring System	CCT and HRCT
	CXR vs CT # Abnormal	CCT: Pleural disease 58/159 Fibrosis 9/159 HRCT: pleural disease 49/159, fibrosis 20/159
	Conclusions	CCT more sensitive for pleural disease. HRCT more sensitive for parenchymal abnormality.
De Raeve 2001 (33)	Disease	Asbestos pleural disease
	Mean Exposure	≥10 years
	Population	100 civil servants in office building with asbestos
	CT Scoring System	Intra- and interobserver variation;-3 readers
	CXR vs CT # Abnormal	18/100 had plaques on HRCT.
	Conclusions	Consensus plaques in 18/100, diagnosed by all 3 observers in only 8. Good intraobserver variation λ=0.68, moderate to fair interobserver variation λ=0.26-0.48 Diagnosis of subtle plaques requires strict definition of plaques.

Table 1: Sensitivity of CT vs CXR in diagnosis of pneumoconiosis (continued)

Reference	Reference Summary	
Gevenois 1998 (32)	Disease	Asbestosis, asbestos pleural disease, diffuse pleural thickening
	Mean Exposure	≥10 years
	Population	231 compensation-seekers Excluded those with obvious calcified plaques and with ILO score>1/1
	CT Scoring System	Consensus reading; two radiologists
	CXR vs CT # Abnormal	CT normal in 132 (57%). Plaques in 72 (31%). Diffuse thickening in 32 (14%). Parenchymal bands in 35 (15%), septal/intralobular lines in 11 (5%), honeycombing in 6 (3%), round atelectasis in 8 (3%)
	Conclusions	Plaques or diffuse pleural thickening were not statistically associated with signs of asbestosis. Three distinct clusters of abnormality were identified: plaques, diffuse pleural thickening (with parenchymal bands and round atelectasis), and asbestosis.
Al-Jarad 1993 (34)	Disease	Asbestosis
	Mean Exposure	11 years
	Population	53 asbestos workers Profusion >1/0 in 32 ≤1/0 in 21
	CT Scoring System	Comparison of CXR, CT, and time expanded waveform analysis of auscultation
	CXR vs CT # Abnormal	32>1/0 on CXR 42 with HRCT parenchymal abnormalities
	Conclusions	HRCT abnormal 31/32 with CXR profusion > 1/0, 8/11 with 1/0, 2/4 with 0/1, and 1/17 with 0/0 Time expanded waveform analysis about similar in detection rate Lower specificity Waveform analysis is more sensitive than auscultation for detection of asbestosis

Table 1: Sensitivity of CT vs CXR in diagnosis of pneumoconiosis (continued)

Reference	Reference Summary	
Topcu 2000 (35)	Disease	Asbestosis
	Mean Exposure	53 years
	Population	26 environmentally exposed (Turkey) Profusion $\leq$1/0 in 24 Extensive plaques on CXR obscuring lungs
	CT Scoring System	Prevalence study.
	CXR vs CT # Abnormal	2/26 on CXR vs 24/26 on HRCT
	Conclusions	Parenchymal bands in 92%, interlobular lines in 81%, intralobular in 46%, subpleural lines in 46%, fine honeycombing 38%, coarse honeycombing 27%, round atelectasis 19%, apical pleural thickening 35%. High prevalence of parenchymal abnormalities in those with extensive pleural disease. Apical pleural thickening may be increased, but no control group.
Tiitola 2002 (36)	Disease	Asbestos-related pleural disease
	Mean Exposure	26 years
	Population	602 exposed 50 controls (30 with possible asbestos exposure). Diagnosis of asbestos related pleural disease (N=601) or asbestosis (N=85, and 20 were nonsmokers).
	CT Scoring System	Observer agreement study, comparison with controls
	CXR vs CT # Abnormal	NA
	Conclusions	Observer agreement moderate to good λ=0.75 for disease extent. Bilateral pleural disease seen in 64% of controls and 95% of workers. Extent, thickness, and prevalence of calcification were all greater in the exposed group. Bilateral pleural plaques may occur in unexposed or minimally exposed individuals. Extent of pleural abnormality > 45 cm^2 was best discriminant between controls and exposed.

Table 1: Sensitivity of CT vs CXR in diagnosis of pneumoconiosis (continued)

Reference	Reference Summary	
Huuskonen 2001 (37)	Disease	Asbestosis
	Mean Exposure	26 years
	Population	602 exposed, 49 controls (30 with possible asbestos exposure) Diagnosis of asbestos related pleural disease (N=601) or asbestosis (N=85, of whom 20 were nonsmokers)
	CT Scoring System	Receiver operating characteristic (ROC) curve for CT criteria vs clinical diagnosis of asbestosis
	CXR vs CT # Abnormal	NA
	Conclusions	Area under ROC curve for CT was 0.89, compared with 0.76 for ILO score of CXR. Highest score seen in insulators.
Vehmas 2003 (38)	Disease	Asbestos-related CT changes
	Mean Exposure	26 years
	Population	587 exposed: 18 never smokers, 406 ex-smokers, 163 current smokers
	CT Scoring System	Prevalence of findings among smoking groups
	CXR vs CT # Abnormal	NA
	Conclusions	Emphysema and airway wall thickening were related to smoking. Curvilinear lines and septal thickening appeared less frequent in smokers. Difficult to interpret this study because of lack of prone images, and small number of nonsmokers.
Harkin 1996 (39)	Disease	Asbestosis
	Mean Exposure	Exposure > 5 years Latency > 20 years
	Population	107 subjects, of whom 37 also agreed to pulmonary function testing (PFT) and broncho alveolar lavage (BAL). 37 exposed: 8 nonsmokers, 12 exsmokers, 17 current smokers
	CT Scoring System	Correlate ILO score, CT, physiology, lavage
	CXR vs CT # Abnormal	9/37 CXR vs 11/37 HRCT

Table 1: Sensitivity of CT vs CXR in diagnosis of pneumoconiosis (continued)

	Conclusions	26 were normal by HRCT- CXR was concordant in 23. 11 were abnormal by HRCT- CXR was concordant in 6. Pleural disease correlated with lung volumes. ILO score performed about as well as CT score. Small sample size; results difficult to interpret.
Murray 1995 (7)	Disease	Asbestosis
	Mean Exposure	NA
	Population	49
	CT Scoring System	Comparison of scan readings based on more or less limited sampling
	CXR vs CT # Abnormal	CXR showed < 50% of abnormalities on CT
	Conclusions	Supine scans do not add to detection of asbestosis. Use of single scan increased observer disagreement.
Majurin 1994 (8)	Disease	Asbestosis
	Mean Exposure	Exposure > 20 years
	Population	45 clinical suspicion asbestosis
	CT Scoring System	Comparison of visibility of findings at different mAs
	CXR vs CT # Abnormal	CT confirmed parenchymal abnormality seen on CXR in 37/45 (82%)
	Conclusions	Visibility of short (reticular) lines decreases progressively below 200 mAs. Lower dose scans may be useful. Study needs to be repeated with newer equipment.
Jarad 1992 (24)	Disease	Asbestos-related pleural and lung disease
	Mean Exposure	Exposure >10 years Latency > 20 years Mean 34 years
	Population	60 CXR showed lung or pleural disease.
	CT Scoring System	Observer variation in scoring, correlation with PFT
	CXR vs CT # Abnormal	Pleural disease 54/60. Fibrosis (>0/1) 51/60. Pleural disease 59/60. Fibrosis 45/60.
	Conclusions	Observer variation was lower for CT than for CXR. Correlation with physiology was similar, but CT has advantage of detecting emphysema. 9/51 patients with fibrosis by CXR had no fibrosis on CT

Table 1: Sensitivity of CT vs CXR in diagnosis of pneumoconiosis (continued)

Reference	Reference Summary	
Klaas 1993 (40)	Disease	Asbestosis
	Mean Exposure	Exposure 23 years Latency >14 years Mean 37 years
	Population	75 of whom16 met clinical criteria for asbestosis (including CXR≥ 1/1).
	CT Scoring System	Evaluation of gallium scanning and HRCT
	CXR vs CT # Abnormal	Pleural disease 53/75 Fibrosis (≥1/0) 34/75 Fibrosis 59/75
	Conclusions	CT high probability in 44/59 (88%) without clinical asbestosis and in 15/16 with clinical asbestosis. Gallium scan positive in 52/59 without asbestosis and 15/16 with asbestosis.
Staples 1989 (15)	Disease	Asbestosis
	Mean Exposure	> 10 years
	Population	169 asbestos-exposed with profusion <1/0 on CXR
	CT Scoring System	Comparison of workers with normal or near-normal parenchyma on CT and those with abnormal CT.
	CXR vs CT # Abnormal	HRCT abnormal in 57/167 (54%)
	Conclusions	NA

Table 2: Relationship between CT findings and functional abnormalities in pneumoconiosis

Reference	Reference Summary	
Bergin 1986 (9)	Disease	Silicosis
	Mean Exposure	19 years
	Population	17 men (15 smokers); 6 controls without exposure
	CT Scoring System	Grade 0=no nodules Grade 1=small number of nodules Grade 2=many nodules Grade 3 = confluence of nodules Grade 4 = confluence of nodules over 2 slices (PMF)
	Study Design	Comparison of CXRs vs CTs in known silicotics. Slightly impaired lung function – means forced expiratory volume in one second (FEV1), total lung capacity (TLC), DLCO > 80%).
	Results	Good correlation between mean attenuation values and visual CT scores vs ILO profusion.
	Conclusions	CT better for detection of emphysema associated with silicosis than CXR.
Begin 1988 (41)	Disease	Silicosis
	Mean Exposure	All > 20 years
	Population	94 workers (80 granite workers) referred to compensation board; analyzed by smoking history
	CT Scoring System	ILO system
	Study Design	Patients grouped by results: 1=normal, 2=simple silicosis, 3=simple on CXR but comp on CT, 4=both show complicated Lung volumes, DLCO, compliance, exercise gas exchange
	Results	Group 3 had significantly worse PFTs than Group 2; including lung volumes, gas exchange and airflow obstruction.
	Conclusions	Recommend CT scan in those with CXR simple silicosis since more likely to show complicated disease associated with decreased lung function.

Table 2: Relationship between CT findings and functional abnormalities in pneumoconiosis (continued)

Reference	Reference Summary	
Collins 1993 (42)	Disease	CWP
	Mean Exposure	26 years
	Population	29 coal miners; smoking histories examined; excluded those with airflow limitation
	CT Scoring System	2 independent radiologists: 0=no nodules 1=1-5 nodules 2=6-10 nodules 3=TNTC; focal emphysema
	Study Design	CXR profusion: 9 had 0/0; 5 had 0/1; 6 had 1/0; 1 had 2/1 Spirometry, lung volumes, resting ABG
	Results	HRCT more sensitive than CXR in showing nodules and focal emphysema; no correlation with PFT abnormalities.
	Conclusions	Selection bias to healthy miners
Cowie 1993 (43)	Disease	Silicosis
	Mean Exposure	29 years
	Population	70 older gold miners with and without silicosis
	CT Scoring System	Cat 0=no nodules Cat 1= few nodules Cat 2 = intermediate # Cat 3 = innumerable nodules
	Study Design	70/242 with exposure randomly selected to have CT
	Results	Association with diffuse emphysema and silicosis: 14% without silicosis vs 50% with silicosis had CT emphysema; increasing % with higher profusion; emphysema significantly associated with decreased FEV1/forced vital capacity (FVC).
	Conclusions	NA

Table 2: Relationship between CT findings and functional abnormalities in pneumoconiosis (continued)

Reference	Reference Summary	
Lamers 1994 (44)	Disease	CWP
	Mean Exposure	> 20 years underground
	Population	35 retired coal miners with normal CXR (≤0/1); cumulative dose calculated; 20 healthy controls
	CT Scoring System	2 independent radiologists; 4 categories: 0=normal 1=few nodules 2=moderate opacities 3=numerous
	Study Design	FEV-1, TLC, DLCO
	Results	Tendency to higher cumulative dust exposure between HRCT groups 1 and 4; PFTs did not differ between groups.
	Conclusions	Small numbers; one of the few studies to examine cumulative dust exposure and HRCT score.
Begin 1995 (45)	Disease	Silicosis Asbestosis
	Mean Exposure	NA
	Population	207 consecutive workers referred to compensation board (66 silicosis, 45 silica exposed; 37 asbestosis, 59 exposed); low CXR profusion
	CT Scoring System	3 readers ILO system for opacities Presence, type, extent, severity by zone, and severity score for emphysema
	Study Design	Lung volumes; spirometry, DLCO, rest arterial blood gases (ABG)
	Results	Nonsmokers: emphysema in 1/20 without pneumoconiosis and 8/11 with pneumoconiosis. Smokers: emphysema in 55% silica exposed and 29% asbestosis exposed.
	Conclusions	Significant CT emphysema and abnormal PFTs in workers with pneumoconiosis and in smokers with silica exposure.

Table 2: Relationship between CT findings and functional abnormalities in pneumoconiosis (continued)

Reference	Reference Summary	
Talini 1995 (11)	Disease	Silicosis
	Mean Exposure	29 years
	Population	27 workers (8 smokers, 13 ever smokers, 6 non-smokers) diagnosed with silicosis by history and CXR $\geq$ 1/0.
	CT Scoring System	2 independent readers Categories 1-4 nodules scoring per Bergin; grades 1-4 proportional area with emphysema.
	Study Design	Spirometry, lung volumes, diffusion capacity
	Results	HRCT grade of emphysema and higher profusion score associated with reduced DLCO Significant correlation between HRCT grade emphysema and profusion score.
	Conclusions	Higher reader concordance with HRCT than CXR. Poor concordance with CXR and HRCT in early stage silicosis. Profusion of opacities on HRCT correlated with PFTs, irrespective of smoking or bronchitis.
Gevenois 1998 (32)	Disease	Silicosis, CWP
	Mean Exposure	17 years
	Population	48 coal miners, 35 silica exposed referred to compensation board; 40 unexposed
	CT Scoring System	2 independent readers; no profusion scoring of Micronodules
	Study Design	Comparison of CXR vs CT vs PFTs
	Results	Micronodules on CT scan are not associated with PFT abnormalities; CT detected micronodules in 23/46 (50%) with CXR<1/1.
	Conclusions	NA

Table 2: Relationship between CT findings and functional abnormalities in pneumoconiosis (continued)

Reference	Reference Summary	
Ooi 2003 (14)	Disease	Silicosis
	Mean Exposure	28 years
	Population	Recruited 76 patients with silicosis based on history and CXR $\geq$ 1/0.
	CT Scoring System	2 radiologists; 5 CT parameters: Begin scale nodular profusion (NP), PMF (>1.5 cm opacity), NP plus emphysema (NPI), emphysema index (EI) , mean lung attenuation
	Study Design	Quantified pack years and exposure years; Borg scale dyspnea grade Spirometry, lung volumes, DLCO
	Results	HRCT showed 18 with simple silicosis; 58 with PMF. PMF and EI were best independent determinants of FEV1, FEV1/FVC and TLC. Mean lung attenuation was best determinant of FVC, DLCO and Borg scale dyspnea.
	Conclusions	PMF is an independent predictor of airflow obstruction. Neither duration of silica exposure nor cigarette consumption had effect on lung function. Mean lung attenuation is an indicator of lung restriction in silicosis.
Wollmer 1987 (20)	Disease	Asbestosis
	Mean Exposure	NA
	Population	33 workers (27 smokers), 39 controls (19 smokers) Shortness of breath $\geq$ Grade 1, or crackles, or CXR profusion $\geq$ 1/0, or abnormal spirometry
	CT Scoring System	Density measurements at periphery of lung
	Study Design	Comparison of lung density in workers vs controls, stratifying for smoking Lung volumes, resistance, elastic recoil
	Results	Lung density lower in nonsmoking asbestos workers than in nonsmoking controls.
	Conclusions	Lung density correlates with TLC in exposed group.

Table 2: Relationship between CT findings and functional abnormalities in pneumoconiosis (continued)

Reference	Reference Summary	
Begin 1993 (28)	Disease	Asbestosis
	Mean Exposure	NA
	Population	61 referral for evaluation for asbestos related disease
	CT Scoring System	Similar to ILO
	Study Design	Correlation with physiology, comparison with CXR Lung volumes, P(A-a)O2 DLCO
	Results	Similar correlations for CXR and CT
	Conclusions	NA
Eterovic 1993 (21)	Disease	Asbestosis
	Mean Exposure	NA
	Population	Histologically proven asbestosis 7 early asbestosis (profusion ≤1/0), 15 late asbestosis, 13 controls, all nonsmokers
	CT Scoring System	CT histogram parameters (applied to raw data) 3-point visual probability score for asbestosis
	Study Design	Comparison of controls, early, late disease Volumes, DLCO, ABG
	Results	Histogram parameters separated controls, early and late disease. Correlations with DLCO slightly stronger for histogram than for visual score.
	Conclusions	Unclear why expiratory images were used, small n
Neri 1996 (46)	Disease	Asbestos pleural and lung disease
	Mean Exposure	Mean 21.6 Latency 21.6 years
	Population	119 shipyard workers with normal CXR (no pleural disease, profusion ≤1/0)
	CT Scoring System	Presence or absence of parenchymal or pleural abnormally.
	Study Design	Prevalence study; comparison of exposure groups
	Results	50 had plaques only, 31 had plaques and parenchymal abn, 7 had parenchymal abn only. All 22 workers exposed 15 years had pleural abnormalities, 50% had parenchymal abn. Parenchymal abn increased with smoking history, and with duration of exposure.
	Conclusions	Type of parenchymal abn not specified

Table 2: Relationship between CT findings and functional abnormalities in pneumoconiosis

(continued)

Reference	Reference Summary	
Schwartz 1990 (47)	Disease	Asbestos-related pleural and lung disease
	Mean Exposure	NA
	Population	Asbestos-exposed with normal parenchyma on CXR and varying levels of pleural disease on CXR
	CT Scoring System	NA
	Study Design	Evaluation of pleural and parenchymal disease and lavage findings as determinants of restrictive lung function Lung volumes, DLCO
	Results	Pleural disease (by CXR) was the strongest determinant of pulmonary restriction.
	Conclusions	Small n
Staples 1989 (15)	Disease	Asbestos
	Mean Exposure	> 10 years
	Population	169 asbestos-exposed with profusion < 1/0 on CXR
	CT Scoring System	Group 1 (n=76): normal or mild focal abnormalities at ≤ 2 levels Group 2 (n=57): multifocal/ diffuse, bilateral, multiple Levels Group 3(n=36) indeterminate-excluded
	Study Design	Lung volumes, DLCO, dyspnea grade
	Results	Those with abnormal CT had significantly lower vital capacity and DLCO, and higher dyspnea grade.
	Conclusions	NA

Table 3: Relationship between CT findings and histopathologic findings in pneumoconiosis

Reference	Reference Summary	
Akira 1989 (26)	Disease	Silicosis
	Mean Exposure	NA
	Population	2 postmortem specimens from patients with silicosis
	CT Scoring System/Design	HRCT performed on 2 inflated and fixed post mortem lung specimens
	Results	Low attenuation on HRCT=focal dust emphysema. Central dot=fibrous nodule surrounded by vesicular emphysema. P opacities=irregular fibrosis around respiratory bronchioles
	Conclusions	Focal dust emphysema (small areas of low attenuation) more common with p opacities. Study qualitative.
Lee 1999 (48)	Disease	DMLD (diffuse micronodular lung disease)
	Mean Exposure	4/40 with silicosis, 2/40 with CWP
	Population	40 patients with biopsy proven DMLD due to HP(3), DPB(4), sarcoidosis(2), TB(12), infectious bronchiolitis 4), dust disease(6)
	CT Scoring System	3 independent radiologists: Scored nodule location, size, margin definition, coalescence, cavitation, distribution Correlated HRCT findings with biopsy (TBBX, VATS, thoracotomy)
	Results	Centrilobular micronodules found in 1 CWP; perilymphatic micronodules in 5/6; mediastinal LN enlargement in 2/6; upper and middle zone predominant in 2/6. Pathology in dust disease showed gray-black 0.5-5.0 mm fibrotic nodules-peribronchiolar, perivascular and subpleural interstitium
	Conclusions	HRCT findings correlated with pathologic description of pneumoconiosis. Nodules mainly perilymphatic in location on CT (also true for sarcoidosis and amyloidosis).

Table 3: Relationship between CT findings and histopathologic findings in pneumoconiosis (continued)

Reference	Reference Summary	
Akira 1990 (49)	Disease	Asbestosis
	Mean Exposure	Exposure 21 years Latency 31 years.
	Population	7 with asbestosis at autopsy
	CT Scoring System	4-point scale In vitro post-mortem CT-Direct rad-path correlation
	Results	Intralobular lines=peribronchiolar fibrosis Interlobular lines=fibrosis or edema Pleural-based opacities=subpleural fibrosis Ground glass=edema or fibrosis Subpleural curvilinear lines=confluent peribronchiolar fibrosis
	Conclusions	CT reflects pathology in established asbestosis.
Gamsu 1995 (29,30)	Disease	Asbestosis
	Mean Exposure	Exposure 21 years Latency 53 years
	Population	30 with asbestosis exposure, HRCT and histologic material available
	CT Scoring System	4-point scale of extent and severity; 6 features Relationship between CT scores and histologic DX of asbestosis
	Results	Histologic asbestosis present in 9/14 patients with normal or near-normal CT, and in all 16 of those with CT scored as consistent with or probable asbestosis. Asbestosis more likely with increasing number of different types of abnormality.
	Conclusions	CT will not detect all asbestosis. Multiple CT findings, present bilaterally and at multiple levels, usually indicate asbestosis.
Ren 1991 (50)	Disease	Asbestosis
	Mean Exposure	NA
	Population	29 patients with pleural plaques at autopsy
	CT Scoring System	Probability score for asbestosis In vivo study of lungs
	Results	Only 8/29 with plaques had documented asbestos exposure, and only 2 had asbestosis. CT showed equal prevalence of abnormalities in control and plaque groups.
	Conclusions	Very difficult to interpret because of inadequate documentation of exposures, heavy selection bias.

Table 4: Progression of CT abnormalities in patients with early pneumoconiosis

Reference	Reference Summary	
Bourgkard 1998 (51)	Disease	CWP
	Mean Exposure	NA
	Population	80 miners, >10 yrs face work, with 0/1 or 1/0 CXR profusion >10 yrs. with normal CXRs and 80 miners <2 yrs. with normal CXRs
	CT Scoring System	2 independent readers; profusion by zone (0=absent, 1=rare, 2=intermediate, 3=high)
	Study Design	Longitudinal, 1990, 1994; cumulative coal mine dust exposure calculated
	Results	Progression over 4 years associated with micronodules on CT, wheeze, high cumulative dust exposure.
	Conclusions	CT improved diagnostic precision and predicts evolution to pneumoconiosis.
Akira 1991 (52)	Disease	Asbestosis
	Mean Exposure	Exposure 24 years Latency 31 years
	Population	NA
	CT Scoring System	4-point scale for peripheral and central extent of 6 types of abnormality-2 observers
	Study Design	2 scans taken 12-37 months apart
	Results	21 patients had abnormal CT. Progression of findings occurred in 9/23—more common in smokers and in those scanned at 2-3 year interval. Centrilobular nodules became confluent.
	Conclusions	Findings of early asbestosis may progress over time. Appropriate followup interval is probably 2-3 years.

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Discussion of Role of CT Scanning in Pneumoconiosis Screening

Drs. Lynch and Rose presented summary slides for discussion based on the draft manuscript. There was extensive and animated discussion from workshop participants, as outlined below. Recommendations from this workshop are not consensus statements, but individual opinions of some, not necessarily all, of the participants.

REVIEW: CONCLUSIONS OF THE WORKSHOP PAPER

Many participants suggested the following modification to the summary:

- HRCT is more sensitive than chest radiograph in detection of interstitial abnormalities.
- HRCT is more sensitive than chest radiograph in detection of emphysema.
- HRCT improves detection of coalescent/conglomerate opacities in silicosis and CWP.
- Among experienced readers, HRCT appears to be associated with less interobserver variability (better reader concordance) than the chest radiograph
- Lung function deficits are more strongly associated with abnormalities on HRCT than on chest radiographs.
- HRCT is more sensitive and specific than the chest radiograph for identification of asbestos-related pleural disease.

KNOWLEDGE GAPS

Specific knowledge gaps were reviewed and discussed, including the validity of HRCT findings in pneumoconiosis, the optimal imaging technique, and CT scoring system, the optimal frequency or interval for screening, and the clinical management of CT findings.

BARRIERS TO USE OF CT

Barriers to more widespread use of CT include cost (including social costs), difficulty with access, radiation dose, and the possibility that alternative screening approaches may be preferable. It was reiterated several times during the workshop that screening should be done with well-defined purposes in mind, either treatment or prevention. This core concept is particularly important in evaluating screening tools for pneumoconioses, long latency diseases with limited treatment options. It was felt that CT probably fits best with a multi-pronged clinical approach, perhaps as a secondary measure following symptom/exposure questionnaires and/or measures of lung function. Regarding cost, it is possible that a limited CT acquisition approach might decrease the cost of examination. Regarding radiation, the participants reflected that breast is the critical at-risk organ, which may be less of a concern in predominantly male workers, and that addition of a lateral chest radiograph to the standard PA screening film increases radiation dose three-fold.

CT TECHNIQUE

Many participants felt that the optimal method would be a contiguous prone acquisition with a multi-channel scanner, using as low a radiation dose as possible. Both thin and thick sections would be reconstructed from this acquisition. However, further validation of low-dose acquisition techniques in evaluation of the lungs and pleura will be important. A limited number of expiratory images should be included in conditions where obstructive lung disease is a prominent feature (e.g., black lung, silicosis, and hypersensitivity pneumonitis).

APPROPRIATE POPULATIONS FOR SCREENING

Because of limited options for prevention and/or treatment of asbestosis, it was felt that the benefit of CT screening in asbestos-related disease was primarily in detection of asbestos-related lung cancer. However, further insight into the value of CT in this context awaits the outcome of ongoing U.S. national lung screening trials. In patients with suspected silicosis or coal workers' pneumoconiosis, where detection of disease may result in medical removal from the environment and/or treatment of exposure-related complications such as infection, it was felt that there was a role for CT in "secondary screening" of workers in several specific contexts: workers with boundary chest radiographs (0/1, 1/0), those with abnormal spirometry, and those with higher profusion radiographs in whom conglomerate masses are more likely to be detected on CT.

CT SCORING METHODOLOGY

The most important role for the use of CT in pneumoconiosis screening or diagnosis is determination of the presence or absence of pleural or parenchymal abnormalities. Reference images will probably be necessary, primarily with reference "boundary images" for minimal disease. Determination of extent of disease may be based on semiquantitative estimation of percentage of lung involved or on quantitative imaging techniques. Any scoring system adopted should also be applicable to non-pneumoconiotic occupational interstitial diseases such as hypersensitivity pneumonitis, chronic beryllium disease, etc.

ACTION ITEMS/SUGGESTIONS FOR TARGETED RESEARCH:

Workshop participants discussed ways to address the knowledge gaps and cost considerations that included the following suggestions for further research.

(1) Information on the correlation between CT and pathologic findings in pneumoconioses is currently very limited, and should be expanded. With this in mind, some workshop participants recommended that NIOSH explore research collaboration with the lung tissue registry currently being established by NHLBI.

(2) Given concerns about CT radiation dose and cost, further efforts should be made to evaluate the efficacy of lower dose CT techniques for identifying parenchymal and pleural disease.

(3) Additional investigation should focus on the efficacy of quantitative CT for determining extent of disease.

(4) NIOSH should communicate with investigators in other countries (Finland, Germany, Japan, Belgium, etc.) to identify CT algorithms, protocols, and scoring systems currently in use elsewhere.

(5) NIOSH should consider convening a follow-up workshop or working group to address and expand the research questions and hypotheses outlined. ACR and ATS/ACCP should be urged to co-sponsor this effort, and NIOSH should continue to play a leadership role in fostering necessary collaborations between radiologists and occupational lung disease experts to facilitate further investigation.

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