Impact of Body Mass Index on the Detection of Radiographic Localized Pleural Thickening

Theodore C. Larson, MS, Alfred Franzblau, MD, Michael Lewin, MS, Alyson B. Goodman, MD, MPH, Vinicius C. Antao, MD, MSc, PhD

Rationale and Objectives: Subpleural fat can be difficult to distinguish from localized pleural thickening (LPT), a marker of asbestos exposure, on chest radiographs. The aims of this study were to examine the influence of body mass index (BMI) on the performance of radiograph readers when classifying LPT and to model the risk of false test results with varying BMI.

Materials and Methods: Subjects (n = 200) were patients being screened or treated for asbestos-related health outcomes. A film chest radiograph, a digital chest radiograph, and a high-resolution computed tomography (HRCT) chest scan were collected from each subject. All radiographs were independently read by seven B readers and scored using the International Labour Office system. HRCT scans, read by three experienced thoracic radiologists, served as the gold standard for the presence of LPT. We calculated measures of radiograph reader performance, including sensitivity and specificity, for each image modality. We also used logistic regression to estimate the probability of a false-positive and a false-negative result while controlling for covariates.

Results: The proportion of false-positive readings correlated with BMI. While controlling for covariates, regression modeling showed the probability of a false-positive result increased with increasing BMI category, younger age, not having pleural calcification, and among subjects not reporting occupational or household contact asbestos exposure.

Conclusions: Clinicians should be cautious when evaluating radiographs of younger obese persons for the presence of asbestos-related pleural plaque, particularly in populations having an anticipated low or background prevalence of LPT.

Key Words: Radiograph; pneumoconiosis; predictive values.

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Localized pleural thickening (LPT) is the most common health outcome associated with inhalation exposure to asbestos (1). The chest radiograph is the most frequently used modality to screen for asbestos-associated abnormalities, including LPT. However, it can be difficult to distinguish LPT from subpleural fat on chest radiographs (2,3) and increased body mass index (BMI) has been associated with apparent pleural thickening (4).

Libby, Montana, was the site of a vermiculite mining and processing operation throughout much of the 20th century. Although vermiculite from other sources has not been linked to adverse health effects, Libby vermiculite contained elongate mineral particles comprising a mixture of asbestiform amphiboles, including winchite, richterite, and tremolite asbestos (5). In addition to occupational asbestos exposures at the Libby vermiculite operation, exposures also occurred among household contacts of those workers, and numerous exposure pathways existed for other residents of Libby (6). Consistent with pervasive asbestos exposures, radiographic surveys have found pleural abnormalities among these vermiculite workers and their families and among other Libby residents (6,7).

To our knowledge, no study has employed a "gold standard" (such as chest high-resolution computed tomography [HRCT]) to quantify the degree of misclassification of LPT on chest radiographs associated with BMI. Using patient data from Libby, our first goal was to examine the influence of BMI on measures of radiograph reader performance for the detection of LPT, including sensitivity, specificity, and predictive values. Our second goal was to model the association between BMI and false-positive and false-negative radiographic readings.

MATERIALS AND METHODS

Subjects and Radiologic Image Reading

Informed consent was obtained under an institutional review board–approved protocol. Subjects (n = 200) were

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From the Division of Toxicology and Human Health Sciences, Agency for Toxic Substances and Disease Registry, 4770 Buford Highway NE, MS F57, Atlanta, GA 30341 (T.C.L., M.L., V.C.A.); Department of Environmental Health Sciences, School of Public Health, University of Michigan, Ann Arbor, MI (A.F.); and National Center on Birth Defects and Developmental Disabilities, Centers for Disease Control and Prevention, Atlanta, GA (A.B.G.). Received July 31, 2013; accepted September 10, 2013. **Address correspondence to:** T.C.L. e-mail: TLarson@cdc.gov

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participants of a study assessing film and digital radiographs to determine their comparability for the classification of pneumoconiotic pleural plaque (8). All were patients being treated or screened for asbestos-related health outcomes in Libby, Montana. Subjects were consecutive patients selected on the basis of having a retrospectively collected HRCT scan collected within 24 months of enrollment that was also collected for the purpose of classifying pneumoconiosis. On enrollment, film and digital radiographs for each subject were collected on the same day. Patient height and weight were measured by a clinician and recorded along with sex, smoking history, and self-reported asbestos exposure (occupational, household contact, or residential). All subject data and images were redacted for identifiable information. Ten readers evaluated study images. Each film and digital radiograph was independently read by seven experienced B readers (mean years of B reading experience = 23.5; range 11–32 years) using the 2000 International Labour Office (ILO) classification for pneumoconiosis (9). Each HRCT scan was read by three thoracic radiologists (mean years of experience = 18.7; range 4–32 years) using a classification scheme analogous to that of the ILO (10). Included in this analysis were the evaluations of seven readers × 200 subjects = 1400 readings for each radiographic modality. Here, the unit of analysis for both radiographic and HRCT data was the hemithorax; consequently, 400 hemithoraces were evaluated, resulting in 2800 hemithorax readings for each radiographic modality. All readers were aware that study subjects were patients from Libby but were blinded to other subject data.

Outcome Definitions

Radiographic LPT was defined dichotomously as pleural plaque detected in-profile, face-on, on the diaphragm, or at another site and excluded subjects with diffuse pleural thickening (DPT). Serving as the gold standard for presence of pleural abnormalities, LPT on HRCT was defined dichotomously as thickening of the parietal or diaphragmatic pleura, without subpleural fibrosis, detected by at least two of three radiologists, and excluded subjects with visceral pleural thickening. This reader-majority definition resulted in a single HRCT result for each hemithorax. We defined DPT dichotomously on radiographs as costophrenic angle obliteration with coexistent chest wall diffuse thickening in the same hemithorax and on HRCT as visceral pleural thickening, with the presence of subpleural fibrosis or parenchymal bands, detected by at least two of three radiologists in the same hemithorax.

Covariate Definitions

BMI was calculated from measured height and weight. In addition to being analyzed as a continuous variable, BMI was classified into standard mutually exclusive categories (normal [<25.0 kg/m^2], overweight [25.0–29.9 kg/m^2], obese [30.0–39.9 kg/m^2], or morbidly obese [≥40.0 kg/m^2]) (11). Age was modeled as a continuous variable. Asbestos exposure category was defined as mutually exclusive categories: occupational, household contact, or resident in hierarchical order (i.e., occupational trumped household contact, which trumped residential). To avoid zero cells in multiway tables when modeling, we collapsed occupational and household contact exposure into a single category. For all models, we evaluated the statistical significance of patient gender, the presence of radiographic pleural calcification by hemithorax, and smoking status.

Analysis

We fit models estimating radiograph reader performance and for the association between BMI and false-positive and false-negative radiographic readings. Both types of models used HRCT as the gold standard for the presence of abnormalities. Because the 14 radiograph reading observations for each subject were likely correlated, we employed generalized estimating equations (GEE) to fit models that account for clustered data (12) using logistic regression to model sensitivity, specificity, predictive values, and false-positive and false-negative values (13,14). An overview of the modeling methods can be found in the Appendix. We used the GENMOD procedure in SAS 9.3 (SAS Institute Inc., Cary, NC) to fit all models and for the calculation of confidence intervals.

RESULTS

Table 1 shows characteristics of subjects by BMI category. More than half of all subjects were obese (48%) or morbidly obese (9%) and none had a BMI <19 kg/m^2. One hundred forty-three (72%) were male and the majority (n = 103; 52%) reported residential exposure only (i.e., no occupational or household contact exposure). Median age was about 10 years lower among subjects with a normal BMI compared with other BMI categories.

Table 2 shows the unadjusted performance of film and digital radiographs overall (among all hemithorax readings) and by BMI category. Comparing each performance parameter for film and digital radiographs shows similar results for each modality. Because these results were similar, we report only film results for the remainder of this article. No strong trend was detected for any of the performance parameters except for proportion of false-positive (1−positive predictive value [PPV]) results, which correlated with BMI; and PPV, which inversely correlated with BMI.

Table 3 shows GEE models for the odds of a false-positive (1−PPV) result. In the first model, with BMI as a categorical predictor, the odds ratios for a false-positive result increased with BMI but were only statistically significant (P < .05) for readings of obese and morbidly obese subjects. The parameter for age was also statistically significant and indicated an inverse association with odds of a false-positive result. Being a worker or household contact or having pleural calcification was

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