Abstract

Nuclear weapons industry workers are recognized as being at risk for a variety of exposures, including various radionuclides, beryllium, asbestos, high explosives and tankars, all of which have been implicated in the pathogenesis of occupational lung disease. Limited epidemiological data is available on the association between pulmonary physiology and radiobiology evidence of occupational lung disease in this population. Former DoE nuclear weapons workers from a nuclear weapons assembly facility received a chest x-ray as part of the DOE Former Worker Medical Screening Program. Of the 757 screened workers, we found 45 (5.9%) with parenchymal abnormalities defined as ILO small size nodules or micronodules and 37 (4.8%) workers with isolated pleural and 19 (2.5%) with coincident parenchymal and pleural abnormalities. No statistically significant association was found between ILO abnormalities and exposures under study, but in logistic regression models controlling for age, sex, race, smoking, and isolated pleural abnormalities were statistically significantly associated (p<0.05) with abnormal spirometry defined based on NHANES III lower limit of normal (LLN) values. Workers with parenchymal abnormalities had six-fold statistically significant increase in odds of testing below 60% of FVC/predicted, when compared to those with normal spirometry results.

Cohort selection based on subcontractor employment records, plant radiation dosimetry records, union seniority records and employment validation by other former workers. Participants recruited by mail, telephone, press releases, town hall meetings and word of mouth.

All former workers participating in the screenings offered CXR and spirometry with the most recent results used for analysis. Postero-Anterior (PA) films reviewed by 3 experienced ILO readers blinded to radiologist’s reports and each other’s readings. Parenchymal abnormalities defined as median ILO profusion score ≥18. Pleural abnormalities confirmed by at least 2 of 3 readers.

Spriometry performed according to ATS guidelines, using NHANES III reference population and ACGEM abnormality algorithm. Use of normal (LLN) values for interpretation. For comparison purposes results interpreted according to fixed ‘predicted cut-off point (%Pred).

Nuclear Weapons Workers

Located in Middletown, IA (Des Moines County) - over 19,000 acre Government Owned Contractor Operated (GOCO) facility with >1000 buildings, 142 miles of roads and 103 miles of railroad tracks.

Built between 1941-1943 as a conventional munitions (DoD) Loading, Assembly and Packing (LAP) facility. Atomic weapons assembled, disassembled and repaired between 1949 and mid-1975 on Line 1 under Atomic Energy Commission (AEC, pre-DoE) contractual agreements with Silas-Mason Company.

Production terminated/moved in 1975 to Pantex, Amarillo, TX

Methods

The only available historical exposure data – limited beryllium surface wipe sample reports for 1970-1974 - served as indicators of the presence and relative levels of beryllium on surfaces in various locations within the plant - these could not be used to directly estimate workers’ inhalational exposure to beryllium at the plant.

A study of surface contamination at this facility in 2007 revealed only two beryllium samples out of one hundred collected throughout the facility which exceeded the DoE surface contamination housekeeping level of 3 μg/cm² and both of these were from surfaces in the area in which millwrights had used belt sanders to occasionally resurface alloy tools. (Sander son et al., JOEH 57(7):475, 2008)

Job codes, job titles, and work tasks were reviewed by industrial hygienists and a group of former workers to develop a qualitative exposure matrix (JEM) for beryllium, asbestos, high explosives and barium. The estimates for each job code/category were based on task frequency and proximity to potential sources of airborne exposures and reflected the group’s consensus.

Job Exposure Matrix

Iowa Army Ammunition Plant (IAAAP)

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Nuclear Weapons Workers

Approximately 7,000 workers worked on or were exposed to Line 1 operations (a.k.a. Division B) between early 1949 and mid-1975.

Substantial cross-over of workforce with adjacent conventional munitions manufacturing lines (95-100% of DoE workers worked on DoD lines too during their tenure at the plant)

DoD lines are still in operation – currently approx. 600 employees

Primary exposures: - Ionizing radiation - High Explosives incl. Barium - Beryllium - Asbestos - Epoxy adhesives - Solvents - Curing agents

Results

Table 1. Characteristics of coal-returned workers by ILO abnormality categories (Yes ILO vs. No ILO abnormality)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Yes ILO (n=45)</th>
<th>No ILO (n=614)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>63.6 ± 9.7</td>
<td>59.0 ± 9.8</td>
<td>0.01</td>
</tr>
<tr>
<td>Gender</td>
<td>38 (84.4%)</td>
<td>231 (73.1%)</td>
<td>0.05</td>
</tr>
<tr>
<td>Race</td>
<td>37 (82.2%)</td>
<td>230 (73.1%)</td>
<td>0.76</td>
</tr>
<tr>
<td>Smoking status</td>
<td>25 (55.6%)</td>
<td>231 (73.1%)</td>
<td>0.19</td>
</tr>
<tr>
<td>Presidential rank</td>
<td>24 (53.3%)</td>
<td>227 (71.9%)</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table 2. Logistic regression models for exposure & prevalence of ILO nodular abnormalities

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.04 (0.99-1.09)</td>
</tr>
<tr>
<td>Gender</td>
<td>1.40 (0.83-2.38)</td>
</tr>
<tr>
<td>Smoking status</td>
<td>0.87 (0.50-1.53)</td>
</tr>
<tr>
<td>Presidential rank</td>
<td>0.67 (0.42-1.07)</td>
</tr>
</tbody>
</table>

Summary of Findings/Conclusions

The 5.9% prevalence rate of parenchymal abnormalities in this study is higher than rates found in other DoE studies (2.2% in Dement et al., 2003 AJMI, 43:559-573) while the 2.4% rate of pleural abnormalities is lower than rates from other nuclear weapons sites (3.2% and 19.9% in Dement et al., 2003 AJMI, 43:559-573 and 3.7% and 11.3% in Maki et al., 2005, 48:365-372).

None of the modeled exposures was statistically significantly associated with the increase in risk of ILO abnormalities. Age was a very strong confounder (p<0.01) but the effect of age could not be discriminated from cumulative exposure (age vs. asbestos or beryllium p>0.05).

A statistically significant (or borderline) association found between isolated parenchymal abnormalities and coincident pleural and parenchymal abnormalities and impairment of lung function on spirometry. Based on currently recommended LLN based interpretation protocol and %Pred protocol – consistent with previous studies of asbestos exposed workers.

The association changed from obstructive using %Pred protocol to restrictive and severe using LLN protocol.

A marked shift in spirometry characterization - the prevalence of obstructive airways is significantly lower by LLN based compared to the fixed cut-off %Pred protocol (5.6% vs. 27.9%, p<0.001), while restrictive physiology is more prevalent by LLN criteria compared to the %Pred cut-off point (26.9% vs. 19.0%), (p<0.001).

Could this be the effect of age? A marked one-way shift found in other studies (Aggarwal et al., 2006) especially in individuals >65. The mean age of participants with parenchymal and pleural abnormalities in this study 7% (41); 13% of screened participants over the age of 80 and NHANES III equations based on population 8-80 years of age.

The results of this study confirm the need to screen former weapons workers for pulmonary health effects of airborne exposures in the manufacture of both conventional and nuclear weapons.

Further population based studies are needed to investigate the observed shift in interpretation of spirometry results especially in older populations. Linear models from NHANES population may need to be revised for the extremes of age.