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Electricians' chrysotile asbestos exposure from electrical products and risks of mesothelioma and lung cancer

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ABSTRACT

Both mechanistic and epidemiology studies indicate chrysotile asbestos has a threshold below which it does not cause mesothelioma or lung cancer. We conducted a critical review to determine whether electricians are at increased risk for these cancers and, if so, whether their exposure to chrysotile in electrical products could be responsible. We found that most, but not all, epidemiology studies indicate electricians are at increased risk for both cancers. Studies that evaluated electricians' exposure to asbestos during normal work tasks have generally reported low concentrations in air; an experimental study showed that grinding or drilling products containing encapsulated chrysotile resulted in exposures to chrysotile fibers far below the OSHA permissible exposure limit and the cancer no observed adverse effect level. Studies of other craftsmen who often work in the vicinity of electricians, such as insulators, reported asbestos (including amphibole) exposures that were relatively high. Overall, the evidence does not indicate that exposure to chrysotile in electrical products causes mesothelioma or lung cancer in electricians. Rather, the most likely cause of lung cancer in electricians is smoking, and the most likely cause of mesothelioma is exposure to amphibole asbestos as a result of renovation/demolition work or working in the proximity of other skilled craftsmen.

1. Introduction

The term "asbestos" refers to several types of mineral fibers with similar, but clearly distinct, chemical structures (IARC, 1977). Three types of asbestos fibers were widely used commercially: chrysotile, crocidolite, and amosite. Other asbestos fiber types were not used as widely. The fiber types may be grouped into two categories based on their physical properties. Chrysotile is a hydrated magnesium silicate serpentine mineral with the chemical composition $Mg_6Si_4O_{10}(OH)_8$. Chrysotile asbestos fibers consist of thin, flexible fibrils resembling scrolls or cylinders (WHO, 1986; ATSDR, 2001). Chrysotile fibers are shorter and cleared more quickly from the body after inhalation than are amphibole fibers, which are more durable and tend to be straight and brittle (ATSDR, 2001).

Electrical materials that historically contained asbestos, such as wire insulation, circuit board materials, and motor controllers and associated plastic components, typically were made with chrysotile asbestos (Mangold et al., 2006; Williams et al., 2007). Wire insulation contained 24–40% chrysotile asbestos, while resin products used in circuit boards and motor controllers and associated plastic components contained 1–31% chrysotile asbestos (Williams et al., 2007; Faulring et al., 1975; Mowat et al., 2005). The asbestos in these products was generally encapsulated and bound within a matrix such as a resin or plastic material.

Electricians likely encountered many other types of asbestos-containing products during their work and from working near others using asbestos (*i.e.*, bystander exposure). For example, electricians were likely exposed to asbestos-containing insulation during renovation and/or demolition work necessary to access wiring and cables such as thermal and acoustic spray insulation, which contained both chrysotile and amphibole asbestos (up to 85% amphibole prior to 1970) (Williams et al., 2007). Electricians were also often exposed to asbestos-containing products that were used by other skilled craftsmen working in the same vicinities, such as plumbers/pipefitters, sheet metal workers, and insulation installers. In fact, measures of bystander exposure to amphibole asbestos during installation of thermal insulation were quite high (Williams et al., 2007).

Asbestos exposure is a known risk factor for both mesothelioma and lung cancer, although a number of studies have shown that chrysotile asbestos is much less potent than amphibole asbestos in inducing these cancers (for review, see Doll and Peto, 1985; Gibbs, 1994; Hodgson and Darnton, 2000, 2012; US EPA, 2003; Berman and Crump, 2008a,b; Berman, 2011). There is also evidence that suggests chrysotile may not cause mesothelioma in the

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absence of significant tremolite contamination (Berman and Crump, 2008b). We conducted a critical review to determine whether evidence indicates that electricians are at increased risk of mesothelioma or lung cancer and, if so, whether this could be due to exposure to electrical products containing chrysotile asbestos.

2. Methods

We searched PubMed, Scopus, and TOXLINE for relevant articles through April 2013 using the following key words: electricians/electrical/electric, occupation/occupations/occupational, workers, mesothelioma, lung cancer. We also reviewed the reference lists of the studies we identified.

We critically reviewed the epidemiology literature evaluating electricians and mesothelioma or lung cancer. We considered the strength of reported associations and consistency of reported effects across studies, as well as how occupation was defined in each study. We also determined whether any quantitative or qualitative information on asbestos exposure was provided.

To compare chrysotile asbestos exposure concentrations to those concentrations associated with increased cancer risk, we researched electricians' exposures to airborne asbestos fibers in general and products containing encapsulated chrysotile specifically; we also researched bystander exposure. We then compared electricians' chrysotile exposures to those in automobile brake workers, who have not been shown to have an increased risk for mesothelioma or lung cancer (when smoking is accounted for).

3. Results

3.1. Epidemiology studies

We identified eight case-control, five cohort, and 10 proportionate mortality (PMR) studies that assessed mesothelioma risks among electricians, mostly in Europe and the US, and generally through occupation-based surveys. These are summarized in detail in the Supplemental Material. Of these, cohort and case-control studies are much more informative because of methodological limitations with PMR studies (*e.g.*, PMR tends to overestimate mortality experience) (Wong, 1983). The majority of these studies reported elevated mesothelioma risks (most risk estimates <3) but did not allow for an assessment of risks from asbestos. These studies generally classified occupation at a single time point (*e.g.*, last held occupation at time of death) and collected limited, if any, information on other jobs held by study subjects. In addition, generally little, if any, qualitative or quantitative information regarding potential exposures to asbestos is available for the job categories representing electricians (such as typical tasks, work practices, and materials used over time). Because electricians may have had other jobs during which they were exposed to asbestos and may have been exposed to amphibole asbestos while working as electricians, one cannot conclude from the epidemiology studies whether mesothelioma risks, if elevated, were due to any particular exposure.

We identified 19 case-control, eight cohort, and six PMR studies that assessed lung cancer risks among electricians, generally through occupation-based surveys (see Supplemental Material). The majority of these studies reported small, elevated risks (mostly ranging from 1 to 2) but suffered from many limitations that likely affected the interpretation of results. For example, like studies that evaluated mesothelioma, these studies generally collected limited information on other jobs held by study subjects and no data on asbestos exposure. In addition, while studies that did not account for smoking (Milne et al., 1983; Finkelstein, 1995; Bouchardy et al., 2002; Menck and Henderson, 1976; Guberan et al., 1989; Leigh, 1996; Andersen et al., 1999; Koskinen et al., 2002; Stocks et al., 2011; Minder and Beer-Porizek, 1992; Dong et al., 1995; Robinson et al., 1995; Fear et al., 1996; Robinson et al., 1999; NIOSH, 2003) generally reported an association between being an electrician and lung cancer risk, only three of the sixteen epidemiology studies that adjusted for smoking status reported an increase in lung cancer risk among electricians (Bovenzi et al., 1993; Decoufle et al., 1977; Morabia et al., 1992). It is well known that blue collar workers, especially in the construction trades, have higher smoking rates than the general population (Okechukwu et al., 2012). Both smoking itself and smoking combined with asbestos exposure increase lung cancer risk, although smoking has not been associated with mesothelioma (National Toxicology Program, 2005; ATSDR, 2008; O'Reilly et al., 2007).

Overall, many electricians smoked, may have had other jobs at which they were potentially exposed to asbestos, and/or may have been exposed to amphibole asbestos while working as electricians (McDonald et al., 2001; Teschke et al., 1997; Hodgson et al., 1988; Butnor et al., 2002; Newhouse et al., 1985; Williams et al., 2007). The epidemiology studies collectively indicate that electricians may be at increased lung cancer risk from smoking, but the lack of information related to exposures make it impossible to draw conclusions regarding whether any particular exposure may be responsible for mesothelioma.

3.2. Measurements of asbestos fibers

Consideration and comparison of historical quantitative data on asbestos inhalation studies are complicated by a number of different methods having been used to sample and measure asbestos levels in air. Since the late 1960s, most investigators have used a method involving collection of fibers on a cellulose membrane followed by examination *via* phase-contrast microscopy (PCM), a technique in which a specialized filter is used to enhance visual detection of very small or translucent objects (Edwards and Lynch, 1968; Bayer et al., 1969). In the 1980s, another method for counting fibers, transmission electron microscopy (TEM), was developed (NIOSH, 1994). TEM offers advantages over PCM because fibers of smaller size and width can be detected and it has the ability to distinguish between asbestos and non-asbestos fibers, as well as different fiber types (ATSDR, 2001). Although the evidence indicates that historic PCM results, such as those described below, overestimate asbestos exposure concentrations, for practical reasons and for establishing historical standardization, PCM is still the primary method specified by the National Institute of Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Agency (OSHA) for analyzing asbestos fibers in air samples (NIOSH, 2010).

3.3. Historical electrician exposure to airborne asbestos fibers

Many investigators have evaluated electricians' exposures to airborne asbestos during routine work (Table 1). Although these studies do not typically differentiate between amphibole and chrysotile fiber, they provide information on general levels of exposure. Overall, electrician exposures were relatively low, although some higher concentrations were measured when electricians were involved with steam turbine revisions or power generation work. Regardless of the work tasks, however, it is unlikely that electricians would have been exposed to asbestos concentrations above the OSHA Permissible Exposure Level (PEL) (0.1 f/cc). In the studies described below, concentrations are reported as PCM unless otherwise noted.

Three reports described by Williams et al. (2007) did not specify whether the exposures were to amphibole or chrysotile asbestos.