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Malignant Mesothelioma and Asbestos Exposure among Auto Mechanics: Appraisal of Scientific Evidence

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In 1986 the U.S. Environmental Protection Agency (EPA) issued an official guideline on the prevention of asbestos disease among auto mechanics. In the EPA guideline, malignant mesothelioma was listed as a consequence of exposure to asbestos fibers from brake linings and clutch facings among auto mechanics. EPA formulated its 1986 opinion by relying solely on a few outdated case reports and not on epidemiologic studies. A review of the literature indicates that there are six epidemiologic studies providing relevant information on malignant mesothelioma among auto mechanics. Three of the six studies had already been published by 1986, the year in which EPA issued its guideline. The results of the six studies were remarkably consistent in that all six studies reported no increased risk of malignant mesothelioma among auto mechanics. The relative risks reported in the six studies ranged from 0.62 to 1.00. Based on a meta-analysis of the combined data of all six studies consisting of approximately 1500 malignant mesothelioma cases, the mesothelioma relative risk for auto mechanics is 0.90 (95% confidence interval 0.66–1.23). An application of Hill's causation criteria to epidemiologic data of malignant mesothelioma among auto mechanics clearly demonstrates that auto mechanics do not have an increased risk of malignant mesothelioma as a result of exposure to asbestos fibers from brake linings and clutch facings. However, in spite of the scientific evidence, EPA has not modified or revised its 1986 guideline. Occupational regulatory policies and guidelines, when based on proper scientific evidence, are invaluable and can prevent avoidable diseases in workers or other exposed individuals in the general public. On the other hand, it is the regulators' responsibility to develop, modify, and revise policies and guidelines in accordance with the most relevant and the latest scientific data. In this instance EPA as a regulator has not fulfilled its responsibility of providing the most accurate and up-to-date information to the workers or the general public. © 2001 Academic Press

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INTRODUCTION

Regulatory policies and guidelines for occupational exposures are intended to prevent avoidable diseases among workers and are supposed to be based first and foremost on scientific evidence. Definitive scientific evidence, however, may take years or even decades to accumulate. It is, therefore, the regulators' responsibility to develop, to update, and to revise, if necessary, policies and guidelines in accordance with the latest available scientific data. Unfortunately, this is not always the case. An example is the U.S. Environmental Protection Agency's (EPA's) guideline for the prevention of asbestos disease among auto mechanics who are potentially exposed to asbestos fibers from brake linings and clutch facings.

In 1986 EPA issued an official guideline, in which malignant mesothelioma was listed as a consequence of exposure to asbestos fibers generated from working with friction products such as brake linings and clutch facings among auto mechanics (EPA, 1986). In the 1986 EPA document several references were cited in support of the Agency's opinion on malignant mesothelioma among auto mechanics. All references cited were case reports. Because not all malignant mesothelioma cases are related to occupational exposure to asbestos (Peterson *et al.*, 1984; Pelnar, 1988), using case reports as evidence for causation is not only inappropriate but also misleading. For example, based on the Finnish Tumor Registry, malignant mesothelioma cases have been reported among the following occupations which do not entail asbestos exposures: judge, banker, bookkeeper, musician, school teacher, tailor, student, nurse, midwife, cook, seamstress, and maid (Nurminen, 1975). Based on these case reports, one cannot conclude that these occupations are at an increased risk of developing malignant mesothelioma. Such a conclusion must be based on epidemiologic studies relevant to the occupations in question. The 1986 EPA document did not cite any epidemiologic studies of malignant mesothelioma among auto mechanics, even though three epidemiologic studies providing relevant information on malignant mesothelioma among auto mechanics had been published by 1986 (see below).

Case reports are reports of isolated cases of diseases in individuals with certain characteristics or potential risk factors. However, the underlying population at risk is not defined in case reports and, therefore, no measure of disease frequency can be estimated. Furthermore, case reports do not involve any comparison to individuals without the characteristics (or exposures) and, therefore, cannot provide any measure of risk relative to individuals with no exposure. In its 1986 document EPA did not discuss the uncertainties of relying on case reports alone, even though the limitations of case reports are well recognized by scientists and regulators alike. For example, in its monographs on carcinogenicity evaluation, the International Agency for Research on Cancer (IARC, 1989) discussed the uncertainties of case reports: "Case reports usually lack complete ascertainment of cases in any population, definition or enumeration of the population at risk and estimation of the expected number of cases in the absence of exposure." Thus, case reports, in or by themselves, cannot be used as evidence for causation.

Case reports, however, do serve some useful purposes: alerting researchers of the potential association between the exposure and disease in question and providing valuable information for priority setting in allocating research resources. However, it must be understood that case reports do not provide any definitive evidence for causation in or by themselves. A proper causation assessment must be based on appropriate epidemiologic studies. With regard to the use of epidemiologic studies in causation assessment, IARC (1989) remarked: "Cohort and case-control studies relate individual exposure to the agent under study to the occurrence of cancer in individuals, and provide an estimate of relative risk as the main measure of association."

Epidemiologic studies have both confirmed as well as refuted associations previously suggested by case reports. Although it is prudent for regulators to issue early warnings at the first sign of danger suggested by case reports, it is equally prudent for regulators to revise their positions if subsequent epidemiologic studies prove otherwise. In the case of malignant mesothelioma and asbestos exposure among auto mechanics, as will be demonstrated below, proper epidemiologic studies are available and they refute the association suggested by earlier case reports.

The following example illustrates the danger of relying on case reports. In 1991, Woitowitz and Rödelsperger reported several cases of malignant mesothelioma in garage mechanics at a clinic in Giessen, Germany. No information on the size of the underlying population of garage mechanics at risk was available and no measure of risk was provided. Nevertheless, based on the few cases alone, Woitowitz and Rödelsperger (1991) concluded: "In summary, we have found an increased *incidence* (emphasis added) of mesothelioma among car mechanics exposed only to chrysotile." Wong (1992) pointed out that the Woitowitz and Rödelsperger (1991) report was not an epidemiologic study, but a case report. As such, it would not have been possible to calculate an *incidence* of mesothelioma among garage mechanics, since the underlying population of garage mechanics at risk was undefined and unknown to the authors. Furthermore, no conclusion on the relationship between car mechanics and mesothelioma should be drawn from such a case report. Subsequent to this exchange in the literature, Woitowitz and Rödelsperger (1994) did complete an epidemiologic case-control study of mesothelioma and garage mechanics. The analysis indicated that there was no increased risk of mesothelioma in garage mechanics (see below). Based on their 1994 epidemiologic investigation, Woitowitz and Rödelsperger reversed their earlier opinion based on the 1991 case report and concluded: "From these results there is no evidence that car mechanics are exposed to increased risk of mesothelioma even if they do brake repairs." This example serves to demonstrate the treacherous nature of relying on case reports for causality assessment. Evidence for a causal relationship must be based on epidemiologic studies.

EPIDEMIOLOGIC STUDIES OF MESOTHELIOMA AMONG AUTO MECHANICS

Because malignant mesothelioma is a relatively rare disease, the study design of choice is case-control study. The measure of risk in a case-control study is derived by comparing the proportion of cases (individuals with the disease) with exposure to that among the controls (individuals without the disease). In a large case-control study of malignant mesothelioma in North America, McDonald and McDonald (1980) ascertained, through 7400 pathologists in North America, all fatal cases of malignant mesothelioma in Canada between 1960 and 1972 and all fatal cases of mesothelioma in the United States in 1972. Patients diagnosed with nonpulmonary malignant tumors at the same hospitals were selected as controls. A one-to-one case-to-control ratio was used. Cases and controls were matched with respect to sex, age, and year of death. Employment histories of both cases and controls were obtained through a blinded

TABLE 1

Risk of Malignant Mesothelioma by Occupation in a Case-Control Study in Canada and the United States, 1960–1972

Occupation or industry	Relative risk
Insulation	46.0
Asbestos products and manufacturing	6.1
Heating trades	4.4
Shipyards	2.8
Construction industry	2.6
Garage mechanics	0.9

Source. McDonald and McDonald (1980).

interview. Analysis was based on a comparison of the occupational exposure histories of 480 cases and their controls. For insulators, a significant increase of mesothelioma risk was found, with a relative risk of 46-fold. For asbestos production such as mining and milling, the relative risk was 6.1. Workers in heating trades (furnaces, boilers, plumbing, steam pipes, and welding) were reported to have a relative risk of 4.4. For shipyard workers the risk was 2.8 times that of the general population (Table 1). On the other hand, there were 11 mesothelioma cases who had worked as garage mechanics, comparable to 12 controls who had done so. In a correspondence, one of the authors stated: "The equal numbers of garage workers in cases and controls indicates (sic) that no increased risk of garage work was found in our study" (letter from A. D. McDonald to O. Wong dated June 4, 1986). The relative risk of mesothelioma for garage mechanics based on this study was estimated to be 0.91, similar to the background risk of 1.00 for individuals with no occupational exposure to asbestos. The corresponding 95% confidence interval (95% CI) was (0.39–2.13). McDonald and McDonald (1980) concluded: "no increase in risk was found in garage workers, certainly exposed to chrysotile from brake linings." Incidentally, the authors also stated: "For nearly half the male cases and for about 5% of female cases, the tumor could be attributed to occupational exposure to asbestos, of which a fifth were in shipyards." This observation emphasizes the large number of mesothelioma cases that are not related to occupational exposure to asbestos.

In 1983 another case-control study of malignant mesothelioma and occupation that provided information on auto mechanics was reported by Teta *et al.* (1983). Cases were identified primarily through the Connecticut Tumor Registry (Connecticut State Health Department), one of the oldest and most comprehensive tumor registries in North America. The case ascertainment was supplemented by a search of records at the largest Veterans Administration hospital in the state. The study consisted of 220 cases diagnosed between 1955 and 1977. Controls were randomly selected from the mortality registry in the state during the same time interval. Medical, demographic, and occupational exposure information was obtained for both cases and controls. Plumbers and pipefitters were found to have significantly increased risk (relative risk of 3.87). A significantly elevated relative risk of 2.25 was also found for cabinetmakers and carpenters. The relative risk of mesothelioma for "automobile repair and related service" was 0.65. The finding was based on 6 subjects who had worked as auto mechanics, and the corresponding 95% CI was rather wide (0.08–5.53). Even though the study was relatively small, the result indicated that there was no increase of mesothelioma associated with garage work, which was consistent with the result reported in the much larger study by McDonald and McDonald (1980).

In a case-control study conducted by epidemiologists at the National Cancer Institute (NCI), the occupational exposures of 259 mesothelioma patients diagnosed between 1975 and 1980 in New York State (exclusive of New York City) and Los Angeles County were compared to those of the controls (Spirtas *et al.*, 1985). Significantly elevated relative risks were reported for workers in several occupations: furnace or boiler installation or repair, 4.5 (95% CI 2.5–8.2); shipbuilding, ship demolition, or shipyard work, 4.3 (95% CI 2.5–7.4); and insulation, 3.2 (95% CI 2.1–5.0). In contrast, the relative risk for "brake lining installation and repair" was 1.0 (95% CI 0.6–1.6). That is, mesothelioma risk for workers engaged in brake lining installation and repair was the same as the general population. In a second report based on the same database, Spirtas *et al.* (1994) focused their analysis on attributable risk of asbestos exposure in general, and no individual risk estimates were calculated for specific occupations separately. However, the numbers and percentages of cases and controls in each occupation were reported. For several occupations, a higher percentage of cases than controls was reported: furnace or boiler installation or repair, 51 (24.5%) vs 39 (7.3%); insulation, 83 (39.9%) vs 83 (15.6%); shipbuilding or repair, 67 (32.2%) vs 40 (7.5%); and plumbing or heating, 72 (34.6%) vs 125 (23.5%). On the other hand, there were 33 (15.8%) cases and 72 (13.5%) controls who had engaged in brake lining work or repair. The almost equal percentages of cases and controls indicated that there was no increased risk associated with brake lining work, consistent with the more specific result presented in the earlier report (Spirtas *et al.*, 1985).

In a recent case-control study conducted at the Institute and Outpatient Clinic of Occupational and Social Medicine of the Justus-Liebig University in Giessen, Germany, 16 (4.9%) of the 324 cases of mesothelioma were classified as motor vehicle mechanics, compared to 16 mechanics (5.1%) among 315 hospital controls and 12 mechanics (6.6%) among 182 population controls (Woitowitz and Rödelsperger, 1994). According to the authors, the motor mechanics began their employment between 1925 and 1972. Based on a comparison to the combined hospital and population controls, the relative

TABLE 2
Risk of Malignant Mesothelioma by Occupation in a Case-Control Study in British Columbia, 1990–1992

Occupation	Relative risk	95% CI
Sheet metal workers	9.6	1.5–106
Plumbers and pipefitters	8.3	1.5–86.3
Shipbuilding workers (not classified elsewhere)	5.0	1.2–22.7
Welders	3.9	0.8–21.8
Bricklayers, plasterers, and cement workers	3.5	0.9–14.0
Miners, drillers, and blasters	3.4	0.9–13.1
Construction foremen	3.1	0.9–11.0
Stationary engineers and boilermakers	1.8	0.5–5.9
Office clerks and secretaries	1.3	0.5–3.5
Teachers and librarians	1.0	0.2–3.7
Sales clerks	0.9	0.4–2.1
Vehicle mechanics	0.8	0.2–2.3

Source. Teschke *et al.* (1997).

risk for all motor vehicle mechanics was 0.87 (95% CI 0.46–1.64). More specifically, for motor vehicle mechanics definitely engaged in brake service, the relative risk was 0.76 (95% CI 0.28–2.05). The authors concluded: "From these results there is no evidence that car mechanics are exposed to an increased risk of mesothelioma even if they do brake repairs."

In another recent case-control study in British Columbia, the investigators at the University of British Columbia and the University of Washington compared the asbestos exposure histories of 51 cases of pleural mesothelioma to those of 154 population-based controls (Teschke *et al.*, 1997). The mesothelioma cases, diagnosed between September 1990 and August 1992, were identified through the British Columbia Cancer Agency. Interviews to obtain exposure histories were conducted by a registered nurse, and the exposure information was reviewed by an industrial hygienist. The following significant risk ratios were reported for several occupational groups: 9.6 for sheet metal workers, 8.3 for plumbers and pipefitters, and 5.0 for shipbuilding workers (Table 2). In contrast, there were 6 mesothelioma cases and 20 controls who had worked as vehicle mechanics, and the relative risk was 0.8 with a 95% CI of (0.2–2.3). Thus, there was no increased risk reported for vehicle mechanics in the University of British Columbia/University of Washington study. The investigators also examined the risk for mechanics who were specifically involved in brake lining installation or repair. Again, no increased risk was found (relative risk of 0.3, 95% CI 0–1.4). Thus, the authors concluded: "As with vehicle mechanics in the occupational analysis, a history of brake lining installation or repair had a risk estimate below 1.0."

Finally, the Institute of Epidemiology and Clinical Research in Spain conducted a case-control study of mesothelioma and occupation (Agudo *et al.*, 2000). The study consisted of 132 confirmed mesothelioma cases diagnosed in two provinces, Barcelona and Cádiz. Age- and sex-matched controls were selected from other patients admitted to the same hospitals. The occupational exposure histories of 132 mesothelioma cases were compared to those of 257 matched controls. For occupations with at least 5 cases or a significant relative risk, the numbers of cases and controls as well as relative risks were reported. Significantly elevated relative risks were reported for machinery fitters (3.59), machinery fitters and assemblers (4.07), electrical fitters (9.10), plumbers (7.49), and bricklayers (1.99). The authors reported 3 mesothelioma patients who had worked as vehicle mechanics, compared to 14 controls. Because the number of cases in vehicle mechanics was 3 (less than 5) and the relative risk was not significant, no risk estimate was presented in the report. However, based on the numbers presented by the authors, the relative risk was estimated to be 0.62 (95% CI 0.17–2.25). Thus, there was no increased risk of mesothelioma among vehicle mechanics in Spain. The authors also stated: "Overall, 37% of cases of mesothelioma in our population are attributed to a sure (or almost sure) occupational exposure to asbestos and this proportion comes up to 62% when occupations with any probability of exposure are included." This observation underscores the high proportion of malignant mesothelioma cases not related to occupational exposure to asbestos.

META-ANALYSIS

Based on these epidemiologic studies, clearly there is no evidence to support or even to suggest an association between an increased risk of mesothelioma and exposure to brake linings or clutch facings among garage mechanics. On the contrary, the six studies reviewed above provide strong evidence that garage mechanics' mesothelioma risk is similar to that in the general population. None of the six studies reported any increased mesothelioma risk among auto mechanics. Some of the individual studies were relatively small, and the precision of the risk estimates might not have been as high as we would prefer (as indicated by the wide 95% CIs). Because of the consistency of the results, the precision of the risk estimate can be improved by combining these studies through a meta-analysis. The primary purpose of the meta-analysis was to provide a summary measure of risk with improved precision (i.e., a narrower 95% CI). Meta-analysis is a well-accepted procedure in reviewing and summarizing epidemiologic studies of individuals with similar exposures (Wong and Raabe, 1996). For example, meta-analysis was used by the Surgeon General's Committee (1964) in summarizing epidemiologic studies on smoking and cancer.

An obvious benefit of meta-analysis is the increase in sample size and the narrow confidence interval of

TABLE 3
Individual Study Results and Meta-analysis of Malignant Mesothelioma among Auto Mechanics

Study (author and year)	Relative risk	95% CI
London School of Hygiene and Tropical Medicine, United Kingdom (McDonald and McDonald, 1980)	0.91	(0.39–2.13)
Connecticut State Health Department (Teta *et al.*, 1983)	0.66	(0.08–5.53)
U.S. National Cancer Institute (Spirtas *et al.*, 1985, 1994)	1.00	(0.60–1.60)
Justus-Liebig University, Germany (Woitowitz and Rödelsperger, 1994)	0.87	(0.46–1.64)
University of British Columbia and University of Washington (Teschke *et al.*, 1997)	0.80	(0.20–2.30)
Institute of Epidemiology and Clinical Research, Spain (Agudo *et al.*, 2000)	0.62	(0.17–2.25)
Combined data of all six studies (meta-analysis)	0.90	(0.66–1.23)

the summary risk estimate based on the pooled or combined data. In reviewing studies for carcinogenic potential, IARC (1989) commented: "When several epidemiological studies show little or no indication of an association between an agent and cancer, the judgment may be made that, in the aggregate, they show evidence of lack of carcinogenicity." Such a situation calls for the application of meta-analysis. With regard to the use of meta-analysis in this context, IARC stated: "In addition, all studies that are judged to be methodologically sound should be consistent with a relative risk of unity for any observed level of exposure to the agent and, when considered together, should provide a pooled estimate of relative risk which is at or near unity and has a narrow confidence interval, due to sufficient population size."

The results of the six case-control studies of mesothelioma are presented in Table 3. The relative risks reported in the six individual studies ranged from 0.62 to 1.00. The result of the meta-analysis (i.e., the summary relative risk) based on all six studies is also presented in Table 3. The weights used in the meta-analysis were inversely proportional to the variance of the risk estimates in the individual studies (Armitage and Berry, 1994). In other words, larger studies received more weight and vice versa. According to the meta-analysis of the combined data of all six studies consisting of approximately 1500 mesothelioma cases, the mesothelioma relative risk for auto mechanics is 0.90 (95% CI 0.66–1.23). Thus, Table 3 shows that all six studies, individually or in aggregate, demonstrate that auto mechanics are not at an increased risk of malignant mesothelioma, when compared to the general population.

DISCUSSION

More than three and half decades ago the criteria for assessing causation in chronic diseases, such as cancers, was formulated by Hill (1965) and utilized by the Surgeon General's Committee in assessing the relationship between smoking and cancer (Surgeon General's Committee, 1964) as well as by IARC in the evaluation of carcinogenicity of substances (IARC, 1989). Hill's criteria include strength of association, consistency of association, specificity of association, dose–response (or exposure–response) relationship, and temporality or latency. In evaluating the causal relationship, if any, between exposure to asbestos fibers from brake linings and clutch facings among auto mechanics and malignant mesothelioma, Hill's criteria must be considered and applied directly to the relevant epidemiologic data.

With respect to strength of association, the meta-analysis of the combined data from all six studies shows a summary relative risk of 0.90, meaning no increased risk. Furthermore, the narrow 95% CI (0.66–1.23) of the summary relative risk is indicative of the large underlying database and the precision of the summary risk estimate. Furthermore, the results of the individual studies are remarkably consistent in that none of the studies shows an increased risk.

Specificity in both exposures and disease endpoints is one the most important criteria in causation assessment (Wong, 1993). If the subject matter is exposure to asbestos from friction products among auto mechanics, we must base our evaluation on studies of auto mechanics and not on other occupations. For example, it is not valid to apply results of studies of insulators or shipyard workers to auto mechanics, because workers in these vastly different occupations are exposed to different types of asbestos as well as to different concentration levels of asbestos. In the studies reviewed above, mesothelioma risk of not only all garage mechanics but also those specifically engaged in brake repairs was assessed.

Exposure–response relationship is yet another important causation criterion. Fiber measurement studies have indicated that garage mechanics are exposed to extremely low levels of asbestos as a result of the thermal transformation of asbestos fibers during the braking process. The asbestos fibers in brake linings are entirely chrysotile fibers in a bonded or encapsulated state. During braking, a temperature in excess of 700–800°C is reached, and the chrysotile fibers break down to forsterite (an anhydrous magnesium silicate), which is nonfibrous. Studies have shown that brake lining dust contains extremely little recognizable chrysotile fibers, which are mostly embedded in the plastic bonding material, and that the amount of free chrysotile fibers is less than 0.1 to 1% and most fibers are less than 0.5 μm in length (Hatch, 1970; Lynch, 1968; Davis and Coniam, 1973; Williams and Muhlbaier, 1982).

TABLE 4
Time-Weighted Average Exposures to Asbestos at Garages

Study (authors and year)	Location	Fiber concentration (f/cc)
Rödelsperger *et al.*, 1986	Germany	0.025
Kauppinen and Korhonen, 1987	Finland	<0.05
Moore, 1988	Pennsylvania, U.S.A.	<0.002
Cheng and O'Kelly, 1986	Hong Kong	0.05
NIOSH, 1980a,b	Ohio, U.S.A.	0.04

Industrial hygiene studies have demonstrated that the typical 8-h time-weighted-average (TWA) exposures among auto mechanics at garages range from less than 0.002 to 0.05 fiber/cc (Table 4) (Rödelsperger *et al.*, 1986; Kauppinen and Korhonen, 1987; Moore, 1988; National Institute of Occupational Safety and Health, 1980a,b; Cheng and O'Kelly, 1986). Thus, the 8-h TWA exposure to asbestos among auto mechanics is well below the safety standards mandated in most countries (for example, 0.1 fiber/cc in the United States), which should provide adequate protection to auto mechanics. In fact, according to the Committee on Hygienic Standards of the British Occupational Hygiene Society (BOHS), such fiber concentrations would have been categorized as "negligible" (Levadie, 1984). Given such extremely low exposures, it is not surprising that none of the epidemiologic studies reported an increased mesothelioma risk among auto mechanics.

In investigating occupational cancers, an adequate time interval between exposure and the development of disease must be allowed to account for the long latency of the disease. Since brake linings and clutch facings have been in commercial use for decades, latency is not a concern in case-control studies. For example, Woitowitz and Rödelsperger (1994) reported that the motor vehicle mechanics in their study began employment as mechanics between 1925 and 1972, which would have provided a more than sufficient time interval between exposure and disease development. Thus, the lack of an increased mesothelioma risk among auto mechanics cannot be attributed to an inadequate latency in the studies reviewed.

The application of Hill's causation criteria to epidemiologic data of mesothelioma among auto mechanics has clearly demonstrated that auto mechanics do not have an increased risk of malignant mesothelioma as a result of exposure to asbestos fibers from brake linings and clutch facings.

It may be of interest to point out that there is no increased risk of lung cancer, an asbestos-related cancer, among auto mechanics. In its 1986 document on auto mechanics, EPA cited one study in reference to lung cancer. The study cited was a cohort study of workers at an amosite factory in Paterson, New Jersey, that supplied the U.S. Navy with asbestos insulation for pipes, boilers, and turbines during World War II (Seidman *et al.*, 1979). The authors characterized the workers' exposure as "intense work exposure to amosite asbestos." This study, which was based on workers with intense exposure to amosite, was totally inappropriate for assessing risk in auto mechanics, who are exposed to extremely low levels of chrysotile. Wong (1993) reviewed cohort studies of auto mechanics in relation to lung cancer. Individual cohort studies consistently indicated that there was no increased lung cancer risk: the standard mortality ratios (SMRs) were 0.92 among bus garage mechanics in London (Rushton *et al.*, 1983; Rushton, 1987), 1.15 among garage mechanics in Stockholm (Gustavsson *et al.*, 1990), and 1.01 among auto mechanics in Denmark (Hansen, 1989). The summary SMR based on a meta-analysis of all three cohort studies was 1.01 (95% CI 0.80–1.26) (Wong, 1993). Similarly, case-control studies reported no significantly elevated lung cancer risk ratios among auto mechanics from different locations: 1.06 in France (Benhamou *et al.*, 1988); 0.9 in New Mexico (Lerchen *et al.*, 1987); 1.2 in Louisiana, Florida, Pennsylvania, Virginia, and New Jersey (Vineis *et al.*, 1988); and 0.7 in nine metropolitan areas in the United States (Detroit, Chicago, Philadelphia, Pittsburgh, New York, Long Island, San Francisco, Birmingham, and Atlanta) (Morabia *et al.*, 1992). Thus, epidemiologic studies indicate that auto mechanics are not at an increased risk of lung cancer as a result of working with brakes and clutches. However, it should be pointed out that these studies on lung cancer in auto mechanics were published after EPA had issued its 1986 document.

CONCLUSION

In 1986 EPA issued its guideline on the prevention of asbestos disease among auto mechanics. In the guideline, EPA's claim that auto mechanics were at an increased risk of developing mesothelioma was based on a few case reports published between 1965 and 1982. No epidemiologic studies were included in EPA's guideline. As reviewed above, three epidemiologic studies of malignant mesothelioma among auto mechanics had been published by 1986 (McDonald and McDonald, 1980; Teta *et al.*, 1983; Spirtas *et al.*, 1985). All three studies involved auto mechanics in the United States, and none of the three studies reported an increased risk of malignant mesothelioma among auto mechanics. It is not clear why EPA did not include these three studies in its guideline, particularly in view of the fact that one of the studies was conducted by another federal health agency, the National Cancer Institute (Spirtas *et al.*, 1985), and a second one was funded by the National Cancer Institute and conducted by the Connecticut State Health Department (Teta *et al.*, 1983).

Furthermore, subsequent to the publication of EPA's 1986 guideline, a second analysis of the NCI study had been published (Spirtas *et al.*, 1994) and three additional new studies had appeared (Woitowitz and Rödelsperger, 1994; Teschke *et al.*, 1997; Agudo *et al.*, 2000). [The Woitowitz and Rödelsperger (1994) paper was presented at the 1993 International Workshop on Health Associated with Chrysotile Asbestos held in Jersey, Channel Island, whose list of participants/attendants included an official from U.S. EPA.] Again, none of the additional new studies reported an increased risk of mesothelioma. In spite of the remarkably consistent findings of no increased risk of malignant mesothelioma among auto mechanics from these studies, EPA has not revised its 1986 guideline. [A recent (May 2001) search of EPA's Web site reveals that the 1986 EPA guideline "Gold Book" is still on EPA's current list of asbestos publications available to the public.] Regulatory agencies, such as EPA, are charged with the responsibility of protecting public health. It is, therefore, prudent for them to issue early warnings if a danger is suspected, even in the absence of adequate scientific data. However, as discussed above, this was not the case for EPA's 1986 guideline. In this instance, adequate scientific data were available but ignored. As such, EPA as a regulator has not fulfilled its responsibility of providing the most accurate and up-to-date information to the workers or the general public.

Occupational regulatory policies and guidelines, when based on proper scientific evidence, are invaluable and can prevent avoidable diseases in workers or other exposed individuals in the general public. On the other hand, regulatory polices and guidelines that are not based on the most complete and up-to-date scientific evidence are not only incorrect but also misleading. It is the regulators' responsibility to develop, modify, and revise policies and guidelines in accordance with the most relevant and the latest scientific evidence. In particular, the reluctance of regulators to revise policies and guidelines when new scientific data become available is inexplicable.

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