But other than mesothelioma? An estimate of the proportion of work-related cancers in Quebec

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ABSTRACT

Background  More than 30 exposures in the workplace are proven carcinogens. In the present study, we aimed to estimate the burden of occupational cancer in Quebec so as to increase awareness among stakeholders and to prioritize research activities.

Methods  Work-attributable fractions—that is, the proportions of cancers attributable to work—as published in Finland and the United Kingdom were applied to Quebec 2002–2006 cancer incidence and mortality data to estimate the number of work-related cases for 28 cancer sites.

Results  Overall, 6.0% of incident cancers (men: 9.1%; women: 2.7%) and 7.6% of cancer deaths (men: 11.8%; women: 2.8%) could be attributable to work, resulting annually in an average of 2160 new cancer diagnoses and 1190 cancer deaths in Quebec. Incident cancers of the lung, prostate, skin, bladder, and (female) breast were the most numerous; cancer sites resulting in more deaths were lung, (female) breast, and pleura. During the same period, compensation statistics reported annual averages of 94.3 incident cancers and 61.9 cancer deaths, mostly involving mesothelioma (64% of compensated incident cancers) and lung cancer (30% of compensated incident cancers).

Conclusions  Increased recognition of workplace cancers by all stakeholders, from workers and employers to treating physicians, will foster appropriate preventive measures for safer workplaces.

Key Words  Work-related cancers, attributable fraction, compensation statistics, research priorities

INTRODUCTION

Since Sir Percival Pott reported, in 1775, an association between exposure to soot and scrotal cancer in chimney sweeps, numerous cancer sites have been associated with an individual’s occupation—including, for example, bladder cancer in pigment makers and lung cancer in uranium miners. An occupational cancer can be suspected if it arises after exposure in the workplace to a chemical, physical, or biologic agent known to be strongly linked to the number of new diagnoses (incidence) of cancer. So far, sufficient human evidence has led to about 30 cancer sites being associated with occupation.

Most public health interventions are justified by the severity of the disease and the numbers at risk. A widely used parameter for setting priorities in this context is the “population-attributable fraction,” which estimates the proportion by which the incidence of a disease would be reduced if a given risk factor (exposure) were to be removed in a population.

Since as early as 1981, a few estimates of the proportion of cancers attributable to occupational exposures have been published. One of the most widely cited figures, 4% of all cancer deaths, was calculated by Doll and Peto for cancer deaths occurring before the age of 65 in the United States. However, more recent calculations, including cancers after retirement, fluctuated between 8% and 20%. Since early as 1981, a few estimates of the proportion of cancers attributable to occupational exposures have been published. One of the most widely cited figures, 4% of all cancer deaths, was calculated by Doll and Peto for cancer deaths occurring before the age of 65 in the United States. However, more recent calculations, including cancers after retirement, fluctuated between 8% and 20%.

To raise awareness among stakeholders and to help prioritize research activities, the present study set out to estimate, based on work published for Finland and Great Britain, the number of work-related cancer cases in Quebec.
METHODS

Cancer Data
The number of incident cancer cases and cancer deaths registered from 1 January 2002 to 31 December 2006 for all Quebec residents were obtained from the Quebec Tumour Registry and the Mortality Database (principal cause of death was retained for the analysis). The 28 cancer sites retained were selected based on annual frequency, their association with workplace exposures, and the availability of published population-attributable fractions by sex.

Selection of Work-Attributable Fractions
The use of work-attributable fractions published for other jurisdictions requires comparability of the exposure types and levels for the two populations of workers during the relevant period of exposure. For cancers diagnosed during 2002–2006, that period spans 1970–1990 (allowing for a 12- to 36-year latency period between exposure and diagnosis). A second requirement is that both populations have roughly similar risk factors. Two countries with industrial profiles comparable to those of Canada have published attributable fractions for more than 25 cancer sites: Finland and Great Britain.

Comparability of industrial profiles was verified using data compiled by the International Labour Organization (http://laborsta.ilo.org/) showing that, between the 1970s and the 1990s (when exposures could have initiated a cancer diagnosed in the 2000s), the proportions of workers by industry were rarely more than a few percentage points different between the countries of interest.

Smoking and alcohol intake are among the most important confounding factors for cancer. Statistics from the World Health Organization, computed similarly for all countries, showed that Canadian smoking and alcohol drinking habits were more comparable with those reported for the United Kingdom than for Finland. More detailed methods and results of comparisons between those countries have been published elsewhere.

Calculation of the Work-Attributable Fractions
Three estimates of work-attributable fractions were computed separately for men and women: a lowest estimate (from the study with the lowest proportion), a highest one (from the study with the highest proportion), and a “plausible” value. The three estimates of work-attributable fractions for each cancer site can be found elsewhere.

The “plausible” value was obtained according to 1 of 4 situations (Figure 1). When only one study reported an attributable fraction, that fraction was retained. For cancer sites associated by the International Agency for Research on Cancer with both tobacco smoking and alcohol consumption, the lowest published fraction was selected because an underestimate of the attributable proportion was preferred when both lifestyle habits could causally be associated with the cancer site. For cancer sites associated with tobacco but not alcohol, fractions from the U.K. study were preferred because the lifestyle habits of the British were more similar to those of Canadians during the relevant period of exposure.

For the remaining cancer sites, the arithmetic mean of the attributable fractions from the two available studies was used.

Compensation Data
Depersonalized compensation data were obtained from the Quebec Workers’ Compensation Board. For incident cancers, compensation claims filed during 2005–2007 were retained; for cancer deaths, claims accepted during 2003–2005 were analyzed.

RESULTS
Table 1 presents the average annual number of incident cases of cancer, the work-attributable fractions of those cancers, and the corresponding estimates of the annual number of cases for men. Table 2 presents the same information for women. For both sexes combined, 6% of all incident cancers were plausibly attributable to work (estimates: 5.0%–8.4%, low to high), which corresponds to between 1800 and 3000 of the 36,000 incident cancers diagnosed annually on average in Quebec during 2002–2006.

Cancers of the trachea, bronchus and lung, prostate, breast, skin, bladder, and colon, together with mesothelioma and non-Hodgkin lymphoma would be the most numerous work-related cancer sites or types among Quebeckers. With respect to mortality (Table 3), 1070–1700 of the 15,600 annual cancer deaths in men and women could be attributable to work—that is, between 6.9% and 10.9% of all cancer deaths (11.0%–17.3% in men, 2.1%–3.6% in women). The most numerous work-related deaths would result from the work-attributable cancer sites or types already mentioned, except for skin and bladder cancer, for which mortality is low.

A comparison of cancer compensation statistics and our estimated number of work-related cases showed that the largest compensation proportion was attributable to mesothelioma, whose average annual proportion of compensated cases was 53.1% of the estimated number of mesothelioma cases attributable to work. The proportion...
for work-related lung and bladder cancers was much lower, at 2.9% and 4.5% of compensated cases respectively. Of the other cancer sites, fewer than 0.2% of cases were compensated during 2005–2007.

### DISCUSSION

Based on cancer statistics for 2006, it was estimated that 6.0% of incident cancers and 7.6% of cancer deaths in Quebec could be attributable to work, resulting in an average of 2150 new cancers and 1200 cancer deaths annually. Between 21% and 29% of lung cancers in men and about 5% in women are deemed work-related; numerous occupational lung carcinogens have been identified, and lung cancers indeed constitute close to half of all work-related cancers. Nonmelanoma skin cancers are the most frequent tumours among Canadians, and several occupational exposures—such as ultraviolet and ionizing radiation, and chemical agents such as polycyclic aromatic hydrocarbons, arsenic, and nitrosamines—increase their incidence. Only a handful of occupational carcinogens have been linked to breast or prostate cancers, and their work-attributable proportion is low; however, the frequency of those cancer sites is high, and their estimated work-related numbers are not negligible. In Quebec, bladder cancer is the 4th most frequent cancer in men and the 7th in women. More than 10 agents or exposures found in the workplace are proven bladder carcinogens, but very few bladder cancers are compensated. Asbestos fibres are the only agents linked, with...
sufficient evidence, to mesothelioma in humans\textsuperscript{13}, and estimates of the proportion of cases attributable to occupational exposures generally fall in the 75\%-98\% range\textsuperscript{6}, which explains the fact that mesothelioma is the cancer with the largest number of compensated cases in Canada\textsuperscript{17}. In the present study, the proportion of work-related cancers estimated for 28 cancer sites are comparable to those estimated in Alberta based on 10 cancer sites (8.6\% of incident cases)\textsuperscript{18}.

The number of individuals compensated for occupational cancers was less than 6\% of the estimated number of work-related cases during the middle part of 2000–2010. Our results are comparable to those of other Canadian researchers: Teschke and Barroetavena\textsuperscript{19} estimated that fewer than 10\% of occupational cancers were compensated in 3 Canadian provinces, and they attributed the largest part of the deficit to underreporting by workers. Despite that underreporting, the number of compensated cancer deaths has been increasing across Canada and is now comparable to or surpasses the number of compensated deaths from accidents and from other occupational diseases\textsuperscript{17}.

\begin{table}
\centering
\caption{Incident cancer cases, work-attributable fractions, and cases attributable to work for women in Quebec, 2002–2006}
\label{table:incidence}
\begin{tabular}{l|c|c|c|c|c|c|c}
\hline
Cancer site or type & Carcinogenic lifestyle habit & New cases annually\textsuperscript{b} & Plausible work-attributable fraction (%)\textsuperscript{c} & Annual cases attributable to work (n) \hline
Buccal cavity\textsuperscript{d} & T, A & 157.0 & 0.3 & 0.5 & 0.5 & 0.5 \\
Pharynx & T, A & 70.6 & 0.5 & 0.4 & 0.4 & 1.7 \\
Esophagus & T, A & 75.0 & 0.2 & 0.2 & 0.2 & 0.8 \\
Stomach & T & 298.0 & 0.3 & 0.9 & 0.9 & 16.1 \\
Colon\textsuperscript{d} & T, A & 1,613.0 & 0.0 & 0.0 & 0.0 & 0.0 \\
Rectum\textsuperscript{d} & T, A & 410.4 & 0.1 & 0.4 & 0.4 & 0.4 \\
Liver & T, A & 145.4 & 0.1 & 0.1 & 0.1 & 7.7 \\
Pancreas & T & 507.6 & 0.01 & 0.1 & 0.1 & 17.8 \\
Sinuses and nasal cavity & T & 23.0 & 19.8 & 4.6 & 4.6 & 4.6 \\
Larynx & T, A & 71.4 & 0.5 & 0.4 & 0.4 & 1.1 \\
Trachea, bronchus, lungs & T & 2,710.8 & 5.3 & 143.7 & 143.7 & 143.7 \\
Mesothelioma & & 28.0 & 53.8 & 15.1 & 7.0 & 23.1 \\
Bone & & 31.4 & 0.3 & 0.1 & 0.0 & 0.2 \\
Skin & & & & & & \\
Melanoma\textsuperscript{d} & & 235.6 & 0.4 & 0.9 & 0.9 & 0.9 \\
Nonmelanoma & & 1,002.4 & 2.5 & 24.6 & 11.0 & 38.1 \\
Breast & A & 5,177.0 & 4.6 & 238.1 & 88.0 & 238.1 \\
Uterine cervix & T & 294.2 & 0.7 & 2.1 & 2.1 & 17.4 \\
Uterus\textsuperscript{d} & & 872.6 & 1.1 & 9.6 & 9.6 & 9.6 \\
Ovary & T & 693.2 & 0.5 & 3.5 & 3.5 & 14.6 \\
Bladder & T & 501.4 & 1.9 & 9.5 & 9.5 & 9.5 \\
Kidney & T & 465.2 & 0.04 & 0.2 & 0.2 & 3.7 \\
Brain & & 239.8 & 0.7 & 1.7 & 0.2 & 3.1 \\
Thyroid\textsuperscript{d} & & 538.2 & 0.02 & 0.1 & 0.1 & 0.1 \\
Hodgkin disease\textsuperscript{d} & & 84.4 & 0.0 & 0.0 & 0.0 & 0.0 \\
Non-Hodgkin lymphoma & & 695.4 & 2.1 & 14.6 & 7.6 & 21.6 \\
Multiple myeloma\textsuperscript{d} & & 247.2 & 0.1 & 0.2 & 0.2 & 0.2 \\
Leukemia & T & 424.2 & 1.5 & 6.4 & 2.1 & 10.6 \\
ANNUAL TOTAL & & 17,612.4 & 477.7 & 284.2 & 585.2 & \\
\hline
\multicolumn{3}{l}{ALL CANCERS (\%)} & & & 3.3 \\
\multicolumn{3}{l}{100.0} & & & & \\
\hline
\end{tabular}
\begin{flushleft}
\textsuperscript{a} Tobacco smoking (T) or consumption of alcoholic beverages (A) classified as carcinogenic (Group 1) for the mentioned cancer site by the International Agency for Research on Cancer (http://monographs.iarc.fr/ENG/Classification/).
\textsuperscript{b} Arithmetic mean of new cancer cases registered annually for 2002–2006 (Quebec Tumour Registry).
\textsuperscript{c} Work-attributable fractions selected from Finnish\textsuperscript{5} and British\textsuperscript{6} studies according to the process depicted in Figure 1.
\textsuperscript{d} Plausible, low, and high estimates are derived from one study only.
\end{flushleft}
\end{table}
Methodology Considerations

Although Finland and the United Kingdom are comparable to Canada with respect to industrial activities and lifestyle habits, uncertainties could have been introduced by using work-attributable fractions calculated for other regions. We chose not to use burden indicators such as years of life lost or disability-adjusted life-years, which would have introduced additional uncertainties, given that certain input variables often have to be attributed based on few data—for example, life expectancy associated with each cancer, tailored to the age distribution of the considered population, and the weights given to each cancer, generally attributed based on subjective judgment (albeit by experts) and also tailored to the age of the population.20

Our calculations could be underestimated, because not all occupational carcinogens were taken into account. The list of proven carcinogens established by the International Agency for Research on Cancer increases regularly.
as more human evidence becomes available. Moreover, conservative selection of published attributable fractions probably also led to an underestimation of the proportions of work-related cancer cases. Although concomitant exposures to carcinogens do happen\textsuperscript{21}, it was not possible to consider joint effects, because little epidemiologic evidence on possible interactive effects has been built, apart from those for smoking as a co-exposure\textsuperscript{24}.

Despite the uncertainties and potential biases in the two original studies and in our application of external attributable fractions to Quebec data, we believe that the problems are not so great as to invalidate the resulting estimates.

**CONCLUSIONS**

The present work points to lung carcinogens as important targets for research and intervention. More precise estimates of human impact and economic costs might be warranted to justify large investments, but increased recognition of workplace cancers by all stakeholders, from workers and employers to public health officials and treating physicians, is the stepping stone toward preventive interventions for safer workplaces.

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**CONFLICT OF INTEREST DISCLOSURES**

We have read and understood Current Oncology's policy on disclosing conflicts of interest, and we declare that we have none.

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**REFERENCES**