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ORIGINAL ARTICLES

# Effects of separately ventilated smoking lounges on the health of smokers: is this an appropriate public health policy?

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**Abstract**

***Background*** **– There is some evidence that smokers may face an increased risk of lung cancer from environmental tobacco smoke (ETS) exposure. We considered the possibility that policies exposing smokers to high ETS levels in smoking lounges may have an adverse effect on the health of smokers.**

***Objective*** **– To compare the potential impact of a separately ventilated smoking lounge (SVSL) policy and a smoke-free workplace policy on lung cancer mortality among smokers.**

***Methods*** **– We modelled the change in lung cancer mortality among smokers currently employed at workplaces that do not regulate smoking after implementation of a SVSL policy and a smoke-free policy. Outcomes of each policy were determined for a wide range of possible assumptions. Threshold analyses were performed to define the levels of key parameters at which the basic results of the model would change.**

***Results*** **– Under a wide range of plausible assumptions, a SVSL policy was predicted to result in substantial lung cancer mortality among smokers, while a smoke-free policy was predicted to prevent many lung cancer deaths among smokers. The finding that the effects of a smoke-free policy were favourable was robust, holding true unless it was assumed that ETS exposure has no effect on lung cancer risk among smokers.**

***Conclusion*** **– The potential adverse health effects of ETS on smokers should be considered in regulating smoking in the workplace.**

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Keywords: nicotine; smoking; tobacco smoke pollution; ventilation

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## Introduction

Environmental tobacco smoke (ETS) is now well recognised as a significant health hazard.[1–4] The workplace is a major source of ETS exposure,[3,5–8] and the National Institute for Occupational Safety and Health (Cincinnati, Ohio) has identified workplace ETS exposure as an occupational health hazard.[9] In the US, many state and local governments have begun to regulate this public health hazard by restricting smoking in the workplace.[10] The federal government is now considering similar regulations. A bill (HR 3434) was introduced in the last session of Congress that would have prohibited smoking in almost all workplaces except in smoking lounges that are separately ventilated.[11] The Occupational Safety and Health Administration (OSHA) published a proposed rule requiring that smoking be prohibited in the workplace or restricted to separately ventilated areas.[7]

Most legislation that regulates ETS exposure in the workplace has been designed solely to protect non-smokers from the health hazards of ETS. Many policymakers, therefore, have opted to require policies that restrict smoking in the workplace to separate areas, under varying ventilation standards, rather than prohibiting smoking completely. The rationale behind this approach is that non-smokers will be protected from ETS exposure. However, smokers may also face an increased risk of lung cancer from ETS exposure,[12–18] and a recent study suggested that a policy that permits smokers to concentrate in a small area could considerably increase their risk of cancer.[19] Since federal, state, and local governments are now considering both legislative and regulatory action to restrict smoking in the workplace, the potential effects of the creation of smoking lounges on the health of smokers should be examined.

In this paper, we compare the potential effects on the health of smokers of two policies: (a) one that restricts smoking to a separately ventilated smoking lounge (SVSL); and (b) a policy that prohibits smoking in the workplace (smoke-free policy). For each, we model the change in lung cancer mortality among smokers that would occur under a range of assumptions and estimate the number of lives saved or lost among smokers because of the policy.

## Methods

We used the following estimates to evaluate the impact of a SVSL or smoke-free policy on smokers who are currently employed at workplaces that do not restrict smoking.

- The initial relative lung cancer mortality rate for smokers and non-smokers who are exposed to ETS in the workplace compared with persons who are not exposed to ETS in the workplace

- The change in workplace ETS exposure for smokers and non-smokers after a SVSL or smoke-free policy is implemented
- The new relative lung cancer mortality rate for smokers and non-smokers at the new levels of workplace ETS exposure
- The change in the mortality rate for lung cancer among smokers and non-smokers
- The ratio of lives lost or saved among smokers to lives saved among non-smokers under each policy
- The number of lives lost or saved among smokers under each policy.

Because of considerable uncertainty in many of the assumptions used, we ran the model for a wide range of plausible assumptions. The analysis is intended to provide a range of outcomes expected under a broad set of plausible assumptions, rather than to determine a single best estimate of the likely outcome. In addition, we conducted threshold analyses of key parameters in the model to define the levels at which the results of the model would change.

We used nicotine as a marker for ETS exposure because it is rarely found other than in tobacco smoke, easily measured using well-defined methods, and has been measured extensively in a variety of workplace environments.[2,20] For this analysis, we looked at smoking in the office setting because of the abundance of data on nicotine levels in offices. We estimated the change in lung cancer mortality for employees currently at workplaces without smoking restrictions because they are likely to experience the greatest change in ETS exposure after a change in smoking policy. Using a 1991 estimate from the National Health Interview Survey (NHIS), about 29.7 million non-smoking workers (35.9% of all non-smoking workers) are employed in workplaces that allow smoking in work areas (Centers for Disease Control and Prevention, Office on Smoking and Health, unpublished data, 1994).

We begin by describing the assumptions used in the model and our reasoning in determining the range of assumptions tested in the model. We then demonstrate the model for one set of assumptions. Finally, we present the range of outcomes predicted by the model for a broad range of plausible assumptions, and present the results of threshold analyses for important parameters in the model.

## ASSUMPTIONS: INITIAL LUNG CANCER RELATIVE RISK

### *Non-smokers*

Few of the studies that have examined the health risks of passive smoking provide estimates of the risk associated with exposure to ETS in the workplace alone. Many of the studies that do estimate the risk of workplace exposure have small sample sizes because many participants did not work outside the home. This problem led Woodward[21] to suggest that a more accurate estimate of the risks associated with exposure to ETS in the workplace could be obtained by extrapolating from the established risks associated with exposure to ETS in the home. Because there is no physiological difference related to the environment in which exposure occurs, OSHA concluded that risk estimates based on residential exposures should accurately reflect occupational risks for most workplaces.[7] This is the approach we take in this paper. Nevertheless, as a check of our assumptions, we do report risk estimates from the studies that did examine ETS exposure in the workplace separately.[22–31]

Six meta-analyses have been published of the epidemiological studies that examined the relative risk of lung cancer among non-smokers who lived with a spouse who smoked compared with non-smokers who lived with a spouse who did not smoke.[2,3,32–35] In these reviews, the investigators reported summary relative risks of between 1.05 and 1.4; five of the six studies reported estimates of between 1.2 and 1.4.[2,3,32–34] This is the range of risk estimates we used in this analysis.

Levels of exposure to ETS in workplaces and homes have been compared in two published reports that reviewed sampling data from over 20 studies.[3,36] In both reviews, average nicotine levels in homes and offices were found to be similar. The average nicotine level was 4.1 $\mu g/m^3$ in 940 offices studied and 4.3 $\mu g/m^3$ in 91 residences with a smoker present.[36] The duration of exposure to ETS in workplaces and homes is also similar, based on time-budget and exposure diary studies.[36–38] Because both the average level of ETS exposure and the duration of exposure appear to be similar for the home and workplace, we estimate that the relative risk of mortality from lung cancer that is associated with exposure to ETS in the workplace is the same as that for exposure in the home (1.2–1.4).

The risk estimates for lung cancer in the studies that examined the effects of workplace ETS exposure[22–31] support the assumption of a small elevated risk of lung cancer among non-smokers exposed to ETS in the workplace (table 1).

### *Smokers*

Of the studies that examined the relationship between ETS exposure and lung cancer risk, we found seven that examined this relationship specifically among smokers[12–18] (table 2). Five of these seven studies reported an elevated risk of lung cancer among smokers who were exposed to ETS in the home,[12–16] one found no difference in lung cancer risk,[17] and one found a decreased lung cancer risk.[18] None of these results were statistically significant.

We conducted a meta-analysis of the six case-control studies that examined lung cancer risk among exposed smokers (one study[16] was a cohort study). Data were obtained from the published reports or from the authors for five of these studies.[12,13,15,17,18] Using the Mantel-Haenszel method for pooling of uniform

*Table 1 Studies that examined the risk of lung cancer among non-smokers associated with exposure to environmental tobacco smoke (ETS) in the workplace*

| Study | Odds ratio and 95% CI* | Comments |
|---|---|---|
| Brownson *et al*, 1992[22] | 1.2 (0.9–1.7) | For non-smoking women at highest quartile of ETS exposure at work |
| Fontham *et al*, 1994[23] | 1.39 (1.11–1.74) | For non-smoking women exposed to ETS in occupational environments |
| Garfinkel *et al*, 1985[24] | 0.93 (0.73–1.18) | For non-smoking women exposed to ETS at work for the last 25 years |
| Janerich *et al*, 1990[25] | 0.91 (0.80–1.04) | For non-smokers with a differential of 150 person years of exposure to ETS at work |
| Kabat and Wynder, 1984[26] | 3.3 (0.9–12.7) | For non-smoking men |
| | 0.7 (0.3–1.6) | For non-smoking women |
| Kalandidi *et al*, 1990[27] | 1.39 (0.73–2.66) | For non-smoking women exposed to ETS at work |
| Lee *et al*, 1986[28] | 1.6 (0.3–10.2) | For non-smoking men with any ETS exposure at work |
| | 0.6 (0.1–2.5) | For non-smoking women with any ETS exposure at work |
| Shimuzu *et al*, 1989[29] | 1.2 | For non-smoking women exposed to ETS at work |
| Svensson *et al*, 1989[30] | 1.2 (0.4–2.9) | For non-smoking women exposed to ETS at home or at work |
| Wu-Williams *et al*, 1990[31] | 1.1 (0.9–1.6) | For non-smoking women exposed to ETS at work |

*95% Confidence interval. If not given in paper, confidence intervals were calculated from published data (if possible).

*Table 2 Studies that examined the risk of lung cancer among smokers associated with exposure to environmental tobacco smoke (ETS) in the home*

| Study | Risk estimate* and 95% CI† | Comments |
|---|---|---|
| Akiba *et al*, 1986[12] | 1.2 (0.8–1.8) | For ever-smoking men married to an ever smoker |
| | 1.6 (0.6–4.5) | For ever-smoking women married to an ever smoker |
| Buffler *et al*, 1984[13] | 1.28 (0.91–1.79) | For ever-smoking men who lived with a regular smoker |
| | 1.80 (0.92–3.58) | For ever-smoking women who lived with a regular smoker |
| Correa *et al*, 1983[14] | 1.03 | For smoking women who live with smoking husbands |
| | 1.5 | For light-smoking men (< 20 pack years) married to heavy smokers (> 40 pack years) |
| Geng *et al*, 1987[15] | 1.9 (0.9–4.1) | For smoking women who live with smoking husbands |
| Hole *et al*, 1984[16] | 1.13 (0.79–1.63) | Relative risk of lung cancer for ever-smokers living with other ever-smokers; adjusted for quantity smoked |
| Humble *et al*, 1987[17] | 1.0 (0.8–1.4) | For current smokers married to another smoker; adjusted for quantity smoked |
| Koo *et al*, 1984[18] | 0.47 (0.20–1.09) | For ever-smoking women who live with a smoker |

*Odds ratio unless specified. All studies but one[16] were case-control studies.
†95% Confidence interval. If not given in paper, confidence intervals were calculated from published data (if possible).

stratum-specific estimates,[39] we determined a pooled risk estimate for these five studies. Confidence intervals were determined using the method of Gart and Cornfield.[40] To be conservative, we used the pooled odds ratio of 1.3 (95% CI = 1.1 to 1.5) as the upper bound estimate for our analysis. This value is consistent with the EPA's finding of a pooled odds ratio of 1.25 in a meta-analysis of seven studies that examined the risk of lung cancer among female smokers exposed to ETS.[3]

Although the overall evidence suggests a relationship between ETS exposure and lung cancer among smokers, the potential role of confounding by amount smoked is addressed in only two studies. It is possible that smokers who live with other smokers smoke more than smokers who live with non-smokers, and that this could explain the observed findings. Unpublished data from the 1992 NHIS showed that the mean self-reported number of cigarettes smoked per day by married, current everyday smokers who report that two or more people smoke in the home is 22, compared with 19 for those who report that none or one person smokes in the home. Humble *et al*[17] found an odds ratio for lung cancer of 1.2 for current smokers married to a smoker, but the odds ratio decreased to 1.0 when adjusted for amount smoked. Hole *et al*,[16] in the only cohort study of the group, found a relative risk of lung cancer of 1.13 among ever-smokers who lived with other ever-smokers, controlling for amount smoked. As it is possible that the elevated lung cancer risk among smokers with ETS exposure is caused by confounding by amount smoked, we used a relative risk of 1.0 as the lower bound estimate for our analysis.

Because the levels of ETS exposure in homes and offices and the amount of time spent in the home and workplace appear to be similar,[3, 36–38] we assumed that the relative risk of mortality from lung cancer associated with exposure to ETS in the workplace is similar to the relative risk associated with exposure to ETS in the home. Thus, we used a relative risk range of 1.0–1.3 in this analysis.

## ASSUMPTIONS: CHANGE IN WORKPLACE ETS EXPOSURE

### *Non-smokers*

For this analysis, we assumed that policies restricting smoking to a separately ventilated lounge will eliminate non-smokers exposure to ETS.

### *Smokers*

Nicotine levels in office workplaces have been studied extensively.[20, 36] A review of measurements in 940 workplaces reported a weighted average nicotine concentration of 4.1 μg/m$^3$.[36] Measurements taken in designated smoking areas were excluded from this analysis, so this level of nicotine probably represents a good estimate of the baseline level of exposure to nicotine produced by other smokers in workplaces that do not restrict smoking.

Because smokers may tend to congregate, we calculated the weighted mean of the average reported nicotine concentrations in workplace areas where smoking was permitted, using the same method.[36] Of the nine studies reviewed by Guerin *et al*,[20] the weighted mean nicotine level in the 81 offices studied was 6.6 μg/m$^3$. We used this as an alternate estimate of the baseline nicotine level to which smokers are exposed.

We are aware of three studies in which nicotine levels were measured in smoking lounges. Vaughan and Hammond[41] reported a nicotine concentration of 70–77 μg/m$^3$ in a well-ventilated (20 air changes per hour) smoking lounge with separate ventilation. Two other studies measured nicotine levels in smoking lounges that were not separately ventilated. These studies reported nicotine levels that were similar to the level found by Vaughan and Hammond. Hammond reported nicotine levels of between 40 and 85 μg/m$^3$ in a smoking lounge (Hammond SK, Pasenka J, Fragala G. Restricting smoking in the workplace: concentrations of particles and nicotine in smoking lounges. Presented at the American Industrial Hygiene Conference, Akron, Ohio, May 1988). The maximum levels at four different locations within the lounge on four separate days were about 75, 55, 75, and 85 μg/m$^3$. Sterling reported a mean nicotine concentration of 75 μg/m$^3$ in a designated smoking office.[42]

Because the findings of the three studies are quite consistent, we use 70 μg/m$^3$ (the low estimate reported for a separately ventilated smoking lounge) as the expected nicotine concentration in smoking lounges. The ventilation conditions in the lounge sampled in the Vaughan and Hammond study are probably comparable to the conditions that could be reasonably expected under a policy that allows separately ventilated smoking lounges in all workplaces.

In workplaces that implement a designated smoking area, smokers would no longer be able to smoke at their desks and the duration of their exposure to ETS would decrease. We assume, conservatively, that smokers are currently exposed for a full eight hours per workday. We model changes in exposure under two assumptions – that smokers would be exposed for either one or two hours a day.

We assume that a smoke-free policy would eliminate smokers exposure to ETS in the workplace. Although some smokers might still be exposed to ETS outdoors, we assume that the magnitude and duration of this exposure would be minimal.

#### ASSUMPTIONS: NEW LUNG CANCER RELATIVE RISK

*Non-smokers*

Because we assume that restricting smoking to a smoking lounge that is separately ventilated will eliminate exposure to ETS for non-smokers, the new mortality rate for lung cancer will be the same as the rate for non-exposed non-smokers.

*Smokers*

We assumed a linear relationship between changes in ETS exposure and changes in excess risk of lung cancer mortality for smokers. This appears to be a reasonable assumption based on data for non-smokers. Of the 17 studies reviewed by the US Environmental Protection Agency that provided dose-response data on household ETS exposure and lung cancer risk among non-smokers,[3] at least 11 appear to support the assumption of an approximately linear relationship between changes in ETS exposure and changes in excess lung cancer risk. In our sensitivity analyses, we tested the assumption of a logarithmic relationship between changes in ETS exposure and changes in excess lung cancer risk.

#### ASSUMPTIONS: BASELINE NUMBER OF LUNG CANCER DEATHS AMONG NON-SMOKING EMPLOYEES EXPOSED TO ETS

OSHA has estimated that the lung cancer risk for non-smoking employees exposed to ETS over their working lifetime is one in 1000 and that between 19% and 49% of non-smoking workers are exposed to ETS at work.[7] Our model applies only to the estimated 29.7 million non-smokers employed at worksites that currently allow smoking in work areas. We assumed, conservatively, that 19% (5.6 million) of these non-smokers are exposed to ETS at work. Using the OSHA risk estimate, an estimated 5600 deaths from lung cancer would be expected among these non-smokers over the next 45 years. This is probably a quite conservative estimate because the ETS exposure rate in workplaces that do not restrict smoking is probably much higher than 19%.

#### SAMPLE CALCULATION

A sample calculation of the impact of a SVSL policy (table 3) and a smoke-free policy (table 4) on lung cancer mortality among smokers is shown for the following assumptions.

- The initial lung cancer relative risk for non-smokers exposed to ETS is 1.3
- The initial lung cancer relative risk for smokers exposed to ETS is 1.1
- The baseline level of workplace nicotine exposure for smokers is 4.1 μg/m$^3$
- The duration of ETS exposure for smokers under a SVSL policy is one hour.

## Results

Table 5 shows the results of the model for many of the assumptions considered (including the extreme cases). The model is most sensitive to the baseline relative risk for smokers. At a relative risk of 1.0, neither policy would have any effect on lung cancer mortality among smokers. At a slightly elevated relative risk of

*Table 3 Model of the impact of a separately ventilated smoking lounge policy on lung cancer mortality among smokers*

| | Smokers | Non-smokers |
|---|---|---|
| Baseline lung cancer mortality relative risk associated with workplace ETS exposure | 1.1 | 1.3 |
| Baseline lung cancer mortality rate for workers with ETS exposure | 1.1 ($M_S$)* | 1.3 ($M_N$)† |
| Baseline level of nicotine exposure | 4.1 µg/m³ | 4.1 µg/m³ |
| Level of nicotine exposure after creation of a smoking lounge | 70 µg/m³ | 0 |
| Ratio of duration of workplace ETS exposure after creation of smoking lounge to baseline duration of exposure | 1 hour/8 hours = 0.125 | 0 |
| Ratio of total workplace ETS exposure after creation of smoking lounge to baseline exposure | (70/4.1) (0.125) = 2.1 | 0 |
| Excess lung cancer mortality risk after creation of smoking lounge | 2.1 (0.1 ($M_S$) = 0.21 ($M_S$) | 0 |
| New lung cancer mortality rate after creation of a smoking lounge | $M_S$ + (0.21) ($M_S$) = 1.21 ($M_S$) | $M_N$ + 0 ($M_N$) = 1.0 ($M_N$) |
| Change in lung cancer mortality rate after creation of smoking lounge | 1.21 ($M_S$) − 1.1 ($M_S$) = 0.11 ($M_S$) = 1.81 ($M_N$)‡ | 1.3 ($M_N$) − 1.0 ($M_N$) = −0.3 ($M_N$) |
| Ratio of increase in lung cancer mortality rate among smokers to decrease in lung cancer mortality rate among non-smokers | 1.81 ($M_N$)/0.3 ($M_N$) = 6.0 | |
| Estimated ratio of lives lost among smokers to lives saved among non-smokers‖ | 6.0/3 = 2.0 | |
| Lives saved among non-smokers¶ | 5600 | |
| Lives lost among smokers | 5600 × 2.0 = 11 200 | |

*$M_S$ = Mortality rate for lung cancer among smokers without exposure to ETS at work.
†$M_N$ = Mortality rate for lung cancer among non-smokers without exposure to ETS at work.
‡$M_S$ = 17 ($M_N$), from CPS-II prospective study.[44] (The lung cancer mortality rate among smokers was about 17 times higher than among non-smokers.)
‖Assuming three times as many non-smokers as smokers are affected by policy. US adult smoking prevalence is about 26%, based on data from the 1992 National Health Interview Survey.[45]
¶From Occupational Safety and Health Administration risk estimate[7]; lung cancer deaths over a 45-year period.
ETS = environmental tobacco smoke.

*Table 4 Model of the impact of a smoke-free workplace policy on lung cancer mortality among smokers*

| | Smokers | Non-smokers |
|---|---|---|
| Baseline lung cancer mortality relative risk associated with workplace ETS exposure | 1.1 | 1.3 |
| Baseline lung cancer mortality rate for workers with ETS exposure | 1.1 ($M_S$)* | 1.3 ($M_N$)† |
| New lung cancer mortality rate after implementation of smoke-free policy | $M_S$ | $M_N$ |
| Change in lung cancer mortality rate after implementation of smoke-free policy | $M_S$ − 1.1 ($M_S$) = −0.1 ($M_S$) = −1.7 ($M_N$)‡ | $M_N$ − 1.3 ($M_N$) = −0.3 ($M_N$) |
| Ratio of decrease in lung cancer mortality rate among smokers to decrease in lung cancer mortality rate among non-smokers | −1.7 ($M_N$)/0.3 ($M_N$) = 5.7 | |
| Estimated ratio of lives lost among smokers to lives saved among non-smokers‖ | 5.7/3 = 1.9 | |
| Lives saved among non-smokers¶ | 5600 | |
| Lives saved among smokers | 5600 × 1.9 = 10640 | |

*$M_S$ = Mortality rate for lung cancer among smokers without exposure to ETS at work.
†$M_N$ = Mortality rate for lung cancer among non-smokers without exposure to ETS at work.
‡$M_S$ = 17 ($M_N$), from CPS-II prospective study.[44] (The lung cancer mortality rate among smokers was about 17 times higher than among non-smokers.)
‖Assuming three times as many non-smokers as smokers are affected by policy. US adult smoking prevalence is about 26%, based on data from the 1992 National Health Interview Survey.[45]
¶From Occupational Safety and Health Administration risk estimate[7]; lung cancer deaths over a 45-year period.
ETS = environmental tobacco smoke.

1.1, however, the policies would produce markedly different effects, even under the most conservative assumptions. Under such assumptions, our model predicts that a SVSL policy would result in about 2600 deaths from lung cancer among smokers, whereas a smoke-free policy would prevent about 8000 lung cancer deaths among smokers over a 45-year period. For a wide range of assumptions tested, a SVSL policy would result in a substantial number of deaths from lung cancer among smokers, whereas a smoke-free policy would prevent a substantial number of such deaths.

The finding that a smoke-free policy produces substantially better outcomes than a SVSL policy in terms of the health of smokers is not particularly sensitive to our range of assumptions about baseline relative risk for non-smokers, baseline nicotine exposure, or duration of ETS exposure under a SVSL policy. A threshold analysis revealed, however, that a SVSL policy would reduce ETS exposure among smokers (and decrease mortality if the relative risk is greater than 1.0) if baseline nicotine exposure is higher than 8.8 µg/m³ (assuming one hour of ETS exposure in a smoking lounge) or 17.5 µg/m³ (assuming two hours of exposure) (table 5). Similarly, if the level of nicotine exposure in a smoking lounge is lower than 53 µg/m³ (assuming a baseline level of 6.6 µg/m³ and one hour of exposure) or 33 µg/m³ (assuming a baseline level of 4.1 µg/m³ and one hour of exposure), a SVSL policy would reduce ETS exposure among smokers (results not shown). If the duration of smoking lounge ETS exposure were two hours, the corresponding threshold values would be 26 and 16 µg/m³. ETS exposure among smokers would also decrease if the duration of exposure in lounges were less than

*Table 5 Impact of a smoke-free (SF) policy* vs *a separately ventilated smoking lounge (SVSL) policy on lung cancer mortality among smokers**

| *Lung cancer RR: smokers* | *Lung cancer RR: non-smokers* | *Baseline nicotine level: smokers (μg/m³)* | *Duration of ETS exposure SVSL (hours)* | *Policy* | *Outcome†* |
|---|---|---|---|---|---|
| 1.0 | 1.2–1.4 | 4.1 or 6.6 | 1 or 2 | SVSL<br>SF | 0 affected<br>0 affected |
| 1.1 | 1.2 | 4.1 | 2 | SVSL<br>SF | 52000 **lost**<br>16000 saved |
| | 1.3 | 4.1 | 2 | SVSL<br>SF | 35000 **lost**<br>11000 saved |
| | | 6.6 | 2 | SVSL<br>SF | 17000 **lost**<br>11000 saved |
| | | 4.1 | 1 | SVSL<br>SF | 11000 **lost**<br>11000 saved |
| | | 6.6 | 1 | SVSL<br>SF | 3000 **lost**<br>11000 saved |
| | 1.4 | 6.6 | 1 | SVSL<br>SF | 3000 **lost**<br>8000 saved |
| 1.2 | 1.2 | 6.6 | 1 | SVSL<br>SF | 10000 **lost**<br>32000 saved |
| | 1.3 | 6.6 | 1 | SVSL<br>SF | 7000 **lost**<br>21000 saved |
| | 1.4 | 6.6 | 1 | SVSL<br>SF | 5000 **lost**<br>16000 saved |
| 1.3 | 1.2 | 4.1 | 2 | SVSL<br>SF | 156000 **lost**<br>48000 saved |
| Threshold analyses | | | | | |
| 1.0–1.3 | 1.2–1.4 | 8.8 | 1 | SVSL | 0 lives affected |
| 1.0–1.3 | 1.2–1.4 | 17.5 | 2 | SVSL | 0 lives affected |
| 1.0–1.3 | 1.2–1.4 | 4.1 | 0.47 | SVSL | 0 lives affected |
| 1.0–1.3 | 1.2–1.4 | 6.6 | 0.75 | SVSL | 0 lives affected |
| 1.1 | 1.3 | 10.7 | 1 | SVSL<br>SF | 2000 saved<br>11000 saved |
| | | 20 | 1 | SVSL<br>SF | 6000 saved<br>11000 saved |

*Outcomes are lung cancer deaths among smokers over a 45-year period attributable to, or prevented by, a change in workplace smoking policy, using the model and assumptions presented in this paper.
†Numbers are rounded to the nearest thousand.
RR = relative risk.

0.47 hours (baseline nicotine level of 4.1 μg/m³) or less than 0.75 hours (baseline nicotine level of 6.6 μg/m³) (table 5). The finding that a smoke-free policy would save lives among smokers is not sensitive to these parameters, and would hold for all assumptions except for a baseline relative risk of 1.0 for smokers exposed to ETS.

In conditions under which a SVSL policy would reduce mortality among smokers by reducing ETS exposure, our model predicts that a smoke-free policy would reduce mortality to a greater extent. Using a baseline nicotine level of 10.7 μg/m³, a relative risk of 1.1 for smokers and 1.3 for non-smokers, and one hour of lounge ETS exposure, our model predicts that a SVSL policy would save 2000 lives, while a smoke-free policy would save 11 000 lives among smokers over a 45-year period (table 5). Under the assumption of a baseline nicotine level as high as 20 μg/m³, a SVSL policy would save 6000 lives under these conditions, compared with the 11 000 lives saved under a smoke-free policy (table 5).

The basic findings of our analysis are not very sensitive to our least certain assumption – a linear relationship between excess risk and exposure. If excess risk were proportional to the logarithm of exposure (an assumption that would tend to minimise any potential impact of a SVSL policy), then under the assumptions in table 3, a SVSL policy would be expected to result in 3000, rather than 11 000, lung cancer deaths among smokers. Under the most conservative assumptions in our model, applying a relative risk of 1.1 for smokers exposed to ETS and a logarithmic dose-response relationship produces an estimate that a SVSL policy would result in 970 lung cancer deaths among smokers over a 45-year period.

## Discussion

There are limited data on the potential health effects of ETS exposure among smokers and the potential level of exposure to ETS in separately ventilated smoking lounges. Nevertheless, policymakers must decide whether to implement a SVSL or a smoke-free policy for workplaces. This study modelled the impact of a SVSL and a smoke-free policy on lung cancer mortality among smokers under a range of plausible assumptions and performed threshold analyses to determine key parameter values at which the basic findings of the model would change. We attempted to use the best data available, erring on the side of using data that would favour a SVSL policy.

Neither a smoke-free policy nor a SVSL policy had any impact on lung cancer mortality among smokers when the relative risk associated with ETS exposure among smokers was 1.0. At modestly elevated relative risks, most assumptions we modelled suggested that a smoke-free policy would prevent deaths among smokers while a SVSL policy would increase the number of deaths among smokers. If the duration of smoking lounge ETS exposure is one hour, then baseline nicotine levels above 8.8 μg/m³ and smoking lounge nicotine levels below 53 μg/m³ would reduce lung cancer mortality among smokers. However, a smoke-free policy would reduce deaths from lung cancer among smokers to a greater extent under these conditions. Under no conditions does a SVSL policy produce better outcomes than a smoke-free policy.

All models are limited by the need to use imperfect data and to make certain assumptions. However, our finding of a major benefit of a smoke-free policy compared with a SVSL policy under the assumption of a slightly elevated lung cancer risk among smokers exposed to ETS appears to be robust. The range of estimates used, although imperfect, represent the best available data from the literature. Moreover, a smoke-free policy appears to be preferable to a SVSL policy in terms of smokers' health even when major alterations are made in nearly every assumption in our model to favour a SVSL policy.

Although ETS is known to increase lung cancer risk among non-smokers and five of seven studies found some evidence of an elevated lung cancer risk among smokers exposed to ETS, the observed findings could well be due to confounding by amount smoked. There is not sufficient evidence from available data to conclusively determine whether ETS exposure truly increases cancer risk among smokers. Future epidemiological studies are unlikely to provide an answer, because large sample sizes would be needed to control adequately for level of mainstream smoking. Therefore, a policy decision will likely need to be made in the absence of conclusive knowledge of the relative risk associated with ETS exposure for smokers. It is in this situation that a sensitivity analysis is most helpful. Our analyses suggest that a SVSL policy would increase deaths among smokers and a smoke-free policy would prevent many deaths among smokers under a wide range of plausible assumptions. Even under assumptions that are not as well supported by the data, where policies would reduce mortality among smokers, a smoke-free policy would save significantly more lives. Under no assumptions would a SVSL policy be preferable. Therefore, in the face of uncertainty concerning the potential effects of ETS on smokers, a smoke-free policy may be the most appropriate policy to regulate smoking in the workplace.

In addition to data limitations, this analysis has other important limitations. Major changes in smoking prevalence may occur in the next 45 years. If smoking prevalence decreases significantly, the number of deaths among smokers exposed to ETS would be less than predicted by our model. If worksites respond to a smoke-free requirement by providing outdoor, enclosed shelters for smokers, then ETS exposure among smokers may remain significant, resulting in fewer lives saved than predicted by our model. Ventilation rates may vary widely in smoking lounges. The data used in our model were derived from measurements in a lounge with a moderately high ventilation rate of 20 air changes per hour. It is not clear whether such a ventilation rate could be widely achievable in practice.

One critical assumption made in this analysis is that no leakage of ETS from separately ventilated smoking lounges would occur. However, preliminary data suggest that even with separate ventilation, ETS can still enter non-smoking areas.[19,41,43] If this is the case, then smoke-free policies would be preferable to SVSL policies in protecting non-smokers as well as smokers from ETS exposure.

A further limitation of our analysis is that it does not consider the possibility that implementation of workplace smoking policies may reduce mortality among smokers by reducing tobacco consumption. If smoke-free policies reduce tobacco consumption to a greater extent than SVSL policies, then the public health benefits of smoke-free policies are likely to be even greater.

Finally, our analysis considers only mortality from lung cancer. If ETS exposure is also related to mortality from heart disease among smokers, as some evidence suggests,[4] the public health benefits of a smoke-free policy compared with a SVSL policy may be heightened even further.

The results of this analysis suggest that the potential adverse health effects of ETS on smokers should be considered in regulating smoking in the workplace.


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