ORIGINAL ARTICLE

The economic burden of environmental tobacco smoke in the first year of life

G M Leung, L-M Ho, T-H Lam

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See end of article for authors' affiliations
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Correspondence to:
Dr G M Leung, Department of Community Medicine, 21 Sassoon Road, Faculty of Medicine Building, University of Hong Kong, Pokfulam, Hong Kong; gmleung@hku.hk

Accepted
3 February 2003
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Aims: To examine the population impact and economic costs associated with environmental tobacco smoke (ETS) in Chinese infants with non-smoking mothers.

Methods: Prospective, population based birth cohort study in Hong Kong, 1997–98. Main outcome measures were: doctor consultations and hospitalisations; adjusted odds ratios for higher utilisation by service type for each of the ETS exposure variables; corresponding population attributable risks (PARs); and associated extra health care costs.

Results: For the 1997 annual birth cohort, ETS exposure through the mother in utero was positively associated with higher consultation (adjusted odds ratio (OR) 1.26) and hospitalisation (OR 1.18) due to any illness. This translated into 7.4% of all inpatient episodes in the first year of life, representing an additional 1581 hospital attendances that cost over US$2.1 million. The corresponding PAR for outpatient services was 7.7%, where the majority was due to respiratory or febrile illnesses, accounting for $0.44 million in extra costs. Postnatal exposure to ETS at home was linked to higher rates of hospitalisations for any illness compared with non-exposed infants (OR 1.12), which led to 662 extra hospitalisations consuming $0.90 million, where the associated PAR was 3.1%.

Conclusions: Assuming that ETS was causally associated with health services use, about 9% of the total direct medical costs in the first year of life can be attributed to passive smoking. The community, as well as the private citizen, needs to be made aware of the costs foregone from exposure to tobacco smoke as well as the potential savings from a smoke-free society.

Estimating the societal impact of environmental tobacco exposure (ETS) in infants and children, the extent of that exposure, and the economic costs associated with it are important in providing the information necessary for evidence based action to reduce the public health consequences of ETS on paediatric and perinatal health.[1] Specifically, if ETS is estimated to have a large impact on health costs, policymakers are more likely to invest in intervention programmes to reduce ETS exposure of infants and young children.

Health impact can be measured using established procedures such as the population attributable risk (PAR) method. This combines the relative risk of disease in exposed children with the prevalence of exposure in the population to estimate the proportion of disease caused by passive smoking. From a public and preventive health perspective, even if each exposed individual is only slightly affected in terms of ill health, the potential avoidable burden of disease in the whole population can be substantial if the prevalence of exposure is high.[2] Such is the case for tobacco related disease where almost half of the world's children are exposed to ETS. In some parts of Asia, for example Japan, this rate exceeds 60%.[3] In addition, estimating the cost of children's exposure to tobacco smoke is important in evaluating tax and fiscal policy, as well as managing the ever upward public and private health care cost spirals.[4] Economic impact studies are also useful from a health services perspective because they highlight the potential savings if exposure of infants and children to environmental tobacco smoke is eliminated or at least minimised.[1]

While the biological and clinical effects of ETS on infants and children have been consistently and conclusively shown,[5 6] there are only sparse and contradicting reports in the literature about whether these effects lead to higher health services use by exposed subjects. Recently, we confirmed that exposure to ETS translated into higher services use by exposed infants during the first 18 months of life in a population based birth cohort of Hong Kong infants in 1997.[7] In the present study, we report the PARs and costs of the additional service utilisation associated with ETS exposure in this birth cohort.

Of note, the rate of maternal smoking (4.6%) is very low compared with other developed economies such as the United States (31.7%).[8] This makes Hong Kong an ideal setting to study the independent effects of ETS from non-maternal sources on infants' health. It is often difficult to completely disentangle the effects of ETS from smoking by mothers versus others in communities where the maternal smoking prevalence is high, because post hoc adjustment is less than ideal in isolating such effects.

We therefore specifically examined the contribution of ETS from fathers and other household contacts to extra health care costs as a result of infants' morbidity exclusive of maternal smoking. Our objectives were to study the effects of ETS on the population attributable risks and direct medical costs in a birth cohort of local Chinese infants who had non-smoking mothers.

METHODS

Sources of data

Details of the study methodology have been published previously.[7] We report here a synopsis of the methods. Data for this paper were drawn from a prospective birth cohort study conducted at all 47 maternal and child health centres (MCHCs) of the Hong Kong Government's Department of Health in 1997. The vast majority of infants in Hong Kong, regardless of the family's ability to pay, visit the MCHCs for preventive care and immunisations. For the index year, 92% of all infants born in Hong Kong attended an MCHC at least

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once.[9] The sampling frame consisted of all infants brought to an MCHC for their first visit after birth in April and May of 1997. The response rate to our study was 95%, accounting for 88% of all births in the period. There were 8327 mother-infant pairs in the final cohort. Among other items, mothers provided information on breast feeding history, household smoking habits, mode of delivery, and other demographic, obstetric, behavioural, and potential confounding variables via a standardised self administered questionnaire at their first MCHC visit (baseline) and at 3, 9, and 18 months after birth. In particular, questions ascertaining household smoking habits included maternal and paternal smoking as well as smoking by other household members both during pregnancy and after birth. Utilisation of health services was measured by the number of physician consultations and episodes of hospitalisations since the last MCHC follow up, excluding preventive visits such as vaccinations and regular well-baby checks. Mothers were also requested to provide information on the type of illness (respiratory illness, febrile illness, and other illnesses) leading to the consultation or hospitalisation episode, the type of clinic or hospital attended (public versus private) and the associated fees and charges for each episode. Those respondents who failed to provide some of the detailed data on type of facility visited or amounts paid for health care did not differ in the baseline characteristics from those who did provide complete data; we have therefore assumed that the corresponding group mean costs also apply to them by extrapolation. To minimise recall bias, parents were given the health services utilisation questionnaires to take home and were asked to fill in the form whenever the infant was taken for a consultation or was hospitalised. In this way, the outcomes of interest were documented prospectively and recorded as they occurred. Using telephone interviewing, trained research assistants contacted those who could not complete the questionnaire, and followed up those who did not return the questionnaire in time to ensure optimal follow up.

The project received ethics approval from the Ethics Committee of the Faculty of Medicine, University of Hong Kong.

Statistical analysis

To determine the risk ratios associated with ETS exposure, we employed multivariable logistic regression analyses to study the association between ETS patterns and doctor consultations and hospitalisations of infant subjects as recorded during follow up visits at 3, 9, and 18 months of age. Variables included in the model were selected if they were associated with a p value <0.05 at bivariable analyses or were included based on known confounders documented in previous literature.[5–7] The following independent variables were included in the final model: breast feeding practice (ever versus never), birth weight (<2500 g, 2500–2999 g, 3000–3499 g, 3500–3999 g, ≥4000 g), method of delivery (normal vaginal, vaginal assisted with suction or forceps, caesarean section), mother's age (≤24, 25–29, 30–34, ≥35 years), mother's education level (6th grade or less, 7th to 9th grade, ≥10th grade), full time job held by mother (yes or no), and birth order of infant (first, second, third, or more). The analysis was restricted to infants who had non-smoking mothers (that is, never smoking status since pregnancy), as documented in the baseline survey.

Doctor consultations were dichotomised as either lower or higher utilisation. Infants were defined as higher "utilisers" of medical services if they had more consultations than the median among the sample, adjusted for length of follow up pro rata. Specifically, we calculated, pro rata, the monthly number of outpatient visits per month for each infant, then determined whether use of services was lower or higher than the median monthly number of consultations in the sample

and dichotomised subjects accordingly. Hospitalisations (that is, inpatient admissions) were similarly coded. Higher utilisers of hospital services were in fact those who had ever (one or more hospitalisation episodes) been admitted. The results of this part of the analysis have been reported, and the present study adopted the final adjusted odds ratios (ORs) as the basis for the main part of the analysis.[7]

To assess the incremental adverse health impact due to ETS, taking advantage of the population based design of the study, we calculated the respective adjusted PARs and their 95% confidence intervals directly from logistic regression for each of the passive smoking exposure variables.[10] This statistical approach allows for an unbiased estimate of the PAR, even when the prevalence of the outcome of interest (that is, higher utiliser in our case) does not satisfy the "rare disease" assumption, as well as adjusts the estimated effect of one form of ETS exposure for the effects of others and those of potential confounders.[10] Only those variables that were shown to be significantly associated with higher use of health services in the earlier part of the analysis were included for PAR calculations.[7]

For the estimation of additional costs due to ETS exposure in these infants in terms of an annual birth cohort, we first worked out the total number of "higher" utilisers for the population by multiplying the total number of infants born in Hong Kong in the year 1997 with the prevalence of "higher" utilisers for the different categories of consultations and hospitalisations. Next, multiplying these estimates of the total number of "higher" utilisers with the respective differences in the mean number of episodes between "higher" and "lower" utilisers (that is, the number of episodes above and beyond those expected of a "lower" utiliser, since all infants were expected to generate some health service episodes) per individual for the various outpatient and inpatient use categories, the total number of extra episodes generated by the "higher" utilisers for the different categories were found. Taking these numbers together with the ETS exposure PARs, we calculated the number of extra episodes attributable to each ETS variable. Finally, we estimated the total extra cost attributable to each ETS variable to be the product of the number of extra episodes attributable to ETS and the mean associated cost for the study sample specific for that particular type of episode. We also calculated the overall relative contribution of public versus private funding to the total extra costs generated through the different types of ETS exposure.

The results were standardised pro rata to yearly estimates and converted to 1997 US dollars (pegged exchange rate US$1 = HK$7.8, £0.61, or €0.85) for easy interpretation. All analyses were conducted using Stata version 6.0.[11]

RESULTS

In a previous paper[7] we have reported detailed information on parent-infant characteristics, exposure patterns to tobacco smoke, and utilisation of health services. Briefly, only 4.6% of the mothers were ever smokers since conception and were subsequently excluded from the analysis, while 33.6% of fathers reported smoking at the baseline MCHC visit. Of the non-smoking mothers, 50.5% and 14.2% reported occasional and daily ETS exposure during pregnancy respectively. After birth, infant exposure to ETS at home from paternal and other smoking was documented in 41.2% of households. These statistics are consistent with results from previous surveys of children and youth in Hong Kong over the past decade.[12–14]

Table 1 presents the annualised mean, median, 5th and 95th centile numbers of episodes, in terms of consultations and hospitalisations, and the associated unit costs for both lower utilisers and higher utilisers. Higher utilisers attended slightly more than 10 ambulatory, curative (that is, non-preventive) visits in the first year of life compared to only three visits for lower utilisers. Similarly, we observed 1.3 inpatient episodes

Table 1 Health services utilisation and associated costs in the first year of life for the 1997 birth cohort

| | | Annual number of episodes | | | | | | Cost per episode (US$) | | | | Relative contribution to the cost (%) | |
| | | Mean | | | | | | | | | | | |
	Proportion of higher utilisers (%)	Overall	Lower utiliser	Higher utiliser	Median	5th centile	95th centile	Mean	Median	5th centile	95th centile	Private sector	Public sector
Consultation													
Respiratory/fever	46.0	6.7	2.6	8.8	5.0	0	17.0	27	24	13	45	89.2	10.8
Any illness	47.9	8.0	3.0	10.4	7.0	0	21.0	27	24	14	45	87.3	12.7
Hospitalisation													
Respiratory/fever	18.1	0.2	0	1.1	0	0	1.0	1253	1142	381	2564	21.1	78.9
Any illness	28.4	0.4	0	1.3	0	0	2.0	1354	1142	381	3045	18.3	81.7

Table 2 Costs of hospitalisation due to any illness in the first year of life attributable to ETS exposure for the 1997 annual birth cohort

| | | | Adjusted OR* | | PAR (%) | | | | Relative contribution to the cost (%) | |
	Prevalence (%)	Crude OR	Point estimate	95% CI	Point estimate	95% CI	Extra number of episodes attributable to ETS	Total extra cost (US$1000)	Private sector	Public sector
Exposure to ETS during pregnancy										
No	34.9	1	1							
Yes	65.1	1.20	1.18	(1.05 to 1.31)	7.4	(2.3 to 12.2)	1581	2142	18.3	81.7
Paternal smoking										
No	68.8	1	1							
Yes	31.2	1.17	1.08†	(0.96 to 1.21)	1.8	(−0.9 to 4.4)	N/A	N/A	N/A	N/A
Smoking by others										
No	85.8	1	1							
Yes	14.2	1.27	1.18‡	(1.01 to 1.37)	1.7	(0.1 to 3.3)	364	492	18.3	81.7
Exposure to ETS at home (by father and others)										
No	61.1	1	1							
Yes	38.9	1.19	1.12	(1.00 to 1.25)	3.1	(0.0 to 6.2)	662	897	18.3	81.7
Total number of smokers at home										
None	61.4	1	1							
1 smoker	30.7	1.13	1.07	(0.95 to 1.20)	1.4	(−1.2 to 4.0)	N/A	N/A	N/A	N/A
≥2 smokers	7.9	1.43	1.30	(1.08 to 1.58)	1.6	(0.4 to 2.8)	342	463	18.3	81.7

OR, odds ratio; CI, confidence interval; PAR, population attributable risk.
N/A denotes items not calculated because the associated PARs did not achieve statistical significance at the 0.05 level.
*Odds ratios are adjusted for maternal education level, maternal full time employment, maternal age, birth order, method of delivery, birth weight, and breast feeding.
†Additional adjustment for smoking by others.
‡Additional adjustment for paternal smoking.

versus none in higher and lower utilisers for any illness. The mean unit cost for an outpatient appointment was about US$27 and that for an inpatient episode $1354. These are broadly in line with corresponding figures from a survey of medical insurers in Hong Kong for the year 2000,[15] where the average insured individual claimed $31 per outpatient episode and $1469 for an inpatient visit. These claim figures are about 10–15% higher than our empirical observations, probably because only about 30% of the local population are covered by private health insurance and those covered tend to be more affluent and may seek more expensive care compared to the general population.[16] Inflation, however, should have had little influence given the Asian financial crisis in the interim. The relative contributions to the cost of care as shown in table 1 are also similar to government figures showing that the overall market share split for ambulatory care between private and public providers is 85:15 and that for hospitalisation services 8:92.[16] Perinatal and paediatric service use might have tilted towards more private care given the widely perceived convenience and better quality of care by and preference for private providers among the local population.[16]

Tables 2 and 3 detail the costs attributable to ETS for associations which achieved statistical significance at the 0.05 level only as previously reported.[7] Specifically, table 2 shows the extra costs incurred as a result of hospitalisation for different categories of ETS exposure both during and after pregnancy. For our 1997 annual birth cohort, ETS exposure in utero was responsible for generating an additional 1581 inpatient episodes in the first year of life that cost over $2.1 million. Similarly, postnatal ETS exposure at home from fathers and other household contacts led to 662 extra hospitalisations consuming $0.9 million on the population level. There was also a clear dose-response effect with increasing numbers of smokers at home (p < 0.05, test for linear trend), in terms of PAR, extra episodes, and associated costs.

Focusing on the public health and economic impact due to prenatal ETS exposure via non-smoking mothers, table 3 documents the different utilisation patterns by episode type and also in terms of type of illness. Such in utero exposure accounted for $437 000 in outpatient visits alone, where the majority was due to respiratory or febrile illnesses. A similar pattern for inpatient visits was also noted.

To put these attributable costs into perspective, we calculated the total direct medical costs reported for our sample and projected these for the 1997 annual birth cohort in Hong Kong for the first year of life to be $39.4 million, composed of $28.9 million in hospitalisations and $10.5 million in outpatient visits. The corresponding amounts attributable to ETS exposure in utero and postnatally at home were $3.04 million in hospital admissions and $0.44 million in

Table 3 Costs of health services utilisation in the first year of life attributable to ETS exposure during pregnancy for the 1997 annual birth cohort

		Adjusted OR*		PAR (%)				Relative contribution to the cost (%)	
	Crude OR	Point estimate	95% CI	Point estimate	95% CI	Extra number of episodes attributable to ETS	Total extra cost (US$1000)	Private sector	Public sector
Consultation									
Respiratory/fever	1.20	1.19	(1.08 to 1.31)	6.0	(2.6 to 9.4)	10274	273	89.2	10.8
Any illness	1.28	1.26	(1.14 to 1.39)	7.7	(4.3 to 10.9)	16192	437	87.3	12.7
Hospitalisation									
Respiratory/fever	1.14	1.11	(0.98 to 1.27)	5.7	(−1.3 to 12.2)	N/A	N/A	N/A	N/A
Any illness	1.20	1.18	(1.05 to 1.31)	7.4	(2.3 to 12.2)	1581	2142	18.3	81.7

OR, odds ratio; CI, confidence interval; PAR, population attributable risk.
N/A denotes items not calculated because the associated PARs did not achieve statistical significance at the 0.05 level.
*Odds ratios are adjusted for maternal education level, maternal full time employment, maternal age, birth order, method of delivery, birth weight, and breast feeding.

outpatient consultations, totalling $3.48 million annually (that is, 8.8% of total direct medical costs).

DISCUSSION

We found that ETS exposure at any time from the prenatal period through the first year of life produced substantial morbidity in this Hong Kong Chinese birth cohort that had a significant public health impact both in terms of increased health services use and direct economic costs. By the PAR method, in utero exposure to ETS through non-smoking mothers appeared to have imposed a greater population illness burden than postnatal home smoking by fathers and other household contacts. Almost 9% of the total direct medical costs in the first year of life can be attributed to ETS exposure. The representativeness of the study population base, prospective design, and high rates of coverage and follow up make it unlikely that the findings as described are a result of selection or information bias. We also assessed and controlled for known and potential confounders by multivariable adjustment procedures. Unlike previous studies[8 17 18] that relied on routine databases and subsequent projections or modelling, our analyses were based on empirical data collected specifically for the purpose of addressing our research question. A recent analysis of data[19] from the Avon Longitudinal Study of Pregnancy and Childhood (ALSPAC) also found a similar, independent effect for in utero tobacco smoke exposure (via smoking mothers) as well as a dose-response effect for postnatal ETS exposure. The consistency of evidence, combined with the biological plausibility of our observations as previously discussed,[7] lends added support to the argument that these associations were causal in nature.

The economic burden estimated in this study is likely a significant underestimate of the true cost associated with ETS exposure to infant health. According to the traditional taxonomy of economic cost used in the evaluation of health care interventions, there are three separate categories of costs: direct, indirect, and intangible.[20] Direct costs include medical care, personal, and other non-health care costs. Direct medical costs are those incurred by the health care system in the treatment or prevention of the condition. These may include costs directly related to the interventions for the condition studied, costs induced as a result of the intervention or information provided by it, costs required to manage side effects or complications as a consequence of the intervention, and all additional health care resources needed to treat conditions that occur during years of life expectancy added by the intervention. We have included most of these items of direct medical costs in the study. However, from an economic perspective, we are interested in assessing all opportunity costs, or what alternative investments could be made with the same resources now directed towards health care. The other cost

categories, not having been taken into account in this study, that make up the total opportunity cost associated with the effects of ETS exposure on infant health include the following:

(1) Direct personal costs—include transportation expenses to and from care facilities, costs of providing services in the home and community, and of support services for recuperation, rehabilitation, and coping with the disease.

(2) Direct non-health care costs—are those that are not directly related but attributable to the interventions associated with the condition, usually borne by other sectors such as welfare and education.

(3) Indirect costs—include changes in the productive use of time by patients and others. The two most important elements are usually the time costs to patients and caregivers waiting for treatment or the time spent in hospital, and the productivity loss in paid and unpaid economic activity due to premature death or disability. These are especially important in costing infant health where parents need to accompany the baby for appointments and inpatient stays as a matter of course compared to other age groups where it is deemed more voluntary and variable.

(4) Intangible costs of illness—attempt to provide some measure of the psychological burden and stress on patients, families, and caregivers, and of any improvements in quality of life as a result of interventions. These are notoriously difficult to estimate and are highly controversial as to whether they should be included in economic assessments.

The annual savings that can potentially materialise from eliminating household ETS exposure, either through the smokers quitting or at least smoking outside of the home, are far greater than the few million dollars of extra health care cost documented in our results. Other corollary net savings would include the cost of illness estimates[1] for morbidity and mortality related to other non-smoking household members such as mothers.[21] In addition, should the smokers themselves decide to quit, the savings from fewer adverse health outcomes due to active smoking plus those of their coworkers due to passive smoking would be enormous.

One major methodological limitation of the study bears mention. We were not able to give a precise estimate of the total direct medical costs due to the different categories of ETS exposure, because some of the PARs and therefore associated costs are not additive. For instance, it would be incorrect to sum up the costs due to "exposure to ETS during pregnancy" and "exposure to ETS at home (fathers and others)" in table 2 to give an overall cost attributable to ETS exposure both in utero and after birth. Although there are epidemiological methods proposed for evaluating PARs of risk factor combinations,[22 23] they are not applicable here since our exposure variables in the previous example are both related to

smoking by overlapping groups of smokers albeit at different time periods. Nonetheless, the ultimate goal of the paper is to provide scientific evidence necessary for action to reduce the public health consequences of ETS on paediatric and perinatal health.

The present data support the revision of public policy to reflect an evidence based approach to the promotion of smoking cessation in all household members, during as well as after pregnancy, for reducing the public health and economic impact due to infant illnesses. The public needs to be made aware of the costs foregone from exposure to tobacco smoke as well as the potential savings from a smoke-free society. The private sector bears a significant proportion of these extra costs and stands to gain substantially if the exposure is eliminated. On an individual level, the privatisation of these findings is also important. There should be more effective health education interventions targeted at family members who smoke, which not only emphasises the health benefits from quitting but also the personal economic implications associated with their smoking in terms of insurance premiums and out of pocket medical expenses.

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Authors' affiliations

G M Leung, L-M Ho, T-H Lam, Department of Community Medicine, University of Hong Kong Medical Centre

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"Oh boy. That habit is gonna cost us . . ." Illustration by Jack Maypole, MD