Breast-feeding and Environmental Tobacco Smoke Exposure

Allan B. Becker, MD; Jure Manfreda, MD; Alexander C. Ferguson, MD; Helen Dimich-Ward, PhD; Wade T. A. Watson, MD; Moira Chan-Yeung, MD

**Background:** Exposure to environmental tobacco smoke is associated with adverse effects in infants and children.

**Objective:** To explore whether an increase in urinary cotinine fumarate level is caused by ingested nicotine and cotinine in breast-feeding infants.

**Methods:** We studied newborns at risk for developing asthma and allergies based on a strong family history. We measured urinary cotinine levels in the infants as a measure of environmental tobacco smoke exposure and cotinine levels in the breast milk of breast-feeding mothers.

**Results:** Of 507 infants, urinary cotinine levels during the first 2 weeks of life were significantly increased in infants whose mothers smoked. Breast-fed infants had higher cotinine levels than non-breast-fed infants, but this was statistically significant ($P < .05$) only if mothers smoked. Urinary cotinine levels were 5 times higher in breast-fed infants whose mothers smoked than in those whose mothers smoked but did not breast-feed.

**Conclusions:** Mothers should be encouraged to not smoke, and parents must be advised of the potential respiratory and systemic risks of environmental tobacco smoke exposure to their child, including the potential for future addiction to smoking.


**EXPOSURE** to environmental tobacco smoke (ETS) has been associated with multiple adverse health effects in infants and children. Maternal smoking during pregnancy is associated with premature delivery; intrauterine growth retardation; decreased birth weight, head circumference, and length; perinatal complications, including sudden infant death syndrome; and problems of neurodevelopmental impairment, attention-deficit/hyperactivity disorder, inflammatory bowel disease, and strabismus. Postnatal ETS exposure is associated with the increased occurrence of respiratory illnesses in infants. Maternal smoking in the postnatal period has greater impact than paternal smoking on respiratory illnesses in infants.

We initiated a study of asthma prevention in newborns with a high risk for developing asthma and allergies, based on a strong immediate family history. As a component of this study, we measured their urinary cotinine fumarate levels as an indication of ETS exposure. We found that, in infants of mothers who smoked, urinary cotinine levels of breast-fed infants were much higher than of those not breast-fed. Therefore, we explored whether this increase was caused by ingested nicotine and cotinine in breast-feeding infants.

Results of urinary cotinine measurements in infants during the first 2 weeks of life are shown according to exposure to ETS and feeding in Table 1. Infants whose mothers smoked had significantly higher urinary cotinine levels than those whose mothers did not. Breast-fed infants had higher urinary cotinine levels than those not breast-fed, although this was statistically significant ($P < .05$) only if the mother smoked. For mothers who did not smoke, infants exposed to ETS had higher urinary cotinine levels than those with no exposure. However, this difference was also statistically significant ($P < .05$) only for breast-fed infants.

Table 2 shows the results of breast milk cotinine measurements. Breast milk cotinine levels were significantly higher among moth-
PARTICIPANTS AND METHODS

Urine samples were collected from 507 infants enrolled in an asthma and allergy prevention study during the first 2 weeks of life. After it became apparent that urine cotinine levels were markedly increased among breast-feeding infants whose mothers smoked, we obtained breast milk samples from 30 mothers who continued to breast-feed at the time of their next scheduled study visit (4 months after delivery). Five of these mothers also continued smoking. Among the 25 non-smoking, breast-feeding mothers, 20 had no ETS exposure and 5 had some ETS exposure. Exposure to ETS was defined as the presence of a spouse or other individual who smoked in the home. Breast milk and urine samples were frozen at −20°C until they were assayed.

COTININE ASSAY

The samples of urine and breast milk were assayed for cotinine using a double antibody radioimmunoassay. Briefly, 0.1 mL of urine or 0.1 mL of cotinine standard (20–2000 pg) was added to a test tube followed by 0.1 mL of tritiated cotinine. Anticotinine antiserum, 0.1 mL, was added to each tube and mixed. The tubes were incubated at 37°C for 18 hours. After incubation, 0.1 mL of goat antirabbit gamma globulin was added to each tube, followed by 0.1 mL of goat antirabbit gamma globulin. The tubes were centrifuged at 1000 rpm for 30 minutes. The supernatant was removed, and the pellet was dissolved in 0.1 mL of 0.1 mol/L sodium hydroxide. Ecoline, 2.5 mL, was added, and the radioactivity was counted in a beta-counter. A standard curve was constructed, and the concentration of cotinine in the samples was read from the standard curve. Cotinine level was measured in the urine, and the results were expressed in nanograms per milligram of creatinine.

STATISTICAL ANALYSIS

A logarithmic transformation was applied to cotinine data because its distribution was not normal. Means of transformed data were compared with analysis of variance and t tests. Means and 95% confidence intervals were calculated using transformed data. Antilog values of transformed means (geometric means) and 95% confidence intervals were calculated to report data on the original scale. Statistical significance for the difference between 2 groups was set at P < .05; this condition was met when the 95% confidence interval of the 2 means compared did not overlap.

COMMENT

We found increased urinary cotinine concentrations in infants with ETS exposure. Such levels were significantly higher among infants breast-fed by mothers who were exposed to ETS, particularly mothers who smoked. The extremely high level of urinary cotinine in breast-fed infants of mothers who smoked is likely to be a combination of inhaled and ingested nicotine and cotinine. Our data suggest that, among mothers who smoke and breast-feed, the elevated cotinine level in infants is caused by inhalation and ingestion. Also, breast milk is the major contributor to an infant's urinary cotinine level. In a recent study, Mascola et al demonstrated a similar dramatic increase in urinary cotinine levels in older infants who were breast-fed by mothers who were smokers. However, the researchers did not directly measure the levels of breast milk cotinine. In our study, the breast milk cotinine levels of mothers who smoked was high. Luck and Nau found that breast milk cotinine and nicotine levels were, on average, about 3 times higher than the plasma cotinine and nicotine levels determined simultaneously, suggesting that products of tobacco smoke are concentrated in breast milk. However, they did not demonstrate significant differences between infants exposed only by “passive smoking” from their mother and those breast-fed by mothers who smoked. In our study, levels of urinary cotinine in breast-fed infants whose mothers smoked were significantly increased and, on average, were 5 times higher than those whose mothers smoked but did not breast-feed. In fact, the lowest urinary cotinine level in a breast-fed infant whose mother smoked was substantially higher than the highest urinary cotinine level in an infant who was not breast-fed and whose mother smoked.

We demonstrated increased urinary cotinine levels in breast-fed infants whose mothers had passive ETS exposure compared with those who were breast-fed and whose mothers did not have ETS exposure. There was a trend of similar increases in urinary cotinine levels in infants who were not breast-fed but whose mothers had passive ETS exposure, although this did not reach levels of statistical significance. Cotinine levels in the breast milk of non-smoking moth-

<table>
<thead>
<tr>
<th>Cotinine Level, Geometric Mean (95% CI), ng/mg of Creatinine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast-fed Infants</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Mother is a nonsmoker</td>
</tr>
<tr>
<td>No ETS exposure</td>
</tr>
<tr>
<td>ETS exposure</td>
</tr>
<tr>
<td>Mother is a smoker</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

aETS indicates environmental tobacco smoke; CI, confidence interval.
ers with ETS exposure were not significantly elevated compared with those of nonsmoking mothers without ETS exposure. However, at the time we measured breast milk cotinine levels, there were only 5 mothers continuing to breast-feed who had passive ETS exposure. Thus, elevated cotinine concentrations in the urine of infants of nonsmoking mothers with ETS exposure may result more from inhalation than from ingestion.

Exposure to ETS primarily by inhalation has been associated with the increased occurrence of respiratory illnesses, decreased pulmonary function, and increased bronchial responsiveness. It is not clear whether ingested tobacco products play any role in these problems. In a recent study, maternal smoking was associated with an increased risk for respiratory illness during the first year of life. However, the risk for respiratory illness was 7 times higher in infants not breast-fed compared with those breast-fed whose mothers smoked. This suggests that the ingested components of tobacco products from breast milk do not place infants at greater risk for respiratory complications and that breastfeeding is protective against respiratory illness.

Little is known about the effect of ETS exposure during pregnancy and infancy on the child's subsequent smoking behavior. Results of a recent study demonstrated that maternal smoking during pregnancy increased the probability of smoking in adolescent girls, after adjusting for postnatal smoke exposure. Another study found that the risk of adolescents taking up smoking was related to cotinine content in their saliva 6 years earlier, which was unrelated to the number of smokers in the home. These data suggest that the systemic effects of ETS exposure during pregnancy, and possibly early in life, may lead to an increased risk of addiction to tobacco. Also, ETS exposure during pregnancy and early in childhood has been associated with systemic, nonrespiratory health effects such as neurodevelopmental delay, attention-deficit/hyperactivity disorder, inflammatory bowel disease, and strabismus. It is not clear how much postnatal ingested nicotine products play a role in these developmental problems.

We conclude that it is important for women to stop smoking from the time of conception to protect their children from the long-lasting harmful effects of prenatal and postnatal exposure. There is strong public awareness of the risks of smoking during pregnancy, but mothers may once again start smoking after the birth of the child. Mothers should be encouraged to breast-feed yet discouraged from smoking. Parents who smoke must be advised of the potential increased risk to their child, not only for respiratory problems but also for systemic problems, including neurodevelopmental abnormalities and the potential for the future addiction of that child to smoking.

Accepted for publication November 12, 1998.

The cotinine radioimmunoassay kit was provided by Helen van Lunen, PhD, Brandeis University, Waltham Mass. Reprints: Allan B. Becker, MD, Children's Hospital of Winnipeg, 820 Sherbrook St, Room AE101, Winnipeg, Manitoba, Canada R3A 1R9 (e-mail: becker@ccumanitoba.ca).

**REFERENCES**