Original Study

The Collection and Analysis of Carbon Monoxide Levels as an Indirect Measure of Smoke Exposure in Pregnant Adolescents at a Multidisciplinary Teen Obstetrics Clinic

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A B S T R A C T

Study Objective: In this study we aimed to collect and analyze CO levels as an indirect measure of smoke exposure in pregnant adolescents.
Design, Setting, and Participants: Participants included pregnant adolescents who received antenatal care over 18 months (2012-2013) at the Multidisciplinary Teen Obstetrics Clinic at a tertiary-care hospital in Southeastern Ontario.
Interventions: The CO breath test is a noninvasive method that is used to assess smoke exposure, in which nonsmokers have levels of 0-6 ppm, and levels of 7-10, 11-20 and more than 20 ppm are consistent with light, typical, and heavy smokers, respectively. Expired CO, smoking status, cigarette number, and home secondhand smoke exposure were documented at 3 clinic visits.
Main Outcome Measures: To determine mean CO levels as a measure of smoke exposure and prevalence of secondhand smoke exposure.
Results: The mean age of participants was 17.6 years. CO means (ppm) across 3 visits were 6.0, 5.9, and 4.8. Sixty-two percent of patients were self-reported nonsmokers, 38% were self-reported smokers (n = 93). CO means (standard error of the mean) were consistently different for nonsmokers vs smokers at visits 1 to 3, respectively: 2.9 (0.79) vs 9.7 (1.8); 3.0 (0.71) vs 12.9 (2.2), and 2.4 (0.71) vs 8.8 (1.5; $P < .01$, *t* test; n = 91). Of patient's highest CO (COmax), 62%, 9%, 15%, and 12% had levels of 6 or less, 7-10, 11-20, and greater than 20, respectively. Eighty-four percent of pregnant adolescents had home secondhand smoke exposure, which included 40% of nonsmokers and 100% of smokers (n = 57). Although most nonsmokers had a COmax of 6 or fewer ppm, 56% of smokers had COmax greater than 10 ppm ($P < .05$, χ^2).
Conclusion: Emphasis on smoking cessation is imperative in pregnant adolescents and should particularly target partners and families, because secondhand smoke exposure was very prevalent.
Key Words: Adolescent, Smoking, Smoking cessation, Pregnancy, Pregnancy in Adolescence, Carbon monoxide (CO)

Introduction

Smoking during pregnancy is associated with adverse outcomes, including premature rupture of membranes and preterm delivery. Moreover, associated risks to the fetus include short-term (eg, low birth weight) and long-term adverse effects (eg, behavioral problems).[1–4] In the United States over the past 50 years, the prevalence of smoking during pregnancy has decreased significantly, from 40% in 1960 to 13.8% in 2005.[5] However, this lower prevalence rate is not reflected in the pregnant adolescent population. The National Institute for Health and Clinical Excellence of the United Kingdom study reported that 45% of female adolescents smoke during pregnancy.[6] Similarly, a recent retrospective population-based cohort study of singleton birth records in the province of Ontario found that pregnant adolescents had a greater rate of smoking (38.8%) compared with pregnant adult women (11.9%).[7]

Adolescent smoking, including in pregnant adolescents, is influenced by familial and peer factors.[8] Over a third of adolescent smokers report obtaining their cigarettes from family, friends, and others.[9] Nearly two-thirds of pregnant adolescents live with a smoker.[10] Not surprisingly, adolescent smoking during pregnancy has been shown to be positively correlated with familial smoking behaviors and best friends' and boyfriends' substance use.[11]

Measurement of cotinine levels, a nicotine metabolite in serum and urine, is a biochemical method used to assess smoking status[12,13]; however, it is expensive and requires special handling and equipment. Measurement of CO in expired air is the most inexpensive and most easily measured biochemical indicator of tobacco smoking. One cigarette contains various chemicals, including between 10 and 23 mg of CO.[14] CO in expired air is considered a valid measure of smoking status, with high sensitivity and specificity.[15,16] The CO breath test is used to measure and calculate percentage of carboxyhemoglobin (COHb) and CO levels in parts per million. The concentration of CO in end-expired air after breath-holding correlates closely with COHb concentrations.[17] CO freely crosses the placenta, and fetal hemoglobin preferentially traps CO. Fetal COHb levels

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Table 1
Expired Carbon Monoxide Levels, Smoking Status, and Correlating Maternal and Fetal Percentage of Carboxyhemoglobin Levels

	Maternal CO Level, ppm	Maternal % COHb	Fetus %FCOHb
≥20 ppm heavy smoker	>20	>3.20	>6.26
	20	3.20	6.26
	19	3.04	5.95
	18	2.88	5.63
	17	2.72	5.32
	16	2.56	5.00
11-20 ppm typical smoker	15	2.40	4.69
	14	2.24	4.38
	13	2.08	4.07
	12	1.92	3.76
	11	1.76	3.44
	10	1.60	3.13
7-10 ppm light smoker	9	1.44	2.82
	8	1.28	2.50
	7	1.12	2.19
	6	0.96	1.88
	5	0.80	1.56
≤ 6ppm non smoker	4	0.64	1.20
	3	0.48	0.94
	2	0.32	0.63
	1	0.16	0.31

%COHb, percent carboxyhemoglobin; %FCO2, percent fetal carboxyhemoglobin. Adapted from the CO Measurement Table.[25]

of mothers who smoke have been found to be more than double that of nonsmokers' (Table 1).[18]

Many models of antenatal care include the CO breath test as a routine vital sign measure, and use it as part of programs tailored for smoking cessation. In the community where this study took place, the Public Health Unit along with other primary care providers, established a smoking cessation program for pregnant, postpartum, or breastfeeding women and their partners. As part of this initiative toward smoking cessation, the CO breath test has been integrated into antenatal and postnatal clinical care environments as a routine measure. This provided an ideal opportunity to incorporate the CO breath test into the Multidisciplinary Teen Obstetrics Clinic. A previous publication from this particular clinic reported a much higher rate of self-reported smoking among pregnant teens (52%) than a matched group of pregnant adults (12.5%; Dr Kieran Moore, personal communication, October 4, 2012).[19]

Several studies have assessed the use of the CO breath test in pregnant women and its use for determining smoking status, smoking cessation, and environmental smoke exposure.[4,20–23] However, data pertaining to expired CO levels in pregnant adolescents is limited. Albrecht et al[22] demonstrated that compared with saliva cotinine levels, expired CO was a more sensitive indicator of smoking cessation, and self-report was more specific and a better indicator of continued smoking. However, only adolescents who smoked during pregnancy and were involved in cessation interventions were assessed. To our knowledge, there are no observational data available regarding expired CO levels as an indirect measure of smoke exposure in nonsmoking and smoking pregnant adolescents. Therefore, the aim of this study was to determine the CO levels as an indirect measure of smoke exposure in all pregnant adolescents cared for at the Multidisciplinary Teen Obstetrics Clinic. A secondary aim was to determine the prevalence of secondhand smoke exposure in the pregnant adolescent's home environment.

Materials and Methods

This research was conducted with approval from the Queen's University Health Sciences and Affiliated teaching Hospitals Research Ethics Board (File Number 6006754). This single-center study was conducted at the Multi-Disciplinary Teen Obstetrics Clinic at a medium-sized tertiary care center in Southeastern Ontario. The design was for a prospective observational study, with data collected over an 18-month period (February 2012-July 2013).

As described herein, the CO breath test is a noninvasive biochemical method that can be used to assess smoke exposure (first or secondhand). The CO breath test was used as a routine vital sign measure in the antenatal clinic at first visit, approximately 28 weeks' gestation, and approximately 36 weeks' gestation. Kingston, Frontenac, Lennox, and Addington Public Health provided the Micro CO Meter (Micro Direct, Lewiston, ME). The same calibrated Micro CO Meter was used for each measurement. Those performing the measure at the clinic were trained beforehand. The CO breath test was proposed to the patient during the antenatal visit, and its function explained to the patient before its use. The patient was instructed to inspire fully and breath-hold, if possible, for 15-20 seconds. When the countdown on the Micro CO Meter was complete, the patient was asked to seal their lips around the disposable tube mouthpiece and exhale slowly and fully. The screen then displayed the expired CO level in parts per million.

In addition to the CO level, the data collected included smoking status (yes/no), number of cigarettes smoked (for patient and partner), and secondhand smoke exposure status at home (either partner or other). This included partners, family members, and parents, because as opposed to pregnant adults who live independently (with or without a spouse or children), pregnant adolescents more often live with their parents. As mentioned, data were collected at 3 antenatal visits (first visit, and at approximately 28 and 36 weeks).

Data were entered into an Excel spreadsheet and imported into IBM SPSS version 22.0 for Windows (IBM, Armonk, NY) for analysis. A descriptive analysis was completed for all data, including frequencies and percentages for categorical data and means, SDs, and standard error of the mean (SEM) for continuous data. Although reference data were elusive, the manufacturer's information that accompanied the Micro CO Meter categorized CO levels in parts per million and smoking status as follows: less than 6 (nonsmoker), 7-10 (light smoker), 11-20 (typical smoker), and more than 20 (heavy smoker; refer to Table 1).[24,25] Across the 3 visits during which data were obtained, the maximum CO level (COmax) was used as the highest category. Categorical data were analyzed using χ^2 tests (Pearson or Fisher exact as appropriate). Continuous data were analyzed using independent samples *t* test (Mann-Whitney *U* if required) and repeated measures analysis of variance