Associations between maternal exposure to incense burning and blood pressure during pregnancy

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Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; BIGCS, Born in Guangzhou Cohort Study.

Abstract

Incense burning is a popular practice in Asian and Arabic countries. Previous studies show that incense burning was associated with increased risks of adverse outcomes among non-pregnant population. However, very few studies explored its health effects among pregnant women, who are more susceptible to environmental stressor. We aimed to examine the association between incense burning at home and hypertensive disorders as well as blood pressure levels during pregnancy, using data from 10,563 pregnant women recruited in Born in Guangzhou Cohort Study, China between January 2013 and December 2015. Information on frequency and duration of exposure to incense burning were collected at early and late pregnancy using questionnaire. Data on outcome variables, including hypertensive disorders diagnosis and blood pressure levels at the final antenatal visit before delivery, were extracted from medical records. We used Poisson regression model and General Linear Model to examine the associations between incense exposure and the outcomes. We found incense use at early pregnancy was not significantly associated with outcomes. Pregnant women who frequently smelled the incense burning at late pregnancy was associated with higher risk of hypertensive disorders (relative risk, 1.84; 95% confidence interval, 1.14-2.98) and higher levels of blood pressure (1.6 mmHg increase of systolic blood pressure; 95% confidence interval, 0.4-2.8 mmHg) before delivery, compared to those did not burn incense. These associations tended to more evident among women without active and passive smoking. We did not observe significant dose-response relationship between exposure duration and the risk of hypertensive disorders. We firstly reported exposure to incense burning was associated with the risk of hypertensive disorders and blood pressure levels during pregnancy. Given hypertensive disorders in pregnancy are well-established risk factors for a variety of adverse outcomes and the incense burning is a modifiable factor, our finding may have important public health significance.

Keywords: Incense burning; gestational hypertension; blood pressure; pregnancy; birth cohort; China

1. Introduction

Incense burning at home is a popular practice in Asia and Arabic countries for ritual or religious purpose. Previous studies have already characterized the emissions from incense burning to comprise a mixture of hazardous substances, including particulate matter ($PM_{2.5}$ and PM_{10}) , carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) (Lin et al., 2008) , as well as a number of volatile organic compounds (Ho and Yu, 2002; Jetter et al., 2002) . Increasing body of evidence, generated from studies mainly conducted in Asian and Arabic countries, has demonstrated that increased risks in nasopharyngeal carcinoma (He et al., 2015; Xie et al., 2014), lung cancer (Friborg et al., 2008; Tang et al., 2010), and asthma (Al-Rawas et al., 2009; Alrawas et al., 2009; Wang et al., 2011) associated with incense burning. However, the potential effect on cardiovascular health has only been explored in a cohort study of Singaporean Chinese women (aged 45-70 years), which found long-term incense use was associated with higher risk of cardiovascular mortality (Pan et al., 2014).

During pregnancy, cardiovascular system is under stress due to the various cardiac/hemodynamic changes, including increased cardiac output, intravascular volume, and peripheral vascular resistance (Duvekot and Peeters, 1994; Yoder et al., 2009). Consequently, pregnant women could be more susceptible to environmental stressors. Given the evidence for an association between air pollution and elevated systolic blood pressure in non-pregnant population (Norris et al., 2016; Truong and Jaumard, 2011), it is reasonable to hypothesize incense burning may represent a risk factor for elevated blood pressure during pregnancy, sharing the same

pathophysiological mechanisms of hypertension following exposure to air pollution in the general population as suggested previously (Brook and Rajagopalan, 2009; Brook et al., 2010). To date, few studies have explored the relationship between household air pollution and hypertensive disorders during pregnancy (Agrawal and Yamamoto, 2014; Quinn et al., 2015; Wylie et al., 2015), and none have specifically examined the effects of incense burning. As hypertensive disorders during pregnancy are well-established risk factors of maternal and neonatal mortality and morbidity (Duley, 2009), there is a need to clarify the relationship between incense burning, a modifiable risk factor, and hypertensive disorders to inform public health strategy for its prevention.

The current study aims to examine the associations between incense burning at home and hypertensive disorders as well as blood pressure levels during pregnancy in a large birth cohort study in south China.

2. Material and methods

2.1. Study design and participants

The Born in Guangzhou Cohort Study (BIGCS) is a prospective study initiated by the Guangzhou Women and Children's Medical Center (GWCMC), China; details of which have been described previously (Qiu et al., 2017). Pregnant women were eligible if they were of Chinese nationality, able to understand Mandarin or Cantonese language, residents of Guangzhou who were at <20 weeks of gestation and who intended to deliver at GWCMC, and to remain in Guangzhou for at least three years after delivery. Self-administered questionnaires were conducted at recruitment

(around 16 weeks of gestation), between 23 and 28 weeks of gestation, and during the third trimester (after 33th gestational week and prior to delivery), respectively. The study protocol was approved by the Institute Ethics Committee of the GWCMC, and all participants provided written informed consent prior to their enrollment.

In the present report, we included pregnant women who were recruited between January 2013 and December 2015, since the items of incense exposure were added to questionnaires after 2012. Those with multiple pregnancies (n=266), terminations of pregnancy (n=137), pre-hypertension before pregnancy (n=10), missing data on hypertensive disorders (n=724) and incense burning (n=129), and who withdrew their consent (n=487) were excluded, resulting in 10,563 women in this analysis (Figure 1).

2.2. Incense exposure

Participants were asked whether incense was ever burnt in their household (yes/no) during the period from the start of pregnancy to the date of the baseline questionnaire as well as the period from the 20th gestational week to the date of the third trimester questionnaire. At each time point, participants who gave an affirmative response were asked to specify the frequency (no/ occasionally/ frequently) of smelling incense burning, and the number of times per week and the duration (in minutes) of exposure each time where appropriate. In this report, incense exposure was quantified by frequency (no incense burning, yes but never or only occasional smelling of incense, and frequent smelling) and duration of incense exposure per week, derived by multiplying the number of times per week by the duration of exposure each time.

2.3. Outcomes

Hypertensive disorders were defined as the presence of any of the following diagnoses: gestational hypertension, preeclampsia, and eclampsia, extracted from medical records after delivery. Gestational hypertension (10^{th} revision of the International Classification of Diseases [ICD-10] O13) was defined as new onset of hypertension (systolic blood pressure >140 mm Hg and/or diastolic blood pressure >90 mm Hg) after 20 weeks gestation; preeclampsia (O14) was defined as new onset of hypertension and the coexistence of proteinuria or organ dysfunction; eclampsia (O15) was defined as seizures in a patient with pre-eclampsia that could not be attributed to other causes (The American College of Obstetricians and Gynecologists, 2013).

Data on maternal systolic (SBP) and diastolic blood pressure (DBP) at the final antenatal visit, measured using an automatic blood pressure monitor (OMRON HBP-9020, Kyoto, Japan), were extracted from maternal antenatal care records. Before each measurement, participants were asked to seat in an upright position with back support for five minutes.

2.4. Covariates

From the baseline questionnaire we collected information on maternal age (continuous), monthly income (<1500/ 1500-4500/ 4501-9000/ ≥9001 yuan), education level (middle school or below/ vocational or technical college/ undergraduate/ postgraduate), pre-pregnancy body mass index (BMI, calculated from self-reported height and weight, continuous), parity (primipara/ multipara), hypertensive disorders during previous pregnancy (yes/ no), active (yes/ no) and

147 passive smoking (yes/ no) during pregnancy.

148 **2.5. Statistical analysis**

149 Differences in maternal characteristics by incense exposure during early pregnancy
150 were evaluated using Student's t-test or Mann-Whitney U test for continuous
151 variables and χ^2 test for categorical variables. Poisson regression models with robust
152 variance were used to compute relative risks (RR) and their corresponding 95%
153 confidence interval (CI) for the association between hypertensive disorders and
154 exposure frequency. We also used general linear models to explore the effects of
155 different exposure frequencies on the blood pressure levels at the final antenatal visit.
156 Incense exposure at early and late pregnancy was included separately in the models.
157 All regression analyses for hypertensive disorders were adjusted for maternal age,
158 monthly income, education, pre-pregnancy BMI, parity, active and passive smoking
159 during pregnancy, and analyses for blood pressure levels at the final antenatal visit
160 were additionally adjusted for SBP or DBP mutually.

161 We then restricted to pregnant women who occasionally and frequently smelled
162 incense burning to explore the dose-response relationship between exposure duration
163 and the outcomes.

164 Because the use of incense was related to maternal characteristics, we further
165 examined the relationship between incense burning exposure and the outcomes in
166 stratifying for maternal smoking status, parity, and monthly income. We also
167 performed several sensitivity analyses to examine the robustness of the results, by
168 restricting the dataset to pregnant women without hypertensive disorders during

previous pregnancy, who were younger than 35 years or gave term births, and by additionally adjusting for alcohol drinking (yes/ no), thyroid disease during pregnancy (yes/ no) and the duration of exposure to passive smoking (minutes/week).

All analyses were performed using SAS statistical software version 9.2 (SAS Institute Inc., Cary, NC, USA). A two-tailed p-value of less than 0.05 was considered statistically significant.

3. Results

In this population, 25.4% (2662/10483) and 22.7% (2019/8908) reported incense was burnt in their household at early and late pregnancy, respectively. Of these women, 35.0% (929/2662) and 24.6% (496/2019) reported they frequently smelled the incense burning at the respective time points. Maternal characteristics by incense burning at early pregnancy are presented in Table 1. Pregnant women who burnt incense at their homes were more likely to be younger, of lower socio-economic status, and be exposed to passive smoking (Table 1). The incidence of hypertensive disorders was 2.8% overall.

Table 2 shows the association between frequency of smelling incense and the risk of hypertensive disorders. Compared to those who did not burn incense at early pregnancy, women who burn but never or occasionally smelled (RR, 1.06; 95% CI, 0.73-1.54) and frequently smelled incense (RR, 1.14; 95% CI, 0.73-1.79) had similar risk of hypertensive disorders. However, women who frequently smelled burning incense at late pregnancy had a significantly increased risk (RR, 1.84; 95% CI, 1.14-2.98) after adjusting for potential confounders. In subgroup analyses, the

frequency of smelling at early pregnancy was not associated with the risk of hypertensive disorders at each stratum (Table 3). For incense burning at late pregnancy, frequent smelling was associated with higher risk of hypertensive disorders among women without active and passive smoking (RR, 2.51; 95% CI, 1.24-5.06) but not among those who had active or passive smoking (RR, 1.57; 95% CI, 0.81-3.02). The RRs for frequent smelling at late pregnancy were similar across different subgroups by maternal parity and income although most did not reach statistical significance (Table 3).

Women who frequently smelled incense had higher levels of SBP at the final antenatal visit before delivery compared to the non-users both at early pregnancy (mean difference, 0.9 mmHg; 95% CI, 0.0-1.7 mmHg) and late pregnancy (1.6 mmHg; 0.4-2.8 mmHg). Frequencies of smelling incense burning were not significantly related to DBP levels. Figure 2 shows the results stratifying for various subgroups. At early pregnancy, higher SBP levels were only observed among nulliparous women who frequently smelled incense (mean difference, 1.1 mmHg; 95% CI, 0.1-2.0 mmHg). For late pregnancy, frequent smelling was associated with 2.4 mmHg (95% CI, 0.3-4.4 mmHg) higher in SPB levels among those without active and passive smoking, but not among women who had active or passive smoking (mean difference, 1.0 mmHg; 95% CI, -0.5-2.45 mmHg). There was no significant difference in DBP levels between frequency groups of incense burning across different subgroups.

When restricted to those who burnt incense, we did not find any dose-response relationship between exposure duration and the risk of hypertensive disorders and the

blood pressure levels at the final antenatal visit, both at early and late pregnancy (P values > 0.05) (data not shown).

Additional adjustment for alcohol drinking, thyroid disease during pregnancy and the duration of exposure to passive smoking did not substantially change our results (data not shown). Similar results were found when restricted the dataset to pregnant women without hypertensive disorders during previous pregnancy, who were younger than 35 years or gave term births (data not shown).

4. Discussion

In this large prospective cohort study, frequent smelling of incense burning at late pregnancy was associated with higher risk of hypertensive disorders (RR, 1.84; 95% CI, 1.14-2.98) and higher SBP levels (1.6 mmHg increase; 95% CI, 0.4-2.8 mmHg) before delivery. These associations were stronger among woman without active and passive smoking. To the best of our knowledge, our study is the first to explore the relationship between incense burning and the risk of hypertensive disorders among pregnant women.

Although ambient air pollution, such as particulate matter, nitrogen oxides (NO_2, NO_x) and CO, have been suggested as risk factors of pregnancy-induced hypertension (Hu et al., 2014; Pedersen et al., 2014), few studies have explored the effects of indoor air pollution (Agrawal and Yamamoto, 2014; Quinn et al., 2015; Wylie et al., 2015). A previous study conducted in Ghana reported exposure to CO from wood smoke was positively associated with blood pressure during pregnancy (Quinn et al., 2015). A cross-sectional analysis found that households using biomass and solid fuels

were associated with higher risk of preeclampsia or eclampsia in Indian women (Agrawal and Yamamoto, 2014). In addition, a recent randomized intervention study in pregnant Nigerian women suggested the use of clean cooking fuel (kerosene) was associated with reductions in blood pressure during pregnancy, compared to those women who used firewood (Alexander et al., 2017). On the contrary, another study in central East India observed a lower risk of maternal hypertension associated with the use of wood as cooking fuel (Wylie et al., 2015). However, all these studies only focused on the use of biomass and solid fuels and have not explored other potential sources of indoor air pollution, specifically incense burning. In the present study, we report an association between incense burning and a higher risk of hypertensive disorders and higher blood pressure levels, in line with previous evidence relating to ambient and indoor air pollution (Agrawal and Yamamoto, 2014; Alexander et al., 2017; Hu et al., 2014; Pedersen et al., 2014; Quinn et al., 2015). In addition, the effects of frequent smelling of incense burning appeared to be evident among women without active and passive smoking than those who had active or passive smoking. We speculate that women who had active or passive smoking have already been exposed to very high levels of pollutants from smoking, such that additional contribution from incense burning would be minimal (Pan et al., 2014).

The mechanism underlying the detrimental effects of incense burning may be similar to those of air pollution, via induction of oxidative and inflammatory mediators in lung epithelial cells (Cohen et al., 2013), which are then released into maternal circulation and indirectly mediating cardiovascular response (Brook, 2008;

Brook and Rajagopalan, 2009). In addition, previous studies have also demonstrated that higher levels of air pollutant exposure (PM_{10}, NO_2) may elevate anti-angiogenic factors from placenta (Eh et al., 2012), which in turn may result in maternal intravascular inflammatory response, and eventually leading to the development of preeclampsia during pregnancy (Steegers et al., 2010).

Compared to other study designs, recall bias could be minimized in this prospective study. Our study also benefited from the inclusion of both frequency and duration of incense burning at both early and late pregnancy, as opposed to a previous study that used a binary variable to assess associations of incense exposure with birth size (Chen and Christine, 2016). The relatively large sample size has been important for the exploration of the small effects of incense burning. However, our findings should be interpreted with caution. Firstly, although we were able to adjust for many potential confounders in our analysis, residual and unmeasured confounding could be present. Secondly, generalizability of our findings may be limited as BIGCS participants were not representative of Guangzhou and tended to have higher education levels (Qiu et al., 2017). Thirdly, we relied on self-reported incense use as personal exposure data, as well as other objective measurements of indoor air pollutant levels were not available. Nevertheless, previous studies have shown incense burning could lead to significant air pollution. For example, a study in Hong Kong, China showed levels of particulate matter and gaseous pollutants in temples during peak period were much higher than those during non-peak period (Wang et al., 2007). A Taiwanese study found incense burning were the main sources of indoor particle

matter and polycyclic aromatic hydrocarbons (Li and Yusun, 2000; Liao et al., 2006).

5. Conclusions

Exposure to incense burning was associated with higher risk of hypertensive disorders and higher levels of blood pressure. Hypertensive disorders during pregnancy are well-established risk factors for a number of short- and long-term adverse outcomes. Given the incense burning is a modifiable risk factor, our finding may have important public health significance.

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Figure legends

Figure 1. Flowchart of participant inclusion. BIGCS, Born in Guangzhou Cohort Study.

Figure 2. Difference (mmHg) in blood pressure levels at final visit before delivery between no incense burning (reference group), never/ occasional smelling and frequent smelling of incense burning among different subgroups. SBP, systolic blood pressure; DBP, diastolic blood pressure. Adjusted for maternal age, monthly income, education, pre-pregnancy BMI, parity, active and passive smoking during pregnancy, and SBP or DBP where appropriate.