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Preterm Delivery in Boston Before and After September 11th, 2001

Janet W. Rich-Edwards^{*,†}, Ken P. Kleinman^{*}, Emily F. Strong^{*}, Emily Oken^{*}, and Matthew W. Gillman^{*,‡}

^{*} Department of Ambulatory Care and Prevention, Harvard Medical School and Harvard Pilgrim Health Care; Boston, Massachusetts

[†] Department of Maternal and Child Health, Harvard School of Public Health, Boston, Massachusetts

[‡] Department of Nutrition, Harvard School of Public Health, Boston, Massachusetts

Abstract

Background—We hypothesized that stress induced by the terrorist attacks of September 11, 2001 might shorten pregnancy. To test this hypothesis, we compared gestational duration and risk of preterm delivery among women who were pregnant on September 11 with women who had delivered before that date.

Study Design—We conducted a matched cohort study among pregnant women enrolled in the Boston-based cohort study Project Viva between 1999 and 2001. Each of 606 participants, pregnant on September 11, 2001, was matched to 1 or 2 participants who delivered before that date.

Results—Compared with women who delivered before September 11th, women who were pregnant on September 11th had mean gestation length that was 0.13 weeks longer (95% confidence interval = −0.05 to 0.30) and an odds ratio for preterm delivery before 37 weeks' gestation of 0.60 (0.36 to 0.98). Only women exposed in the first trimester had longer gestation.

Conclusions—Contrary to expectation, Boston-area women who were pregnant on September 11th had a lower risk of preterm delivery than women who delivered before that date. Although the interpretation of this finding is difficult, it is clear that the acute psychologic stress documented nationwide after the terrorist attacks did not increase the risk of preterm delivery in this population at some distance from the attacks.

The terrorist attacks on September 11, 2001 were the most traumatic national event in recent United States history. Most adults viewed live media coverage of the attacks or graphic depictions of their aftermath over the following weeks.^{1,2} National surveys have since documented elevated rates of posttraumatic stress disorder, significant psychologic distress, and major depression among Americans, especially those living in New York City or those who had family or friends injured or killed in the attacks.^{1–5} Although psychologic distress was highest among New York City residents,³ symptoms of distress and trauma were evident across the country.^{2,3} Distress symptoms were highest among younger adults, women, and those with a history of psychologic disorders before September 11th.^{1–3}

Psychosocial stress and anxiety have been associated with shortened pregnancy duration in several studies.^{6–9} The terrorist attacks constitute an acute community stressor whose personal relevance and perceived severity vary considerably among individuals. A recently published abstract¹⁰ reported an elevated rate of spontaneous abortion among women pregnant on or shortly after September 11th in New York City. In a study of air pollution after the World Trade Center collapse, Berkowitz and colleagues¹¹ reported intrauterine growth restriction, but no

difference in gestation length, for 187 women in lower Manhattan compared with 2367 women from upper Manhattan. Aside from these brief reports, there are almost no studies of the impact of terrorism on gestational duration. We investigated pregnancy duration after exposure to the terrorist attack among pregnant women living in the Boston metropolitan area, overall and accounting for trimester of pregnancy on September 11, 2001.

METHODS

Population

We examined gestational duration among pregnant women enrolled in Project Viva, a prospective cohort of pregnancy and early childhood. The primary aims of this study are to investigate the role of maternal diet and psychosocial factors as predictors of pregnancy outcome and childhood health.¹² In April 1999, Project Viva began enrolling pregnant women at their first prenatal visit to 1 of 8 Boston-area obstetrics offices of Harvard Vanguard Medical Associates, a large group-based medical practice. Participants were eligible if they were carrying a singleton pregnancy less than 22 weeks' gestation and had no plans to terminate the pregnancy or leave the Boston area; 64% of eligible women enrolled. Research assistants administered interviews and questionnaires to Project Viva participants at their first pre-natal visit (average 10 weeks' gestation), at midgestation (26 – 28 weeks' gestation), and in the hospital postpartum. Project Viva is approved by the Human Studies Committee at Harvard Pilgrim Health Care. All participants gave written informed consent at enrollment.

There were 2495 enrolled participants whose last menstrual period was on or before September 11, 2001. We excluded women for whom race/ethnicity was unknown. We excluded from the pool of unexposed participants the 13 women whose due dates were after September 11th but who delivered before September 11th because their exposure status was ambiguous; furthermore, given our strategy of matching on gestational age at exposure described subsequently, their inclusion in the unexposed pool would have artifactually shortened gestational duration among the unexposed, because there would be no equivalent censoring event among women pregnant on September 11th.

The present analysis pertains only to gestational length among singleton pregnancies lasting at least 20 weeks for which we could obtain gestational length data. We therefore excluded women who miscarried before 20 weeks, carried twins or triplets, moved from the study area during pregnancy, or disenrolled before delivery. The remaining 1354 women who delivered before September 11th and the 606 women who were pregnant on September 11th comprised the pool of eligible unexposed and exposed participants, respectively.

Matching

As noted by Glynn et al,¹³ the expected remaining duration of pregnancy changes over the course of pregnancy as pregnancies survive the risk of miscarriage and preterm delivery. Thus, a woman in her third trimester has, *a priori*, a longer expected gestational length than a woman in her first trimester. To account for the dependence of expected gestation length on the gestational age at September 11, 2001, we matched each woman pregnant on September 11th to an unexposed control of the same gestational age in weeks. This matching process allowed us to compare exposed and unexposed pregnancies with equal expected remaining duration of gestation. We also matched on maternal race/ethnicity (white, black, Hispanic, Asian, other), spontaneous versus induced births, and maternal age (within 5 years). Two unexposed matched controls were randomly selected for each exposed participant from the pool of eligible women who delivered before September 11, 2001. For 28 exposed women, we were able to find only 1 unexposed match. For this analysis, we compared the gestational duration of 606 participants who were pregnant on September 11, 2001, to that of 1184 women who delivered between

November 4, 1999, and September 10, 2001. Matching was based on factors associated with exposure, not on pregnancy outcome case-control status; thus, the analysis is a matched cohort design.

Definition of Gestational Length

Over 90% of Project Viva participants received an ultrasound assessment of gestational age during their second trimester. We calculated gestational length as date of delivery minus date of last menstrual period, except when an ultrasound indicated a gestational length more than 10 days discrepant from that based on last menstrual period, in which case we estimated gestational length from the ultrasound data.

Definition of Covariates

Participants were considered to have a positive history of depression if they responded “yes” to the question, “Before this pregnancy, was there ever a period of time when you were feeling depressed or down or when you lost interest in pleasurable activities most of the day, nearly every day, for at least 2 weeks?” plus *either* were told by a healthcare professional that they were depressed *or* were prescribed a medication for depression. Midpregnancy depression status was assessed by the Edinburgh Depression Scale¹⁴; a score >12 indicated depression. In early pregnancy, we measured social support from spouse or partner as well as from family and friends.¹⁵ We examined depression and social support as effect modifiers (by stratification) and as potential intermediate variables (by adjustment).

To test for confounding not captured by matching on race/ethnicity and maternal age, we adjusted for maternal education (in 5 categories), household income as a percent of the federal poverty level (continuous),¹⁶ and health center at which participants were recruited (8 centers). Adjustment for household poverty level made a small difference to the effect estimate of exposure to September 11th and was included in the regression models. Adjustment for other potential confounders did not materially alter the estimates associated with exposure to September 11th, and they were dropped from the models.

Statistical Analysis

The analytic approach to our matched data was generalized linear mixed models,¹⁷ as suggested by Brown and Prescott.¹⁸ For the length of gestation, this is a linear mixed model fit using in SAS Proc Mixed (version 8.2; SAS Institute, Cary, NC). The estimates from this model may be thought of as exactly like the estimates from ordinary least-squares regression. For preterm birth, the model is the GLMM version of logistic regression, fit using the GLIMMIX macro in SAS version 8.2. The estimates from this model are conditional on gestation lasting at least a given period of time, a subtle difference from ordinary logistic regression.¹⁹ Another advantage of the GLMM is that it permits a variable number of matches per “case.” For the preterm analysis, we included only women exposed before 37 weeks gestational age along with their matches.

RESULTS

The length of pregnancy in this cohort ranged from 26.3 to 42.9 weeks, with a mean of 39.5 ± 1.8 weeks. There were 111 preterm (<37 completed weeks) deliveries among the 1790 women (6.2%). Table 1 presents risk factors for preterm delivery by exposure status.

Table 2 presents gestational duration and risk of pre-term delivery by exposure status. Women who were pregnant on September 11th had slightly longer pregnancies (mean duration = 39.61 weeks) than women who delivered before the terrorist events (39.5 weeks). Suspecting that scheduled deliveries might have been postponed by the terrorist events (causing longer

pregnancies among exposed women who were induced), we examined whether exposure affected the timing of spontaneous ($n = 1179$) and induced ($n = 611$) deliveries differently. There were no material differences in mean gestation length among matched pairs of spontaneously delivered pregnancies; gestation for exposed women was 0.05 (−0.15 to 0.25) weeks longer. Among induced deliveries, there was a suggestion that exposure was associated with slightly later delivery (0.32 weeks; [0.02 to 0.65]). However, the tendency to longer pregnancy among induced exposed women was weakest for women in their third trimester on September 11th (data not shown), suggesting that the difference between exposed and unexposed pregnancies was not driven by postponement of inductions, which are most likely to be scheduled at term. Furthermore, as evident in the cumulative frequency of delivery displayed in Figure 1 (available with the electronic version of this article), the tendency of unexposed women to deliver earlier was not confined to term pregnancies.

The cumulative frequency of delivery depicted in Figure 1 shows that the differences in gestation length between exposed and unexposed women emerged before 37 weeks' gestation. The odds ratio of preterm delivery before 37 weeks' gestation among those exposed to September 11th was 0.60 (0.36 to 0.98) compared with those who delivered before September 11th (Table 2). The odds of delivering preterm were greatly reduced only among women exposed in the first trimester; later exposure was not associated with risk of preterm delivery. The odds ratio of preterm delivery associated with exposure was similar for spontaneous (0.60; 0.29 to 1.25) and induced (0.58; 0.29 to 1.14) deliveries. The odds of preterm delivery before 35 weeks, a more clinically significant end point, were 34% lower among exposed women (0.66; 0.31 to 1.43).

Hypothesizing that any impact of the event would have been greater among women with a history of psychologic illness before pregnancy, we examined the impact of September 11th among women with and without a self-reported history of depression. Among the 12% of the cohort with a history of depression, exposure to September 11th was unassociated with pregnancy duration (−0.10 weeks shorter among exposed; −0.64 to 0.44). Among the larger group of women with no history of depression, exposure was associated with 0.19 longer weeks' duration of pregnancy (0.01–0.38). Reports of second-trimester depression and social support were similar when measured before and after September 11th. Adjustment for these potential mediators of the association between terrorism and gestational duration did not materially alter the findings.

DISCUSSION

Contrary to our expectation, we found evidence of reduced risk of preterm delivery among mothers exposed September 11th compared with women who had delivered before September 11th. This finding was particularly strong for women exposed early in pregnancy and among women with no history of depression.

Any systematic differences between exposed and unexposed women in our study would have been the result of changes in the population of participants over the course of the study. Although the mix of health centers at which we recruited changed over time, adjustment for recruitment site made no material differences to our estimates. Similarly, the improvement in retention rate from 90% to 94% over the course of the study is too small to have greatly affected results; furthermore, disenrolled women were less likely to deliver preterm, which would have caused a bias in the opposite direction. Thus, differences in enrollment and retention over time seem unlikely to explain our findings.

We did not have a direct measure of the level of distress experienced by these Boston-area mothers. In our cohort, the prevalence of depression was similar before and after September

11th. Although symptoms of posttraumatic stress disorder and depression clearly rose in New York City after the attacks on the World Trade Center,^{3,4} the particular reactions of Boston residents were not quantified in the national surveys. Estimates of the prevalence and extent of distress among Americans outside New York City have varied widely.^{1–3} Thus, although the women in our metropolitan Boston cohort undoubtedly shared the anxiety of the nation, it is not clear to what extent they experienced clinically significant psychologic distress.

Although many Americans reported heightened anxiety after the attacks, few studies have addressed physical health consequences for those indirectly exposed. Severity of asthma increased in Manhattan; however, this increase was attributed to the combined impact of psychologic distress and the smoke that hung in New York City air after the attacks.⁵ In New York City, Veterans Affairs clinics saw no short-term increase in visits in the weeks after September 11th,²⁰ and urgent and emergent visits to a managed care plan in Northern California dropped during the first 6 weeks after the attacks.²¹

Only 2 short reports have been published with respect to pregnancy outcomes after September 11th. Berkowitz and colleagues¹¹ reported reduced fetal growth, but not reduced gestation length, among women in lower Manhattan versus upper Manhattan after the collapse of the World Trade Center Towers. However, this study was intended to measure the impact of air quality at various distances from Ground Zero, rather than the psychologic stress of terrorism, which was felt throughout the city. Because all women in their study were pregnant on September 11th, it is not a test of whether or not women were exposed to the terrorist events. Spandorfer and colleagues¹⁰ examined women undergoing in vitro fertilization cycles over 13 weeks that included September 11th. Although conception rates were similar before and after the terrorist attacks, patients who became pregnant in the weeks after September 11th had a pregnancy loss rate of 47.9% compared with 28.6% among women pregnant in the weeks before September 11th. Because all women were exposed to September 11th during their first trimester, this study suggests a potential impact of psychologic stress that is isolated to the periconceptional period.

It is possible that the very low rate of preterm delivery (2.5%) we observed among women exposed in the first trimester could reflect a type of “competing mortality” bias. If, as suggested by Spandorfer’s data,¹⁰ pregnancies most susceptible to psychologic distress aborted before 20 weeks, and if these stress-vulnerable, aborted pregnancies would have been more likely to deliver preterm had they lasted until 20 weeks, then our low rate of preterm delivery among pregnancies surviving to 20 weeks could theoretically be an artifact of competing mortality in the first 20 weeks. Several studies indicate a higher risk of preterm delivery among women with a history of spontaneous abortion.^{22–25} Although our own data (Fig. 1) do not suggest a higher rate of (largely second trimester) miscarriage among women exposed to September 11th, many spontaneous abortions could have occurred before women were enrolled in our study at their first prenatal visit.

We hypothesized that exposure to September 11th would be associated with shortened pregnancy duration and increased risk of preterm delivery, and that the impact would be greater among women exposed earlier in gestation. Instead, we observed the opposite; there was a reduction in risk of preterm delivery, especially with first-trimester exposure. This phenomenon was driven by a very low rate of preterm delivery among women in their first trimester of pregnancy on September 11th. We cannot determine whether this unexpected 40% reduction in risk of preterm delivery associated with indirect exposure to terrorist events is the result of chance, competing mortality, or other factors.

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TABLE 1

Characteristics of Women Who Were Pregnant on September 11, 2001 ("Exposed") and Women Who Delivered Before That Date ("Unexposed")

	Exposed (n = 606)	Unexposed (n = 1184)
Matched factors *		
Gestational age at event or matching (weeks); mean $\pm$ SD	19.6 $\pm$ 11.9	19.6 $\pm$ 11.9
Maternal age (years); mean $\pm$ SD	32 $\pm$ 5	32 $\pm$ 5
Maternal race/ethnicity (%)		
White	67	69
Black	15	15
Hispanic	9	7
Asian	6	6
Other	3	3
Spontaneous birth	65	66
Unmatched factors; %		
History of depression	11	12
Second-trimester depression [†]	9	9
Low partner social support [†]	9	10
Low family/friends support [†]	18	16
Maternal education		
High school or less	13	11
College	60	57
Graduate school	30	29
Percent of federal household poverty level		
<100%	3	3
100–299%	15	14
$\geq$ 300%	82	84

* Slight differences in frequencies of matched factors for exposed and unexposed participants arise from the 1:1 matching ratio for 28 participants (as opposed to 1:2 for most participants).

[†] For these 3 items, exposed women who completed the early and midpregnancy questionnaires *before* September 11th are excluded to provide a better measure of potential change in social support and depression before and after the event. Depression is defined by a score >12 on the Edinburgh postnatal depression scale. Low social support is defined as a score of ≤ 10 on the Turner social support scale.

TABLE 2
Pregnancy Duration (Gestational Length, in Weeks) and Risk of Preterm Delivery (<37 wk Gestation) Among Pregnant Women Exposed and Unexposed to September 11, 2001, With Differences, Odds Ratios, and 95% Confidence Intervals Derived From Generalized Linear Mixed Models

	Gestational Length		Difference (95% CI)*		Preterm Delivery		Odds Ratio* (95% CI)
	Exposed (n = 606) Mean ± SD	Unexposed (n = 1184) Mean ± SD			Exposed (n = 606) No. (%)	Unexposed (n = 1184) No. (%)	
All women	39.6 ± 1.71	39.5 ± 1.8	0.13 (−0.05 to 0.30)		29 (4.8)	82 (6.9)	0.60 (0.36 to 0.98)
Timing of exposure							
1st trimester (n = 587)	39.7 ± 1.2	39.4 ± 2.1	0.22 (−0.08 to 0.53)		5 (2.5)	30 (7.7)	0.26 (0.09 to 0.75)
2nd trimester (n = 518)	39.4 ± 2.2	39.3 ± 1.9	0.05 (−0.28 to 0.37)		13 (7.4)	29 (8.5)	0.77 (0.34 to 1.73)
3rd trimester (n = 685)	39.7 ± 1.6	39.7 ± 1.5	0.11 (−0.17 to 0.40)		11 (4.8)	23 (5.1)	0.92 (0.40 to 2.09)

* Overall estimates are derived from models, including exposure status, trimester at exposure, and household poverty level. Estimates stratified by trimester of exposure are derived from models that include these terms plus interactions between exposure status and trimester at exposure.