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Ebony B. Carter
Washington University School of Medicine in St. Louis

Jennifer J. Stuart
Harvard T.H. Chan

Leslie V. Farland
Harvard T.H. Chan

Janet W. Rich-Edwards
Harvard T.H. Chan

Chloe A. Zera
Brigham and Women's Hospital

See next page for additional authors

Authors
Ebony B. Carter, Jennifer J. Stuart, Leslie V. Farland, Janet W. Rich-Edwards, Chloe A. Zera, Thomas F. McElrath, and Ellen W. Seely

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Pregnancy Complications as Markers for Subsequent Maternal Cardiovascular Disease: Validation of a Maternal Recall Questionnaire

Ebony Boyce Carter, MD, MPH,[1,*] Jennifer J. Stuart, MSc,[2,3,*] Leslie V. Farland, MSc,[2] Janet W. Rich-Edwards, ScD,[2,3] Chloe A. Zera, MD, MPH,[4] Thomas F. McElrath, MD, PhD,[4] and Ellen W. Seely, MD[5]

Abstract

Background: We designed and tested the validity of a questionnaire to characterize maternal recall of pregnancy complications associated with increased future cardiovascular disease risk, based on the 2011 American Heart Association (AHA) guidelines.

Methods: A maternal recall questionnaire of pregnancy history was administered to 971 patients who had participated in a previous cohort study of 1,608 pregnant women. Medical records from the study pregnancy served as the gold standard. Prevalence, sensitivity (sens), specificity (spec), positive predictive value (PPV), negative predictive value (NPV), and/or Spearman's correlation coefficients (r) were calculated for each question.

Results: A total of 526 (54%) individuals recontacted responded. Respondents were more likely to be older, white, educated, and nulliparous and were less likely to deliver low-birthweight infants in the study pregnancy than were individuals who did not respond. Mean length of recall was 4.35 years (standard deviation [SD] 0.46) postpartum. Maternal recall was most accurate for gestational diabetes (sens: 92%, spec: 98%, PPV: 79%, NPV: 99%), infant birthweight ($r = 0.95$), and gestation length ($r = 0.85$). Maternal recall was modest for preeclampsia (sens: 79%, spec: 97%, PPV: 68%, NPV: 98%) and pregnancy-associated hypertension, including preeclampsia or gestational hypertension (sens: 60%, spec: 95%, PPV: 64%, NPV: 94%).

Conclusions: This validation study demonstrated that the majority of women could accurately recall a history of gestational diabetes, infant birthweight, and gestational age at delivery, 4 years postpartum on average. Recall of preeclampsia and pregnancy-associated hypertension overall was modest. Maternal report of these pregnancy conditions may help clinicians identify women at increased risk for cardiovascular disease.

Introduction

Pregnancy complications, including gestational diabetes,[1–5] hypertension in pregnancy,[6–10] low birthweight,[11–13] and preterm delivery,[12,14] are risk factors for developing cardiovascular disease (CVD) later in life.[15–18] The 2011 American Heart Association (AHA) ''Guidelines for the Prevention of Cardiovascular Disease in Women'' recommended that healthcare providers take a history of these pregnancies to identify women whose pregnancy history places them at increased risk for future CVD.[19] However, there is a paucity of data regarding which questions should be asked to solicit pregnancy complication history and whether a woman's response accurately reflects her pregnancy history.[20]

We designed and evaluated the validity of a brief questionnaire for maternal recall of pregnancy complications associated with increased future CVD risk, including gestational

[1]Department of Obstetrics and Gynecology, Division of Maternal Fetal Medicine, Barnes-Jewish Hospital, Washington University School of Medicine, St. Louis, Missouri.
[2]Department of Epidemiology, Harvard T.H. Chan School of Public Health, Boston, Massachusetts. [3]Connors Center for Women's Health and Gender Biology, Division of Women's Health, Brigham and Women's Hospital, Boston, Massachusetts.
[4]Department of Obstetrics and Gynecology, Division of Maternal Fetal Medicine, Brigham and Women's Hospital, Boston, Massachusetts.
[5]Department of Medicine, Division of Endocrinology, Brigham and Women's Hospital, Boston, Massachusetts.
*Co–first authors.

diabetes, preeclampsia, gestational hypertension, low infant birthweight, and preterm birth.

Materials and Methods

A questionnaire was designed based on a review of the maternal recall literature on gestational diabetes,[21] preeclampsia,[22,23] birthweight,[24–26] and gestational age at delivery.[26–35] The questionnaire was piloted among the first 10 patients scheduled on a given day in both a general obstetrics and a maternal fetal medicine practice who agreed to complete the survey. A research assistant interviewed each patient following completion of the survey, recording feedback to refine the questionnaire accordingly. The pilot and final surveys were approved by the Institutional Review Board for Brigham and Women's Hospital at Partners Healthcare in Boston, MA.

The questionnaire (Fig. 1) asked about each pregnancy complication in a number of ways in order to identify a smaller set of best-performing questions, which were determined by a joint review of all test statistics for each question relative to the other questions. The survey was administered to patients who agreed to be contacted for future research after participating in an earlier pregnancy study at Brigham and Women's Hospital.[36] Briefly, the earlier study was a cohort study of pregnant women ($n = 1{,}608$), initiating prenatal care between October 2006 and February 2009 to test the utility of angiogenic markers for predicting preeclampsia.[36] Patients

Maternal Recall Questionnaire

				Question Completion Rate
1.	**During the study pregnancy, did you have gestational diabetes?**	□Yes	□No	98%
2.	During that pregnancy, did you have			
	a. To do home fingerstick blood sugar monitoring?	□Yes	□No	99%
	b. To take medicine to regulate your blood sugar (including insulin)?	□Yes	□No	99%
	c. High blood sugar?	□Yes	□No	99%
	d. Diabetes of pregnancy?	□Yes	□No	99%
3.	Did you have high blood pressure (hypertension) before the study pregnancy?	□Yes	□No	99%
4.	**During the study pregnancy, did you have high blood pressure or hypertension?**	□Yes	□No	99%
5.	**During that pregnancy, did you have pre-eclampsia, eclampsia, pregnancy induced hypertension, or toxemia?**			99%
	a. □No, I had none of these conditions			
	b. □Yes, I had pre-eclampsia			
	c. □Yes, I had eclampsia			
	d. □Yes, I had pregnancy induced hypertension			
	e. □Yes, I had toxemia			
6.	During that pregnancy, did you have?			
	a. High protein in the urine	□Yes	□No	99%
	b. Seizures or convulsions	□Yes	□No	99%
7.	**What was the birthweight of that baby (in pounds and ounces or grams)?**			
	_____ lbs ____ oz OR _____ grams			94%
8.	What was the size of your baby at birth?			100%
	□ Small			
	□ Average			
	□ Large			
	How did you choose this category? _____			
9.	Which of the following is closest to the weight of your baby born during the study?			99%
	□ Less than 3 lbs 5oz (1500 g)			
	□ 3 lbs 5oz - 5 lbs 7 oz (1500 - 2499 g)			
	□ 5 lbs 8 oz - 8 lbs 13 oz (2500 - 4000 g)			
	□ Greater than 8 lbs 13 oz (4000 g)			
10.	**How many weeks pregnant were you when you delivered?** ___ weeks			98%
11.	Did you deliver before, on or after your due date?			98%
	□ More than 1 week before my due date			
	How many weeks early? _____weeks early			
	□ Within one week of my due date			
	□ More than 1 week after my due date			
	How many weeks late? _____weeks late			
12.	Is there anything else you would like us to know about the pregnancy? _____			

Bolded items within each category denote best-performing questions, as determined by the authors based on data analysis, and could form the basis of a brief questionnaire.

FIG. 1. Maternal recall questionnaire.

were eligible for inclusion if they were at least 18 years of age and less than 16 weeks pregnant. The earlier study was approved by the Institutional Review Board at Partners Healthcare. The current survey queried patients regarding the pregnancy captured in the earlier study, since this was the pregnancy for which we had complete data.

For the current study, gestational diabetes mellitus (GDM) was defined by either clinical criteria (''gestational diabetes'' written in patient's chart by a clinical provider) or laboratory criteria (≥ 2 abnormal values on 100 g glucose tolerance test using Carpenter Coustan criteria).[37,38] Women with preexisting Type 1 or Type 2 diabetes, confirmed by medical record review, were excluded from the primary analysis for GDM.

Preeclampsia was defined by new-onset hypertension (systolic blood pressure [SBP] ≥ 140 mm Hg or diastolic blood pressure [DBP] ≥ 90 mm Hg on two occasions ≥ 6 hours apart) and proteinuria (> 300 mg in 24 hours or a protein-to-creatinine ratio > 0.20 when a 24-hour urine was not available) after 20 weeks of pregnancy.[36] Superimposed preeclampsia was diagnosed if a woman had chronic hypertension (SBP ≥ 140 mm Hg or DBP ≥ 90 mm Hg) that predated pregnancy or was present before 20 weeks with worsening hypertension and new-onset proteinuria, as previously defined. Gestational hypertension was defined as new-onset hypertension (SBP ≥ 140 mm Hg or DBP ≥ 90 mm Hg) on two occasions at least 6 hours apart without proteinuria after 20 weeks of pregnancy.[36] As ''pregnancy-induced hypertension'' was included without definition in the AHA guidelines, we defined it in this study as pregnancy-associated hypertension, including gestational hypertension or preeclampsia. Women with chronic hypertension were excluded from the primary analyses for preeclampsia and pregnancy-associated hypertension. Sensitivity analyses included women with preexisting chronic hypertension and expanded the medical record definition of both preeclampsia and pregnancy-associated hypertension to additionally include superimposed preeclampsia.

Infant birthweight was obtained from the delivery record. Preterm delivery was defined as delivery prior to 37 weeks gestational age. Patients had an ultrasound prior to 15 weeks as part of the protocol for the earlier study. Gestational age was calculated by last menstrual period (LMP) if the first-trimester ultrasound confirmed the due date within 7 days or if the second-trimester ultrasound was consistent with LMP dating within 10 days. If ultrasound dating was more than 7 or 10 days different, respectively, from the due date obtained from LMP, the pregnancy was redated according to the earliest ultrasound available.[39]

Potential respondents were initially contacted by letter and e-mail, if available. Each patient was given a unique identifier number at the initial point of contact to match her responses to her pregnancy data. The letter gave patients the option to complete an online survey, an enclosed paper survey returned in a prepaid envelope, or a blank survey returned with only their unique identifier to opt out of the study. The e-mail gave patients the option of clicking a link to an online survey or simply clicking replying (without text) to opt out. A trained research assistant called patients who did not reply to the initial letter/e-mail or opt out of the study. An IRB-approved script was used to administer the questionnaire by phone. Patients who still did not complete the letter/e-mail/phone survey or opt out of the study received a second e-mail or letter, respectively. Study data were collected and managed using Research Electronic Data Capture (REDCap), initiated at Vanderbilt University (Nashville, TN) by a consortium of institutions. This secure Health Insurance Portability and Accountability Act (HIPAA)-compliant electronic data capture tool was hosted at Brigham and Women's Hospital.[40]

The Student's *t*-test was used to compare the demographics of the earlier study's patients who agreed to be contacted for future studies versus those who did not and for respondents versus nonrespondents to the questionnaire for the current study. Medical records from the study pregnancy served as the gold standard. Prevalence of the given condition, pretest probability, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for all questions pertaining to GDM, preeclampsia, and pregnancy-associated hypertension overall. Sensivity represents the percentage of women who correctly indicated the condition on the questionnaire, among those with the condition; specificity is the percentage who correctly indicated on the questionnaire that they did not have the condition, among those who did not have the condition. The PPV is the proportion of accurate positive maternal recall according to the medical record; the NPV is the proportion of accurate negative maternal recall according to the medical record. Spearman correlation coefficients were calculated for questions regarding infant birthweight and gestational length. Completion rates were calculated for all survey questions.

Stratified analyses for potential confounding variables were performed. A Mantel-Haenszel analysis was used to stratify answers to questions by length of time from delivery to recall.

Results

There were no significant differences between the 971 patients who agreed to be recontacted after the earlier study and the 365 who did not with regard to age, parity, education, race, or any pregnancy condition of interest. The overall response rate was 54% ($n = 526$). Of these respondents, 61% responded by mail, 23% online, and 17% by phone. Mean length of recall was 4.35 years (standard deviation [SD] 0.46) postpartum. Twenty-one of the 971 women we attempted to contact were not reachable by mail, e-mail, or phone. Eleven patients actively opted out of the study.

Respondents were more likely to be older, nulliparous, Caucasian, and more highly educated than non-respondents (Table 1). There were no significant differences between respondents and non-respondents with regard to the presence of GDM, preeclampsia, or gestational age at delivery; however, non-respondents were more likely to deliver low birthweight infants (13% vs. 7%).

Gestational diabetes

In our sample, 7.4% of women ($n = 39$) had GDM, according to medical records. Table 2 shows the test characteristics for five questions regarding history of GDM. All questions had high specificity and NPV, varying from 96% to nearly 100% for both. Question 1 (''Did you have gestational diabetes?'') had a sensitivity of 92%, indicating that this question captured the vast majority of record-defined cases.

Table 1. Demographic and Pregnancy Characteristics of Survey Respondents and Non-respondents

	Total (n = 971)		*Completed survey (n = 526)*		*Did not complete survey (n = 445)*	
Variable	n	*Mean (SD)/ percent*	n	*Mean (SD)/ percent*	n	*Mean (SD)/ percent*
Age at study pregnancy (years)*	954	32.1 (5.7)	519	33.0 (5.0)	435	31.1 (6.2)
Gestational age (weeks)	971	38.5 (2.3)	526	38.6 (2.1)	445	38.4 (2.5)
Birthweight (grams)[*,a]	932	3,244 (635)	487	3,301 (578)	445	3,183 (687)
Nulliparous*	419	43.2	245	46.6	174	39.1
Education*						
Less than high school	36	3.8	5	1.0	31	7.1
High school graduate	92	9.6	34	6.6	58	13.3
Technical school	142	14.9	47	9.1	95	21.7
Some college	308	32.2	188	36.2	120	27.5
College graduate	378	39.5	245	47.2	133	30.4
Race/Ethnicity*						
White	619	63.7	388	73.8	231	51.9
African American	126	13.0	47	8.9	79	17.8
Asian	56	5.8	27	5.1	29	6.5
Hispanic	119	12.3	47	8.9	72	16.2
Other	51	5.3	17	3.2	34	7.6
Singleton	909	93.6	488	92.8	421	94.6
Chronic hypertension	59	6.1	33	6.3	26	5.8
Gestational hypertension[b]	49	5.0	24	4.6	25	5.6
Preeclampsia[c]	78	8.0	38	7.2	40	9.0
Superimposed preeclampsia	21	2.2	12	2.3	9	2.0
Diabetes[d]	28	2.9	17	3.2	11	2.5
Gestational diabetes	77	7.9	39	7.4	38	8.5
Preterm (< 37 weeks)	152	15.7	78	14.8	74	16.6
Low birthweight (< 2,500 g)*	91	9.8	35	7.2	56	12.6

[a]Singleton births only.
[b]Not including preeclampsia.
[c]The seven respondents with HELLP also had preeclampsia and are included among the $n = 38$.
[d]Includes types 1 and 2.
*$p < 0.05$ comparing respondents to non-respondents.
HELLP, hemolysis, elevated liver enzymes, low platelets; SD, standard deviation.

However, 79% of women who answered yes to this question had medical record evidence of having had GDM (PPV). Question 2a (''During [the study] pregnancy, did you have to do home fingerstick blood monitoring?'') had a similar sensitivity to that of question 1, with a slightly lower PPV of 77%. Question 2d (''Did you have diabetes of pregnancy?'') had lower sensitivity (85%) but a slightly higher PPV at 83%. Question 2b (''Did you have to take medicine to regulate your blood sugar [including insulin]?'') and question 2c (''Did you have high blood sugar?'') performed less well in terms of sensitivity; question 2b had a 95% PPV, the highest of all the GDM items tested.

Table 2. Maternal Recall of Gestational Diabetes, Using Medical Records as Gold Standard

		Medical record						
Survey questions	*Maternal report*	*GDM (n = 39)*	*No GDM (n = 470)*	*Pretest probability (%)*	*Sensitivity (%)*	*Specificity (%)*	*PPV (%)*	*NPV (%)*
1. During the study pregnancy, did you have gestational diabetes?	Yes	34	9	7.4	91.9	98.1	79.1	99.3
	No	3	452					
2. During that pregnancy, did you have:								
A. To do home fingerstick blood sugar monitoring?	Yes	36	11	7.8	92.3	97.6	76.6	99.3
	No	3	453					
B. To take medicine to regulate your blood sugar (including insulin)?	Yes	18	1	7.6	47.4	99.8	94.7	95.9
	No	20	464					
C. High blood sugar?	Yes	25	16	7.6	65.8	96.6	61.0	97.2
	No	13	448					
D. Diabetes of pregnancy?	Yes	33	7	7.7	84.6	98.5	82.5	98.7
	No	6	458					

GDM, gestational diabetes mellitus; NPV, negative predictive value; PPV, positive predictive value.

Preeclampsia

In our sample, 7.2% of women ($n = 38$) had medical record evidence of preeclampsia. The performance of questions for preeclampsia is shown in Table 3. Specificity and NPV for all questions pertaining to preeclampsia were high, ranging from 93% to 100% for specificity and from 92% to 99% for NPV. The primary question used to obtain maternal report of preeclampsia was question 5 (''During that pregnancy, did you have preeclampsia, eclampsia, pregnancy-induced hypertension, or toxemia?'') (Fig. 1). Women responded by checking the box(es) next to the condition(s) they had or by checking a box to indicate none. When positive maternal report of preeclampsia was defined as checking any of the conditions (5b–5e), the sensitivity for preeclampsia was 84% and PPV was 56%. When positive maternal report of preeclampsia was alternatively defined as indicating ''Yes, I had preeclampsia,'' regardless of their responses to eclampsia, pregnancy-induced hypertension, or toxemia, specificity (97%) and PPV (68%) improved, sensitivity decreased to 79%, and NPV remained unchanged (Table 3).

We also evalauted combinations of well-performing questions to determine whether these improved the test characteristics, relative to a single question for preeclampsia. When we defined positive maternal report of preeclampsia as saying ''Yes, I had preeclampsia'' to question 5 and ''Yes'' to ''During that pregnancy, did you have high protein in your urine?'' (question 6), the PPV for preeclampsia improved from 68% to 78%. However, this improvement in PPV was at the cost of a loss in sensitivity, which dropped from 79% to 55%. Since low birthweight and preterm birth can be consequences of a preeclamptic pregnancy, we additionally validated maternal report of (1) preeclampsia and low birthweight, (2) preeclampsia and preterm birth, and (3) preeclampsia, low birthweight, and preterm birth against medical record evidence of preeclampsia. The PPVs for these combinations were 100%, 77%, and 100%, respectively, with concomitant decreases in sensitivity to less than 35%. The absolute number of women who reported both low birthweight and preeclampsia was small ($n = 6$), and the completion rate decreased when multiple maternal responses were required. Additional preeclampsia analyses including patients with chronic hypertension (thereby capturing superimposed preeclampsia) showed similar results (data not shown).

Pregnancy-associated hypertension

Sixty-two women (12%) had medical record evidence of pregnancy-associated hypertension (preeclampsia or gestational hypertension). The best-performing single question for pregnancy-associated hypertension was ''During the study pregnancy, did you have high blood pressure or hypertension?'' (60% sensitivity, 95% specificity, 64% PPV, and 94% NPV) (Table 4, question 4). A higher PPV of 71% for pregnancy-associated hypertension was observed for the combined response of ''No'' to question 3 (''Did you have high blood pressure [hypertension] before the study pregnancy?'') plus a response to question 5 (''During that pregnancy, did you have preeclampsia, eclampsia, pregnancy-induced hypertension, or toxemia?'') of ''Yes, I had pregnancy-induced hypertension'' (response B) or ''Yes, I had preeclampsia'' (response D). This combination resulted in a lower sensitivity (53%), higher specifitity (97%), and slightly lower NPV (93%) (Table 4). Additional analyses including patients with chronic hypertension (thereby capturing superimposed preeclampsia) showed similar results (data not shown).

Birthweight

In our sample, 7.2% ($n = 35$) of the women delivered a low-birthweight infant during the study pregnancy. Women were asked about the birthweight of their child in three ways. The vast majority of women completed all three items: 94% completed the free-text response (in pounds and ounces or grams; question 7), 100% the ''small, medium, or large'' item (question 8), and 99% the categorical question (question 9). Table 5 shows the mean differences and Spearman correlation coefficients, comparing maternal recall of birthweight using free text to that recorded in the medical record. Mothers were accurate in their recall of infant birthweight, with small mean differences and a correlation coefficient of 0.95. Comparing the midpoints (assigning birth weight $< 1{,}500$ g to the smallest and $> 4{,}000$ g to the largest open-ended categories) of the four birthweight categories (question 9) against medical record birthweight yielded a correlation coefficient of 0.85 ($p < 0.0001$). Although both free-text and categorical birthweight questions performed well, the free-text option seemed to generate a more accurate response. However, 29 (5%) more patients answered the categorical question than the free-text question, representing the only question in the survey showing a discrepancy in the number of patients answering one of the questions among a group of questions for a given condition.

Figure 2 shows a linear relationship between medical-record-documented birthweight and free-text maternal recall of birthweight. The figure also differentiates patients who categorized their babies as small, medium, or large. In response to the accompanying question (''How did you choose this category?''), most patients stated that their rationale was based on comparison to other children or in response to comments made by healthcare providers. A Bland-Altman plot analysis showed no consistent bias or pattern of underestimating/overestimating infant birthweight in maternal recall (data not shown).

Gestational length

In our sample, 14.8% ($n = 78$) of the women delivered preterm in the study pregnancy. Table 5 shows the mean differences and Spearman correlation coefficients for maternal recall of gestation length using free text (question 10) and categories (question 11), compared to the medical record. To create a continuous variable from the categorical response to question 11 (''Did you deliver before, on, or after your due date?''), 40 weeks was assigned to those selecting the response ''within one week of my due date.'' For individuals selecting one of the other responses, the number of weeks early or late was subsequently scaled, subtracting from or adding to 40 weeks gestation. Table 5 shows that, with regard to gestation length, both question 10 (''How many weeks pregnant were you when you delivered?'') and question 11 (''Did you deliver before, on or after your due date?'') achieved Spearman correlation coefficients of 0.85 compared to medical record gestation length. Question 10 (''How many

TABLE 3. MATERNAL RECALL OF PREECLAMPSIA, USING MEDICAL RECORDS AS GOLD STANDARD

Survey questions	*Maternal report*	*Medical record: Pre-eclampsia (n=38)*	*Medical record: No pre-eclampsia (n=455)*	*Pretest probability (%)*	*Sensitivity (%)*	*Specificity (%)*	*PPV (%)*	*NPV (%)*
4. During the study pregnancy, did you have high blood pressure or hypertension?	Yes	27	31	11.9	71.1	93.3	46.6	97.4
	No	11	419					
5. During that pregnancy, did you have preeclampsia, eclampsia, pregnancy-induced hypertension, or toxemia? Response B, C, D, or E: B. Yes, I had preeclampsia. C. Yes, I had eclampsia. D. Yes, I had pregnancy-induced hypertension. E. Yes, I had toxemia.	Yes	32	25	11.7	84.2	94.4	56.1	98.6
	No	6	424					
Response B, C, or E: B. Yes, I had preeclampsia. C. Yes, I had eclampsia. E. Yes, I had toxemia.	Yes	30	14	9.0	79.0	96.9	68.2	98.2
	No	8	435					
Response B: Yes, I had preeclampsia.	Yes	30	14	9.0	79.0	96.9	68.2	98.2
	No	8	435					
Response C: Yes, I had eclampsia.	Yes	0	1	0.2	—	99.8	—	92.2
	No	38	448					
Response D: Yes, I had pregnancy-induced hypertension.	Yes	7	12	3.9	18.4	97.3	36.8	93.4
	No	31	437					
Response E: Yes, I had toxemia.	Yes	0	1	0.2	—	99.8	—	92.2
	No	38	448					
6a. During that pregnancy, did you have: High protein in the urine?	Yes	24	21	9.2	63.2	95.3	53.3	96.8
	No	14	429					
Seizures or convulsions?	Yes	—	—	—	—	100.0	—	92.2
	No	38	449					
5. During that pregnancy, did you have preeclampsia, eclampsia, pregnancy-induced hypertension, or toxemia? Yes, I had preeclampsia. AND 6. During that pregnancy, did you have high protein in the urine? Yes.	Yes	21	6	5.5	55.3	98.7	77.8	96.3
	No	17	443					
5. During that pregnancy, did you have preeclampsia, eclampsia, pregnancy-induced hypertension, or toxemia? Yes, I had preeclampsia. AND Low birthweight[a]	Yes	6	0	1.4	21.4	100.0	100.0	95.0
	No	22	415					
5. During that pregnancy, did you have pre-eclampsia, eclampsia, pregnancy-induced hypertension or toxemia? Yes, I had preeclampsia. AND Preterm birth[b]	Yes	13	4	3.5	34.2	99.1	76.5	94.6
	No	25	439					
5. During that pregnancy, did you have Preeclampsia, eclampsia, pregnancy-induced hypertension, or toxemia? Yes, I had preeclampsia. AND Low birthweight[a] AND Preterm birth[b]	Yes	6	0	1.4	21.4	100.0	100.0	94.9
	No	22	410					

[a]Low birthweight is defined as maternal report of <2,500 grams or <5 pounds and 8 ounces in response to question 7: ''What was the birthweight of that baby (in pounds and ounces or grams)?''

[b]Preterm birth is defined as maternal report of <37 weeks gestation in response to question 10: ''How many weeks pregnancy were you when you delivered?''

TABLE 4. MATERNAL RECALL OF PREGNANCY-ASSOCIATED HYPERTENSION, USING MEDICAL RECORDS AS GOLD STANDARD

		Medical record						
Survey Questions	*Maternal report*	*Pregnancy-associated hypertension (n = 62)*	*No pregnancy-associated hypertension (n = 431)*	*Pretest probability (%)*	*Sensitivity (%)*	*Specificity (%)*	*PPV (%)*	*NPV (%)*
4. During the study pregnancy, did you have high blood pressure or hypertension?	Yes	37	21	11.9	59.7	95.1	63.8	94.2
	No	25	405					
AND								
3. Did you have high blood pressure (hypertension) before the study pregnancy? No.	Yes	31	17	9.9	50.8	96.0	64.6	93.1
	No	30	407					
5. During that pregnancy, did you have preeclampsia, eclampsia, pregnancy-induced hypertension, or toxemia?								
Yes, I had pregnancy-induced hypertension.	Yes	10	9	3.9	16.1	97.9	52.6	88.9
	No	52	416					
AND								
3. Did you have high blood pressure (hypertension) before the study pregnancy? No.	Yes	8	6	2.9	13.1	98.6	57.1	88.7
	No	53	417					
3. Did you have high blood pressure (hypertension) before the study pregnancy? No.	Yes	37	23	12.5	60.7	94.5	61.7	94.3
AND								
4. During the study pregnancy, did you have high blood pressure or hypertension? Yes.								
OR								
5. During that pregnancy, did you have preeclampsia, eclampsia, pregnancy-induced hypertension, or toxemia? Yes, I had preeclampsia.	No	24	396					
3. Did you have high blood pressure (hypertension) before the study pregnancy? No.	Yes	32	13	9.4	52.5	96.9	71.1	93.3
AND								
5. During that pregnancy, did you have preeclampsia, eclampsia, pregnancy-induced hypertension, or toxemia? Yes, I had pregnancy-induced hypertension. OR Yes, I had preeclampsia.	No	29	406					
3. Did you have high blood pressure (hypertension) before the study pregnancy? No.	Yes	37	23	12.5	60.7	94.5	61.7	94.3
AND								
4. During the study pregnancy, did you have high blood pressure or hypertension? Yes.								
OR								
5. During that pregnancy, did you have preeclampsia, eclampsia, pregnancy-induced hypertension, or toxemia? Yes, I had pregnancy-induced hypertension. OR Yes, I had preeclampsia.	No	24	396					

Medical record evidence of pregnancy-associated hypertension (gestational hypertension or preeclampsia) is defined as nonproteinuric or proteinuric new-onset high blood pressure (SBP ≥ 140 mm Hg or DBP ≥ 90 mm Hg).

DBP, diastolic blood pressure; SBP, systolic blood pressure.

Table 5. Mean Difference and Spearman Correlation Coefficients, Comparing Birthweight and Gestational Length from Maternal Recall and Medical Record

Medical record	*Maternal report mean ± SD*	*Medical record mean ± SD*	*Mean difference*[a] *± SD*	*Spearman correlation coefficient*
Question 7: ''What was the birth weight of that baby?''				
Overall $n = 477$	3,306 ± 599	3,301 ± 582	4 ± 166	0.95
Among LBW mothers (< 2,500 g) $n = 35$	1,949 ± 555	1,981 ± 485	−32 ± 256	0.92
Among non-LBW mothers (≥ 2500 g) $n = 442$	3,413 ± 455	3,406 ± 445	7 ± 157	0.93
Question 10: How many weeks pregnant were you when you delivered?				
Overall $n = 503$	39 ± 2	39 ± 2	0 ± 1	0.85
Among preterm mothers (< 37 weeks) $n = 73$	35 ± 3	35 ± 2	0 ± 2	0.82
Among non–preterm mothers (≥ 37 weeks) $n = 430$	39 ± 1	39 ± 1	0 ± 1	0.78
Question 11: Did you deliver before, on, or after your due date?				
Overall $n = 518$	39 ± 4	39 ± 2	0 ± 3	0.85
Among preterm mothers (< 37 weeks) $n = 78$	35 ± 3	35 ± 2	0 ± 2	0.82
Among non–preterm mothers (≥ 37 weeks) $n = 440$	39 ± 3	39 ± 1	0 ± 3	0.78

[a]Mean difference is relative to the medical record (gold standard) value, where difference = maternal report – medical record value.
LBW, low birthweight.

weeks pregnant were you when you delivered?'') performed better among preterm mothers, and both questions had a similar number of patient responses.

Additional analyses

Since this cohort tended to be older, with a mean maternal age of 33 (SD 5) years, and was highly educated (47% college graduates), we did a stratified analysis of the best-performing questions (bolded in Fig. 1) by age and education, using a Pearson correlation coefficient for continuous variables and a Breslow-Day test for homogeneity of odds ratios for categorical variables. An analysis of the youngest quartile of patients, who were less than or equal to 25 years of age, compared to those greater than 25, showed no difference in patient response to the questions for GDM, preeclampsia, pregnancy-associated hypertension, birthweight, or gestational length. Similarly, a comparison of patients stratified by college degree showed no difference in correct responses to questions for any outcome of interest.

A Mantel-Haenszel analysis of the best-performing questions for each pregnancy outcome of interest stratified by length of time between delivery and recall (using the median time of 3.6 years as the cutpoint) showed no difference in maternal recall by time since delivery.

Discussion

In this study, we validated questions for maternal recall of pregnancy complications, predictive of future cardiovascular outcomes. We found that, on average, 4 years after pregnancy, several methods of querying GDM, birthweight, and

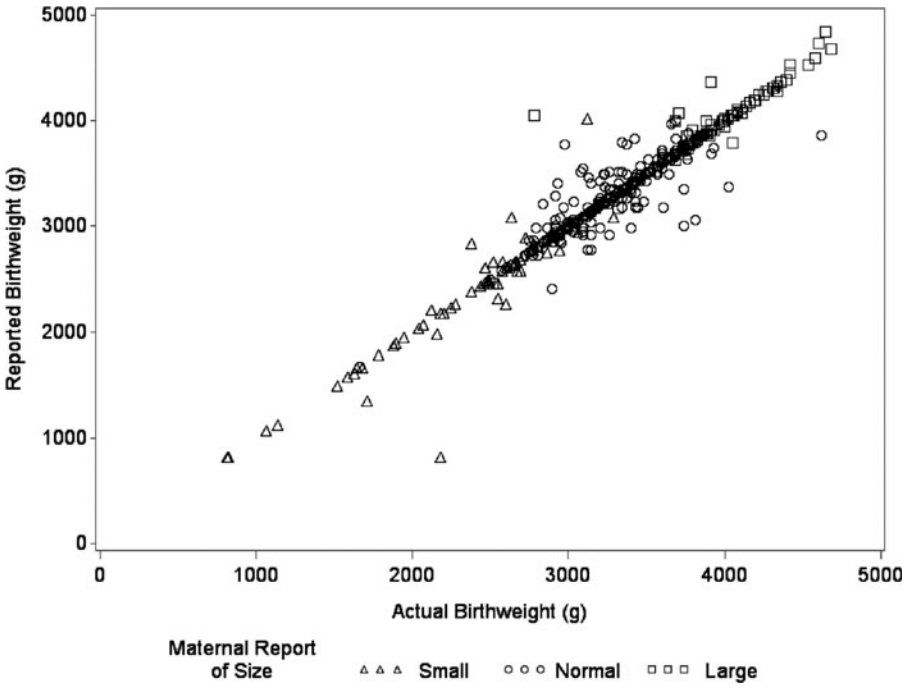

FIG. 2. Maternal recall of birthweight and infant size vs. medical record birthweight.

gestational length produced a high degree of accuracy as determined by high sensitivity/specificity/NPV and moderate PPV for GDM and high correlation coefficients for birthweight and gestational length. Although maternal recall of preeclampsia alone and pregnancy-associated hypertension overall were specific and yielded good NPVs, the recalls demonstrated modest sensitivities and PPVs.

The terminology ''pregnancy-induced hypertension (PIH)'' rather than ''gestational hypertension'' was used in the questionnaire, as it was thought to be the term most commonly used clinically at the time study patients delivered. However, for this group of women, who delivered between 2006 and 2009, ''pregnancy-induced hypertension'' performed poorly as a measure of gestational hypertension, preeclampsia, and pregnancy-associated hypertension overall. Similarly, asking women about ''toxemia'' was neither sensitive nor had a high PPV for preeclampsia. Instead, the best measure of preeclampsia came from asking a woman whether she had ''preeclampsia.'' However, even this question would detect only 79% (sensitivity) of women who had a history of preeclampsia in a clinical practice. In our study population, only 68% (PPV) of women who reported preeclampsia were accurate, according to medical records. The fact that maternal recall of pregnancy-associated hypertension appears to be less accurate than other pregnancy complications likely reflects multiple sources of error, including poor clinician-patient communication or poor maternal recall, which may be significantly improved with better patient education about key obstetrical events.[41]

If the goal of obtaining a patient history is to confirm preeclampsia in an individual, the physician will likely prioritize a high PPV (i.e., having a higher probability that the individual reporting preeclampsia truly has it) over a high sensitivity, which represents the likelihood that a true preeclamptic is able to report it. In that case, the addition of ''high protein in the urine'' to maternal report of ''preeclampsia,'' with an increase in PPV from 68% to 78%, might be the physician's best option to feel confident about a maternal report from an individual patient. However, if the physician is looking to capture as much of the true preeclampsia patient population as possible, the sensitivity should be priorizited over the PPV; as such, it may be best to stick with the single question about preeclampsia, given the resultant drop in sensitivity from 79% to 55% with the addition of the proteinuria question. This example illustrates a tradeoff between a broad capture of a population at risk versus precision with a given patient.

In addition to preeclampsia, the AHA recognizes pregnancy-induced hypertension (presumably gestational hypertension with or without preeclampsia/proteinuria) as a marker of cardiovascular risk. Within this study, we were able to evaluate various combinations of questions regarding hypertension to detect this more inclusive category of pregnancy-associated hypertension. Although no particular combination of questions was clearly superior to another, it does appear that combined maternal responses may outperform the validity of an individual question to detect pregnancy-associated hypertension. For example, a question ruling out chronic hypertension improved the PPV of individual questions about preeclampsia and hypertension in pregnancy to detect medical record pregnancy-associated hypertension.

We attempted to design and validate a maternal recall questionnaire to capture multiple pregnancy complications associated with cardiovascular risk. Previous literature has reported on maternal recall of a single pregnancy complication. The ability of women to accurately recall history of gestational diabetes has been documented previously by Hosler et al. using the New York State Pregnancy Risk Assessment Monitoring System (PRAMS).[21] At 2–6 months after delivery, there was a 93.8% agreement with a kappa of 0.53 for maternal report of ''high blood sugar (diabetes)'' during pregnancy and birth certificate record of gestational diabetes. Although their study did not assume a gold standard, our study used medical records as the gold standard and found maternal report of GDM to be both valid (sensitivity 92%) and accurate (PPV 79%) with longer maternal recall.

A review of the literature on maternal recall of pregnancy-associated hypertension found low sensitivity, with estimates ranging from 57% to 87% and consistently high specificity ($>90\%$), similar to our study.[42] Diehl et al.[23] obtained the best validity estimates from a six-question survey of preeclampsia, reporting 80% sensitivity, 96% specificity, 51% PPV, and 99% NPV, after a mean recall of 27 years. We found strikingly similar test characteristics—79% sensitivity, 97% specificity, 68% PPV, and 98% NPV—for the single item ''Did you have preeclampsia?'' recalled an average of 4 years after pregnancy. It is possible that the single question regarding preeclampsia performs better among more recent pregnancies, perhaps due to more consistent clinician use of the word ''preeclampsia'' with today's mothers.

Two studies assessed related pregnancy outcomes of birthweight and preterm delivery in the same population. Little et al. conducted a validation study among 377 women in a Washington State health maintenance organization. They reported greater than 90% agreement when asking women to recall infant birthweight and greater than 80% agreement with regard to gestational length, compared to hospital and birth certificate records.[26] In the other study, Dutch researchers demonstrated small but statistically significant mean differences in recalled birthweight and gestational age after 10–12 years: 25 grams for birthweight and 0.6 days for gestational age.[25]

Our study had several limitations that should be considered when interpreting the results. The women in this cohort were questioned 3 to 6 years after the reference pregnancy. It is unclear how well these questions would perform in a population further removed from pregnancy. However, a review of 10 maternal recall papers on preeclampsia did not find a consistent effect of recall length from pregnancy on accuracy of maternal report.[42] With regard to generalizability, women who responded to the questionnaire were more likely to be educated and Caucasian than were nonrespondents; however, a stratified analysis in our study population suggested that this did not alter the results. Furthermore, the study population came from a single tertiary referral center with a higher prevalence of the pregnancy complications than is seen in the general public. The predictive values of the items will depend on the prevalence of the underlying condition in a population. In our sample, the prevalence of GDM (7.4%) and preeclampsia (7.2%) was higher than it may be in other populations, driving the predictive value of a positive maternal recall higher and the predictive value of a negative maternal recall lower than might be observed elsewhere. In particular,

the PPV for preeclampsia, already modest in this setting at 68% for the best-performing question, would be expected to be lower still where the prevalence of preeclampsia is less than 7%.

Important strengths of this study include the large sample size of 526 women and asking about each pregnancy complication of interest in multiple ways to determine best-performing questions in a constant population of patients. We took this one step further by comparing the completion rate of questions in each category, since a high correlation coefficient for a question may not matter if patients are less likely to answer the open-ended question because they are unsure of the exact response value. We performed subgroup analyses, not typically conducted in previous studies, looking among patients with preexisting diabetes, gestational hypertension, superimposed preeclampsia, and the extremes of birthweight and gestational age.

Current strategies for women with a history of hypertensive pregnancy include counseling and increased monitoring of modifiable risk markers (i.e., blood pressure, cholesterol) are benign and relatively inexpensive. When the cost of ''treating'' someone at risk for CVD does not have major negative side effects, a low PPV, such as that seen for preeclampsia, should not preclude the clinician from obtaining pregnancy history and initiating a risk-reduction plan where appropriate. Maximizing sensitivity to capture a broad population at heightened CVD risk, even at the cost of PPV, may better serve the goal of preventing CVD.

In summary, if a woman says that she did not have a pregnancy complication, the consistently high specificity and NPVs observed in this study indicate that her self-report is very likely to be accurate. Similarly, women seem able to recall GDM, gestation length, and birthweight accurately, whereas maternal recall of pregnancy-associated hypertension is less so. Surveys such as this one may prove useful indicators of a parous woman's cardiovascular risk. The best-performing questions from our study (see Fig. 1, bolded items) may form a foundation to help clinicians elicit a focused history of GDM, preeclampsia, pregnancy-associated hypertension, preterm birth, and infant birthweight.

Conclusions

This study demonstrates the validity of maternal recall of important pregnancy events by defining parameters including sensitivity, specificity, PPV, NPV, and correlation coefficients for questions concerning pregnancy complications associated with increased risk of future CVD. A validated survey instrument is crucial to help clinicians elicit the pregnancy history recommended by the AHA[19] in order to identify and address a woman's cardiovascular risk factors and, hopefully, improve her lifetime disease trajectory.

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Address correspondence to:
Ebony Boyce Carter, MD, MPH
Department of Obstetrics and Gynecology
Division of Maternal Fetal Medicine
Barnes-Jewish Hospital
Washington University School of Medicine
660 South Euclid Avenue
Maternity Building, 5th Floor, Campus Box 8064
St. Louis, MO 63110

E-mail: cartere@wudosis.wustl.edu