Tracking Pregnancy Complications and Engagement with Remote Patient Monitoring in Prenatal Care: Retrospective Review

Meylakh Barshay, Crystal Zang, Taylor Bolden, Lauren Rosenfeld, Kathryn Marko, Andrew Sudimack, Anish Sebastian, Aditya Loganathan, Yan Ma, Andrew Meltzer

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Abstract

Background: Mobile technology has the potential to supplement traditional prenatal care and improve screening and compliance with recommended screening tests. While previous research has shown high patient satisfaction with mobile technology in prenatal care, it remains unclear how integrating the recording of remote vital signs into pre-existing clinical workflows can enable improved clinical outcomes.

Objective: In a multicenter retrospective study, we aimed to identify predictors of engagement with remote patient monitoring (RPM) using the Babyscripts™ digital health tool and to determine if low engagement correlated with adverse events.

Methods: In a university-based obstetrics practice, pregnant patients were provided the Babyscripts™ mobile digital health platform alongside standard care. The digital health platform allowed for tracking of gestational weight gain and blood pressure and delivered timed education on expected symptoms and recommended screening tests during pregnancy. Patients were included in the study if they began using the RPM before the end of the first trimester and excluded if pregnancy outcomes were unavailable. We conducted a chart review of each patient's prenatal care and delivery using trained abstractors and structured data collection forms. RPM engagement was defined as the number of weeks with at least one remote vital measurement. Outcomes such as pregnancy complications were considered individually and as a composite outcome. We employed multivariate logistic regression to identify predictors of engagement and complications.

Results: Our study encompassed 823 patients, including 28% who identified as Black, 32% Medicaid/Medicare recipients, 43% over age 35, and 5% with a history of hypertension. Of these, 37 developed preeclampsia or pregnancy-induced hypertension, and 288 experienced at least one maternal complication. We discovered that age was positively associated with increased engagement (1.21%, 95% CI, 0.67-1.74%, increase per one-year increment in age). Conversely, belonging to a distressed community and greater than one prior full-term pregnancy was linked to reduced engagement, with decreases of 7.9% (95% CI: 1.2%-14.6%) and 12.16% (95% CI: 5.2%-19.1%) respectively. RPM engagement did not correlate with occurrence of pregnancy-related complications (OR = 1.006, 95% CI: 1.000-1.012).

Conclusions: In summary, lower engagement with an RPM appears to be connected to residence in a distressed community but not an increase in pregnancy complications. Increased age and first-time pregnancies were associated with higher RPM engagement. Future studies should assess whether engagement with prenatal care digital health platforms can modify risk factors for pregnancy complications. Clinical Trial: NA

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Tracking Pregnancy Complications and Engagement with Remote Patient Monitoring in Prenatal Care

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Methods

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Tracking Pregnancy Complications and Engagement with Remote Patient Monitoring in Prenatal Care: Retrospective Review

Introduction

In the United States, nearly 4 million live births occur each year, and prenatal care is one of the most widely utilized types of preventative healthcare. [1] In general, the goal of prenatal care is to maximize the chances of a healthy delivery and mitigate any potential complications for the pregnant person and fetus. [2] Standard activities of prenatal care, such as monitoring gestational weight gain and blood pressure and providing timely educational material may be performed remotely instead of via in-person visits.[3] RPM tools also been associated with improved patient convenience and satisfaction.[4] Patients have described easier communication, reduced overall cost, and fewer missed in-person appointments. [5-8] The COVID-19 pandemic accelerated the use of RPM, digital health tools, and telemedicine across a wide variety of medical fields with potential benefits including a reduced time to diagnosis and improved access to specialist care. [8-14] In addition, remote technology allows for higher-frequency data collection compared to traditional in-person office visits. [13] The increased data collection has the potential to lead to more accurate predictors of pregnancy complications and provide more timely feedback to physicians and patients. [15,16] The objective of this study was to describe the prenatal care and pregnancy outcomes in patients who used the Babyscripts ™ prenatal care digital health platform and identify predictors of RPM engagement and complications of pregnancy.

Methods

We performed a large retrospective study of pregnant patients who used a prenatal care digital health platform as a supplement to routine prenatal care in a university-based academic practice. Data from outpatient electronic health record (EHR) Allscripts, inpatient EHR Cerner, and RPM were combined for each pregnancy. Chart review followed established guidelines, including structured data sheets, abstractor training, and approximately 10% second abstractor check.[8] The primary outcome was the development of preeclampsia (PEC). Secondary outcomes included a composite of pregnancy-related complications. We calculated summary statistics, including means for continuous variables, counts, and percentages for categorical variables, including baseline characteristics (Table 1), delivery outcomes (Table 2a), and pregnancy complications for the maternal cohort (Table 2b) and neonatal cohort (Table 2c). We estimated if participants lived in a distressed community by zip code using the distressed community index (DCI, https://eig.org). We investigated the association between past obstetric history, race, ethnicity, insurance status, DCI status, and RPM engagement using multivariate linear regression. We further examined the impact of RPM engagement on binary complication outcomes adjusting for baseline characteristics through multivariate logistic regression. RPM engagement was defined as the percentage of weeks that a patient performed remote patient monitoring with a connected blood pressure device. Coefficient estimate (for linear regression), odds ratio (for logistic regression), 95% confidence interval (CI), and p-value were reported. All p-values were 2-sided, with a p-value <0.05 being considered statistically significant. R version 4.3.2 was used for analysis.

The Babyscripts digital health platform consisted of a mobile app with RPM that interfaced with a wireless scale and sphygmomanometer to track gestational weight gain

and blood pressure, in addition to providing evidence-based educational information timed to the gestational age of the pregnancy. Engagement was calculated as percentage of active weeks with at least one blood pressure reading. The educational information was focused on common symptoms of pregnancy, avoiding modifiable risk factors (including alcohol consumption, tobacco, or drug abuse), optimizing nutrition and gestational weight gain. The digital health tool generated an alert if the participant recorded an abnormal blood pressure or weight measurement. The alert was sent to a call center who then phoned the patient and the on-call provider to coordinate further care as needed.

Results

In total, 823 patients were enrolled in the study and used the Babyscripts digital health tool. The average age was 34 years old, and more than 50% were non-white. While most participants lived in mid-tier to prosperous communities, 144 (17.5%) lived in distressed communities, and 261 (31.7%) were on Medicaid. The mean number of prenatal care visits was 10.5 and patients received an average of five ultrasounds over the course of their prenatal care (Table 1). Approximately 25% of pregnancies were delivered by cesarean section, and most (88%) patients received post-partum care and counseling (Table 2a). Preeclampsia was documented in 37 (4.5%) patients at an average gestational age of 33.8 weeks (Table 2b). There were seven (0.9%) cases of twins and among the neonates, 83 (9.9%) were admitted to the neonatal intensive care unit (Table 2c).

RPM engagement ranged from 0% to 100%. There were 70 (8.5%) patients with zero engagement. For patients with non-zero engagement, the mean engagement was 47.7% (SD 27.1%). On average, with each year increase in the age of the mother, the total engagement increased by 1.21% (95% CI, 0.67-1.74%). For study participants who lived in an “at-risk” or “distressed” community, we observed a 7.87% (95% CI, 1.19-14.56%) lower engagement than those who were in a comfortable community. On average, engagement for patients with more than one prior full-term pregnancy was 12.16% (95% CI, 5.18-19.13%) lower compared to participants who did not have a prior full-term pregnancy (Table 3).

With a one percent increase in engagement level, the odds of detecting PEC during pregnancy increased by 1.4% (OR:1.014, 95% CI: 0.999-1.846) after adjusting for prior history of PEC and other baseline characteristics. Patients with a history of high blood pressure, hypertension, or prior PEC had 6.84 (95% CI, 1.81-25.91) times higher odds of developing PEC during this pregnancy compared to patients without those risk factors. In addition, we found patients with a history of depression had 4.18 (95% CI, 1.66-10.54) times higher odds of PEC than those who did not have a history of depression. Patients from a “mid-tier distressed” community had 2.71 (95% CI, 1.12-6.59) times higher odds of PEC compared to those from comfortable communities. Table 4).

Pregnancy-related complications were associated with increased age, increased BMI, and not having any prior full-term pregnancies. With a one-year increase in age, the odds of developing pregnancy-related complications increased by 1.107 (95% CI, 1.058-1.159). Patients with a BMI greater than thirty had 2.23 (95% CI, 1.36-3.68) times higher odds of developing a pregnancy-related complication than patients with a BMI lower than twenty-five. On average, patients with one prior full-term pregnancy had 65.3% (95%CI, 46.3-77.6%) lower odds of developing pregnancy-related complications compared to those with

no prior full-term pregnancies. Moreover, patients with two or more prior full-term pregnancies had 82% (95%CI, 64.8-90.8%) lower odds of developing a pregnancy-related complication compared to those with no full-term pregnancies. (Table 5)

Discussion

RPM in prenatal care holds potential for allowing high-touch monitoring of biometric parameters to better predict, detect and manage complications of pregnancy such as preeclampsia, preterm labor, and excessive gestational weight gain. [17-19] Multiple studies have established the feasibility and general patient acceptance of RPM during prenatal care. [20] In this study, one of the largest to assess the use of RPM in actual practice, we highlight risk factors for low RPM engagement and explore how RPM engagement correlates with outcomes. We also identify predictors of engagement with RPM and what patient-level factors are associated with pregnancy complications.

This study adds to the literature in several important ways. Prior studies of RPM in pregnancy have used select patients or early adopters of technology that limited the generalizability of findings. [21] This study included a diverse group of patients in whom 34% were over age 35, 50% were Black, and over 30% were on Medicaid. Moreover, prior studies often did not integrate pregnancy outcomes and traditional EHR data with RPM data.[22] Here, we harmonized data across three disparate sources: inpatient, outpatient, and remotely collected data, allowing a more detailed assessment of associations. Furthermore, unlike other studies that define digital engagement as clicking in an app, we defined engagement as patient sharing of biometric RPM data which we believe is more meaningful definition. [23]

Predictors of RPM engagement included first-time pregnancies, older maternal age, and residence in a comfortable community. The reasons why these factors predict engagement are unclear. We suspect that patients in a first-time pregnancy were more likely to incorporate RPM because they did not have prior experience with a different approach to prenatal care. In addition, we suspect that patients who have had a prior healthy pregnancy may have been less motivated to engage with RPM because of a prior experience without complications. Conversely, older patients may have felt more motivated to engage with the RPM due to concern about the higher risk of complications associated with age. Alternatively, the observed differences could reflect a different approach by providers who were more likely to encourage consistent use of RPM for older patients and/ or less likely to encourage use for patients who had a previous uncomplicated pregnancy.

The observation that lower RPM engagement occurs in patients from at-risk communities may reflect issues with internet connectivity, smartphone functionality, or other socioeconomic barriers. Providers may also not emphasize digital technology platforms with patients in at-risk communities during prenatal care. The findings underscore the barriers to prenatal care that exist in society outside of traditional health risk factors. [24] Disparities in prenatal care and pregnancy outcomes have been well documented. [25] Digital health tools that offer education, screening, and care coordination may contribute to overcoming those barriers. [26]

As a primary outcome, the development of PEC was chosen due to the seriousness of the condition and the need for better detection. Ultimately, PEC was detected in 37 (4.5%) of patients at an average gestational age of 33.8 weeks which is similar to the

national average. [27] Detection was associated with increased engagement with RPM (1.014, 95% CI: 0.999, 1.846). There are several ways to interpret this association. Most likely, if we assume that providers eventually identified every case of PEC, then the finding suggests that engagement was correlated with development of PEC which may imply a self-selection bias among patients (i.e., patients who monitored themselves closely were more likely to be at risk for PEC). This would imply that other risk factors for PEC were driving patient behavior. A less likely explanation is that the incidence of PEC is unrelated to engagement and the finding suggests that providers were less likely to identify or diagnose PEC among lower engagement patients. In this case, encouraging patients at risk for preeclampsia to utilize RPM at increased rates may significantly impact detection and, therefore, outcomes. In theory, the use of RPM might make collection of certain datapoints such as blood pressure and depression easier to monitor providing a more granular understanding of individual risk factors.[28-30] As a next step, randomized control trials are underway to assess the effectiveness, acceptability, and cost of an RPM model of prenatal care versus standard of care.[31]

Limitations

The strengths of this study are that it is a large retrospective chart review using rigorous methodology to assess patients who used the Babyscripts prenatal care digital health tool. The study harmonized three different data sources: outpatient prenatal care, inpatient pregnancy outcomes, and home RPM data. Limitations include enrolling patients who may not represent the general population due to selection bias. However, our patient population was quite diverse and reflects the patient population in many academic medical centers. In addition, charts were manually abstracted and occasionally had missing or incomplete information. Finally, as this was a non-randomized observational study, unmeasured confounders are likely associated with RPM engagement. We attempted to address these limitations with a diverse patient population, the use of high-quality chart review methodology and the use of regression models.

Conclusion

In conclusion, in a large retrospective study of a diverse group of pregnant patients, high engagement with Babyscripts prenatal care digital health tool was associated with increased maternal age and the presence of a first-time pregnancy; low engagement was associated with living in an at-risk or distressed community. Complications of pregnancy were not associated with RPM utilization, however, the odds of detecting preeclampsia increased with increased platform engagement.

Conflicts of Interest

This research was supported by unrestricted grant from 1EQ, Inc. to George Washington University. Anish Sebastian is the CEO of Babyscripts. Andrew Sudimack and Andrew Meltzer are former officers with Babyscripts.

Table 1: Baseline Information about Study Population (N=823)

Baseline Information	
Age (mean, standard deviation)	34.36, 4.89
Race	
Black (n, %)	228, 27.7%
White (n, %)	408, 49.5%
Asian (n, %)	81, 9.8%
Other / Unknown (n, %)	106, 12.9%
Ethnicity	
Hispanic/Latino (n, %)	57, 6.9%
Zip Code Category	
Prosperous (n, %)	206, 25.1%
Comfortable (n, %)	286, 34.8%
Mid-Tier (n, %)	185, 22.5%
Distressed (n, %)	1, 0.1%
At-Risk (n, %)	144, 17.5%
Insurance	
Private (n, %)	547, 66.7%
Medicaid (n, %)	260, 31.7%
Medicare (n, %)	2, 0.2%
Military (n, %)	11, 1.3%
Unknown (n, %)	3, 0.4%
Prior Pregnancy History	
Gravida (mean)	2.36
All Live births (mean)	0.73
AB Spontaneous (mean)	0.41
AB Induced (mean)	0.22
Full-Term Births (mean)	0.69
Pre-Term Births (mean)	0.04
Ectopic (n, %)	20, 2.4%
Multiples (n, %)	7, 0.9%
Prior Pregnancy-Specific Complications	
AMA* (>35 years old) (n, %)	63, 7.7%
Preeclampsia (n, %)	43, 5.2%
Hypertension (n, %)	33, 4.0%
Obesity (n, %)	32, 3.9%
Gestational Diabetes (n, %)	19, 2.3%
Preterm Labor (n, %)	18, 2.2%
Anemia (n, %)	14, 1.7%
Other (n, %)	183, 22.2%
Past Medical History	
None (n, %)	241, 29.3%
Depression (n, %)	123, 14.9%
Asthma (n, %)	80, 9.7%
Hypertension (n, %)	41, 5.0%
Used IVF to conceive baby (n, %)	36, 4.4%
Diabetes (n, %)	8, 1.0%

High Cholesterol (n, %)	2, 0.2%
Medications	
Other medications (n, %)	452, 54.9%
Anti-hypertensive medication (n, %)	33, 4.0%
Diabetes medication (n, %)	10, 1.2%
Weight	
Pre-pregnancy BMI (mass (kg)/height (m)^2)	25.86
Number of Visits (mean)	10.5, 95% CI: (5.9 -15.1)
Total Ultrasounds (mean)	5, 95% CI: (1.6 -8.4)

Table 2a. Delivery Outcomes for Study Population (N = 823)

Type of Delivery/ Complications	
Cesarean (n, %)	209, 25.4%
Vaginal (n, %)	614, 74.6%
Mean Gestational Age at Delivery (week, mean, standard deviation)	39.1, 2.2
Length of Stay after delivery (day, mean, standard deviation)	2.0, 1.2
Multiples (i.e., twins, triplets) (n, %)	13, 1.6%
Post-Partum Visit	
Patient had a post-partum visit (n, %)	715, 87.8%
Days post-partum (mean, standard deviation)	5.9, 1.7
Birth control discussed (n, %)	698, 98.2%
Screened for Postpartum Depression? (n, %)	692, 93.7%
Positive EDPS (>=10) Oost Partum Depression (n, %)	442, 89.1%

Table 2b. Adverse Maternal Outcomes for Study Population (N = 823)

Adverse Events	Frequency, %
Preeclampsia or HELLP	37, 4.5%
Gestational age at time of detection of PEC? (weeks GA)	33.8
Failure to progress (n, %)	65, 8.4%
Non-reassuring fetal status (n, %)	95, 12.2%
Shoulder dystocia (n, %)	7, 0.9%
Postpartum hemorrhage (> 1,000 ml) [check for EBL/QBL] (n, %)	78, 10.0%
Fetal malposition (n, %)	59, 7.5%
Placenta previa (n, %)	4, 0.5%
Uterine rupture (n, %)	2, 0.3 %
Placenta abruption (n, %)	12, 1.6%
Intraamniotic infection (n, %)	30, 3.9%
3rd or 4th-degree perineal laceration (n, %)	20, 2.6%
Maternal death (n, %)	0, 0%
PROM (n, %)	9, 1.1%
Preterm Labor (n, %)	1, 0.1%
Other complications: Isolated maternal fever: Maternal Fever, left broad ligament hematoma, Meconium, Oligohydramnios, Cord Prolapse, Prolapsed cord, Retained placenta (n, %)	27, 3.3%

Table 2c. Adverse Neonatal Outcomes for Study Population (N = 823)

Composite Outcome. Neonatal Complications	
Neonatal Intensive Care Unit, (n, %)	83, 9.9%
Macrosomia (>4000 g), (n, %)	68, 8.2%
Microsomia (<2500 g), (n, %)	60, 7.2%
5 min APGAR abnormal (moderately or very abnormal), (n, %)	15, 1.8%
Stillbirth (n, %)	8, 0.96%
Death prior to discharge, (n, %)	4, 0.48%

Table 3. Predictors of Engagement

Predictors of Engagement	Point Estimate.	2.50%	97.50%	p-Value
Past Obstetric History				
Prior PIH and/or Preeclampsia	6.494	-5.083	18.071	0.27
In Vitro Fertilization (IVF)	2.3	-8.515	13.114	0.68
Prior Pregnancy Complications	1.252	-4.446	6.95	0.67
Prior Miscarriage	-0.584	-5.361	4.192	0.81
Prior Gestational Diabetes	-5.021	-18.96	8.918	0.48
Prior Pre-term Pregnancy	-5.407	-16.91	6.098	0.36
Prior Abortion	-9.872	-16.09	-3.656	0.002
One Prior Full-term Pregnancy	-4.039	-9.054	0.975	0.11
Greater than One Prior Full-term Pregnancy	-12.16	-19.13	-5.183	0.001
Past Non-Obstetric Medical History				
Prior History of Hypertension	2.804	-8.537	14.146	0.63
BMI- Overweight	2.794	-2.284	7.873	0.28
Age Increase (One Year)	1.206	0.669	1.742	<0.001
BMI- Obesity (> 30)	0.816	-5.285	6.917	0.79
Past Medical History – Asthma	-1.505	-8.407	5.398	0.67
Anti-Hypertensive medication	-4.518	-16.09	7.052	0.44
History of Depression	-5.599	-11.3	0.101	0.05
Race / Ethnicity				
Hispanic/Latino	-1.473	-9.817	6.872	0.73
Black	-3.155	-9.744	3.434	0.35
Asian	-4.87	-12.09	2.347	0.19
Insurance Status/ Social Risk				
Insurance-Private	1.932	-3.419	7.283	0.48
From Mid-Tier Distressed Community	-4.822	-9.909	0.265	0.06
From an At-Risk or Distressed Community	-7.873	-14.56	-1.19	0.02
Military Insurance	-11.51	-29.24	6.217	0.2

Table 4. Logistic Regression of Engagement on Preeclampsia (PEC)

From an At-Risk or Distressed Community	-7.873	-14.56	-1.19	0.02
Military Insurance	-11.51	-29.24	6.217	0.2

Predictors of PEC	Odds Ratio	2.50%	97.5%	p-Value
Primary Variable of Interests				
Engagement Levels	1.014	0.999	1.846	0.065
Past Obstetric History				
Prior pregnancy complications - High BP, Hypertension, or PEC	6.841	1.806	25.914	0.005
Prior Gestational Diabetes	0.430	0.027	6.862	0.550
Prior pregnancy complications-Other	0.438	0.122	1.571	0.205
In Vitro Fertilization (IVF)	3.229	0.712	14.647	0.129
Prior Miscarriage	0.537	0.188	1.531	0.245
Prior Abortion	2.382	0.768	7.383	0.133
Had At Least One Prior Full-term Pregnancy	0.146	0.042	0.506	0.002
Prior Pre-term Pregnancy	0.590	0.077	4.502	0.611
Past Non-Obstetric Medical History				
Age	1.046	0.948	1.154	0.372
BMI- Overweight	1.024	0.360	2.908	0.965
BMI- Obesity	2.472	0.831	7.354	0.104
Past medical history - Asthma	0.724	0.148	3.530	0.689
Past medical history - Depression	4.179	1.657	10.539	0.002
Past medical history - Other	1.544	0.634	3.761	0.339
Anti-hypertensive medication	5.875	1.629	21.184	0.007
Other Medications	0.760	0.314	1.840	0.543
Race / Ethnicity				
Asian	1.236	0.277	5.526	0.781
Black	1.128	0.343	4.187	0.713
Social Risk				
From Mid-Tier Distressed Community	2.710	1.115	6.587	0.028
From At-Risk or Distressed Community	0.829	0.178	3.862	0.811

Table 5. Logistic Regression of Engagement on Pregnancy-Related Complications

Predictors of Pregnancy Related Complications	Odds Ratio	2.50%	97.5%	p-Value
Primary Variable of Interests				
Engagement Levels	1.006	1.000	1.012	0.065
Past Obstetric History				
Prior Pre-term Pregnancy	1.146	0.337	3.897	0.827
Ectopic pregnancy	0.426	0.118	1.533	0.191
Prior pregnancy complications-High BP or Hypertension	1.380	0.530	3.591	0.510
Prior pregnancy complications-Preeclampsia	1.031	0.444	2.391	0.944
Prior pregnancy complications-Gestational Diabetes	1.575	0.520	4.770	0.422
Prior pregnancy complications-Preterm Labor	0.931	0.185	4.687	0.931
Prior pregnancy complications-Other	1.213	0.759	1.936	0.420
Prior miscarriage	0.864	0.573	1.304	0.486
Prior abortion	1.051	0.623	1.775	0.851
One Prior Full-term pregnancy	0.347	0.224	0.537	<0.001
More than One Prior Full-term Pregnancy	0.180	0.092	0.352	<0.001
IVF	1.236	0.535	2.856	0.621
Past Non-Obstetric Medical History				
Age	1.107	1.058	1.159	<0.001
BMI 25-30 - Overweight	1.034	0.676	1.582	0.877
BMI >30 - Obesity	2.232	1.356	3.675	0.002
Past medical history - High Blood Pressure or Hypertension	0.548	0.206	1.457	0.228
Past medical history - Asthma	0.887	0.494	1.594	0.689
Past medical history - Depression	1.378	0.863	2.201	0.179
Past medical history - Other	1.093	0.763	1.566	0.626
Anti-hypertensive medication	0.465	0.177	1.222	0.120
Other Medications	0.782	0.550	1.111	0.170
Race / Ethnicity				
Asian	0.978	0.538	1.779	0.943
Black	1.446	0.833	2.508	0.190
Other Race	1.254	0.624	2.521	0.525

Hispanic or Latino	0.944	0.476	1.872	0.868
Insurance Status/ Social Risk				
Military Insurance	0.175	0.020	1.506	0.112
Private Insurance	0.904	0.584	1.399	0.650
From Mid-Tier Distressed Community	0.788	0.518	1.200	0.267
From At-Risk or Distressed Community	0.908	0.514	1.605	0.740

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