ABSTRACT

• **Objective:** To investigate engagement with a bidirectional text messaging system as an alternative to in-person follow-up for postpartum women with hypertensive disorders.

• **Methods:** We utilized rapid-cycle innovation processes to implement postpartum SMS text messaging follow-up in women with hypertensive disorders who delivered between September–December 2014. Patients were given electronic blood pressure cuffs and education before discharge. Standard texts reminded patients to send blood pressures daily on each of the 7 days post discharge. The study obstetrician sent text message responses based on a pre-specified management algorithm. Ability to meet ACOG guidelines was defined as receiving at least 1 reading on post-discharge days 1 or 2 and days 5, 6, or 7.

• **Results:** We enrolled 32 patients. Six (19%) returned for usual care office blood pressure checks. We received at least 1 blood pressure from 27 (84%) participants. Nearly 20 (65%) texted readings on 5 of the 7 days. 27 (84%) texted at least one reading on day 1 or 2, and 21 (66%) texted at least one pressure on day 5, 6, or 7 ($P = 0.001$ vs. usual care). Two patients required medications and none were readmitted for hypertension. Patients reported preference for home testing and text messaging over return visits.

• **Conclusion:** Remote blood pressure monitoring via text messaging is a patient-centered method for postpartum hypertension surveillance. Further testing is needed prior to widespread adoption within the broader obstetric community.

Key words: postpartum hypertension, remote monitoring, text-based intervention.

Hypertensive disease is a leading cause of maternal morbidity and mortality [1,2] and the leading cause of obstetric readmissions, accounting for 27% of obstetric readmissions in the United States in 2009 [3]. The majority of patients readmitted with hypertension have a diagnosis of hypertensive disorder of pregnancy on initial admission for delivery, indicating that these readmissions are the result of disease persistence or progression in contrast to new-onset disease. Peak blood pressure in these patients usually occurs 3 to 6 days postpartum [4–6] and is typically unaccompanied by warning symptoms. For these reasons, identifying patients who are at risk for persistent disease and being proactive in their postpartum care may decrease postpartum stroke and seizure. The recent Hypertension in Pregnancy guidelines provided by the American College of Obstetricians and Gynecologists (ACOG) recommend monitoring blood pressure for at least 72 hours postpartum (inpatient or outpatient) and again 7 to 10 days after delivery in women in whom a hypertensive disease of pregnancy is diagnosed [6].

Although there is a clear need for effective and reliable blood pressure surveillance for high-risk women...
soon after delivery, significant obstacles exist. Our own high-risk blood pressure transition clinic, which occurred every other week and was staffed by maternal-fetal medicine specialists, had an average attendance of only 30% over a 2-year period. Moreover, all of the hypertension-related readmissions occurred in the first 7 days post discharge, which was before the scheduled clinic visit for approximately 50% of patients. Phone call reminders were also found to be an ineffective strategy, as the women did not answer or return voice messages left by the practice. In fact, a postpartum unit quality improvement project validated that follow-up phone calls after discharge from the postpartum unit were less effective than text messaging when reminding women of their blood pressure follow-up appointment at the clinic [7].

As an alternative to in-person visits or traditional voice telephonic communication, mobile phone “Short Message Service” (SMS) text messaging has been used successfully in health care for appointment reminders, result reporting, support of medication and treatment adherence, and dosage adjustment [8–13]. As of 2014, 90% of American adults own a cell phone and over 79% of those send and receive text messages [14]. Among a young population, which is at high risk for hypertensive disorders of pregnancy, data further reveals a preference for text messaging over live calls [15]. Among low-income women under age 30, the rates of cell phone use and text communication are very high [14,15], making text-based surveillance a promising and more patient-centered strategy for a broad population.

We report the results of rapid-cycle innovation and implementation of active, remote surveillance of hypertension with new text message communication strategies in the first 7 days post-discharge. We chose a Plan-Do-Study-Act cycle approach, in which small tests are performed and studied and changes made to accelerate improvement, in order to enhance our ability to acquire blood pressure data [16,17]. The goals of the work were to (1) assess patient engagement using a remote method of blood pressure monitoring, (2) increase ascertainment of postpartum blood pressure data and obtain at least once daily blood pressure readings on all patients on postdischarge days 1–2 and 5–7, which is in accordance with the recommended guidelines [6] for blood pressure surveillance, and (3) address all “at risk” severe range blood pressure readings within a short time interval and prior to the need for readmission. We describe a program of remote blood pressure monitoring and communication via text message designed to increase patient engagement and participation, thereby having the potential to result in earlier interventions, reduce readmissions, and decrease overall morbidity.

**METHODS**

We performed a series of 6 rapid-cycle innovation development and implementation interventions with a cohort of women with chronic hypertension (CHTN), gestational hypertension (GHTN), or preeclampsia (with and without severe features and superimposed) who delivered at our institution between 20 September 2014 and 14 December 2014. All patients were > 18 years old, able to speak and read English, had a hypertension diagnosis listed above, and had access to a cell phone with unlimited text messaging capabilities. Patients received standard postpartum care and were continued or started on antihypertensive medications based on a standardized postpartum hypertension protocol previously developed at our institution (available on request). This project was undertaken as a quality improvement initiative and as such was exempt from formal review by our institutional review board. However, all patients signed a waiver acknowledging that SMS texting is not a secure communications technology. A single research telephone was used for physician-patient communication to further ensure privacy.

Patients who qualified for the intervention study were recruited on the postpartum unit following delivery. Those who agreed to participate were provided with electronic blood pressure monitors (CVS Pharmacy automatic blood pressure monitor and Omron 3 Series upper arm blood pressure monitor) prior to discharge and instructed on their use. Patients were told to expect their first text message reminder to send in their blood pressure the day after discharge; an example of a text reminder is “Good morning. Please send us a blood pressure reading by 12 pm.” Patients were enrolled for 7 days post discharge and were interviewed regarding their experience at the end of their 7-day enrollment. As this was primarily a feasibility and quality improvement study, patients were also instructed to continue to follow up with the standard of care at the hypertension clinic visit.

For each of the 7 days following discharge from the hospital, patients received a standard text message in the morning and afternoon reminding them to text their
blood pressure to the research telephone by a specific time. Reported blood pressures were reviewed and a standard response was sent by the study obstetrician based on an algorithm consistent with the institution’s postpartum hypertension protocol. Patients were sent reminders at all time points whether or not they had texted any BPs.

The ACOG Hypertension in Pregnancy guidelines recommend monitoring blood pressure at 72 hours postpartum (inpatient or outpatient) and again 7 to 10 days postpartum in women diagnosed with a hypertensive disorder of pregnancy [6]. We measured our ability to meet these guidelines by identifying how many patients texted blood pressures on post-discharge days 1 or 2 and post-discharge days 5, 6, or 7, as most patients were discharged home on postpartum day 2 or 3.

Sequential interventions were performed following principles of rapid-cycle validation using a Plan-Do-Study-Act cycle [16,17], each testing new ways to enhance our ability to acquire blood pressure data, but using small samples large enough only to test feasibility and initial responses (Table 1).

Strategies to enhance patient engagement were modified based on patient interviews and results from the immediately preceding cycle (for example, Cycle 1 interview information and results were used to make changes in Cycle 2), as well as studies on telemonitoring adherence in other populations [18]. The program ended after 6 cycles, as the study team felt there was sufficient promise to design an expanded platform suitable for a larger study.

### RESULTS

**Overall**

We enrolled 32 patients across 6 intervention cycles. Aggregate and individual cycle demographics are listed in Table 2. Three patients (9%) had CHTN, 17 (53%) had GHTN, 8 (25%) had severe preeclampsia, and 4 (13%) had superimposed preeclampsia. The mean maternal age was 27 (± 4.6) years and average gestational age at time of delivery was 38w3d (± 5w4d). Mean day of discharge was postpartum day 2 (± 1d). All but 2 patients had singletons (94%).

At the patient level, we received at least 1 blood pressure during the requested time frame from 27 of the 32 patients enrolled (84%). Nearly 65% of patients (20/32) texted at least 1 blood pressure reading on at least 5 out of the 7 days enrolled. Of the 32 patients recruited, 27 (84%) texted at least one blood pressure on cycle day 1 or 2. Twenty-one of the 32 patients (66%) sent in at least 1 blood pressure on day 5, 6, or 7, meeting guideline recommendations for blood pressure measurements on days 7–10 postpartum. Two patients stopped texting blood pressures on cycle day 3 and three stopped responding on cycle day 4. However, all patients who texted blood pressures on days 5–7 were engaged since the start of the trial. Trend of engagement by cycle day is depicted in Figure 1. Only 6 patients (19%) returned for their scheduled office blood pressure check (routine care). None of the patients enrolled were readmitted for hypertension or for any other cause within 30 days of discharge.

### Table 1. Characteristics of the Rapid-Cycle Innovation Strategies Tested

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Hypotheses to Improve Blood Pressure Reporting</th>
<th>Strategy Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reminder texts at standard times</td>
<td>Reminder text at 8 AM and 1 PM</td>
</tr>
<tr>
<td>2</td>
<td>Increase knowledge</td>
<td>Addition of patient education flyer given at time of discharge for review of diagnosis, danger symptoms, and long-term health risk</td>
</tr>
<tr>
<td>3</td>
<td>Increase personalization</td>
<td>Increased personalization (patient and infant name included in messages)</td>
</tr>
<tr>
<td>4</td>
<td>Increase convenience/flexibility</td>
<td>Patients could choose a time that was convenient for them for receiving the reminder texts</td>
</tr>
<tr>
<td>5</td>
<td>Repeat reminder closer to deadline</td>
<td>Message provided “snooze option” to allow for 1 additional reminder Daily “countdown” message (“X days to go”)</td>
</tr>
<tr>
<td>6</td>
<td>Repeat reminder closer to deadline</td>
<td>Message provided “snooze option” to allow for additional reminder “Buddy system” with reminder sent to an identified support person if participant did not respond to morning message</td>
</tr>
</tbody>
</table>

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Patient engagement and cycle outcomes are individually detailed by cycle intervention below and summarized in Table 3. Figure 2 compares patient responses meeting current ACOG recommendations for postpartum hypertension surveillance by cycle.

### By Cycle

#### Cycle 1 - Basic
Cycle 1 tested our basic hypothesis that patients would take their blood pressure at home and transmit the results by text message: 5 of 7 patients responded to our reminders, each transmitting blood pressures on at least 5 of the 7 days requested.

Four severe-range blood pressures, defined as systolic blood pressure $\geq 160$ mm Hg or diastolic blood pressure $\geq 110$ [6], were sent to the physician responder, two times each in 2 patients. All four “at risk” severe blood pressures were addressed within 24 hours of the text message. No medications were initiated, as elevated blood pressures were not persistent and patients were asymptomatic.
Cycle 2 - Education

Patients in Cycle 1 reported during their follow-up interview that they became more aware of the possible morbidity associated with persistent postpartum hypertension as the cycle progressed. Therefore, Cycle 2 tested our hypothesis that focused education would improve patient engagement.

All five patients in this cohort sent in at least one blood pressure during the cycle period. All transmitted at least one blood pressure text on post-discharge day 1 or 2. Four of the five patients (80%) also sent in at least one blood pressure on day 5, 6, or 7.

There were no significantly elevated blood pressures sent to the physician responder.

Cycle 3 - Personalization

Patients in Cycle 2 reported during their interview that they felt the text message responses from the provider were too automated. Cycle 3 tested our hypothesis that added personalization, with patient and infant names included in the messages, would improve engagement.

Three of five patients in this cohort sent at least one blood pressure text on post-discharge day 1 or 2 (60%).

Table 3. Patient Engagement and Trial Outcomes by Cycle

<table>
<thead>
<tr>
<th></th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
<th>Cycle 4</th>
<th>Cycle 5</th>
<th>Cycle 6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients enrolled</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>32</td>
</tr>
<tr>
<td>No. of patients who sent BPs</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>27 (84%)</td>
</tr>
<tr>
<td>% of pts who sent BP at least once/day over 7 days</td>
<td>55 (77)*</td>
<td>77</td>
<td>50 (86)*</td>
<td>63</td>
<td>86</td>
<td>65 (82)*</td>
<td>68</td>
</tr>
<tr>
<td>% of pts who sent BP twice/day over 7 days</td>
<td>27 (37)</td>
<td>48</td>
<td>23 (38)</td>
<td>49</td>
<td>60</td>
<td>52 (66)</td>
<td>36</td>
</tr>
<tr>
<td>% of &quot;at risk&quot; BPs reviewed and addressed &lt; 24 hours</td>
<td>100% (N = 4)</td>
<td>No at risk BPs</td>
<td>100% (N = 1)</td>
<td>100% (N = 5)</td>
<td>100% (N = 4)</td>
<td>No at risk BPs</td>
<td>100% (N = 14)</td>
</tr>
<tr>
<td>No. of antihypertensive medications initiated</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2 (6)</td>
</tr>
<tr>
<td>No. of maternal readmissions</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0 (0)</td>
</tr>
<tr>
<td>No. of patients who presented to follow-up clinic</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>6 (19)</td>
</tr>
</tbody>
</table>

BP = blood pressure.

*Percentage if excluding those who sent no BPs.
Only one patient (20%) also sent in at least one blood pressure on day 5, 6, or 7.

One significantly elevated blood pressure was sent to the physician responder. This blood pressure was addressed within 24 hours of the text message. No medications were initiated, as elevated blood pressures were not persistent and patients were asymptomatic.

**Cycle 4 - Response Timing**

Patients in Cycle 3 had lower response rates than previous cycles and noted that they wanted more flexibility in the time to respond, as their schedules were unpredictable with a newborn at home. Although they enjoyed the personalized aspect, they did not feel it influenced their responses, which is evidenced by the low response rate on days 5, 6, or 7. Therefore, Cycle 4 tested our hypothesis that allowing patients to commit to a time of their choice for receiving the reminder texts would improve their response rate.

All five patients enrolled in this cohort sent in at least one blood pressure. We received at least one blood pressure text on post-discharge day 1 or 2 from all five patients in this cycle (100%). Three of the five patients (60%) also sent in at least one blood pressure on day 5, 6, or 7.

Five severely elevated blood pressures were sent to the physician responder, all from a single patient. This patient had been discharged home on hydrochlorothiazide 12.5 mg for persistently elevated blood pressures while in the hospital after being diagnosed with severe preeclampsia.

All five “at risk” blood pressures were addressed within 24 hours of the text message. On her fifth day of remote surveillance, 5 mg of amlodipine was added to her daily regimen for blood pressures ranging from 150–170/90–110 mm Hg. Her blood pressure at her 6-week postpartum visit was 120/60 mm Hg and she had seen her primary care doctor in the interim for further hypertension management.

**Cycle 5 - Snooze and Countdown**

Although most of the patients enrolled in Cycle 4 stated that they were very busy in the immediate postpartum period and not always able to respond in a timely fashion, allowing patients to receive the reminder text at their own designated convenient time did not increase engagement. Patients reported that while they always carried their cell phones, they did not always carry their blood pressure cuff, limiting their ability to send in a reading at the time of the reminder. Additionally, patients reported feeling less motivated to continue texting blood pressures towards the end of the cycle. Cycle 5 tested our hypothesis that patient engagement would improve if reminder text messages were sent closer to the morning or evening deadline. Patients were provided with the opportunity to request “snooze” response if they did have their cuff accessible. Additionally, standard responses were accompanied by a countdown message. For example, “Your blood pressure looks good. Four more days of checking your blood pressure to go.”
All five enrolled in this cohort sent in at least one blood pressure, and all (100%) transmitted at least one blood pressure text on post-discharge day 1 or 2 and on day 5, 6, or 7. Only two “snooze” requests were made over the course of the arm by a single patient, who responded both times after the additional reminder.

Four severely elevated blood pressures were sent to the physician responder, all from a single patient. This patient was diagnosed with preeclampsia with severe features on delivery admission, and her blood pressures normalized prior to discharge. All four “at risk” blood pressures were addressed within 24 hours of the text message. Due to persistently elevated diastolic blood pressures ranging from 110–120 mm Hg, she was started on hydrochlorothiazide 12.5 mg on day 6 of the cycle and monitored for additional days following cycle completion with improved blood pressures.

**Cycle 6 - Snooze and Support Person**

The patients in Cycle 5 were overall satisfied with their experience and did not provide any suggestions for change. However, we sought to see if integrating support persons into the protocol would affect engagement. Cycle 6 tested our hypothesis that patients would be more engaged if they had a self-identified support person reminding them to text their blood pressures. Patients provided the name of a support person to contact if a morning blood pressure was not received. Additionally, patients received the same “snooze” option as in Cycle 5. A total of five patients were enrolled in this cohort; one patient enrolled in the trial but did not send in any blood pressures despite daily reminders to both her and her support buddy. Only 2 additional buddy notifications were required in patients who did not send in a morning blood pressure reading and both times a subsequent blood pressure was sent. Two “snooze” requests were made over the course of the cycle by a single patient, who responded both times after the reminder.

Four of five patients in this cohort sent at least one blood pressure text on post-discharge day 1 or 2 (80%). Three patients (60%) also sent in at least one blood pressure on day 5, 6, or 7.

There were no significantly elevated blood pressures sent to the physician responder and no medications were initiated.

**Post-Cycle Interviews**

Overall, patients reported satisfaction with the text messaging system in their post-cycle interviews. The convenience of the intervention was acknowledged by many, including one patient who commented that “this was a lot better than having to pay for the bus and waiting for hours in some waiting room.” One patient also reported that the increased awareness was important, stating that “when [she] got home and realized that [her blood pressure] was still high, [she] did her own research and learned more about hypertension and preeclampsia.” Others reported that they still checked their blood pressure after the cycle, and “would have went longer than a week if they had asked me to.”

**DISCUSSION**

Our results suggest that remote blood pressure monitoring via text message communication engages patients and shows promise as a convenient and effective means of hypertension surveillance in the immediate postpartum period, in accordance to ACOG guidelines. Additionally, we were able to test this monitoring system using inexpensive, rapid-cycle validation techniques. Although these techniques are insufficiently controlled and of inadequate statistical power for definitive results, they were able to provide quick evidence toward a pragmatic and workable solution to an important clinical problem within the specific clinical context of our practice, though the results are likely to generalize to other settings. We found varied compliance based on the different engagement strategies, and although no single cycle proved superior, overall patient participation was good and provides a basis for different texting options in future work. Developing a method that both engages patients and is streamlined for providers is critical to our ability to translate this recommendation into practice. Although we did not specifically test how the system works from a provider’s point of view, the study obstetricians believe that this would help and can be fit within the existing workflows of the practices at most institutions.

This rapid-cycle intervention study provides several additional lessons, as we were able to rapidly implement this on our unit and test several hypotheses related to patient engagement. Most patients found the text messaging system to be a convenient way to communicate with their obstetrician. Even when patients had prenatal care at other institutions and delivered at our hospital without a prior patient/physician relationship (n = 5), we were able to engage them in text messaging. However, there was some evidence of patient drop out over the course of the week, as patients were more likely to text in...
blood pressure in the first few days of the cycle than the last few days (Figure 2).

Other telemedicine interventions have been studied in maternity care and have had inconsistent results. The Cochrane review on telephone support for women during pregnancy and up to 6 weeks after birth found that interventions were mainly aimed at smoking cessation, breastfeeding continuation, preterm birth, and postpartum depression [19]. To date, none of the randomized trials in pregnancy or the postpartum period have focused on postpartum hypertension. The results of our interventions are encouraging and support the use of text messaging in obstetrical care, particularly in the postpartum period. While text messaging cannot provide all the information that can be obtained in a doctor's visit, such as physical exam, urine dipsticks, and review of symptoms, it can identify the minority of patients that may need to be seen in the office based on the severity of their blood pressures.

While some cases of postpartum preeclampsia occur in the absence of peripartum disease, most readmitted patients are diagnosed with preeclampsia prior to delivery and readmission is due to worsening or persistence of disease and therefore, potentially preventable. These patients are the primary target of our intervention, as remote hypertension surveillance provides an opportunity to start or adjust medications and minimize both patient inconvenience and hospital cost of a readmission.

However, our feasibility study has some limitations. Despite overall patient satisfaction, acceptability, and compliance with text message monitoring of hypertension, the small sample size and qualitative nature of our cycles merits further pursuit and follow-up studies prior to implementation. Overall, we had only a small number of elevated blood pressures requiring intervention; however, this underscores the need to identify patients most at risk for persistent or delayed hypertension and the importance of developing a method of follow-up that engages all patients. Additionally, as patients were asked to both text in blood pressure values and also present for office visits, and therefore acted as their own control, it is not surprising that more patients were compliant with the simple texting method than standard of care; however, even when comparing texting compliance to historical attendance in our clinic of only 30%, our results remain promising.

While our results are encouraging, we believe it is important to test text messaging surveillance and patient compliance in a larger trial prior to implementing within the broader community. This study provides critical data to support the development of a HIPAA-compliant, automated monitoring system that can provide timely responses to patient texts using a provider derived response to blood pressure values. Future work includes the development of an automated hypertension tool as well as a randomized controlled trial to more rigorously compare office blood pressure visits to remote text message surveillance. If effective, use of text messaging technology may allow for an improved patient partnership and more robust follow-up data, especially in patients with less than optimal compliance, as well as the ability to improve maternal care and decrease morbidity and mortality.

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