BMJ Open Quality

Rapid implementation of blood pressure self-monitoring in pregnancy at a UK NHS Trust during the COVID-19 pandemic: a quality improvement evaluation

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To cite: Lavallee L, Roman C, Brace E, *et al*. Rapid implementation of blood pressure self-monitoring in pregnancy at a UK NHS Trust during the COVID-19 pandemic: a quality improvement evaluation. *BMJ Open Quality* 2024;**13**:e002383. doi:10.1136/bmjoq-2023-002383

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjoq-2023-002383).

Received 18 April 2023
Accepted 13 May 2024

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ABSTRACT

Background This service evaluation describes the rapid implementation of self-monitoring of blood pressure (SMBP) into maternity care at a tertiary referral centre during the COVID-19 pandemic. It summarises findings, identifies knowledge gaps and provides recommendations for further research and practice.

Intervention Pregnant and postpartum women monitored their blood pressure (BP) at home, with instructions on actions to take if their BP exceeded pre-determined thresholds. Some also conducted proteinuria self-testing.

Data collection and analysis Maternity records, app data and staff feedback were used in interim evaluations to assess process effectiveness and guide adjustments, employing a Plan-Do-Study-Act and root cause analysis approach.

Results Between March 2020 and August 2021, a total of 605 women agreed to self-monitor their BP, including 10 women with limited English. 491 registered for telemonitoring (81.2%). 21 (3.5%) took part in urine self-testing. Engagement was high and increased over time with no safety issues. Biggest concerns related to monitor supply and postnatal monitoring. In December 2020, SMBP was integrated into the standard maternity care pathway.

Conclusions This project demonstrated successful integration of SMBP into maternity care. Early stakeholder engagement and clear guidance were crucial and community midwifery support essential. Supplying BP monitors throughout pregnancy and post partum could improve the service and fully digitised maternity records would aid data collection. More research is needed on SMBP in the postnatal period and among non-English speakers. These findings support efforts to implement app-supported self-monitoring and guide future research.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The use of home blood pressure (BP) monitoring in pregnancy has become increasingly common, with a growing evidence base suggesting it can empower women and streamline care. With the onset of COVID-19 pandemic, home BP monitoring acquired new importance within maternity services with its potential to facilitate virtual consultations and therefore limit transmission of the virus.

WHAT THIS STUDY ADDS

⇒ This quality improvement project demonstrates how home BP monitoring, using digital app technology, was successfully integrated into standard maternity care at a large English NHS Trust during the pandemic.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings of this report can be used to support efforts to embed app-supported home BP monitoring within other maternity settings and to guide future research efforts.

INTRODUCTION

Problem

In April 2020, in response to the COVID-19 pandemic and the need to limit in-person consultations,[1 2] the Royal College of Obstetricians and Gynaecologists (RCOG) issued national guidance endorsing self-monitoring of blood pressure (SMBP) in pregnancy and post partum.[3] This initiative was supported by NHS England and NHS Improvement (NHSE/I) who provided 16 000 blood pressure (BP) monitors to NHS maternity providers to distribute free of charge.[4] This paper describes the implementation of SMBP within maternity services at Oxford University Hospitals NHS Foundation Trust (OUH), a large teaching Trust located in South-Central England.

Available knowledge

Hypertensive diseases in pregnancy (HDP) affecting 5–10% of pregnancies in the UK[5] are a significant cause of morbidity and

mortality requiring close observation during pregnancy and post partum.[5]

Home BP monitoring, or self-monitoring (SMBP), is well established within the general hypertensive population[6] and has garnered increasing interest within maternity services. Previous research found that around 20% of pregnant women and half of hypertensive pregnant women in the UK self-monitored,[7] and most UK obstetricians consider SMBP relevant to the management of pregnancy hypertension, particularly since COVID-19.[8]

SMBP has been proven safe, feasible and acceptable to both pregnant women and clinicians, potentially empowering women in their care.[9–13] A pilot study found SMBP facilitated self-titration of BP medication post partum.[14] Recent randomised controlled trials found SMBP made no difference to the timing of hypertension diagnosis, or its control during pregnancy; however, the participants with hypertension reported high home readings prior to diagnosis, suggesting SMBP could expedite care.[12 13] Further research is needed to maximise SMBP benefits.

With the arrival of COVID-19, burgeoning interest in SMBP acquired a new urgency, leading to its rapid implementation within maternity services and an opportunity to undertake real-world analysis.

Rationale and specific aims

At OUH, SMBP was implemented as a quality improvement project (QIP), with interim evaluations and data analysis to assess effectiveness and inform adjustments. This report aims to evaluate processes and outcomes, identify barriers and facilitators and address knowledge gaps to facilitate the uptake and sustainability of SMBP within other maternity services.

METHODS

Context

OUH is a large teaching Trust which oversees more than 7500 births per year.[15] From March 2020, in response to the COVID-19 pandemic, SMBP was phased in to reduce outpatient attendances for women requiring more frequent BP monitoring during pregnancy while providing an additional safety net. A standard operating procedure was developed following RCOG recommendations[3] based on the BUMP 1 and 2 (*Blood Pressure Monitoring in High-Risk Pregnancy to Improve the Detection and Monitoring of Hypertension*) trial designs.[12 13]

Theoretical framework

The project followed the *Plan-Do-Study-Act* (PDSA) model[16] to continually assess and adapt. This involved setting goals and methods, implementing and recording the process, evaluating effectiveness and refining the intervention for standard practice. This cyclical approach was effective in responding to evolving pandemic-related changes in maternity services. Details of each phase are provided in the following sections, with some narrative overlap reflecting the iterative nature of the project.

The PDSA model incorporated *root cause analysis*[17] to identify and address the underlying issues. This involved defining problems, collecting data, identifying causal factors and root causes and implementing solutions where possible.[17] Pandemic constraints meant this had to be rapidly conducted as issues arose, with limited opportunities for formal reflection. However, retrospectively exploring the process provides insight into how a robust SMBP service could be sustained over the longer term.

Objectives (Plan phase of the PDSA cycle)

Primary objective—to safely minimise in-person consultations during the pandemic for women at risk of complications related to hypertension in pregnancy.

Secondary objective—to explore the feasibility of embedding SMBP into standard maternity care beyond the pandemic.

Intervention and strategies for implementation

Eligibility (Plan phase)

The service was offered to pregnant women diagnosed with hypertension and those at 'high risk' for hypertension[3] (online supplemental appendix A). Physicians could also include, at their discretion, women with raised uterine artery Doppler measurements, or two or more 'moderate risk factors' for HDP as per National Institute for Health and Care Excellence guidelines[18] and postpartum women. Women requiring admission under Trust guidelines (eg, severe hypertension or pre-eclampsia with adverse features) were excluded. Individual risk assessments were conducted among those with limited English to determine their capacity to self-monitor independently, and to interpret and communicate results in English.

Enrolment (Do phase of PDSA cycle)

Initially, eligible women received BP monitors and urine testing strips during hospital antenatal appointments. By January 2021, community midwives took on the responsibility for determining eligibility and supplying monitors. Inpatient ward staff could also enrol eligible women upon discharge. A research midwife and two obstetric registrars (LL, AC and SD) registered women on the BUMP+ system (a remote monitoring digital platform) to enable access to the App.

Self-monitoring (Do phase)

Women were supplied with a semiautomated (Cradle VSA[19]) or automated (Microlife WatchBP Home A[20]) home BP monitor and a cuff sized according to their arm measurements. The Microlife monitors—validated for use in pregnancy and pre-eclampsia[19 20]—were loaned and later donated to the Trust by the sponsors of the BUMP 1 and 2 trials. Some women had their own BP monitors which midwives ensured were correctly validated and appropriately sized.

Urine testing strips for proteinuria self-testing were provided at the obstetrician's discretion (vs a prescribed protocol). Women were asked to test their urine on

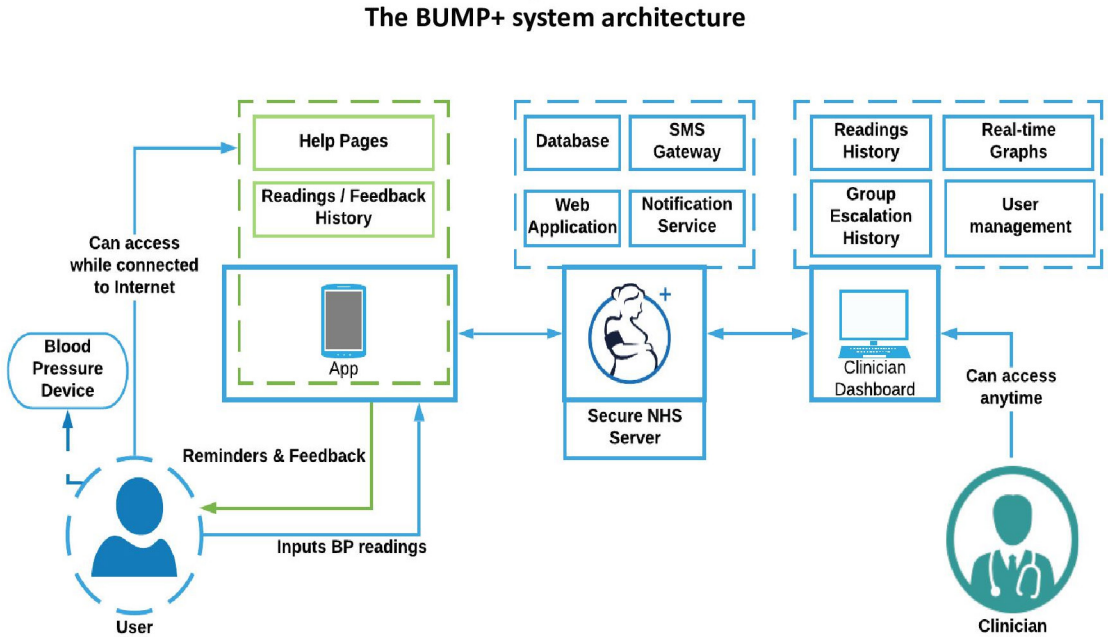

Figure 1 Summary of the BUMP+ app system architecture. BP, blood pressure.

the morning of their virtual appointments with results discussed during consultations.

A clinical team member demonstrated use of the BP monitor and urine testing strips supplemented by written and visual instructions. Women in group 2 (normotensive) were asked to take two BP readings, at least 1 min apart, three times a week and on the morning of any clinic appointments. Those in group 1 (hypertensive) were asked to monitor daily.

Before the mobile phone application (subsequently referred to as 'the app') was introduced, women recorded their readings in a paper diary which they shared with clinicians during consultations. The women received written instructions on actions to take if their BP crossed prespecified thresholds according to RCOG guidelines (online supplemental appendices B and C).

Mobile phone application (Do phase)

The app (initially called the BUMP system) was originally developed for the BUMP 1 and 2 research trials.[12 13] In July 2020, it was updated by the research team to create the BUMP+ app[21] in response to COVID-19 (figure 1).

The app enabled women to digitally record their BP readings which were automatically sent to the secure NHS server, and to receive feedback. It included rule-based algorithms based on threshold BP tables (online supplemental appendices B and C) which processed the BP readings and sent a message indicating: (1) the BP level, (2) the participant's next action and (3) the suggested frequency of BP readings (online supplemental appendix D and C provides further details).

Obstetricians could remotely view submitted readings through a secure website, but not in real time. Training emphasised that women should seek advice from a healthcare professional if prompted by the app feedback or written guidance.

Incorporation of self-monitoring into virtual follow-up (Do phase)

Throughout the pandemic lockdowns, in-person appointments for BP monitoring were often replaced with telephone or video consultations. These appointments supplemented rather than replaced routine antenatal care for women needing additional BP surveillance.

Evaluating the intervention (Study phase)

Measures and analysis

Progress was evaluated in a continuous and iterative fashion using the following indicators:

For the primary objective we compared the number of in-person consultations before and after implementing SMBP and assessed safety outcomes via:

- *Ongoing informal evaluation.* The reduction of in-person consultations was evident in real time as remote consultations alongside SMBP were incorporated. Safety was monitored on a case-by-case basis, with obstetricians determining appointment frequency and type. Any safety concerns were promptly addressed by the clinical team (Study/Act phases).
- *Interim service evaluation involving a medical notes review.* In December 2020, an interim analysis compared remote and in-person antenatal consultations for women who used SMBP and gave birth between March 2020 and August 2021, including Day Assessment Unit (DAU) attendances for BP surveillance.
- *Pregnancy outcomes and demographic data.* Simple descriptive statistics of pregnancy outcomes and demographic data of SMBP users who gave birth by August 2021 provided additional insight into safety and participant characteristics. However, for confidentiality reasons

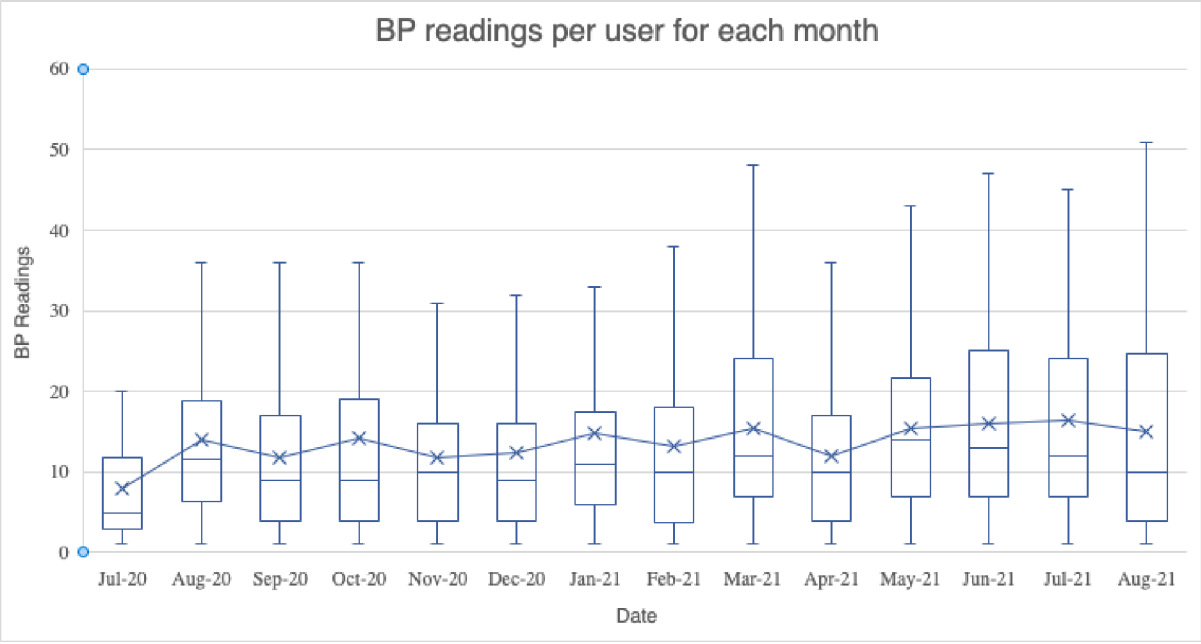

Figure 2 Box plots (median, IQR) of the number of blood pressure (BP) readings submitted per user and per month, between July 2020 and August 2021. SMBP, self-monitoring of blood pressure.

these details are not presented here. This manuscript focuses rather on sharing knowledge gained and lessons learnt while implementing SMBP, particularly regarding sustainability, rather than examining the intervention's benefits and risks.

For the secondary objective we sought to evaluate the acceptability of the intervention to service users and care providers and identify any sustainability issues via:

- *Service user and clinician feedback.* Continuous feedback on SMBP's acceptability was collected informally from both service users and clinicians. Regular meetings were held between those overseeing the service and representatives from various clinical areas to assess progress, evaluate BP, monitor stocks and resolve any challenges (Study/Act phases). Initially biweekly, these meetings became less frequent as SMBP became established. User feedback was also compiled through qualitative interviews for a broader national evaluation, published separately.[22]
- *Intervention fidelity data.* Insight into SMBP's acceptability was also gained from intervention fidelity data, collected during the interim service evaluation for those enrolled on the app (figure 2). While we aimed for high engagement we did not set a specific fidelity rate due to the circumstances surrounding the intervention.
- *Gap analysis.* In March 2021, a gap analysis involving nine community midwifery teams was conducted to address SMBP-related queries and identify concerns. Key findings were summarised and disseminated to the teams for validation before implementing recommended actions (Study/Act phases).

This service evaluation encompasses results from the gap analysis, interim service evaluation, DAU attendances and data on pregnancy outcomes and app usage from March 2020 to August 2021, all presented under the Revised Standards for Quality Improvement Reporting Excellence framework.[23]

RESULTS

Enrolment

Between 17 March 2020 and 31 August 2021, a total of 605 women consented to SMBP—377 women with hypertension (group 1) and 228 women at higher risk of developing hypertension (group 2). 21 women were additionally provided with urine testing strips.

App usage

The BUMP+ app was introduced in July 2020, and up to 31 August 2021, a total of 391 women with a confirmed delivery date had been registered on the BUMP+ system. This included 52 women who began self-monitoring prior to the app's introduction and subsequently switched from paper diaries to the app. An additional 114 women used paper diaries only to record their readings.

Of the 391 women using the app, 85% (n=333) were active users—meaning they submitted at least one BP reading per month. The mean number of readings per woman within this group was 45.8 (median 31, range 1–373).

Within the local guidelines, SMBP was reserved for antenatal use only, with individual exceptions made for postpartum women at the discretion of their obstetrician. However, a number of women continued to monitor their BP following birth. According to the data retrieved from the BUMP+ system:

- 95% (n=333) of the women submitting more than one reading per month did so in the antenatal period.
- 4% (n=14) commenced monitoring in the postpartum period only.
- 23% of women (n=78) submitted both antenatal and postnatal BP readings.

Of the 78 women who submitted readings both before and after birth, 28 continued monitoring for over 21 days post partum, while 15 submitted readings for more than 50 days.

The most common times for submitting readings were morning and evening, with the majority of women measuring their BP at approximately 22:00 hours.

On average, women commenced self-monitoring around 25 weeks' gestation (median 25.3 weeks, mean 25.6 weeks). The mean length of gestation was 38 weeks (median 39 weeks, range 25.3–42.1 weeks).

Intervention fidelity

The total number of monthly readings submitted to the BUMP+ system via the app increased over time (figure 2) as did the number of users.

28% (n=110) of women did not receive any 'overdue' reminders, 72% (n=281) received at least one 'overdue' reminder. Of these, 62% (n=173) received at least two 'overdue' reminders.

10 women with limited English were registered on the BUMP+ system, seven of whom submitted BP readings as requested. Three did not submit any readings; however, they were followed up by their clinicians.

Pregnancy outcomes

27% of the women (n=105) developed raised BP (≥140 mm Hg) prompting their transfer from group 2 to group 1 where they increased their home monitoring to daily readings.

17% (n=105) of women had a diagnosis of pre-eclampsia documented at delivery.

Consultations

In December 2020, an interim service evaluation involving maternity notes review of 290 women who had given birth showed that the majority of antenatal consultations taking place were in person (n=1112 vs 605 tele/video).

DAU attendances for BP review following SMBP adoption showed an overall decline between March and November 2020 compared with the preceding 2 months (ranging from 8 per month before pandemic to 0 per month during pandemic), with the exception of June when UK COVID-19 restrictions were initially eased (eight attendances).

Sustainability (Act phase)

Initially, the SMBP service was managed by hospital-based antenatal clinics with assistance from staff experienced in SMBP clinical trials. However, as the service expanded it became challenging to centrally track the monitors. Responsibility for this task shifted to community midwifery teams, each equipped with a supply of monitors. Eligible women received monitors from their community midwives and returned them at the final postnatal visit. Some women had their own monitors which midwives were responsible for ensuring were correctly validated. The high-risk antenatal clinic and inpatient wards also maintained a supply of monitors for women who might not see community midwives.

To facilitate enrolment on the app and maintenance of a central database, all referrals were initially sent to a secure email account then later the electronic patient record system, with ongoing communication maintained by the secure email account.

In December 2020, SMBP, supported by the app and the BUMP+ system, was embedded in the trusts' standard maternity care pathway.

Contextual elements that interacted with the intervention and unexpected consequences

Feedback from the gap analysis in March 2021 was generally positive but highlighted some key issues hindering the service. Obstetricians sometimes instructed women to see their midwives as frequently, contrary to SMBP guidelines, which created extra work for the midwives (SMBP was meant to replace additional BP monitoring checks, not routine antenatal care).

Some midwives were uncertain about postnatal SMBP eligibility criteria and some mistakenly believed the app data were routinely monitored by clinicians. Each community midwifery team therefore designated an SMBP champion to oversee the service within their team, answer any questions that might arise and ensure the guidelines were being followed correctly.

Urine self-testing was initially part of the service, but its use declined over time. No new testing strips were procured after the initial stock ran out, as they were often surplus to requirements and costly. Consequently, community midwives sometimes had to conduct urine testing themselves, undermining the self-monitoring objective.

The main challenge has been maintaining a consistent supply of BP monitors, particularly those with large cuffs. Initially the Trust received 300 monitors from NHSE/I, plus a further 100 from the BUMP trial. Another 100 monitors were purchased in March 2021, after the decision was made to embed SMBP permanently, but retrieving the monitors proved time consuming and resulted in temporary service suspensions. Some women purchased monitors themselves, but not all could afford them with prices starting at £40.00.[24] Collecting the monitors on discharge helped increase availability but stock issues persist.

The community midwives' feedback informed updates to the SMBP guideline, which were disseminated to relevant staff along with reminders and additional resources via email.

Data quality

Accessing complete clinical data was challenging due to the use of both digital and handheld maternity records,

compounded by pandemic restrictions limiting access to handheld notes. This impacted data collection and analysis capabilities; however, the introduction of the app streamlined SMBP data collection and fidelity assessment. While birth outcome data and most of the maternal demographic data were complete, it is not presented here due to ethical considerations.

DISCUSSION

Key findings

In April 2020, OUH Trust rapidly implemented SMBP following RCOG pandemic guidance backed by strong institutional support and extensive BP monitor procurement. The BUMP+ app and clinician web interface facilitated BP data recording and transmission, fostering patient engagement, including among non-English-speaking women. The PDSA model allowed for continuous evaluation and adaptation amid the pandemic supported by regular meetings and service evaluations for real-time problem resolution. Delegating responsibility to community midwives enhanced intervention management and tailored support for women. No adverse safety events were linked to the intervention, and embedding SMBP into the Trust's maternity care pathway in December 2020 marked a significant step towards long-term sustainability.

Challenges during implementation included: obstetricians deviating from SMBP guidelines, midwives lacking access to BP readings on the BUMP+ website, confusion over postnatal SMBP, misconceptions about clinician monitoring of BUMP+ data, limited urine self-testing and difficulty managing monitors centrally. Responsibility shifted to midwifery teams, improving distribution but sometimes increasing workload. The biggest ongoing challenge was maintaining a consistent supply of BP monitors, particularly those with large cuffs, resulting in occasional service suspensions. Some women purchased their own monitors leading to disparities in service provision.

Root cause analysis (figure 3) reveals several sources of difficulties, including the speed of implementation, access issues, policy and training gaps, communication issues and logistical challenges. These stemmed from the urgency of the pandemic, which necessitated a significant and rapid shift in established practice at a time when maternity services were under extreme pressure,[3] and exacerbated supply management and integration and access issues. Cultural and language considerations also had to be addressed.

Actions were taken to address the challenges: training protocols were enhanced, communication channels strengthened, resource allocation improved and processes were streamlined to alleviate the burden on community midwives. These measures enhanced SMBP implementation and overcame initial obstacles. Continued efforts will ensure its long-term sustainability.

Implications for practice and future research

Considering challenges in monitor retrieval, lack of postnatal SMBP and increased long-term hypertension rates, a case exists for allowing women to permanently keep monitors. Retrieving monitors is time consuming

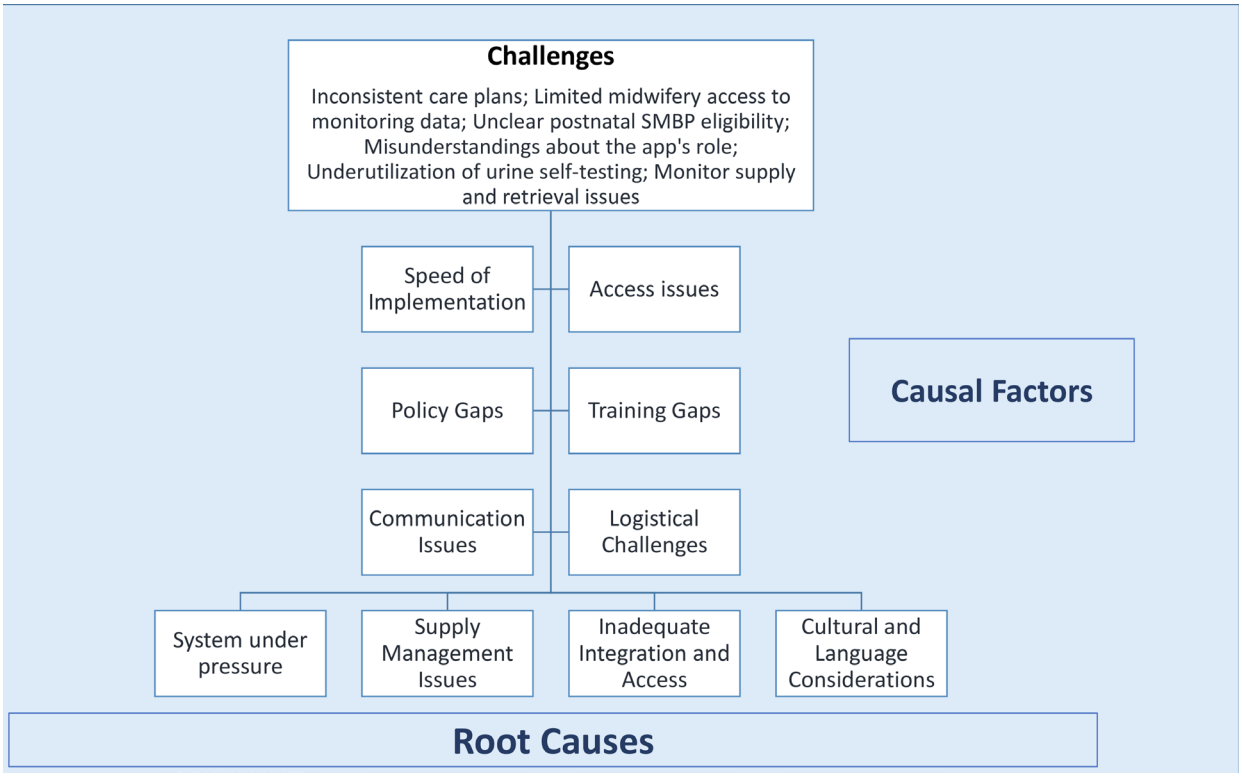

Figure 3 Analysis of the causal factors and root causes of challenges encountered during implementation of self-monitoring of blood pressure (SMBP).

and often fruitless, and evidence supports SMBP's cost-effectiveness.[25 26] The monitors purchased by the Trust ranged from £23.99 to £40.00 each (excluding value-added tax), while an antenatal check in the community costs £51 and a postnatal visit £62.23. If SMBP avoids one face-to-face visit, it offsets the monitor cost. Budgeting for monitors 'on prescription' could optimise resource use and ensure equitable SMBP access.

There is no physiological rationale for hypertensive women stopping SMBP upon birth; evidence supports ongoing monitoring. Postnatal hypertension can persist, or worsen,[5 27] sometimes requiring hospital readmission.[28] Studies indicate high rates of nocturnal and masked hypertension 6–12 weeks post partum in women with pre-eclampsia,[29] suggesting persistent hypertension may go undetected. HDP is also a significant risk factor for future cardiovascular disease,[5] and emerging evidence suggests the degree to which BP is controlled post partum influences longer term BP regulation.[13 30]

More research is needed to guide the use of SMBP in non-English-speaking women. While SMBP acceptability has been studied among various ethnic groups in the general population,[31] evidence specific to non-English speakers is lacking.[9–13] Women with limited English are at higher risk of poor pregnancy outcomes[32] and could benefit substantially from SMBP. This project demonstrates that with adequate support, these women can undertake SMBP effectively, but further evidence-based guidance is needed.

Urine self-testing kits could enhance SMBP benefits. Research shows women can accurately screen for proteinuria,[33] and urine self-testing combined with SMBP could reduce clinic visits, offering greater choice, convenience and efficiency while alleviating maternity service pressures.

Community midwife support was key to successful implementation of the service and their ongoing support is crucial to future sustainability. However, without access to the women's app readings, the full benefits of the service from a midwifery perspective could go unrealised and undermine this support over time.

Community midwives now manage logistical aspects previously handled by obstetricians and a research midwife, ensuring sustainability and efficient resource use. Alternatively, maternity support workers could oversee aspects of the service. Providing community midwives access to the BP readings website would enhance their engagement, achieved through a single user login per team. Future integration of the app with electronic patient records could improve efficiency and accessibility to relevant clinicians.

The original BUMP system was developed for research purposes and updated to a viable clinical solution by the research team in response to the pandemic circumstances. Long-term provision requires support from the Trust's software development and information technology teams or transfer to a commercial option.

Limitations and barriers

The COVID-19 pandemic expedited SMBP adoption at OUH leveraging existing familiarity with the intervention gained via participation in SMBP related trials. Direct support from those already familiar with the intervention also facilitated this process. For maternity care providers lacking similar experience and support, SMBP implementation could prove more challenging.

Our findings may also be less applicable across more ethnically diverse populations, particularly those with a higher proportion of non-English-speaking women.

The urgency with which SMBP had to be implemented, and the use of both paper and electronic maternity records at the Trust, made data collection and analysis difficult. Estimating SMBP's full impact on hospital and clinic attendances was consequently challenging. Centralising referrals to a secure email account enhanced database accuracy while involving a data manager and introducing the BUMP+ system improved data collection. However, fully digitised maternity notes and standardised SMBP documentation methods from the outset would have streamlined the process.

SUMMARY

The purpose of this QIP was to safely minimise in-person consultations while maintaining essential surveillance of women at risk of HDP-related complications at the height of the COVID-19 pandemic. A PDSA approach enabled ongoing assessment and iterative adjustments to be made in support of this objective. Strong institutional support, national guidance and a large supply of BP monitors facilitated successful implementation, with high engagement and safety observed. Challenges included deviations from guidelines, limited access to SMBP readings for midwives and confusion over postnatal use. Maintaining a consistent supply of BP monitors, particularly those with large cuffs, was the biggest challenge, and allowing women to keep monitors permanently could address this. Further research is needed to support SMBP use in women with limited English and explore urine self-testing alongside SMBP. Transitioning to fully digitised maternity records would facilitate data collection. Overall, this project highlights the successful integration of SMBP into maternity care amid the pandemic, with valuable lessons learnt for sustainability and future improvement.

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Acknowledgements The authors thank all the women and maternity staff who have participated in this quality improvement project and contributed to its evaluation. We particularly thank Jane Membury, Beth Albert, Emma Rigby, Cheryl Kergray and Beatrice Culligan who were instrumental in developing and implementing the service, and James Bland for his invaluable assistance with data collection.

Contributors LM and AC conceived the project and secured the equipment funding. EB and LL carried out the gap analysis. LL and CR conducted data collection and carried out the analysis. LL wrote the first draft of the manuscript with significant input from CR. The manuscript was subsequently edited and approved by all coauthors, with LL doing the majority of revision. All authors have read, provided critical revision and approved the final version of the manuscript. LL is guarantor for this manuscript.

Funding This work was supported by the NIHR Oxford and Thames Valley Applied Research Collaboration through its Theme 2 (self-management) workstream. LL, doctoral research fellow (NIHR302993), is funded by the NIHR for part of this research project. CR is supported by the Oxford NIHR Biomedical Research Centre.

Disclaimer The views expressed in this publication are those of the author(s) and not necessarily those of the NIHR, NHS or the UK Department of Health and Social Care.

Competing interests RJM has received BP monitors for research from Omron and has worked with them to develop a telemonitoring system for which consultancy and licensing payments are received by the University of Oxford. RJM is an NIHR senior investigator. LT is supported by the NIHR Oxford Biomedical Research Centre and is a part-time employee and shareholder in Sensyne Health. LM is supported by the NIHR Oxford Biomedical Research Centre and is a part-time employee of EMIS Group. CR reports consultancy fees from Sensyne Health.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval SMBP was registered as a quality improvement project with OUH's clinical governance team (reference 20/03/2020-SUWON-Mackillop) permitting data collection and feedback analysis without formal ethics approval. For confidentiality and informed consent reasons, participant demographics and birth outcomes are omitted from this manuscript.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available.

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