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SAFE@HOME: Cost analysis of a new care pathway including a digital health platform for women at increased risk of preeclampsia

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A B S T R A C T

Objective: To perform a cost analysis of the use of a new care pathway with a digital health platform for blood pressure telemonitoring for women at risk of preeclampsia.

Study design: This is a cost analysis of a case-control study with women with chronic hypertension, history of preeclampsia, maternal cardiac or kidney disease at intake of pregnancy. Antenatal care with a reduced visit schedule and a digital health platform (SAFE@HOME, n = 97) was compared to a retrospective control group (n = 133) with usual care without self-monitoring.

Main outcome measures: Costs per pregnancy (€) of healthcare consumption of antenatal clinic visits, ultrasound assessments, antenatal admissions, laboratory and other diagnostic tests, and societal costs such as traveling and work absence.

Results: Baseline characteristics and perinatal outcomes were similar between both groups. A significant reduction of antenatal visits, ultrasounds and hypertension-related admissions was associated with use of the digital platform. In the SAFE@HOME group, costs of antenatal care, including the costs of the digital platform, were 19.7% lower compared to the control group (median €3616 [IQR 3071 – 5329] vs €4504 [IQR 3515–6923], p = 0.001). Total costs per pregnancy, including societal costs, were also reduced (€7485 [IQR 6338–10,173] vs €9150, [IQR 7546–12,286] p < 0.001). Each euro invested in the platform saved on average €8 of antenatal care resources.

Conclusion: The use of a digital platform for blood pressure and symptom monitoring in antenatal care for high-risk women is associated with lower costs compared to conventional care, while observed maternal and neonatal outcomes are similar.

1. Introduction

Up to 10% of pregnancies is complicated by hypertensive disorders, and this proportion continues to rise [1]. Hypertensive disorders of pregnancy (HDP), including gestational hypertension and preeclampsia, are important causes of maternal and perinatal morbidity and mortality, and require intensified surveillance with frequent monitoring [2]. During repeated antenatal visits, maternal as well as fetal condition are checked to detect onset or progression of hypertensive disease. These planned and emergency visits as well as hospital admissions pose a substantial burden to perinatal care resources [3].

Remote monitoring in addition to antenatal visits has potential to achieve higher-value care for women at high risk for hypertension [4]. Moreover, self-monitoring of blood pressure in pregnancy is increasingly accepted as an alternative to frequent clinic visits [5,6]. Therefore, we developed a digital health platform that allows for repeated blood pressure measurements in combination with preeclampsia symptom reporting during pregnancy [7]. Obstetric care professionals in-clinic monitor these self-measurements and anticipate on values exceeding set thresholds. Together with a predefined antenatal visit schedule from 16 weeks gestational age onwards, this platform was integrated in antenatal care for patients at increased risk of development of preeclampsia.

While patient outcomes and experiences are the primary focus of evaluation of any new intervention, economic impact is also important to allow widespread adoption. Therefore, in this study we performed a cost analysis of use of a digital health platform and new-developed visit schedule in antenatal care for women at risk of hypertensive complications, compared to traditional care without remote monitoring. We used data of healthcare consumption from the SAFE@HOME study, a case-control study of the digital health strategy, to compare direct healthcare costs as well as societal costs of antenatal care.

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2. Methods

2.1. Study design

In the SAFE@HOME study, a prospective group of pregnant women at risk of preeclampsia used a digital health platform facilitating a novel care pathway. This group was compared with a retrospectively selected group of women managed with traditional monitoring. Methods and results are described in detail elsewhere [8].

2.2. Population

Pregnant women with a singleton pregnancy were included if they presented for antenatal care with a new pregnancy in our university hospital (secondary and tertiary level obstetric care) with one of the following risk factors for preeclampsia: chronic hypertension, preeclampsia in a prior pregnancy, or concurrent maternal cardiac or kidney disease.

The prospective group of women (SAFE@HOME group) consisted of women who presented with one of the four risk factors and, after written consent, used the platform in antenatal care. Other inclusion criteria were maternal age > 18 years, access to a smartphone/tablet with Internet and knowledge of Dutch or English language. Exclusion criteria were kidney transplant and arm circumference > 42 cm, due to technical requirements of the monitor.

For the retrospectively selected control group, a database search was conducted to add women who received perinatal care in our centre for one the four mentioned risk factors at start of pregnancy. Those who delivered between 1 and 1-2015 and 31–12-2016 were included. Patients younger than 18 years and kidney transplants were excluded. Antenatal care in the control group was traditionally managed based on the Dutch guideline on hypertensive disorders of pregnancy, but without use of home blood pressure monitoring or a fixed antenatal visit scheme [9].

2.3. Intervention

The intervention combined a digital health platform with a predefined (reduced) antenatal visit schedule. The digital health platform includes an app (Luscii, Focuscura, The Netherlands) and the iHealth Track automated blood pressure monitor, validated in a pregnant population [10]. Use of the platform for blood pressure measurements and symptom reporting was found feasible in our hospital setting prior to study start [7]. After informed consent, participants started telemonitoring from 16 weeks of gestation to delivery date, uploading a single blood pressure on Monday-Friday before 10 AM. In case of hypertension (BP > 140/>90 mmHg) participants would answer an in-app symptom list with 10 yes/no questions regarding hypertension and pregnancy. Values exceeding set thresholds were visible as alerts for the telemonitoring team of our department, who reviewed the alerts at 10.30 AM. If needed, management was discussed with the consulting obstetrician to further inform or instruct participants at home or ask them to visit the hospital for additional observation or follow-up. All alerts in the dashboard had to be switched off manually after review.

Alongside the use of the platform, a multidisciplinary team of obstetricians, internists (cardiologists and nephrologists) and patients predefined a uniform antenatal visit schedule, including structure of the scheduled visits and ultrasound assessments (Fig. 1). This new SAFE@HOME care-pathway, including access to the home-measurements, was embedded in our outpatient department with general visits being performed by hospital-based midwives, gynaecologists in training and supervising obstetricians.

2.4. Data collection

2.4.1. Baseline and outcome characteristics

Patient records were used for data collection on baseline characteristics and maternal and fetal/neonatal outcomes of pregnancy and delivery in both groups. Hypertensive disorders of pregnancy were defined according to criteria of the International Society for the Study of Hypertension in Pregnancy [11]. Healthcare consumption of hospital visits, fetal ultrasound assessments, blood/urine analysis, use of medication and all admissions were extracted from the hospital system of participants.

2.4.2. Cost analysis

This cost analysis used the results of healthcare consumption from one university hospital (2500 deliveries annually, both secondary and tertiary care) that participated in the SAFE@HOME study. Costs were analysed from the perspective of direct healthcare costs, as well as from a societal perspective taking into account work absence and travel costs of study participants and companioning partners. Timeframe of our cost analysis was restricted to antenatal care from the first visit until the admission of delivery, excluding delivery and postpartum care.

For the direct healthcare cost comparison, all procedures regarding antenatal care were obtained from the electronic health records and categorised. The category of outpatient visits included scheduled and unscheduled visits, not followed by hospital admission and performed by hospital midwives or gynaecologist (in training). The ultrasound category included appointments for viability scan and nuchal scan in first trimester, anomaly scan(s) and fetal biometry scans. Number and length of antenatal admissions were also recorded, including reason for admission. The category "Other healthcare costs" included numbers and costs of each individual order for blood and/or urinary analysis, followed by the total costs of all tests performed. Additionally, other diagnostics (such as MRI in pregnancy) were recorded. The last subcategory involved usage of allied health services such as physiotherapists or dieticians. Dutch national tariffs and the Netherlands Healthcare Institute costing manual were used to assign costs to corresponding procedures [12,13]. All costs were converted to 2018 Euros using consumer price indices of Statistics Netherlands. Procedures and costs related to the delivery, postpartum admission and cost of

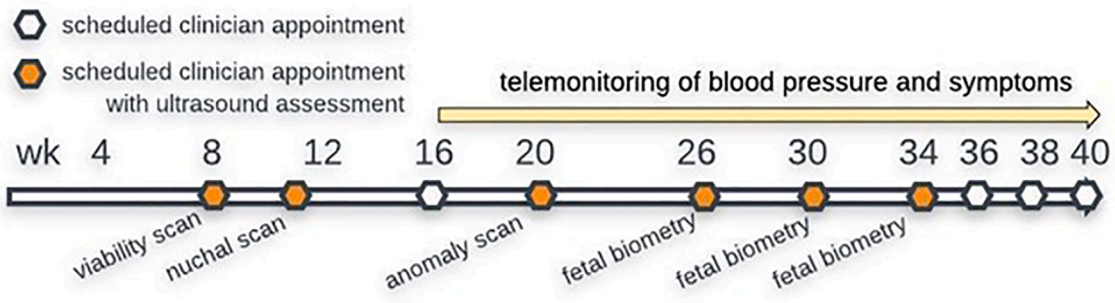

Fig. 1. Predefined antenatal visit schedule as part of the intervention for patients at risk for of development of preeclampsia.

medication use were not included since the scope of this cost analysis was restricted to antenatal care.

Costs associated with the digital health platform were calculated based on time invested by healthcare staff for monitoring purposes, device cost and subscription cost.

For the analysis involving societal costs, data on productivity of study participants and partners were calculated according to Netherlands Healthcare Institute guidelines and were based on figures available from Statistics Netherlands [14]. For travel costs it was assumed that patients lived, on average, 36 km from University Medical Center Utrecht [15]. In the calculations it was assumed that each ultrasound appointment or laboratory test took place on the same day as an outpatient visit or during an admission. For each outpatient visit the participants missed 4 h of work and the partner accompanied the participant with each visit. Maternity leave was not taken into account in these calculations. Since pregnant women have a large degree of freedom when to start leave, no accurate estimation was possible on this matter.

2.5. Statistical analysis

Costing data were summarized as medians with interquartile ranges (IQR), for subtotals and totals. For totals, means are also provided. Statistical significance was determined using Mann-Whitney U tests. Categorical outcome variables with counts and percentages were compared between groups using the chi-square or Fisher's exact test. $P < 0.05$ was considered statistically significant. Statistical analysis was performed with IBM SPSS version 25.

3. Results

In the SAFE@HOME group of the cost analysis, 97 women were prospectively followed during antenatal care with the digital health platform. The control group consisted of 133 women. Demographics including risk factors for hypertensive complications as reason for inclusion are summarized in Table 1. In the telemonitoring group, significantly less women with a history of preeclampsia (19.6 vs 33.1% in usual care, $p = 0.023$) and more women with kidney disease (17.5 vs 4.5%, $p = 0.001$) were included. No differences were observed for age, BMI, ethnicity, education level and parity. History of hypertensive disorders and blood pressure at intake were also similar between groups.

3.1. Perinatal outcomes

Results of maternal and neonatal outcomes did not significantly differ between the two groups, as shown in Table 2 [8]. At time of delivery, incidence of hypertensive diagnoses was similar in both groups, i.e. preeclampsia incidence 19.6% in SAFE@HOME group vs 20.3% in control group ($p = 0.89$). Induction of labour was more common in the SAFE@HOME group. However, no significant differences were found for mode of delivery, gestational age and birth weight at delivery, as well as admission to the NICU.

3.2. Healthcare consumption

Use of the predefined visit schedule alongside remote monitoring of blood pressure was associated with less total antenatal visits compared to the control group (median 13 vs 16, $p < 0.001$) (Supplementary Table 1). Ultrasound assessments (median 6 vs 7, $p = 0.002$) and median number of antenatal admission days (median 4 vs 6, $p = 0.19$) were also lower in the SAFE@HOME group. No difference was found for number of tests of laboratory diagnostics.

3.3. Cost analysis

Table 3 shows the costs associated with use of antenatal care services. In the SAFE@HOME group, a significant cost reduction for direct health care costs of 19.7% or €888 (€3616 vs 4504, $p = 0.001$) was found. This reduction of costs is mainly attributed to the reduction of antenatal visits and antenatal admission days (Supplementary Table 1). Also, a reduction of costs was achieved as more visits were carried out by hospital midwives instead of gynaecologists (in training), as prescribed by the visit schedule. In the analysis 115 euros was taken into account per participant for use of the digital platform and in-clinic monitoring, based on our calculations. For each euro associated with costs of the digital platform, an average of €7.7 was saved for antenatal care resources.

In the additional analysis, costs from a societal perspective were added to direct health care costs. Both travel costs (€245 vs. €280, $p < 0.001$) and loss of productivity costs (€3565 vs €4329, $p < 0.001$) were lower for the SAFE@HOME group.

Combined cost calculations of antenatal care resulted in total savings in healthcare costs and societal costs of 18.2% or €1665 (€7485 vs €9150, $p < 0.001$).

Table 1
Baseline characteristics of the before and after group.

		Telemonitoring (after) n = 97	Usual care (before) n = 133	
Age (years)	mean (SD)	33.8 (4.5)	33.11 (4.7)	0.229
Body mass index (kg/m^2)	mean (SD)	25.3 (4.6)	26.5 (5.8)	0.086
Ethnicity	n (%)			
Caucasian		76 (78.4)	97 (72.9)	0.347
Moroccan / Turkish		14 (14.4)	24 (18.0)	0.466
Afro –Caribbean		4 (4.1)	6 (4.5)	0.887
Other / unknown		3 (3.1)	6 (4.5)	0.584
Education	n (%)			
Primary school or less		3 (3.1)	2 (1.5)	0.652
High school or less		9 (9.3)	5 (3.8)	0.084
Secondary vocational school		35 (36.1)	44 (33.1)	0.636
Higher professional education		26 (26.8)	48 (36.1)	0.137
University graduate		24 (24.7)	34 (25.6)	0.887
Nulliparity	n (%)	30 (30.9)	36 (27.1)	0.523
Smoker	n (%)	2 (2.1)	6 (4.6)	0.472
Psychiatric disorder during pregnancy	n (%)	5 (5.3)	8 (6.3)	0.756
Prior HDP	n (%)	35 (36.1)	68 (51.1)	0.056
Systolic BP at intake (mmHg)	mean (SD)	120 (16.9)	122 (17.8)	0.282
Diastolic BP intake (mmHg)	mean (SD)	74 (12.5)	75 (12.8)	0.417
Risk factor at start of pregnancy	n (%)			
Prior preeclampsia		19 (19.6)	44 (33.1)	0.023
Chronic hypertension		26 (26.8)	45 (33.8)	0.254
Cardiac disease *		35 (36.1)	38 (28.6)	0.227
Kidney disease §		17 (17.5)	6 (4.5)	0.001
Start of telemonitoring	Weeks	17.9 (3.9)	–	–
Duration of telemonitoring	Weeks	20.2 (4.0)	–	–

*e.g. maternal congenital heart disease, arrhythmias, valvular heart disease, aortopathy.
§e.g. (obstetric) antiphospholipid syndrome, systemic lupus erythematosus, chronic kidney disease
(*BP, blood pressure; GA, gestational age; HDP, hypertensive disorder of pregnancy*).

Table 2
Pregnancy outcomes.

		Telemonitoring (after) n = 97	Usual care (before) n = 133	p
Final maternal diagnosis of HDP in current pregnancy	n (%)			
Gestational hypertension		7 (7.2)	4 (3.0)	0.210
Preeclampsia		19 (19.6)	27 (20.3)	0.894
HELLP		1 (1.0)	0 (0.00	0.422
Chronic hypertension without superimposed PE		22 (22.7)	26 (19.5)	0.564
NO HDP (normotensive)		48 (49.5)	76 (57.1)	0.250
Suspected fetal growth restriction	n (%)	12 (12.4)	13 (9.8)	0.532
Steroids administration	n (%)	15 (15.5)	10 (7.5)	0.056
iv magnesium sulphate	n (%)	9 (9.3)	12 (9.0)	0.947
Use of anti-hypertensive drugs < 20 w GA	n (%)	37 (38.1)	41 (30.8)	0.247
Use of antihypertensive drugs > 20 w GA	n (%)	53 (54.6)	58 (43.6)	0.098
iv antihypertensive drugs ante partum	n (%)	4 (4.1)	9 (6.8)	0.391
Iv antihypertensive drugs post partum	n (%)	6 (6.2)	4 (3.0)	0.392
Mode of delivery				
Induction of labour	n (%)	54 (55.7)	51 (38.3)	0.009
because of hypertension	n (%)	29 (53.7)	28 (54.9)	0.902
Primary caesarean section	n (%)	23 (23.7)	34 (25.6)	0.748
because of hypertension	n (%)	6 (26.1)	12 (35.3)	0.463
Vaginal delivery	n (%)	56 (57.7)	72 (54.1)	0.588
Instrumental delivery	n (%)	9 (9.3)	6 (4.5%)	0.148
Secondary caesarean section	n (%)	9 (9.3)	21 (15.8)	0.148
Fetal/neonatal outcome				
GA at delivery (weeks)	mean (SD)	38.3 (2.1)	38.8 (2.3)	0.167
Preterm birth < 37 + 0	mean (SD)	13 (13.4)	20 (15.0)	0.727
Birth weight (grams)	mean (SD)	3069 (6 5 0)	3203 (6 9 4)	0.137
Birth weight < 5th percentile	n (%)	5 (5.2)	12 (9.0)	0.268
APGAR < 7 at 5 min	n (%)	3 (3.1)	7 (5.3)	0.525
NICU admission	n (%)	2 (2.1)	6 (4.5)	0.473
Antepartum fetal death	n (%)	1 (0)	0 (0)	0.422

(GA, gestational age; HDP hypertensive disorder of pregnancy; PE, preeclampsia).

4. Discussion

4.1. Main findings

In the SAFE@HOME study, antenatal care with use of a digital health platform and predefined visit schedule was compared to traditional monitoring of women at increased risk of hypertensive complications in pregnancy. In the SAFE@HOME group, a reduction was found in antenatal visits, ultrasound assessments and antenatal hypertension-related admission, compared to the control group. This study found no differences with regards to (adverse) perinatal outcomes between the two groups.

Results of the cost analysis showed a significant cost reduction for costs of antenatal care services; €3616 in the SAFE@HOME group compared to €4504 in conventional care, median cost difference €888, p = 0.001. This result accounted for a 19.7% cost reduction. When comparing means of total healthcare costs, a difference was found of € 1338 or 18.7% (€5805 vs €7143). Reduction of costs was primarily related to a reduction in clinic visits and a shift of type of obstetric care professionals that performed these visits. Moreover, a shorter length of antenatal hospital admissions was found in the SAFE@HOME group. When adding costs of travelling and work absence (societal costs), costs decreased from €9150 in usual care to €7485 with use of the digital platform (median cost difference €1665 or 18.2%, p < 0.001) (*mean* cost difference €2174).

4.2. Comparison with the literature

Several cost studies of home- or self-monitoring of blood pressure in the hypertensive pregnant population have been performed recently [16–18]. In our study, telemonitoring was started before 20 weeks of gestation. In contrast, participants in the published studies started remote monitoring later in pregnancy, when hypertensive complications occurred, meaning at time of diagnosis of hypertension. In these studies, self-monitoring of blood pressure also resulted in cost savings, mostly achieved by a reduction in hospital visits and antenatal admissions as compared to conventional surveillance. For example, Xydopoulos et al. found a saving of EUR 226–323 per patient per week of home monitoring after diagnosis of hypertension with their results of a case-control study [18]. In the cost-modeling study of Barton et al, outpatient management of patients with gestational hypertension was found cost-effective as the need for inpatient care decreased [16]. Only one study used in-clinic monitoring of patients' home measurements [17].

The use of our digital platform was associated with a reduction of health care consumption and thus with a total reduction of costs. These reductions are consistent with recent studies of remote pregnancy monitoring in different settings (i.e. start of home-monitoring at diagnosis of hypertension in pregnancy) [19,20]. Therefore, blood pressure and symptom monitoring with help of a digital platform is likely to be a cost-saving approach to antenatal care.

4.3. Strengths and limitations

Strength of this study is the direct data extraction of healthcare consumption from electronic patient files of our study center. These data allowed a factual, real life comparison of direct healthcare costs between groups. For the costs associated with use of the digital health platform, a precise calculation was made based on acquisition of blood pressure monitors, subscription fees of the dashboard and time spent by obstetric care professionals in the telemonitoring team for daily monitoring of abnormal values. Addition of these costs to the direct healthcare costs of the telemonitoring participants allowed a complete interpretation of differences between groups. We compared groups of women with risk factors for (development of) preeclampsia at intake, and therefore we were able to compute costs of full antenatal care up to delivery. The results of the cost analysis therefore reflect clinical practice of antenatal follow-up in this risk group, which aids the applicability and generalizability for similar health care settings. Finally, a major strength of this study is the addition of societal costs of travelling and productivity loss due to complete follow-up to the analysis. These results extend the overview of costs associated with care for pregnant women at risk of hypertensive complications.

There are several limitations to the study. The retrospective nature of the control group might have caused substantial selection bias. The two groups were similar regarding to all baseline characteristics, however more women with pre-existent kidney disease, and less women with a history of preeclampsia were included in the SAFE@HOME group. Furthermore, women with arm circumference over 42 were excluded for participation in this group. These differences may have influenced the results of pregnancy outcomes and therefore healthcare consumption and costs. In general, cost analyses are made with calculations based on assumptions of costs for Dutch healthcare, which could hamper extrapolation of results to other countries or settings. Our analysis was

Table 3
Costs of antenatal care.

	Telemonitoring (after) n = 97		Usual care (before) n = 133		Diffe-rence	p-value
Antenatal visits	€ 1862	[1522–2198]	€ 2202	[1826–2627]	€ 340	0,000
Obstetrician (in training)	€ 1530	[1190–1870]	€ 2040	[1275–2380]	€ 510	0,000
Midwife	€ 324	[203–486]	€ 243	[81–689]	- € 81	0,026
Ultrasound assessments	€ 508	[423–592]	€ 592	[508–761]	€ 85	0,002
Antenatal admissions						
All patients - total	€ 0	[0–1336]	€ 0	[0–2672]	€ 0	0,202
Admitted patients only:						
All indications	€ 2672	[1336–6680]	€ 4008	[1336–12,692]	€ 1336	0,415
For PE/HT until delivery	€ 0	[0–6012]	€ 0	[0–1336]	€ 0	0,238
For PE/HT for observation only	€ 0	[0–0]	€ 0	[0–1336]	€ 0	0,007
Other Healthcare Costs						
Laboratory	€ 306	[199–411]	€ 297	[203–420]	- € 9	0,692
Other diagnostics	€ 0	[0–93]	€ 0	[0–46]	€ 0	0,255
Other healthcare costs	€ 0	[0–0]	€ 75	[0–121]	€ 75	0,000
Telemonitoring	€ 115	[115–115]	€ 0	[0–0]	- € 115	0,000
Total healthcare costs, median	€ 3616	[3071–5329]	€ 4504	[3515–6923]	€ 888	0,001
* Total healthcare costs, mean	€ 5805		€ 7143		€ 1338	
Travel costs	€ 245	[192–280]	€ 280	[245–325]	€ 35	0,000
Productivity loss	€ 3565	[2915–4374]	€ 4329	[3565–5093]	€ 764	0,000
TOTAL COSTS -median	€ 7485	[6338–10,173]	€ 9150	[7546–12,286]	€ 1665	0,000
* Total costs- mean	€ 9874		€ 12,048		€ 2174	

All data are euros expressed as medians [interquartile ranges] except for rows indicating means of Total costs for healthcare and Total costs, marked with an *. (PE, preeclampsia; HT, hypertension).

restricted to antenatal care costs. As there were no significant differences in perinatal outcomes between groups, especially with regards to mode of delivery and neonatal outcome, it is legitimate to provide an overview of costs of antenatal care only [18].

4.4. Interpretation and further research

The use of mobile-health technology to assist antenatal care has been suggested before for its advantages regarding access to care, enhanced satisfaction and reduction of health care consumption [4,21,22,23]. However, to implement eHealth-enhanced strategies in antenatal care, a deliberate approach is needed before widespread implementation. Alongside evaluation of effects of telemonitoring on perinatal outcome and patient satisfaction, economic evaluations are needed to determine the added value of digital health strategies.

Cost analysis as performed in this study is of interest to both health care providers, pregnant women and other stakeholders in the process of decision-making in the future of healthcare. For decisions on funding and adoption, governments on national, European and global levels will need health technology assessments [24]. Using the much-needed results of the economic effects of digital health interventions, the advantages to healthcare can be put in perspective to enable further research and implementation [25]. Moreover, an increase of availability of data on outcome and cost effects must help overcome present issues regarding reimbursement and coverage of digital care services.

5. Conclusion

Use of the new visit schedule using the digital health platform of SAFE@HOME is associated with lower costs of antenatal care for women at increased risk of preeclampsia. Furthermore, total costs, including societal costs, were also significantly reduced, compared to traditional follow-up in high-risk pregnancy. In our sample, similar maternal and neonatal outcomes were found. Each euro associated with costs of the digital platform, saved almost €8 on average on antenatal care resources. Digital health interventions for monitoring of (risk of) hypertension in pregnancy are promising tools to achieve higher-value antenatal care.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

None.

Contribution to authorship

JFH, CL, GF and MNB designed the study. JFH and MNB were responsible for the acquisition and interpretation of the data. JFH, CL, AF and MNB drafted the manuscript. All authors edited and revised the manuscript. All authors have read and approved the final version of the manuscript.

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Details of ethics approval

This study was submitted to the Medical Ethics Committee of the University Medical Center in Utrecht (17/424). The committee judged that the Dutch Medical Research Involving Human Subjects Act (WMO) did not apply to this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.preghy.2021.03.004.

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