Technology and Health Care 31 (2023) 1105–1117
DOI 10.3233/THC-220700
IOS Press

Application of remote fetal heart rate monitoring via internet in late pregnancy during the COVID-19 pandemic

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Received 29 October 2022
Accepted 26 February 2023

Abstract.
BACKGROUND: Internet-related technologies have rapidly developed and started to impact the traditional medical practices, which combined wireless communication technology as well as "cloud service" technology with electronic fetal heart monitoring have become a mainstream tendency.
OBJECTIVE: To investigate the clinical application value of remote fetal heart rate monitoring mode (RFHRM) on late pregnancy during the coronavirus disease (COVID-19) pandemic.
METHODS: From March 2021 to February 2022, we recruited 800 cases of pregnant women received prenatal examination at the Anhui Province Maternity and Child Healthcare Hospital. These pregnant women were randomly divided into two groups: the control group ($n = 400$), which was given traditional management, and the observation group ($n = 400$), which received remote monitoring technology on this basis. The two groups were compared with neonatal asphyxia, pregnancy outcomes, Edinburgh postnatal depression scale scores (EPDS), prenatal examination expenses and total time consumption.
RESULTS: There were no statistically significant differences between the groups in pregnancy outcome and neonatal outcome ($P > 0.05$). However, total EPDS score of 12.5% pregnant women in the observation group were higher than 12. The TPE group had significantly higher mean EPDS scores compared with the RFHRM group (7.79 ± 3.58 vs 5.10 ± 3.07; $P < 0.05$). The results showed a significant difference in maternity expenses (2949.83 ± 456.07 vs 2455.37 ± 506.67; $P < 0.05$) and total time consumption (42.81 ± 7.60 vs 20.43 ± 4.16; $P < 0.05$) between the groups.
CONCLUSION: Remote fetal heart rate monitoring via internet served as an innovative, acceptable, safe and effective reduced-frequency prenatal examination model without affecting the outcome of perinatology of pregnant women with different risk factors.

Keywords: COVID-19, prenatal examination, late trimester of pregnancy, fetal monitoring, remote monitoring technology, perinatal outcome

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1. Introduction

The rapid spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2, COVID-19) resulted in thousands of mortalities worldwide each day. Although the COVID-19 virus shares some similarities with the SARS-CoV and the MERS-CoV infection, it is clearly more transmissible [1]. According to the latest guidelines from the World Health Organization (WHO), there are three principal transmission routes for the COVID-19 virus in humans, namely direct contact, aerosol, and droplets [2]. Furthermore, when a person touches the surfaces contaminated with the virus, SARS-CoV-2 is transmitted, too [3]. The risk of viral transmission is higher in the case of short contact with a symptomatic person than with a no-symptomatic person [4]. As a susceptible population for COVID-19, pregnant women are more likely to develop complications and even progress to severe disease. Besides, tremendous stress (e.g., health crises and natural disasters) can rise pre-natal stress and cause pregnant women particularly vulnerable [5,6]. According to the essay by Salari et al., female during the pandemic is at heightened risk of developing depression, anxiety and stress. In addition, the quarantine makes it hard to interact with friends and family [7,8], hospital visitation restrictions and fear of the possibility of intrauterine transmission of COVID-19 to the fetus give more influence to the mental health of mothers-to-be [9,10]. Current studies demonstrated that neonates from COVID-19-infected mothers are tested positive for SARS-CoV-2 soon after delivery and evidence of SARS-CoV-2 has been detected in the placenta of COVID-19 positive mothers [11,12]. However, the results of many studies on the mother-to-child transmission of SARS-CoV-2 are uncertain; Vertical SARS-CoV-2 transmission from mother to neonates is possible but scarce [13,14]. During the COVID-19 pandemic, how to enable pregnant women to receive necessary maternity check-up without exposure to crowded public places is of great importance for health care prevention and control during the late pregnancy.

In the 21st century, Internet plus medical treatment is a new stage and inevitable trend of medical development. The quick adoption of telemedicine during the COVID-19 pandemic has also seen a surge in consumer demand for technologies to support treatment from home [15]. As a novel prenatal examination, remote fetal heart monitoring cannot be limited by time and space, greatly decreasing the risk of external infection of pregnant women over the COVID-19 global pandemic. The popularity of electronic fetal heart monitoring system is highly valued for early detection of fetal abnormalities and prevention of fetal damage. As an important tool for monitoring intrauterine conditions and placental reserve capacity, fetal heart monitoring is widely used in clinical practice during late pregnancy and has contribute to reduce the incidence of adverse pregnancy outcomes [16]. Internet-related technologies have rapidly developed and started to impact the traditional medical practices, which combined wireless communication technology as well as "cloud service" technology with electronic fetal heart monitoring have become a mainstream tendency.

This study mainly discussed the clinical value of remote fetal heart rate monitoring via Internet (RFHRM) in late pregnancy during the COVID-19 epidemic. The purpose of the present study is to construct a novel and reliable Internet based in-home health management system to reduce the risk of outpatient infection of pregnant women over the COVID-19 global pandemic.

2. Materials and methods

2.1. Subjects

Inclusion criteria: Pregnant women received prenatal examination from the obstetric clinic of Anhui Province Maternity and Child Healthcare Hospital during the COVID-19 pandemic on March 2021 to

February 2022. High-risk pregnant women enrolled at 32 weeks or low-risk pregnant women were enrolled after 34 weeks. The pregnant women should be aged between 18 and 45 years; meet the assessment criteria for low-risk or high-risk pregnant women; singleton pregnancy; and agreed to participate in this study and sign the informed consent form. Information related to clinical history such as age and gestational age was also collected.

This clinical observation was approved by the Institutional Ethics Committee of Anhui Province Maternity and Child Healthcare Hospital, and performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments. All selected pregnant women signed the informed consent form. Before the implementation of the study, the clinical trial was registered on www.chictr.org.cn (registration no. ChiCTR2100043971) on March 6, 2021.

Exclusion criteria: Confirmed with twin pregnancy; fetal malposition or fetal anomalies; diagnosed personality disorder, systemic diseases and critical illnesses that prevented them from completing monitoring; inability to use the monitoring system properly and automatic withdrawal woman during the study; and/or infectious diseases, blood diseases.

Grouping: A total of 800 pregnant women who received prenatal examination from March 2021 to February 2022 were randomly selected, including 365 pregnant women with high-risk and 435 pregnant women with low-risk. They were randomly divided into two groups by random number method. Control group received traditional prenatal examination model (TPE), meanwhile observation group applied remote fetal heart rate monitoring (RFHRM). Among them, control group included 188 high-risk and 212 low-risk pregnant women, while observation group included 177 high-risk and 223 low-risk pregnant women. There were no statistically significant differences ($P > 0.05$) between the two groups in terms of general information such as age, gestational age, gravidity, parity, educational level, and high-risk factors, so that they possessed comparability.

2.2. Equipment and methods

TPE group counted fetal movements by themselves at home and went to hospital regularly for routine prenatal examination. The results of the traditional fetal heart rate monitoring are printed by the medical staff in the fetal heart rate monitoring system in hospital. In RFHRM group, pregnant women received an ultrasonic Doppler Electronic Fetal Monitoring (EFM) instrument (model: eFM-30) for fetal heart monitoring, and online guidance and questions and answers (Q&A). RFHRM group used the "Ten months baby remote EFM system" (produced by Laikangning Technology Co., Ltd. Shenzhen, China) rented by the hospital for monitoring. Pregnant women used this system to monitor themselves at home, and transmitted the measured data signals to the system's tag-end server "cloud platform" through APP in smartphone. Then the tag-end server interpreted the monitoring results by auto intelligent (AI), and timely sent messages to notify the medical staff to review the data. Subsequently, the server resent the doctor's diagnosis to the pregnant woman's cell phone via short message service (SMS). If there were any abnormalities, Q&A would have been given to pregnant women in time. RFHRM group required pregnant women to monitor (including remote fetal heart rate monitoring, blood pressure, blood glucose and weight) $\geqslant 2$ times per week, and the APP would report the results and provide internet consultation guidance immediately.

2.3. Monitoring items and methods

2.3.1. Fetal movement and fetal heart monitoring

Abnormal fetal movement: the number of fetal movement < 10 times/2 h or 50% increase or decrease compared with the previous 3 h is abnormal.

Abnormal fetal heart rate: fetal heart rate $>$ 160 beats/min or $<$ 110 beats/min. Non-stress test (NST) abnormalities: (1) baseline abnormalities, fetal heart rate $>$ 160 beats/min or $<$ 110 beats/min. (2) Baseline variability abnormalities: baseline variability 6–25 beats/min is normal variability, amplitude fluctuations disappear as variability absence, $<$ 5 beats/min is minor variability, $>$ 25 beats/min is significant variability. (3) Moderate to severe variability deceleration: There is no fixed relationship between deceleration and contractions, baseline rate increases, amplitude decrease increases, fetal heart rate deceleration $>$ 60 beats/min, duration $>$ 60 s. (4) Acceleration abnormality: 20 min $<$ 1 acceleration more than 15 beats/min, duration 15 s [17].

Monitoring method: RFHRM group monitored 3 times with 20 min each time in every morning, noon and night, at a fixed time. Pregnant women were required to empty their bladder when performing fetal heart monitoring, avoid monitoring after exercise, avoid fasting and starvation, half an hour after meal and take the left side lying position is preferred. If pregnant women feel abnormal fetal movement or other discomfort (such as panic, poor breathing, etc.), the monitoring time should be extended. When abnormal results of fetal heart rate and fetal movement are found, they need to contact the hospital and perform fetal umbilical artery blood flow monitoring and ultrasound examination in time to observe and treat the abnormal condition.

2.3.2. Blood pressure

Hypertension in pregnancy: inclusion and exclusion criteria for out-of-hospital blood pressure monitoring during pregnancy: (1) Inclusion criteria: Refer to the Guidelines for Self-monitoring of Blood Pressure in pregnancy issued by the Royal Society of Obstetricians and Gynaecologists (RCOG) in 2020. (2) Exclusion criteria: Required hospitalized pregnant women such as severe hypertension and pre-eclampsia [18].

(1) Systolic blood pressure (SBP) $\geqq$ 140 mmHg and/or diastolic blood pressure (DBP) $\geqq$ 90 mmHg, or blood pressure is elevated $\geqq$ 25/15 mmHg compared with pre-pregnancy or early pregnancy, and blood pressure is measured at least twice, 6 hours apart. Severe pre-eclampsia blood pressure is SBP $\geqq$ 160 mmHg and/or DBP $\geqq$ 110 mmHg. (2) Dynamic 24 h mean systolic blood pressure (24 h SBP) $\geqq$ 130 and/or 24 h mean diastolic blood pressure (24 h DBP) $\geqq$ 80 mmHg, day-time mean systolic blood pressure (dSBP) $\geqq$ 135 and/or day-time mean diastolic blood pressure (dDBP) $\geqq$ 85 mmHg, night-time means systolic blood pressure (nSBP) $\geqq$ 120 and/or night-time mean diastolic blood pressure (nDBP) $\geqq$ 70 mmHg [19].

Blood pressure monitoring method [20]: In RFHRM group, pregnant women used sphygmomanometer at home and tied the sphygmomanometer sleeve to the brachial artery 2–3 cm over the elbow joint of the left upper arm, then recorded the systolic and diastolic blood pressure values in the morning, midday and evening respectively. Among the pregnant women with gestational hypertension, the blood pressure values were measured during 24 hours on a fixed day of the week, and the time period during the day and night were 6:00–22:00 and 22:00–6:00 respectively. All measurement results were input into the "cloud platform". Among them, the diastolic blood pressure less than 40 mmHg and the systolic blood pressure higher than 220 mmHg were invalid, while the measured data higher than 80% of the total value were valid. The background server analyzed the blood pressure in time, sent the data to the medical staff for review, and given the pregnant women online guidance and answer questions in time if there were any abnormality.

2.3.3. Blood glucose

Gestational diabetes mellitus (GDM): (1) Oral glucose tolerance test (OGTT), glucose values of fasting plasma glucose (FPG), 1 h and 2 h after taken 75 g glucose should be less than 5.1, 10.0, and 8.5 mmol/L (92, 180, and 153 mg/dl) respectively. (2) Fasting plasma glucose (FPG) $\geqq$ 5.1 mmol/L,

directly diagnosed as GDM, without OGTT results; FPG $<$ 4.4 mmol/L (80 mg/dl), the possibility of GDM is very small, without OGTT; FPG $\geqq$ 4.4 mmol/L and $<$ 5.1 mmol/L, further OGTT testing was recommended. (3) Glycated hemoglobin HbA1c $\geqq$ 6.5% [21,22].

Monitoring method: Pregnant women in this study were required to monitor FPG once a week at a fixed time; among them, the pregnant women with GDM monitored blood glucose at seven time points: FPG, 2 h after breakfast, 2 h before lunch, 2 h after lunch, 2 h before dinner, 2 h after dinner and before bedtime at a fixed time respectively each week. If abnormal blood glucose levels were found, the online consultation and possible treatment would be contacted.

2.3.4. Weight

For women with normal pre-pregnancy Body Mass Index (BMI) (18.5$\sim$24.9 kg/m^2), the average weight gain during pregnancy is 12.5 kg in singleton pregnancies, but the rate of weight gain varies during different periods of pregnancy. In 2009, the Institute of Medicine (IOM) recommended that the range of gestational weight gain (GWG) during pregnancy is determined to according the pre-pregnancy BMI of the pregnant woman. The IOM recommended that the appropriate range of GWG should be 12.5$\sim$18 kg, 11.5$\sim$16 kg, 7$\sim$11.5 kg or 5$\sim$9 kg, the corresponding pre-pregnancy BMI respectively should be less than 18.5 kg/m^2, 18.5$\sim$24.9 kg/m^2, 25.0$\sim$29.9 kg/m^2 or more than 30.0 kg/m^2 [23].

Each group was required to record their weight at least twice a week, then calculate BMI and mark it in the weight management scale. Next, it was compared with the weight from the recommendation for pregnant women issued by IOM according to their pregnancy weeks, and the data was transferred to the "cloud platform". Finally, the back-end server would intelligently give corresponding nutritional guidance according to their weight and control the weight of pregnant women within a reasonable range.

2.3.5. Psychosomatic assessment standards

One week after delivery, the pregnant women in both groups were evaluated using the Edinburgh postnatal depression scale (EPDS). EPDS consists of 10 items scored, each with a 4-point scale (0–3), and is designed to select symptoms with postpartum depression. This study utilized a cut off point for depressive symptomatology risk of higher over 12. Anhedonia subscale (items 1 and 2); anxiety subscale (items 3–6); and depression subscale (items 7–10) are 3 subscales from the EPDS [24,25].

2.4. Pregnancy outcome analysis

The mode of delivery was compared between the two groups of pregnant women, including the rate of vaginal delivery, caesarean delivery, premature birth rate, and postpartum hemorrhage rate.

2.5. Neonatal outcome analysis

(1) Neonatal asphyxia: Apgar score was applied to assess the physical condition of neonates in both groups, including heart rate, muscle tone, respiration, skin colour, reflexes, movement and other items, with a score of 10 out of 10. The scores included 8–10 (normal), 4–7 (mild asphyxia), and 0–3 (severe asphyxia). (2) Weight: including low weight babies: new-borns weighing $<$ 2500 g at birth; huge babies: new-borns weighing 4000 g or more. (3) Preterm birth: those terminated at $>$ 28 weeks to $<$ 37 weeks gestation.

2.6. Statistical methods

All data were analysed by SPSS 22.0 software. Unless otherwise stated, t-tests or chi-square tests were employed to compare groups. Measurement data is expressed as x $\pm$ s, and t-test was used for

Table 1
Comparison of general characteristics between the groups

Characteristics	TPE	RFHRM	t	P-value
Number				
Total	400	400	–	–
Low-risk pregnancy	212	223	–	–
High-risk pregnancy	188	177	–	–
Age (y)				
Total	31.94	31.81	0.305	0.761
Low-risk pregnancy	27.01	27.40	−0.973	0.332
High-risk pregnancy	37.48	37.36	0.728	0.467
Height (cm)				
Total	160.05	160.19	−0.325	0.745
Low-risk pregnancy	160.12	160.05	0.126	0.899
High-risk pregnancy	159.96	160.36	−0.617	0.538
Weight (kg)				
Total	71.25	71.39	−0.258	0.796
Low-risk pregnancy	71.51	71.36	0.161	0.837
High-risk pregnancy	70.94	71.44	−0.567	0.571
Systolic pressure (mmHg)				
Total	120.10	121.11	−1.076	0.282
Low-risk pregnancy	118.52	118.16	0.320	0.749
High-risk pregnancy	121.86	124.81	−1.956	0.051
Diastolic pressure (mmHg)				
Total	79.48	79.23	0.332	0.740
Low-risk pregnancy	74.67	74.18	0.564	0.573
High-risk pregnancy	84.90	85.59	−0.762	0.446
Fasting plasma glucose (mmol/L)				
Total	4.74	4.73	0.219	0.827
Low-risk pregnancy	4.64	4.62	0.689	0.491
High-risk pregnancy	4.85	4.87	−0.373	0.709
Postprandial blood glucose (1 h, mmol/L)				
Total	7.69	7.87	−1.851	0.065
Low-risk pregnancy	7.65	7.76	−0.987	0.324
High-risk pregnancy	7.74	8.00	−1.667	0.096
Postprandial blood glucose (2 h, mmol/L)				
Total	6.72	6.72	0.025	0.980
Low-risk pregnancy	6.56	6.55	0.119	0.906
High-risk pregnancy	6.90	6.93	0.007	0.994
TSH (mIU/L)				
Total	1.60	1.63	−0.849	0.625
Low-risk pregnancy	1.53	1.59	−0.745	0.457
High-risk pregnancy	1.67	1.67	0.962	0.337
Cholylglycine (mg/L)				
Total	1.31	1.29	−0.530	0.596
Low-risk pregnancy	1.27	1.19	1.127	0.651
High-risk pregnancy	1.35	1.41	−0.474	0.636

Abbreviation: RFRHM, remote fetal heart rate monitoring; TPE, traditional prenatal examination. Note: There were no significant differences between the groups in general clinical characteristics ($P > 0.05$).

comparative analysis between groups; count data is expressed as rate (%), and χ^2 test was used for comparative analysis between groups. $P < 0.05$ was considered statistically significant.

3. Results

800 pregnant women with gestational ages $>$ 32 weeks were recruited at the Anhui Medical University

Table 2
Comparison of pregnancy outcome between the groups

Pregnancy outcome	TPE	RFHRM	χ^2	P-value
Gestational age (weeks)				
Total	39.10	38.99	0.906	0.365
Low-risk pregnancy	39.21	39.10	−1.007	0.315
High-risk pregnancy	38.97	38.85	0.592	0.554
Premature birth rate (%)				
Total	0.12 (46/400)	0.14 (56/400)	1.124	0.29
Low-risk pregnancy	0.08 (17/212)	0.10 (23/223)	0.686	0.41
High-risk pregnancy	0.15 (29/188)	0.19 (33/177)	0.670	0.41
Postpartum hemorrhage rate (%)				
Total	0.11 (44/400)	0.14 (56/400)	1.646	0.20
Low-risk pregnancy	0.08 (18/212)	0.09 (21/223)	0.114	0.74
High-risk pregnancy	0.14 (26/188)	0.18 (35/177)	2.314	0.13
Caesarean section rate (%)				
Total	0.38 (150/400)	0.44 (175/400)	3.239	0.07
Low-risk pregnancy	0.36 (76/212)	0.39 (88/223)	0.604	0.44
High-risk pregnancy	0.39 (74/188)	0.49 (87/177)	3.545	0.06

Note: There were no significant differences between the groups in the pregnancy outcome ($P > 0.05$).

Table 3
Comparison of neonatal outcome between the groups

Neonatal outcome	TPE	RFHRM	t/χ^2	P-value
Weight of new born (g)				
Total	3403.64	3403.82	−0.005	0.996
Low-risk pregnancy	3449.74	3424.46	0.549	0.583
High-risk pregnancy	3351.65	3377.80	−0.464	0.643
Apgar 1 min $<$ 7 min (%)				
Total	0.18 (72/400)	0.15 (60/400)	1.306	0.253
Low-risk pregnancy	0.15 (32/212)	0.13 (28/223)	0.589	0.443
High-risk pregnancy	0.21 (40/188)	0.18 (32/177)	0.589	0.443
Apgar 5 min $<$ 7 min (%)				
Total	0.13 (53/400)	0.13 (52/400)	0.011	0.917
Low-risk pregnancy	0.13 (27/212)	0.12 (28/223)	0.003	0.955
High-risk pregnancy	0.13 (26/188)	0.14 (24/177)	0.006	0.940

Note: There were no significant differences between the groups in the neonatal outcome ($P > 0.05$).

Affiliated Maternity and Child Healthcare Hospital (03/2021-02/2022). The subjects were randomly divided into TPE group ($n = 400$) and RFHRM group ($n = 400$). In RFHRM group the fetus was monitored remotely at home, while TPE group went to hospital for fetal heart monitoring. The general clinical characteristics of the groups, including maternal age, gravidity, parity, height, weight, blood pressure, fasting plasma glucose, postprandial glucose, thyroid gland function and cholylglycine showed no significant statistical differences by t-test ($P > 0.05$, Table 1). No matter in the low-risk group or in the high-risk group, there were no significant differences between the groups for all general clinical characteristics ($P > 0.05$, Table 1).

Maternal and pregnancy outcomes (mode of delivery, postpartum haemorrhage, etc.) did not differ significantly among the two groups ($P > 0.05$, Table 2). There was no statistically difference between low-risk group and the high-risk group in neonatal outcome (including neonatal birth weight, Apgar score at 1 min, Apgar score at 5 min $P > 0.05$, Table 3).

Table 4
Edinburgh postnatal depression scale between the groups

Scale	TPE	RFHRM	t/χ^2	P-value
EPDS total score				
Total	7.79 ± 3.58	5.10 ± 3.07	11.375	0.000
Low-risk pregnancy	7.87 ± 3.57	4.86 ± 3.10	9.441	0.000
High-risk pregnancy	7.69 ± 3.63	5.42 ± 3.01	6.483	0.000
EPDS subscale analysis				
Anhedonia				
Total	2.63 ± 1.54	1.78 ± 1.22	8.585	0.000
Low-risk pregnancy	2.59 ± 1.52	1.67 ± 1.12	7.212	0.000
High-risk pregnancy	2.67 ± 1.59	1.93 ± 1.34	4.858	0.000
Anxiety				
Total	2.63 ± 1.47	1.64 ± 1.22	10.308	0.001
Low-risk pregnancy	2.67 ± 1.48	1.59 ± 1.16	8.439	0.000
High-risk pregnancy	2.58 ± 1.48	1.71 ± 1.28	6.021	0.000
Depression				
Total	2.54 ± 1.74	1.68 ± 1.34	7.818	0.000
Low-risk pregnancy	2.63 ± 1.68	1.60 ± 1.44	6.822	0.000
High-risk pregnancy	2.44 ± 1.80	1.79 ± 1.20	4.127	0.000
EPDS global score > 12 (%)				
Total	0.13 (50/400)	0.05 (19/400)	15.242	0.00
Low-risk pregnancy	0.10 (21/212)	0.04 (8/223)	6.973	0.008
High-risk pregnancy	0.15 (29/188)	0.06 (11/177)	7.926	0.005

Abbreviation: EPDS, Edinburgh postnatal depression scale. Note: EPDS subscale analysis showed that mean scores for anhedonia, anxiety, and depression were all higher in the TPE group compared with the RFHRM group ($P < 0.05$).

Table 5
Comparison of prenatal examination expenses and total time consumption between the groups

	TPE	RFHRM	t	P-value
Prenatal examination expenses (RMB)				
Total	2949.83 ± 456.07	2455.37 ± 506.67	14.507	0.000
Low-risk pregnancy	2787.65 ± 404.37	2244.80 ± 439.28	13.390	0.000
High-risk pregnancy	3132.7 ± 442.57	2720.66 ± 460.01	8.721	0.000
Total time consumption (h)				
Total	42.81 ± 7.60	20.43 ± 4.16	51.610	0.000
Low-risk pregnancy	38.12 ± 7.27	17.66 ± 1.77	40.780	0.000
High-risk pregnancy	48.10 ± 3.29	23.93 ± 3.65	66.60	0.000

Note: There were statistically significant differences between the groups in prenatal examination expenses and total time consumption ($P < 0.05$).

Table 4 revealed the EPDS (including anhedonia, anxiety, and depression) scores collected from TPE group and RFHRM group. Compared with TPE group, mean EPDS scores were significantly lower in RFHRM group (5.10 ± 3.07 vs 7.79 ± 3.58; $P < 0.05$). The percentage of those cases with a total EPDS score above 12 was also significantly lower in RFHRM group compared with TPE group (4.75% vs 12.5%; $P < 0.05$). Furthermore, EPDS subscale analysis exhibited that the differences were significant in the groups for anhedonia (2.63 ± 1.54 vs 1.78 ± 1.22; $P < 0.05$), anxiety (1.64 ± 1.22 vs 2.63 ± 1.47; $P < 0.05$), and depression (1.68 ± 1.34 vs 2.54 ± 1.74; $P < 0.05$).

It is worth noting that there was a statistically significant difference in prenatal examination expenses (2949.83 ± 456.07 vs 2455.37 ± 506.67 RMB; $P < 0.05$) and total time consumption (42.81 ± 7.60 vs 20.43 ± 4.16 h; $P < 0.05$) between the groups (Table 5).

4. Discussion

As a persistent outbreak of the respiratory disease, currently, COVID-19 is the latest hazard to health across the world [26].ÂăIt was speedily indicated to be caused by a novel coronavirus that is closely associated with the virus that triggers severe acute respiratory syndrome (SARS). For other kinds of coronaviral infections, for example, the SARS-CoV-1 and Middle East respiratory syndrome (MERS) increased risks for adverse outcomes for the fetus and/or new-borns including miscarriages, preterm birth, fetal distress, and FGR with SARS-CoV-1 infection during the second and late trimesters [27,28]. Recent evidence indicates that COVID-19 might cause some severe complications in pregnant women, too [29–33]. Since the world continues to suffer from COVID-19, health care systems have immediately adapted to maintaining access to care while providing recommended social distancing. In the field of obstetric, postponing out-patient treatment probably a sensible choice if remote prenatal examination can rapidly gained popularity.

Prenatal fetal monitoring is a dynamic, real-time prenatal evaluation of fetal growth and health. It is an early warning method for fetal growth development and health status. We have seen a ray of hope within this public health emergency by implementing in-home health management system via Internet (HHI) in response to the COVID-19 pandemic. HHI is a quick and safe solution, maintaining quality of monitoring with low users' burden. The data that it collected are used in the cloud database to evaluate the patient's health, and the effects of all measures are stored. It has been shown that patient health monitoring is a reliable way to improve health effectively [34]. The new generation of RFHRM system consists of monitoring hardware, smart phone APP and the physician system (information analysis centre) [35]. The monitoring hardware is the attached CWFM1 micro fetal heart monitor, which is equipped with 9-chip medical Doppler ultrasound probe, and with a wide beam signal range and 1 MHz ultrasound frequency as well as Bluetooth, which can transmit digital signals to the APP in smartphone. It achieves that by clicking on the smart phone APP interface the information of fetal heart movement will be collected and uploaded simultaneously to save prenatal examination time and expense [36]. At the same time, it can monitor the intrauterine condition of fetal ischemia and hypoxia in real time and transmit the results to the hospital monitoring system. In case of an abnormal situation, it can obtain feedback from doctors and get diagnosis as well as treatment plans for timely treatment. Hospitals also perform continuous, systematic and complete file management to provide a full range of health management service for pregnant women.

Since the birth of the computer, with the continuous improvement of the computer performance, the volume of the continuous shrinking, the use of the continuous simplification, has now penetrated into almost all fields. Its application in the medical field has also made great progress, representing its development level is artificial intelligence (artificial intelligence, AI). Computer-assisted diagnosis and therapy has long been used in the field of obstetrics and gynecology: (1) Obstetric risk score and recommendations, such as the obstetric risk score of Nesbitt et al. [37]. (2) Application in fetal monitoring, such as the monitoring contractions system developed by Henry et al. [38]; the fetal distress monitoring system reported by Sokol et al. [39]; and the "Well-Baby" (baby safety) system designed by Pearlman [40]. (3) Gynecology, such as the gynecological disease diagnosis expert system developed by Small [41]. Generally speaking, with the increasing popularity of artificial intelligence, telemedicine service systems show great potential [42,43]. Online remote fetal cardiac monitoring technology has become a popular area for research in recent years. Gradually altering the conventional diagnosis paradigm, the focus has been applied to the field of prenatal diagnosis which can effectively break the "time" and "space" restrictions, so that patients can understand themselves and the health status of the fetus at any point, and reduce the number of pregnant women interlink and time, early diagnosis and detection of high-risk

pregnancy patients timely, and effective intervention to reduce the incidence of various adverse events and ensure maternal and infant safety complete. At the same time, the application of remote fetal heart rate monitoring can effectively alleviate the problem of the medical and health resources shortage during the COVID-19 pandemic, to reduce the burden of hospitals and health authorities. In addition, it can also limit the social mobility of patients and help to reduce the spread of the virus.

5. Conclusion

In this study, we analyzed whether there were differences in Maternal and pregnancy outcomes and neonatal outcome between the groups, and ascertained the safety of RFHRM in delivery during COVID-19. According to above statistical analysis, it was concluded that there were no differences between TPE group and RFHRM group in terms of pregnancy outcome and neonatal outcome, indicating that this new mode of prenatal examination is secure when applied in clinical practice. While the EPDS score, along with anhedonia, anxiety and depression subscale score were utilized to study psychological-emotional distress in mothers giving birth during the COVID-19 pandemic, we did not use specific criteria defined in the medical literature to confirm whether our sample had postpartum depression. Anyway, the results should not be invalid, because the general demographic variables were similar among each group. Moreover, 12.5% of mothers in TPE group had higher total EPDS scores over 12, which may lead to a higher risk of postpartum depression, and a deeper analysis of the three subscale highlights the additional value of EPDS and facilitates a more accurate assessment of the various negative psychological problems raised in pregnant women during the COVID-19 epidemic. The present findings indicated that risks of postnatal depression are higher in TPE group. Finally, it is vital to note that the total cost and time consumption of prenatal examinations were considerably reduced in RFHRM group.

In conclusion, both for pregnant women in low-risk and high-risk, RFHRM has the advantages for them, such as shortening waiting or medical treatment time, reducing the consumption of human and material resources, optimizing service quality, and providing timely consultation. Concerns about risk of exposure to COVIDâĂŘ19, combined with currently quarantine measures, will render more and more demand for RFHRM in daily prenatal examination. Hence, this study recommend pregnant woman to receive RFHRM service during the COVID-19 pandemic and guide them on how to monitor themselves at home. Admittedly, as an ideal and novel mode of prenatal examination, even though many of above advantages for RFHRM, it needs to be further defined in the specific context of security before it becomes useful. Moreover, the study sample is limited, geographically specific, so we cannot guarantee whether the observed results are completely accurate. We can only describe the outcomes based on the observed sample, and we cannot infer the clinically relevant outcomes of all maternal women behind the sample.Future studies are required to further validate the safety, effectiveness and generalization of RFHRM.

Author contributions

SGZ and WJC: conceptualization, methodology, funding acquisition, resources, supervision; QQJ, XYJ and RW: writing – original draft, investigation, formal analysis; BBW, JL and HY: software, investigation, formal analysis; YTY, WG and WYZ: data curation, supervision.

Funding

This work was supported by the Hefei Municipal Key Research Project of Novel Coronavirus Pneumonia Control and Prevention (Grant no. HWK2020zd008).

Conflict of interest

No potential conflict of interest was reported by the authors.

Data availability statement

The general information that supports the findings of this study are openly available in Figshare at https://doi.org/10.6084/m9.figshare.20678382.v1.

Supplementary data

The supplementary files are available to download from http://dx.doi.org/10.3233/THC-220700.

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