

# Monitoring intrapartum fetal heart rates by mothers in labour in two public hospitals: an initiative to improve maternal and neonatal healthcare in Liberia

**Korpo Borzie**

CB Dunbar Hospital

**Noah Jasper**

CH Rennie Hospital

**David Southall** (✉ [director@mcai.org.uk](mailto:director@mcai.org.uk))

Maternal and Childhealth Advocacy International <https://orcid.org/0000-0001-6599-6011>

**Rhona MacDonald**

Maternal and Childhealth Advocacy International

**Adeyemo Abass Kola**

Maternal and Childhealth Advocacy International

**Obed Dolo**

CB Dunbar Hospital

**Asinya Magnus**

CH Rennie Hospital

**Diane Watson**

Royal Gwent Hospital

**Maire Casement**

Maternal and Childhealth Advocacy International

**Bernice Dahn**

College of Health Sciences

**Wilhelmina Jallah**

Ministry of Health and Social Welfare

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## Research article

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# Abstract

**Background:** In low-resource settings with few health workers, the Fetal Heart Rate (FHR) in women in labour can be inadequately monitored contributing to poor outcomes. An initiative to improve fetal monitoring was implemented in two public hospitals in rural Liberia with extremely limited health workforces, to assess the feasibility of educating women in labour to monitor their FHR and alert their attending midwife of any changes which might indicate fetal distress. **Methods and Interventions:** Over 15 months, 474 women admitted in labour without obstetric complications were approached. After informed consent, 461 agreed (97%) and 13 refused. Those consented were trained to monitor the FHR using a sonicaid for approximately one minute immediately after the end of every uterine contraction and inform her midwife of changes. If relevant changes were confirmed, standard clinical interventions for possible fetal distress (lateral tilt and intravenous fluids and glucose) and, when appropriate, accelerated delivery by vacuum or Caesarean section were undertaken. Participants provided views on their monitoring experience; subsequently categorized into themes. Neonatal outcomes regarding survival, need for resuscitation, presence of birth asphyxia, and treatment were recorded. **Results:** 461 out of 474 women gave consent, of whom 426 (92%) completed the monitoring themselves. 386 (97%) of 400 who gave comments, reported positive experiences and 14 reported only negative experiences. 28 participants identified FHR changes, confirmed in 26 cases. Meconium stained liquor accompanied FHR changes in 18 of these 26 (69%). 13 of these 26 neonates required resuscitation, with 10 admitted to the neonatal unit. One developed temporary seizures suggesting birth asphyxia. All 26 neonates were discharged home apparently well. In 2 mothers, previously unrecognized obstetric complications (cord prolapse and Bandl's ring with obstructed labour) accompanied FHR changes. Resuscitation was needed in 8 neonates without identified FHR changes. One (birth weight 1.3 Kg) could not be resuscitated. There were no intrapartum stillbirths or maternal deaths in participants. **Conclusions:** Women in labour were able to monitor and detect changes in their FHR. Most found the experience positive and empowering. The absence of intrapartum stillbirths and low number of poor neonatal outcomes are promising but warrant further research.

## Background

The need to identify and better manage intrapartum placental insufficiency and fetal distress is particularly relevant in low-income countries, such as Liberia. Yet it is in such settings that the methods and means to do so are severely limited by the lack of health workers and by material poverty. Challenges include the lack of suitably trained birth attendants, particularly in rural settings; the high workload with each attendant often having to care for several women in active labour, especially during the night; and the inability to fund, maintain and interpret fetal monitoring devices. As quoted by The Lancet Every Newborn Study group: *"Sensitive, specific, and simpler methods for detection of fetal compromise during labour could have a major effect on intrapartum stillbirths and early neonatal deaths, as long as linked with emergency obstetric care"* [1].

Globally, intrapartum-related complications are reported to cause an annual 1.2 million stillbirths, 700,000 term newborn deaths, and an estimated 1.2 million newborn babies developing neonatal encephalopathy (birth asphyxia) with 233,000 survivors developing moderate or severe neurodevelopmental impairment [2]. The countries with the highest stillbirth and neonatal mortality rates are in Sub-Saharan Africa [1], where between 25.1 and 34.2 stillbirths occurring for every 1,000 births, with an estimated 51% of these deaths happening

intrapartum [3]. For example, in a rural hospital in Tanzania, the stillbirth rate was 27/1000 live births, with 16/1000 occurring intrapartum [4] and 27% of deaths in the first 6 days of life related to intrapartum causes.

Intrapartum-related neonatal mortality rates are 25-fold higher and intrapartum stillbirth rates up to 50 times higher in the lowest-income countries [5] where rehabilitation services for children with neuro-developmental impairments are poor or absent.

The integration of obstetric and neonatal care to manage complications for both mother and fetus during labour [6] is critically important with task-sharing being particularly relevant in low resource settings. To the best of our knowledge, mothers have not previously participated in FHR monitoring during labour. Their contribution (as a form of task-sharing) could be valuable for the wellbeing of both themselves and their babies and could be of assistance to stretched health care workers. As part of a maternal and neonatal health care improvement initiative, we assessed whether maternal participation of monitoring the FHR during labour is a feasible, effective and sustainable approach to improve intrapartum and neonatal survival in situations with few and / or overworked skilled birth attendants.

## Methods

### Specific Aims and Methods

We have used the revised standards for quality improvement reporting excellence (SQUIRE 2.0) to report this initiative [7].

The first aim of this initiative was to assess the feasibility of educating women in labour to assess the FHR with a portable doppler monitor and alert the attending midwife if they detected changes in the fetal heart rate that might indicate fetal distress.

The second aim of this initiative was to facilitate system changes to educate, enable, and empower the attending midwife to initiate an immediate remedial course of action should she/he be alerted by a woman in labour who detected changes in her fetal heart rate. The questions posed, and the outcomes of the intervention to be measured are shown in Table 1.

**Table 1** Questions to be addressed by this initiative.

Questions to be addressed	Outcomes
<p>1) Can women in labour be educated to detect changes in FHR (especially fetal bradycardia and fetal tachycardia) through self-monitoring of the FHR with a doppler monitor and alert the attending midwife?</p>	<p>1a) Number of women (out of all approached for consent) in two hospital maternity units willing to participate in the self-monitoring initiative</p> <p>1b) Number of women (out of all approached for consent) participating in the self-monitoring initiative who were able to detect FHR changes which were confirmed as abnormal and possibly harmful by the clinically attending midwife.</p>
<p>2) Do attending midwives respond to alerts from women in labour regarding suspected FHR changes and do they initiate the agreed course of action (the birth asphyxia and stillbirth prevention protocol) every time in a timely manner?</p>	<p>2a) Number of times (out of all possible) an attending midwife responded to an alert from a participating woman in labour who self-detected a potentially harmful change in FHR.</p> <p>2b) Action taken by an attending midwife responding to an alert by a woman in labour of a possible FHR change and whether the agreed birth asphyxia and stillbirth prevention protocol had been followed.</p>
<p>3) Did the labouring women find the experience of monitoring their unborn babies helpful?</p>	<p>3a) How many mothers found the monitoring helpful?</p> <p>3b) How many mothers found the monitoring difficult?</p> <p>3c) How many mothers had to discontinue the monitoring</p>
<p>4) What measure could be implemented to improve the attainments of the above first three objectives and result in a sustainable programme?</p>	<p>4a) Improvements in obtaining consent</p> <p>4b) Improvements in the documentation of changes in FHR</p>

	<p>4c) Feedback of results to the midwives on the maternity wards</p> <p>4d) How to achieve sustainability given the temporary availability of trainee obstetric clinicians</p>
<p>5) Was the attending midwife able to initiate an immediate course of treatment when she was alerted by a woman in labour who had identified changes in her FHR?</p> <p>6) Were professionals trained in advanced obstetrics and neonatal care able to provide effective treatment when asked to by the attending midwife?</p>	<p>Treatments given and outcomes in the mother</p> <p>Treatments given and outcomes in the newborn infant</p>

### *Setting*

In Liberia, over the past 6 years, a partnership between the Ministry of Health and Social Welfare (MOHSW), The World Health Organization (WHO), The United Nations Population Fund (UNFPA), the Liberian Board for Nursing and Midwifery (LBNM) and the registered charity (not-for profit organization), Maternal and Childhealth Advocacy International (known as MCAI), has been established to train senior birth attendants (19 midwives and 2 physician assistants) in advanced obstetrics to become obstetric clinicians, able to undertake necessary clinical procedures to expedite the delivery of a distressed fetus, such as vacuum delivery and Caesarean section [8]. 11 obstetric clinicians have completed training and 10 more are currently in the second of 3 years of training.

More recently, the partnership initiated a new programme to improve neonatal resuscitation and hospital neonatal care by training selected nurses and midwives to become advanced neonatal nurse practitioners (neonatal clinicians) and is based in both of the two hospitals involved.

The fetal monitoring project took place in CB Dunbar Hospital and CH Rennie Hospital. The main training hospital for both obstetric clinicians and advanced neonatal nurse practitioners (neonatal clinicians) is CB Dunbar Maternity Hospital in Bong County. Currently there is one fully qualified and licensed obstetric clinician, 4 trainee obstetric clinicians and 9 trainee neonatal clinician practitioners at CB Dunbar Hospital. There are 5 trainee obstetric clinicians at CH Rennie Hospital.

### *Management committee for this health care improvement initiative*

This initiative represented an integrated project between obstetrics and neonatology. Both the 2 qualified and 19 trainee obstetric clinicians and the 9 trainee neonatal clinicians and their trainers were involved.

The management committee oversaw the day to day running of the initiative and was responsible for the data analysis. If there were any problems identified, in particular involving the need for improving the recording methods, the management committee would make the necessary changes to the initiative as appropriate.

Two trainee Obstetric Clinicians (KP and NJ), the international advanced neonatal nurse practitioner (AK) managing the recently established neonatal intensive care unit, led the day to day running of the fetal monitoring component of this initiative.

### *Participants*

Over a 15-month period (from 31 July 2017 to 24 October 2018), 474 women admitted in the active first stage or second stages of labour, who were not experiencing any complications such as haemorrhage, severe pre-eclampsia or obstructed labour, were invited to participate in this health care improvement initiative. Before participation, each mother was asked to give her informed consent. Initially (given a female literacy rate from UNICEF data 2011-2016 [9] of those aged 15 to 24 years of approximately 37%) this consent was requested verbally and recorded and later (after 27<sup>th</sup> April 2018) a dedicated consent form was signed (either by fingerprint or in writing). The consent form (part of the Additional File) was read out and discussed with each woman before she was enrolled in the study. Only women or adolescent girls (those potential participants aged under 18 years) who fully understood what they were being asked to undertake were recruited.

### *Plan of investigation*

Each participating woman was shown by the attending midwife or trainee obstetric clinician how to use a rechargeable, battery operated, fetal doppler heart sound monitoring device, including the best position to place the probe on the abdomen. The mother was also educated in what was a normal heart rate and what was a slow or fast, by tapping out a rhythm. Mothers were asked to monitor for approximately a 60 second period immediately following the end of *every* contraction.

Having determined what was a normal rate, the mother was then asked to identify and immediately inform the attending midwife of any changes in fetal heart rate that she detected. Sometimes, the mothers reported actual heart rates (if literate) but mostly identified a fall or increase in heart rates without counting the numbers involved. The midwives and obstetric clinicians who responded to the mother, recorded and reported the actual heart rates. The Additional File contains the form that was used for the recording process.

The Additional file also contains a summary of clinical data collected on each participant together with the comments made on the monitoring process by the mother, either written directly or for those mothers who were illiterate transcribed for them by the obstetric clinician completing the form.

In all participating women, the partograph was to be completed as normal by the attending midwife every 30 minutes during the first stage and every 5 minutes during the second stage of labour [10,11].

If a participating woman decided that she could not continue to monitor the fetal heart rate, for whatever reason, her wishes were respected and documented as part of the results of this study. If a woman's condition during labour made it difficult for her to continue making recordings, the midwife or obstetric clinician would, if possible and if time allowed, assist or take over the monitoring from her with the woman's permission.

If a woman did not wish to undertake the monitoring herself but still wanted her baby to be monitored, with the mother's permission, the monitoring could be done by an attending midwife or obstetric clinician.

#### *Actions by attending midwives/obstetric clinicians*

The attending midwives at the two hospitals were informed of the plans and scope of the initiative by the management team and educated in their role and responsibilities regarding the initiative, especially that they must, if possible, respond immediately when alerted by the participating women to a change in fetal heart rate and examine the woman. If the FHR was potentially of concern, the midwife would then immediately notify the trainee obstetric clinician and/or doctor on duty who would join the midwife in the management of labour until the heart rate had either recovered or the baby was safely delivered (as per the birth asphyxia prevention protocol: see below). At CB Dunbar Hospital, the trainee neonatal clinician on duty would also be asked to be present at the delivery to resuscitate the neonate if necessary.

#### *The Birth Asphyxia Prevention Protocol*

1. if a participating woman in labour detected a possible FHR change (bradycardia or tachycardia) she immediately notified the attending midwife (who had been introduced to the woman.)
2. The midwife checked the FHR and the mother's condition.
3. If a bradycardia (<120 beats/minute) or tachycardia (> 160 beats/minute) were present, the midwife immediately notified the (trainee) obstetric clinician or doctor on duty.
4. If the heart rate was normal, the midwife immediately began a period of continuous fetal monitoring including the time up to the next contraction. She also listened to the FHR during the whole of the next contraction and immediately following that contraction.
5. If a suspicious FHR was detected during the one minute following the next contraction the midwife took the following actions:
  - (i) ensured the mother was not lying flat on her back by providing left lateral tilt, examined the liquor if membranes had ruptured, and noted whether meconium staining of amniotic fluid was present.
  - (ii) ensured that the obstetric clinician and/or doctor on duty was present
  - (iii) inserted an intravenous cannula and give a bolus of either 0.9% saline or Ringer Lactate solution and where there was suspicion of ketosis add 50% glucose to the IV infusion [11]
6. If there was evidence of fetal distress (late decelerations, persistent bradycardia, persistent tachycardia, meconium stained liquor) then the mother was assessed by the (trainee) obstetric clinician or doctor to manage any maternal obstetric problem that could be responsible for the fetal bradycardia/tachycardia and assess for urgent immediate delivery as follows:

(i) If the cervix was fully dilated and there were no contraindications to instrumental delivery, a vacuum delivery was undertaken.

(ii) if the cervix was not fully dilated, then an emergency Caesarean section (CS) was undertaken provided that by the time the CS was ready to be started the fetus was still alive and the cervix remained not fully dilated. An abdominal ultrasound scan was often helpful at this time.

7) Under either circumstance outlined in 6 above, a neonatal practitioner or midwife experienced in neonatal resuscitation was immediately made available for when the baby is delivered. She/he would ensure that the equipment needed for resuscitation was available and functioning.

*The outcome for the mother and fetus/baby.*

The clinical condition of the baby at birth, the need for neonatal resuscitation, admission to the neonatal unit and any signs of subsequent birth asphyxia (Hypoxic Ischaemic Encephalopathy: HIE) were documented. A clinical summary of the pregnancy and delivery was documented.

*The views of the mothers on the fetal monitoring process.*

From 23<sup>rd</sup> October 2017, through written or verbal comments (the latter transcribed by the attending midwife or obstetric clinician trainee), mothers were asked for their views on the monitoring process.

This situation meant that all 154 participants who had consented at CH Rennie hospital (where the project started on 21<sup>st</sup> March 2018) were approached for comment (except for 1 where the fetus was found to be dead when the mother was being examined on admission). This request for comments was not in place for the 57 of the 307 consented mothers who had enrolled before 23<sup>rd</sup> October 2017 at CB Dunbar Hospital.

Two of the authors (DS and RM) categorised the comments into basic themes. Any discrepancies were discussed and agreed by consensus.

The lead obstetric clinician in each hospital (KP and NJ) was responsible for charging the batteries and for ensuring gel, consent, and monitoring forms were constantly available. Forms were scanned and sent to the UK by MCAI programme and finance managers in Liberia.

*Data analysis*

MCAI was responsible for the data analysis and undertook a descriptive analysis.

## **Ethical Considerations**

### **Ethics approval and consent to participate**

The fetal monitoring project started as a service delivery intervention. However, when the potential significance of the outcomes was identified, it was decided to approach the initiative from a research angle for publication. As a programmatic intervention, it was fully within the domain of the Ministry of Health to implement. Re-framed as a research project, it was relevant to seek National Research Ethics Board (NREB) approval.

In accordance with 45 CFR 46 the research was approved by the National Research Ethics Board (NREB) of Liberia through a full board review. The federal wide assurance number of the NREB is 000 21658 and organisation number 000 8374.

This approval was given after reviewing the documents relating to the initiative / feasibility study/ FHR monitoring project, which included the protocol stipulation that all mothers in labour (themselves individually and whatever their ages) would give their informed consent to be involved in the initiative/feasibility study (FHR monitoring project). Nine participants were aged under 16 years; despite their age, these young participants were pregnant mothers who had given their informed consent to be involved in the monitoring project as per the approved study protocol. Further consent from their parents or guardians was not sought. Because of poverty and complex social circumstances, it is common for mothers in Liberia to be aged under 16 years. Also, young mothers frequently attend the hospitals in labour by themselves, with no legally assigned family members in attendance and sometimes only a traditional birth attendant for support. Many women and adolescent girls do not know their age, and the illiteracy rate in Liberia is high (63%).

### **Consent for publication**

**Consent for Figure 1 was obtained from the patient using the MCAI consent form which is available on request.**

Advice from a practicing lawyer revealed that there was no law in Liberia requiring explicit authorization for use of an anonymized quotation in any publication.

Moreover, the consent, fetal monitoring, and birth summary forms, which included the comments made by mothers, was provided to the NREB as part of the application for approval, allowing them to consider whether it was comprehensive/appropriate in making its determination to approve the study.

## **Results**

### *Consent and monitoring*

Over 15 months from 31 July 2017 until 24 October 2018, 474 women (157 from CH Rennie and 317 from CB Dunbar Hospitals) admitted in the first or second stages of labour and without obstetric complications were approached. 461 gave their informed consent to participate in the FHR monitoring (97%) and 13 refused.

At CH Rennie Hospital, data were collected from 21 March 2018 until 24 October 2018. 157 mothers were approached for consent. Three refused [case number 6 (too much pain); case number 54 (no reason); and case number 75 (no reason)]. In those who refused, only monitoring as part of the partograph, was undertaken.

Three (case numbers 4, 10 and 153) had consented but after monitoring for 8, 12 and 36 contractions respectively, stopped monitoring because of the pain and tiredness.

At CB Dunbar Hospital data were collected from 31 July 2017 until 23 October 2018. 317 mothers were approached for consent. 307 gave their informed consent and 10 refused. In 4 of these cases, where the mother said her pain was too much to allow her to do it, the obstetric clinician or midwife continued to undertake the

monitoring with the sonicaid. In one of these latter 4 cases (CBD 251) a student midwife undertook all of the monitoring and identified a change in FHR (see Table 5). In the other 6 cases, no FHR monitoring was undertaken except as directed as part of the partograph was undertaken.

Out of the 307 mothers who consented, there were 7 cases where the mothers initially refused but then changed their minds and undertook monitoring for the rest of their labour. In one of these latter cases the mother shared the monitoring with her midwife.

In an additional 7 cases, the mother consented but subsequently stopped monitoring (1 through tiredness, 1 because of pain and 5 with no reasons given).

In an additional 19 cases where the mother consented but then stopped monitoring, a midwife or obstetric clinician took over (17 cases) until delivery or shared the monitoring with the mother (2 cases). Of these 19 cases, 14 gave pain as the reason, 4 gave tiredness or weakness and one gave no reason.

426 of 461 (92%) participating mothers were able to complete the monitoring themselves (152 from CH Rennie Hospital and 274 from CB Dunbar Hospital).

### *Maternal age*

Maternal age was available for 445 participants. 52 (12%) were aged under 18 years; 23 mothers aged 17; 20 aged 16; 5 aged 15; 3 aged 14; and one aged 13 years.

*Maternal experiences; the feeling of empowerment experienced by the mothers and the importance of the lack of any pain control that is not available during labour in the public hospitals in Liberia.*

400 participants provided written or verbal (transcribed) comments on their experiences of the monitoring.

386 mothers found listening to their unborn baby a positive experience expressing one or more of the following words or phrases: *alright, not bad, good, fine, helpful, loved or liked it, happy, comfortable, gives me joy, or other positive comments such as "Thank you"*. A selection of these comments is shown in Table 2, including some from mothers who identified changes in FHR.

14 reported only negative comments: 5 reported weakness or tiredness (including feeling nauseated in one case), 7 reported pain (which in 3 interfered with the monitoring), 1 said it was not easy and 1 said it was bad.

**Table 2** Selected maternal comments from participants at CB Dunbar and CH Rennie Hospitals

Case Number	Comment
1 CHR	The monitoring was fine, it gave me courage to go through my pain knowing my baby was fine
16 CHR	The monitoring was good, it made me get closer to my baby..... due to the exercise she will always come to CH Rennie for maternity care during pregnancy
35 CHR	I felt that I am important when you told me to be a part of my baby monitoring process. It helps me a lot
37 CHR	The monitoring was good. It help even us that cannot read or write listen to our own baby
40 CHR	I thank god for the programme I am happy to hear my baby heart-beat. Please continue it
43 CHR	I am comfortable doing this as it helped me form part of my baby monitoring
61 CHR	Listening to my baby heart sound was very helpful to me. I felt that my right was respected as I took in my baby monitoring. Thanks for this program. I am happy.
62 CHR	I am happy to hear my baby heart. I knew that I was carrying a live baby in my womb.
70 CHR	Thank you for this. It help me but I was in pain and so it make me angry first but I overcome it later (aged 16)
95 CHR	Getting involved in the process is something amazing to me. I felt part of my care and thank God that I have a live baby.
156 CHR	I feel important in the coming of my baby. This modern method is very important it help a lot thank you
158 CHR	I like it so much doctor that real good thing the government put in place here. I will tell all my sisters that pregnant to come to the hospital
4 CBD	According to mum it is a good step to do because it helps you to notice danger sooner.
51 CBD	I found the monitoring helpful it helps me go through my pain.
52 CBD	I felt good listening to my baby it helped me to learn a new thing
123 CBD	According to mum, this is the first time seeing patient to be working for herself. She said it is a good thing to do but when in labour is bad because of the pain.
133 CBD	Patient said she's very happy because she seen baby breathing well and she herself

	okay. According to patient any time she pregnant she will come and give birth to CB Dunbar hospital.
138 CBD	According to mum, she love the procedure but is not easy to go through.
139 CBD	According to mum, she love the idea because other pregnant women goes to the hospital and comes back with no baby in their hands it looks sorry full.
151 CBD	Mother said she found the monitoring helpful in that she has a live baby. She was cooperative and was asking other mothers to join the process.
162 CBD	Patient admitted that it was good thing for herself to listen to her baby heart-beat. It made her believe that her baby can breathe inside her mother's womb.
169 CBD	Mother was happy to hear her baby heart beat because she stay in labour for long and worry about her unborn baby
180 CBD	According to patient she was surprised to know that baby heart can beat in the mother stomach and it help her to know about her baby wellbeing.
200 CBD	I like to have the same chance to listen to my unborn baby the next time I am in labour
203 CBD	I enjoy listening to my baby but my next labour there should be pain medicine for labour
239 CBD	It help me to put more effort for my baby. To know that my baby is still living in my stomach.
242 CBD	It is hard to be in pain and monitor your baby. You must be doing it for us. Thank God my baby is living but it is too hard. The machine can cause more pain on the stomach.
255 CBD	It help me because it did not allow me to go to surgery. It help me because my baby was born alive and by normal vaginal delivery. It help me so much even though is more difficult to do but I try doing to have got good result. (vaginal breech delivery).
274 CBD	It is very good and helpful to me. At least all "big bellies" should know how to do the monitoring before the stomach can hurt.
275 CBD	I like the monitoring it make my baby live. No problem with the monitoring. It only hard to hold the machine when your stomach hurting.

Legend to Table 2. *Additional maternal comments following changes in fetal heart rate are reported in Tables 3 and 5 below. Abbreviations are defined in the list given earlier in the*

Out of the 386 providing positive comments, 86 also reported how much they were affected by pain or severe pain. This pain interfered with their ability to undertake the monitoring in 52 of the 86 (60%).

Within the 386 with positive comments, 44 women also reported discomfort, 5 reported tiredness and weakness and 4 reported difficulties applying the sonicaid.

Three mothers said that they would hope that monitoring would be available during their future pregnancies. 6 would return to the hospitals to deliver as a result of the project. An additional 6 mothers said they would hope that monitoring will continue to be available so that other mothers can benefit and 5 said they would encourage other mothers to participate. 9 participants said monitoring helped to cope with labour pain.

#### *Technical and administrative problems identified*

The initial design of the tick sheet documenting each contraction monitored did not always allow enough space to record every contraction and obtaining extension sheets was sometimes a logistic problem. To minimise the workload of the scarce midwifery workforce, forms were also re-designed to record clinical data that were appropriate but not excessive given time restraints.

Due to a communication problem, 69 mothers at CB Dunbar Hospital (between 19 Feb 2018 and 8 May 2018) incorrectly monitored their FHR every 30 minutes (similar to the partograph). However, unlike the partograph, monitoring was always undertaken for the 1 minute immediately following the nearest contraction to each 30-minute window.

#### *Birth/delivery data*

In 461 participants, there were 33 caesarean sections (7.2%) including 14 with FHR changes. There were 20 vacuum deliveries (4.3%) including 9 with FHR changes, (the latter included a mother with a stillborn baby identified during the training in the use of the sonicaid, confirmed by ultrasound scan).

#### *Clinical information and outcomes for participants where changes in FHR were identified.*

**Table 3** Clinical information and outcomes of FHR changes identified by monitoring. Abbreviations: see list

Hospital and number	Maternal age (years) and parity	Change in FHR identified	Action taken	Appar scores at 1 and 5 minutes	Resuscitation given	Maternal comment
CHR 46	29, G5P2	By mother. FHR 115 plus meconium Confirmed by MW	Lateral tilt and intravenous cannula with NS bolus Vacuum delivery	9 and 10	None	According to patient she lost her fetus during past pregnancy. Here she was happy when she noticed her fetal heart beat was dropping and the quick response that was processed
CHR 50	34, G3P2	By MW and mother. No FHR plus meconium	<b>Ultrasound confirmed IUFD.</b> Vacuum delivery was undertaken	NA	NA	NA
CHR 99	17, G2P0	By mother at 46 <sup>th</sup> contraction FHR 109 with meconium	Cervix fully dilated and urged to push	4 and 7	Yes. Bag and mask ventilation, adrenaline and chest compressions for 10 minutes. Admitted to the NNU for post resus care and close monitoring  Discharged aged 7 days.	Listening to my baby heart was good. It help me to know that something was happening to her. No problem with it. Thank you.
CHR 102	19, G2P0	By mother FHR 119 at 49 <sup>th</sup> contraction. There was + meconium present	Vacuum delivery	7 and 10	No	I like the thing I was doing but it was hard to do because of the pain.
CHR 133	23, G2P1	By mother FHR 119, 117, 116. No meconium. patient was not progressing at this stage. 2 cm cervical dilatation with mild contractions.	MW/OC took over the monitoring due to the bradycardia. Doctor contacted. Patient was laterally tilted, given oxygen, D50%, hydrated and rushed to the OR for CS.	7 and 10	No	Thank you for this program. If not so my baby was going to die. The only thing that the pain.

Hospital and number	Maternal age (years) and parity	Change in FHR identified	Action taken	Appgar scores at 1 and 5 minutes	Resuscitation given	Maternal comment
CHR 135	24, G2P1  No previous CS	By mother FHR 163-165 with meconium. Signs of Bandl's ring and obstructed labour with haematuria identified.	Not receiving oxytocin. Emergency CS	9 and 10	No	Thank you for saving my life and my baby. It really helpful to listen to my baby heart to know what was happening to me.
CHR 136	26, G3P2	By mother FHR 119,110,118. No meconium.  OC and doctor contacted and confirmed bradycardia	Given facial oxygen, lateral tilt, N/S and D50%. Patient was 6cm dilated at this stage. Emergency CS	8 and 10	No	I feel good when I was listening to my baby heart. It help me to know what happen to my baby.
CHR 157	19, G1P0	By mother at 46 <sup>th</sup> contraction FHR 117, then 114, then 116, then 113. No meconium. Fully dilated but descent only minus 2	Lateral tilt, D50%, oxygen, NS and FHR still below 120 and when head reached 0 station re: ischial spines after 10 minutes and then vacuum delivery	9 and 10	No	Thank you for what you bringing because when it was not because of it I was not coming to know say my baby heart was not beating good. That just the pain was giving me hard time thank all.
CBD 16	17, G1P0	FHR found to be 95-100 by mother, FHR was repeated by midwife and confirmed low, 95-98, and Doctor on call was also informed.	Patient was placed in a left literal tilt position Patient was reviewed and decision to CS was taken for fetal distress plus prolonged labour	6 and 9	None	Not requested at this stage in programme
CBD 17	22, G3P1	Mother reported a change in FHR but when checked by MW found FHR to be normal at 142. Meconium was present	Doctor informed but no action was considered necessary	6 and 10	None	Not requested at this early stage in programme
CBD 25	14, G1P0	On 11th contraction mother reported slow heart rate. MW was contacted but she found FHR was 153. There was no meconium the OC was contacted.	Mother's membranes were ruptured and vacuum delivery undertaken	7 and 10	None	Not requested at this early stage in programme

Hospital and number	Maternal age (years) and parity	Change in FHR identified	Action taken	Appar scores at 1 and 5 minutes	Resuscitation given	Maternal comment
CBD 33	17, G1P0	Mother noted change and contacted MW on 15th contraction. MW noted FHR 118 and informed OC. Meconium was present repeat fetal heart rate was 105.	Mother put in lateral tilt position and informed Dr who reviewed patient and found fetal heart rates 110, 105, and 108. Emergency CS was performed	8 and 10	None	Not requested at this early stage in programme
CBD 38	22, G2P1	On 11th contraction mother noticed bradycardia. Midwife confirmed FHR 118 put patient in left lateral position and called OC. Grade 3 meconium was present. OC found FHR 110.	Left lateral tilt. Cervix was fully dilated and vacuum delivery undertaken.	6 and 9	Bag and mask ventilation. Admitted NNU for 5 days and treated for sepsis.	Not requested at this early stage in programme
CBD 43	22, G1P0	Yes - by MW following refusal by mother FHR 95-100 on two successive occasions	Lateral tilt and subsequent CS	5 and 7	Bag and mask ventilation and admitted to NNU. No HIE and went home.	Following initial consent, patient later refused to monitor her FHR. Says she was tired of monitoring.
CBD 125	28, G3P2	Mother on 14 <sup>th</sup> contraction noticed change in FHR. And weakness. She called for help and FHR was 102. No meconium was present.	OC contacted, lateral tilt and intravenous (IV) cannula with 500ml of Ringer Lactate given. Normal vaginal delivery followed.	6 and 10	This baby was resuscitated for 5 minutes with bag and mask ventilation and then transferred to the NNU where he was immediately placed on nasal CPAP and an IV line was opened to serve antibiotics because amniotic fluid was also purulent and foul smelling. IV fluid (Dextrose 10%) was set up. Baby was managed for 7 days in the NNU and was discharged home with good outcome.	According to mum monitoring is hard at certain times. She knew her babies heart rate was low and we took quick action and now the baby is in her hands so she thank the organisation.

Hospital and number	Maternal age (years) and parity	Change in FHR identified	Action taken	Apgar scores at 1 and 5 minutes	Resuscitation given	Maternal comment
CBD 128	16, G1P0	On the 14th contraction the mother called the MW because the FHR was low. The MW confirmed FHR 98, called for help and undertook lateral tilt. Meconium was present.	The OC was contacted. She opened IV line and gave R/L 1000 mL, informed the doctor on call. The doctor came and assessed the patient and said we should prepare patient for CS. CS was done for prolonged labour and abnormal FHR.	5 and 10	Neonate was resuscitated for 7 minutes by bag and mask ventilation before transferring to the NNU. She was placed on nasal CPAP for 24 hrs and was also managed for risk of sepsis. Neonate improved after 8 days and was discharged.	According to mum it is okay because this help the doctor nurses to take quick action
CBD 131	15, G1P0	On the 7 <sup>th</sup> contraction, mother detected fetal bradycardia. MW called and checked and confirmed FHR 105. Meconium was present. Grade 3 OC was called.	Lateral tilt was undertaken and fast vaginal delivery arranged as 9cm cervix dilated. Birth weight 1.9Kg small for dates.	7 and 10	Baby was resuscitated for 2 minutes by bag and mask ventilation and then transferred to NNU. She was placed on nasal CPAP for 24hrs and patient condition improved. Baby was also managed for risk of neonatal sepsis because mother's amniotic fluid was purulent, foul-smelling during delivery. The baby was discharged home after 10 days with a weight of 2.3kg	Patient initially refused procedure but later on she was encouraged to do it herself and everything went well
CBD 147	28, G5P4	On 6 <sup>th</sup> contraction, mother detected bradycardia. MW confirmed FHR 108. Meconium was present.	OC contacted. Lateral tilt performed. IV cannula inserted and given NS 500ml. Normal vaginal delivery occurred.	5 and 8 Male	Bag and mask ventilation given. No HIE occurred but he needed 5 days of antibiotics for umbilical infection.	Patient worry when the heart rate was reducing but at last she was happy because her baby came through

Hospital and number	Maternal age (years) and parity	Change in FHR identified	Action taken	Appgar scores at 1 and 5 minutes	Resuscitation given	Maternal comment
CBD 153	32, G5P3	On 2 <sup>nd</sup> contraction monitored, Mother identified rapid heart rate. MW confirmed FHR 190 and called for help,	Doctor called and attended. Lateral tilt and IV cannula and N/S 500ml set up.  Vacuum delivery was undertaken.	6 and 8	Neonatal clinician was called and baby resuscitated with bag and mask ventilation and recovered within 1 minute. Responded well and taken to NNU for suspicion of sepsis. No HIE.	Mother said she was happy with the monitoring because she could have had a dead baby if she didn't monitor. She's also asking other mothers to accept and be part of the process
CBD 158	17, G2P1	On 6 <sup>th</sup> contraction, Mother reported fall in HR. MW confirmed FHR 109 Meconium present.	Lateral tilt applied and IV cannula inserted with R/L 500mls plus Dextrose 50% 30ml. OC contacted and quickly delivered the baby vaginally.	6 and 7	Mildly depressed but no resuscitation needed. Neonatal clinician continued monitoring and care.	Patient was very happy because she call for help and action was taken quickly by the OB clinician and her baby was saved.
CBD 160	26, G3P0	On 27 <sup>th</sup> contraction, Mother detected slowing of FHR. MW confirmed FHR 109. Grade 2 meconium was present. Dr on call contacted.	Lateral tilt and IV cannula inserted. R/L 500mls given IV. Doctor arrived and undertook CS.	7 and 10	Resuscitated for 2 minutes with bag and mask ventilation.	According to mother she was very happy, and she told everybody thanks because of the monitoring her baby was saved
CBD 169	16, G1P0	On 7 <sup>th</sup> contraction mother noted fast heart rate. MW confirmed FHR 167. Patient came in fully dilated but evidence of obstructed labour due to persistent occipito-posterior malposition.	Lateral tilt and IV cannula inserted. NS 500mls given IV. Doctor arrived and undertook CS.	9 and 10	None needed	Mother was happy to hear her baby heart beat because she stay in labour for long and worry about her unborn baby

Hospital and number	Maternal age (years) and parity	Change in FHR identified	Action taken	Appgar scores at 1 and 5 minutes	Resuscitation given	Maternal comment
CBD 172	42, G9P8	On the 7 <sup>th</sup> contraction mother noted a slow heart rate. MW confirmed FHR 102. Meconium was present and a cord prolapse identified.	The OC was notified and implemented knee chest position and inserted NS 300mls into the bladder to reduce cord compression. IV cannula was inserted and NS 500mls given. A CS was then undertaken.	6 and 10  Depressed breathing.	Resuscitated for 1-3 mins with bag and mask ventilation. Taken to NNU as 30 weeks' gestation No HIE. Home after 14 days	According to mother monitoring is good but she cannot continue it herself due to pain. At last she said it help her with a live neonate
CBD 177	17, G2P1 previous CS	On 12 <sup>th</sup> contraction, MW reported a FHR 124. Meconium present. FHR then dropped to 119.	OC was called and after lateral tilt established IV line and gave 500ml NS. A CS was then undertaken.	7 and 8	No resuscitation needed but foul-smelling amniotic fluid at CS led to NNU admission and IV antibiotics.	Mother agreed to the process, she started it but discontinued due to pain and was helped by midwife and OB clinician. Mother said it's a good thing, it help her have a live baby
CBD 188	32, G1P0	On the 8 <sup>th</sup> contraction mother noted a slow heart rate. MW confirmed FHR 110. Meconium was present. OC informed and FHR was 112. Cervix fully dilated.	Lateral tilt and placed in delivery room for vacuum delivery. However, within 5 minutes delivered spontaneously. A very short umbilical cord was present.	5 and 7  Depressed breathing	Resuscitated for 5 mins with bag and mask ventilation and taken to NNU and given antibiotics. Later became stable and discharged.	The monitoring was good, it is a good idea and I hope it will continue because it will save a lot of babies as it did mine. Sometimes the midwives are busy so this will help them, and help us the mothers too. Mother was hospital medical director 's sister in-law

Hospital and number	Maternal age (years) and parity	Change in FHR identified	Action taken	Appgar scores at 1 and 5 minutes	Resuscitation given	Maternal comment
CBD 235	31, G5P4	On the 30 <sup>th</sup> contraction mother noted a slow heart rate. MW confirmed FHR 118.	MW performed lateral tilt and informed the OC and set up IV infusion of R/L 500ml. Dr ordered repeat and FHR 106. Cervix only 4cm dilated. Descent 3 / 5. Discussion for CS was done but no CS materials available so patient was referred to another hospital.	8 and 9	None needed after CS at referral hospital	I like listening to my baby heart but I don't know if my baby will live again now that I am going to a different hospital.  Outcome at second hospital after CS was good for mother and baby.
CBD 251	19, G1P0	On the 20 <sup>th</sup> contraction OC and student MW noted a slow FHR 105. No meconium seen.	Lateral tilt was undertaken. The cervix was already 10 cm dilated and there were poor maternal efforts. An IV cannula was inserted and she was given 30 ml dextrose 50%. Baby was delivered by vacuum.	5 and 6	Yes by neonatal clinician bag and mask ventilation for 5-10 mins. Admitted to NNU for neonatal depression. Neonate recovered quickly on nasal CPAP. Improved and went home well.	Mother had refused monitoring but this was done by student MW.
CBD 272	19 G1P0	On 30 <sup>th</sup> contraction mother noted slowing of FHR. There was no meconium at this time. MW and OC identified FHR of 115, 118,122.	Lateral tilt and Doctor notified. An IV cannula inserted and given N saline 500ml plus Dextrose 50% 30ml. The cervix was  10cm dilated. OC did vacuum with Dr present but failed 3 times. Dr and OC proceeded to immediate CS. Intraoperative meconium was present	5 and 7	Bag and mask ventilation for mild respiratory depression. Recovered rapidly and went home.	The monitoring is good but I was not able to do it all by myself because of the pain and my foot pain. Yes my baby is living so it help. No problem with it but the pain can be too much.

Hospital and number	Maternal age (years) and parity	Change in FHR identified	Action taken	Apgar scores at 1 and 5 minutes	Resuscitation given	Maternal comment
CBD 273	22 G4P0	On 51 <sup>st</sup> contraction mother noted slowing of fetal heart rates. MW recorded FHR 109, 178,120,110,181,102,130  Meconium was present	Lateral tilt was performed, and OC notified. IV fluids were started and 30 ml of 50% dextrose given IV. The doctor was also called and due to FHR changes, high station O, and bad obstetric history (G4P0) proceeded with the OC to CS.	8 and 10	None	The monitor help me to inform the midwife that my baby was not breathing good. So I see it to be good for all the big belly with stomach hurting pain.

Abbreviations are defined in the list given earlier in the manuscript.

Table 3 describes the clinical information and outcomes relating to identified FHR changes. Changes in FHR were reported in 28 of 461 participants (6.1%), which in two cases were not confirmed by the attending midwife giving 26 confirmed cases (5.6%). In 23 of the 26 confirmed cases, the FHR decreased and in 3 the FHR increased. Two changes related to unrecognized obstetric complications, with one mother found to have Bandl's ring with obstructed labour and the other cord prolapse.

One of the 26 changes in FHR was identified by a midwife who had taken-over monitoring from a mother who became too tired to continue. In a second case, the mother had refused to undertake monitoring herself but had consented to the monitoring being undertaken by a student midwife.

In 18 of the 26 (69%) with confirmed FHR changes, there was accompanying meconium-stained liquor.

13 of the 26 (50%) the neonates with prior FHR changes had low Apgar scores and needed resuscitation. There were no deaths following resuscitation. One baby had convulsions managed with phenobarbital, recovered and was feeding normally at discharge home aged 7 days. None of the other 26 neonates developed birth asphyxia (also known as Hypoxic Ischaemic encephalopathy-HIE) .

Six of the 26 with confirmed FHR changes (23%) were born by vacuum, 14 by Caesarean Section (CS) (54%), and 6 (23%) by vaginal delivery. In one case (CBD 272), CS followed a failed vacuum delivery.

*Clinical information and outcomes in 3 newborn infants needing resuscitation at birth where mothers had refused to participate in FHR monitoring.*

**Table 4** Clinical information and outcomes in newborn infants needing resuscitation at birth where mothers had refused consent to participate in the FHR monitoring. For abbreviations see list.

Hospital and number	Maternal age (years) and parity	Change in FHR identified on partograph	Delivery	Apgar scores at 1 and 5 minutes;  Wt. of baby	Resuscitation given	Maternal comment	Other possibly relevant information?
CBD 71	32, G3P2	None	Normal vaginal delivery	2 and 3  3.4Kg	Resuscitated with bag and mask ventilation, chest compressions and oxygen  Admitted NNU but later died aged 2 days from HIE	Mother refused monitoring and staff did not take over	
CBD 184	25, G2P1	None	Normal vaginal delivery	4 and 6  Depressed  2.8Kg	Resuscitation was done with bag and mask ventilation and was taken to the neonatal ward. Treated with antibiotics. Outcome was good and discharged.	None	Patient refused to continue her fetal heart rate monitoring even though she did monitor the first contraction
CBD 192	18, G1P0	None	Normal vaginal delivery	2 and 6  Very depressed	Resuscitated by bag and mask ventilation by neonatal clinician  Died aged 3 days from HIE	None	Patient refused to continue her fetal heart rate monitoring even though she did monitor the first contraction

Abbreviations are defined in the list given earlier in the manuscript.

*Clinical information and outcomes in newborn infants needing resuscitation at birth where mothers had refused to participate in FHR monitoring.*

In one, the baby was born with Apgar scores of 2 at 1 minute and 3 at 5 minutes and, despite resuscitation, died of HIE in the neonatal unit aged 2 days.

In 2 other cases, there were low Apgar scores at 1 and 5 minutes (4 and 6; and 2 and 6) and the babies needed resuscitation. Both were admitted to the neonatal unit. One responded well to resuscitation with no evidence of HIE and was discharged home well. The other died aged 3 days from birth asphyxia/HIE.

*Clinical information and outcomes in 8 neonates needing resuscitation where no FHR changes had been identified*

**Table 5** Clinical information and outcomes in newborn infants needing resuscitation at birth where monitoring had not identified any FHR changes

Hospital and number	Maternal age (years) and parity	Change in FHR identified	Delivery	Appgar scores at 1 and 5 minutes;  Wt. of baby	Resuscitation given	Maternal comment
CBD 164	25, G2P1	None. Monitored only every 30 minutes immediately following 14 contractions	Preterm labour and normal vaginal delivery	5 and 7 depressed at birth  1.8 Kg	Neonatal clinician called, resuscitated with bag and mask for 12 minutes and taken to neonatal ward  No HIE	Mother said the monitoring help her with her baby, she got a live baby. She was willing and cooperative and ask other mothers to accept the monitoring
CBD 176	18, G1P0	None. Monitored only every 30 minutes immediately following 13 contractions	Normal vaginal delivery	5 and 10 depressed at birth  3.9Kg	Neonatal clinician was called, did 10-15 mins bag and mask ventilation. Oxygen saturation 54%. Admitted NNU. No HIE and went home aged 7 days	According to mother the monitoring is good, it help her deliver her baby live. She was interested in doing it
CBD 179	18, G2P1	None. Monitored only every 30 minutes immediately following 11 contractions	Normal vaginal delivery	7 and 10  2.8 Kg	Bag and mask ventilation used  for 5 minutes and then recovered. No HIE	Appreciated the listening to her baby until birth. She recommended that all labouring mothers should be able to listen to their fetus during labour
CBD 224	29, G2P1	No abnormality detected following 12 contractions	Vacuum delivery unable to push	5 and 8  3.9Kg	Resuscitated by bag and mask for 10 minutes. Admitted NNU and given 7 days antibiotics. No HIE.	It help because with all the pain I refused to listen to them. I still got my baby by talking to me good. I found it very good because it help me in getting my baby. No problem.
CBD 238	23, G2P1	No abnormality detected following 15 contractions	Normal vaginal delivery	2 and 0  1.3 Kg  34 weeks' gestation	Resuscitated by bag and mask ventilation plus chest compressions for 25 minutes. But then died.	I like the monitoring. I enjoy listening to my baby even though he didn't survive
CBD 240	15, G1P0	No abnormality detected following 58 contractions	Normal vaginal delivery episiotomy for baby stuck at perineum	5 and 7  2.5Kg	Resuscitated by bag and mask ventilation by neonatal clinician for 8 minutes then improved and discharged. No HIE.	I see the monitoring good for me and my baby because it my make me to know that my baby is still living. 9 <sup>th</sup> grade student
CBD 243	23, Gravida  G2P1	No abnormality detected following 23 contractions	Vacuum for reduced maternal effort	6 and 8  3.1 Kg	Bag and mask resuscitation for 7 minutes. Baby was admitted to the NNU for observation.  No HIE but had malaria and was treated for 10 days and then discharged well.	I like the monitoring. It make me born a living baby but it is hard to do. It is hard to be in pain and holding the machine.  Patient is not literate.

Hospital and number	Maternal age (years) and parity	Change in FHR identified	Delivery	Apgar scores at 1 and 5 minutes;  Wt. of baby	Resuscitation given	Maternal comment
CBD 286	23, Gravida  G1P0	No abnormality detected following 12 contractions	Vacuum for exhaustion: couldn't push	7 and 8  3.3 Kg	Bag and mask resuscitation one-two breaths only before baby breathed. Not admitted to NNU.	I find it good. It help me because my baby is alive. No problem with it.

Abbreviations are defined in the list given earlier in the manuscript.

*Clinical information and outcomes in newborn infants needing resuscitation at birth where monitoring had not identified any FHR changes.*

In addition to the neonates requiring resuscitation where FHR changes had been detected, 8 other neonates *without detected changes* in the FHR required resuscitation (Table 5). One (case CBD 238) was preterm/low-birth weight and died at birth. None of the remaining 7 developed birth asphyxia/HIE.

In one neonate (Case number 224) it was unclear who had undertaken the monitoring and for how long. A vacuum delivery was undertaken for failure to push, Apgar scores were 5 and 8 and the baby required 10 minutes of bag and mask ventilation. He was discharged home aged 7 days well. No evidence of birth asphyxia/HIE was evident on clinical assessment.

Three cases were born following vacuum delivery and 5 cases by vaginal delivery, including in one mother who needed an episiotomy to expedite delivery (case CBD 240).

Three of the neonates had been monitored in utero every 30 minutes only in a temporary deviation to the protocol because of a communication problem with one of the trainee obstetric clinicians but none developed birth asphyxia/HIE.

#### *Costs associated with collecting data*

The costs of the project were low. The fetal doppler monitors (SonicAids: 12 in total) were USD 40 each. Rechargeable AA batteries were used. Additional costs included paper and printing for the consent, data collection and monitoring forms including the internet costs of scanning and sending them to MCAI for analysis and KY jelly (or locally available clear hair gel) for interfacing the ultrasound probe with the abdomen: commercial ultrasound gel was too expensive.

#### *Missing data*

Because of problems with the completion of medical records and the work pressure on the health workers involved, it was sometimes difficult to fill the gaps of any missing information, such as birth weights,

retrospectively. Every effort was made by the management committee to minimise missing data, especially regarding maternal and neonatal outcomes.

## Discussion

### *Summary*

Mothers were able to undertake fetal heart rate monitoring of their unborn babies immediately following the end of every contraction during labour in two rural public hospitals in Liberia, a country with extremely poor resources (both human and material). As 92% of mothers were able to undertake the monitoring themselves until their baby was born, the results show that this approach is feasible.

There is also strong evidence that the vast majority of mothers (386 of 400 mothers) considered the experience to be positive and also empowering and good for them and their babies. In our experience, it is most unusual for mothers in Liberia (as in many other low-resource settings where the hospital workforce is so limited and stretched) to be asked for their opinions on their experiences of labour and how it was managed. Therefore, the comments reported by mothers in this initiative are poignant and provide valuable insights into their experiences of labour, in addition to their experience of undertaking the fetal monitoring themselves.

### *Interpretation*

Since a study of mothers assisting midwives in monitoring the FHRs of their unborn babies has not been previously reported as far as we can identify, it is difficult to compare our results with other studies.

This initiative confirmed that attending midwives responded to alerts from mothers regarding changes in FHR in a timely fashion and that trained, senior, health professionals (trainee obstetric clinicians) and doctors were able to intervene appropriately and promptly. In 26 out of 461 women undertaking monitoring (in one undertaken with consent by a student midwife and the other by the midwife who took over from the mother who became tired), confirmed changes in fetal heart rates were identified. Actions to improve the placental circulation (such as lateral tilt, intravenous 0.9% saline or Ringer Lactate, and intravenous Dextrose), and, where possible, expedited delivery by vacuum or Caesarean section were undertaken following standard obstetric management as recommended by WHO [11].

All 26 neonates with changes in FHR survived, including 13 requiring resuscitation at birth. Ten neonates were admitted to the neonatal unit. One neonate developed birth asphyxia/HIE, but the immediate clinical outcomes of the 25 other neonates were good and all 26 were discharged home apparently well. However, long-term infant follow-up was not undertaken and should be in the future. The presence of neonatal clinicians and a functioning neonatal unit at CB Dunbar hospital were particularly valuable. The presence of neonatal units that can provide advanced neonatal care by appropriately trained nursing staff (also a form of task-sharing) are now being established at 3 other rural county hospitals in Liberia.

In two mothers, the identification of FHR changes revealed previously unrecognized life-threatening obstetric complications. More experience may identify whether maternal FHR monitoring can consistently identify obstetric complications. Our results support Hofmeyr and colleagues [6] who stressed the importance of task-sharing in the integration of obstetric and neonatal care. Rapid access to effective obstetric management if

FHR changes are identified must be ensured. Fetal monitoring in isolation has little value without an available health support system so that appropriate clinical intervention can be promptly undertaken. This situation may not be the case in some resource-limited settings, limiting the applicability of maternal fetal monitoring.

### *Limitations*

Comparing figures with those from Tanzania [4] and from Sub-Saharan African countries [1-3,5], the absence of intrapartum stillbirths in the 461 fetuses monitored is encouraging, as is the low prevalence of birth asphyxia/HIE. However, given no comparator, we cannot conclude that stillbirths and birth asphyxia/HIE can be prevented or reduced by maternal FHR monitoring.

This initiative was conducted in a “real world” setting and suggests that maternal fetal monitoring can be incorporated into the daily work of a busy hospital maternity unit. The constant presence of obstetric clinicians was of considerable assistance, but such experienced health professionals may not always be available and alternative plans to address the health-workforce-shortage may be needed. Even with this additional cadre, communication and adherence to the study protocol were sometimes difficult, depending on the enthusiasm and involvement of all health professionals. Feedback of results to the midwifery workforce appeared helpful. Although we did not explicitly seek the views of attending midwives, the finding that midwives sometimes took over the monitoring if a woman was too tired or in too much pain to do it herself, shows their engagement in the process. More information from midwives could also be useful in helping to improve this technique, make it more sustainable and give a further guide to the additional time needed to undertake maternal-fetal monitoring.

We do not have robust baseline data and cannot therefore comment on whether Caesarean Section and vacuum delivery rates were increased by the maternal FHR monitoring.

The need for resuscitation in 8 of 461 (1.7%) of babies born without FHR changes identified by maternal monitoring, requires future research to ascertain whether changes are being missed or whether in some cases there are no measurable FHR changes identifiable by this monitoring technique in fetuses who subsequently require resuscitation. In particular, it is important to know whether mothers and/or midwives can monitor reliably after every contraction with the same quality during the end of the first and second stages of labour when contractions can be much more painful.

There is no doubt that when appropriately undertaken and documented, with timely responses by care givers, the partograph is of major value in monitoring the obstetric management of labour. In support of Hofmeyr e.al. [6] who stressed the importance of task-sharing (in this case involving mothers), our findings show that it is feasible for pregnant women to perform fetal heart monitoring during labour so that changes in FHR in relation to the end of every contraction are monitored. A decrease in FHR that persists after the end of a contraction or occurs after a contraction is more likely to be pathological (Type 2 decelerations) compared with Type 1 decelerations that recover by the end of a contraction and may be due to head compression. Current WHO recommendations [10,11] specify FHR documentation on the partograph every 30 minutes in the first stage and every five minutes in second stage and not with every uterine contraction as in this programme. Moreover, WHO recommend that the FHR is listened to immediately following the end of a contraction ONLY during initial assessment of the mother during labour, when malpresentation or malposition are present, and when inducing or augmenting labour. This latter WHO guidance means that monitoring of the FHR immediately following each

uterine contraction is not part of the partograph during the majority of labour [10, 11]. Our findings appear to question this guidance, suggesting that WHO guidelines may need to be reconsidered.

Although mothers have so far not been involved in the design of this work, future expansion of the project to include the possible role of female relatives and/or traditional birth attendants in supporting the mothers during monitoring, especially at times when contractions are particularly frequent and painful around the end of the first stage and during the second stages of labour, is planned.

The mothers' comments on the lack of any pain control were of great concern and the mothers were clear about the need for pain control during labour. We have now followed up the need for adequate pain control during labour within the Liberian Ministry of Health and Social Welfare and plan to include input from mothers on the best ways of achieving adequate pain relief during labour.

Some mothers also asked us to teach their relatives and friends the fetal monitoring process and we hope to meet their request by continuing with, and further expanding, the maternal fetal monitoring approach into maternity units throughout Liberia.

Future developments could benefit from the involvement of a female family member or traditional birth attendant to help mothers undertake the monitoring; especially late in labour when the pain of contractions tends to be most severe making monitoring very difficult for some mothers. An introduction to maternal monitoring during labour at antenatal visits may also be beneficial.

## Conclusions

The most promising findings of this initiative were the ability of the mothers to detect fetal heart rate changes, the absence of intrapartum stillbirths, and the low rate of resuscitation and subsequent birth asphyxia/HIE in neonates who had been monitored. An encouraging additional finding is that mothers appear to feel empowered by being involved in monitoring the wellbeing of their unborn babies. If further studies in other settings, involving much larger numbers, continue to show these benefits, this new approach could help reduce the devastating problems of intrapartum stillbirth and birth asphyxia / HIE that are so prevalent in low resource settings.

Given the encouraging findings of this study, we suggest that other hospitals consider introducing maternal FHR monitoring. It does not appear to have any negative consequences and, most importantly, supports the rights of adolescent girls and women by empowering them to become more involved in the welfare of themselves and their unborn babies during one of the most important times in their lives. This initiative is continuing in both hospitals with further expansion planned.

## List Of Abbreviations

CBD	CB Dunbar Hospital
CHR	CH Rennie Hospital
CPAP	Continuous Positive Airways Pressure

CS	Caesarean Section
D50%	Dextrose 50% intravenous solution
FHR	Fetal Heart Rate
HIE	Hypoxic Ischaemic Encephalopathy
IUFD	Intra Uterine Fetal Death
IV	IntraVenous
LBNM	Liberian Board for Nursing and Midwifery
MCAI	Maternal and Childhealth Advocacy International
MOHSW	Ministry of Health and Social Welfare
MW	Midwife
NA	Not appropriate or not available
NNU	Neonatal Unit
NREB	National Research Ethics Board
NS	0.9% saline intravenous solution
OC	Obstetric Clinician
OR	Operating Room
R/L	Ringer Lactate intravenous solution
UNFPA	United Nations Population Fund
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization

## Declarations

### Ethics approval and consent to participate

The fetal monitoring project started as a service delivery intervention; when we realized the significance of the outcomes, we decided to approach it from a research angle for publication. As a programmatic intervention, it was fully within the domain of the Ministry of Health to implement. Re-framed as a research project, it was relevant to seek National Research Ethics Board approval.

In accordance with 45 CFR 46 the research was approved by the National Research Ethics Board (NREB) of Liberia through a full board review. The federal wide assurance number of the NREB is 000 21658 and organisation number 000 8374.

This approval was given after reviewing the documents relating to the initiative FHR monitoring project, which included the protocol stipulation that all mothers in labour (themselves individually and whatever their ages) would give their informed consent to be involved in the initiative (FHR monitoring project). Nine participants were aged under 16 years; despite their age, these young participants were pregnant mothers who had given their informed consent to be involved in the monitoring project as per the approved study protocol. Further consent from their parents or guardians was not sought. Because of poverty and complex social circumstances, it is common for mothers in Liberia to be aged under 16 years. Also, young mothers frequently attend the hospitals in labour by themselves, with no legally assigned family members in attendance and sometimes only a traditional birth attendant for support. Many women and adolescent girls do not know their age, and the illiteracy rate in Liberia is high (63%).

### **Consent for publication**

Consent for Figure 1 was obtained from the patient using the MCAI consent form which is available on request.

Advice from a practicing lawyer revealed that there was no law in Liberia requiring explicit authorization for use of an anonymized quotation in any publication. Moreover, the consent, fetal monitoring, and birth summary forms, which included the comments made by mothers, was provided to the NREB as part of the application for approval allowing them to consider whether it was comprehensive/appropriate in making its determination to approve the study.

### **Availability of data and materials**

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

### **Competing interests**

The authors declare that they have no competing interests.

### **Funding**

This initiative was funded by MCAI (Maternal and Childhealth Advocacy International): Registered as a SCIO (Scottish Charitable Incorporated Organisation) No. SC043467.

Volunteers working for this charity were involved in the design of the study and collection, analysis, and interpretation of data and in writing this manuscript.

The salary of one of the authors, Nurse Adeyemo Kola, who was employed as Master Trainer for the neonatal clinician task-sharing programme was paid for by MCAI. The salary of another of the authors, Dr Obed Dolo, who was employed as Master Trainer for the advanced obstetric clinician training programme was also paid

for by MCAI. A training allowance to assist with training obstetric clinicians at CH Rennie hospital was also paid to another author, Dr Asinya Magnus.

No funding was provided to the authors whose salaries or training allowance were paid for by MCAI. They were not paid to be involved with this present research project.

### **Authors' contributions**

The corresponding author affirms that all authors meet authorship criteria and that no others who have contributed have been excluded.

Midwives and trainee obstetric clinicians KB and NJ were responsible for overseeing consent for and collection of data at CB Dunbar and CH Rennie Hospitals respectively. They checked the drafts of the manuscript as they were prepared. They checked and approved the final version of the paper.

DS is the corresponding author and guarantor for the work. He is the honorary (volunteer) medical director of MCAI. He was jointly responsible for the concept, the design, and the implementation of the study. He was a member of the study management team. He was responsible for obtaining ethical approval for the study in collaboration with the Ministry of Health. He had overall responsibility for analysing the data. He wrote the original draft of the paper and was the lead editor for all subsequent drafts.

RM is the honorary (volunteer) executive director of MCAI and Chair of Trustees and was jointly responsible with Professor Southall for the concept, the design, and the implementation of the study. She was a member of the study management team. She contributed to the analysis of the data, contributed to writing the original draft, and editing subsequent versions. She checked and approved the final version of the paper

AAK was responsible for ensuring that the neonatal care (including neonatal resuscitation) was undertaken appropriately at CB Dunbar Hospital. He has recently helped MCAI establish a county neonatal unit at CH Rennie Hospital. He was responsible for the verification of all the data, especially in cases where fetal heart rate changes were detected and managed. He was a member of the study management team. He checked and approved the final version of the paper

OD was the Medical Director at CB Dunbar Hospital during the first year of the project and was responsible for ensuring that the project was undertaken safely in this hospital. He provided clinical input into the writing of the paper and checked and approved the final version of the paper.

AM is the Medical Director at CH Rennie Hospital and responsible for ensuring that the project was undertaken safely in this hospital. He checked and approved the final version of the paper.

DW was responsible for researching the background to this research and is also the Special Advisor in Medical Ethics and Professional standards for MCAI. She is also an honorary (volunteer) international instructor of the Obstetric Clinician Training Programme in Liberia. She provided clinical input into the writing of the paper and checked and approved the final version of the paper.

MC is an honorary (volunteer) international instructor of the Obstetric Clinician Training Programme in Liberia and works intermittently in CH Rennie Hospital. She was one of the main persons responsible for formulating

the idea to undertake this project based on the high rates of stillbirth and early neonatal deaths in CH Rennie Hospital. She provided clinical input into the writing of the paper and checked and approved the final version of the paper.

BD was the Minister of Health for Liberia during the first year of the research project. She helped to ensure that the project was supported in the two hospitals. She helped with the design of the project and as Vice President of the College of Health Sciences, University of Liberia, provided comments on the draft of the paper and checked and approved the final version of the paper.

WJ has been the Minister of Health in Liberia since the beginning of 2018 and has continued to support the research project in the two hospitals. She also assisted with ensuring that the two hospitals were able to continue with the project following the change in Government of Liberia in January 2018 and has continued to support the further implementation of the project. She provided comments on the draft of the paper and checked and approved the final version of the paper.

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## Additional Files

*Additional File (PDF) Master copy of the consent form, fetal heart rate monitoring and data collection and maternal comment form.*

The consent form provides the information that was either read by each participating mother, if literate, or read to the mother by the obstetric clinician or midwife seeking consent. The form could either be signed by the mother or she could provide her fingerprint from an ink pad.

The fetal heart rate monitoring form was given to each mother who was asked to tick each time she listened to the FHR for approximately one minute following the end of every uterine contraction. If the mother considered that the FHR had changed, she would notify the midwife caring for her who would check the FHR, count it, and write down her own findings on this chart.

The data collection form recorded a summary of potentially relevant clinical data on the labour, delivery, neonatal Apgar Scores at 1 and 5 minutes, and any resuscitation given to the baby. Recorded on this form was any admission of the neonate to the neonatal unit and any treatment given to the baby. The form also

includes a section in which the comments made by mothers on their experience of the monitoring were recorded either by themselves or as transcribed by the attending midwife or obstetric clinician.

## Figures



Figure 1

Mother undertaking fetal monitoring

TIMINGS	31 <sup>ST</sup> JULY 2017	24 <sup>th</sup> OCTOBER 2017	19 <sup>th</sup> February 2018	21 <sup>ST</sup> MARCH 2018	27 <sup>th</sup> APRIL 2018	8 <sup>th</sup> May 2018	24 <sup>TH</sup> OCTOBER 2018
Project active and reported so far in the manuscript							
Project undertaken in CB Dunbar Hospital							
Project undertaken in CH Rennie Hospital							
Request for written or verbal comments from mothers							
Application to NREB							
Request for written rather than informed verbal consent from mothers to participate							
Successive improvements in data monitoring forms completed by mothers							
Communication problem where mothers at CB Dunbar monitored FHR every 30minutes following contractions rather than after every contraction							

Figure 2

Time lines of major inputs to the initiative

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [supplement1.pdf](#)
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