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Intermittent Detection of Fetal Heart Rate Abnormalities Identify Infants at Greatest Risk for Fresh Stillbirths, Birth Asphyxia, Neonatal Resuscitation, and Early Neonatal Deaths in a Limited-Resource Setting: A Prospective Descriptive Observational Study at Haydom Lutheran Hospital

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Key Words
Intermittent fetal heart rate monitoring · Perinatal morbidity and mortality · Millennium Developmental Goal 4

Abstract
Background: Intermittent fetal heart rate (FHR) monitoring during labor using an acoustic stethoscope is the most frequent method for fetal assessment of well-being in low- and middle-income countries. Evidence concerning reliability and efficacy of this technique is almost nonexistent. ***Objectives:*** To determine the value of routine intermittent FHR monitoring during labor in the detection of FHR abnormalities, and the relationship of abnormalities to the subsequent fresh stillbirths (FSB), birth asphyxia (BA), need for neonatal face mask ventilation (FMV), and neonatal deaths within 24 h. ***Methods:*** This is a descriptive observational study in a delivery room from November 2009 through December 2011. Research assistants/observers (n = 14) prospectively observed every delivery and recorded labor information including FHR and interventions, neonatal information including responses in the delivery room, and fetal/neonatal outcomes (FSB, death within 24 h, admission neonatal area, or normal). ***Results:*** 10,271 infants were born. FHR was abnormal (i.e. <120 or >160 beats/min) in 279 fetuses (2.7%) and absent in 200 (1.9%). Postnatal outcomes included FSB in 159 (1.5%), need for FMV in 695 (6.8%), BA (i.e. 5-min Apgar score <7) in 69 (0.7%), and deaths in 89 (0.9%). Abnormal FHR was associated with labor complications (OR = 31.4; 95% CI: 23.1–42.8), increased need for FMV (OR = 7.8; 95% CI: 5.9–10.1), BA (OR = 21.7; 95% CI: 12.7–37.0), deaths (OR = 9.9; 95% CI: 5.6–17.5), and FSB (OR = 35; 95% CI: 20.3–60.4). An undetected FHR predicted FSB (OR = 1,983; 95% CI: 922–4,264). ***Conclusions:*** Intermittent detection of an absent or abnormal FHR using a fetal stethoscope is associated with FSB, increased need for neonatal resuscitation, BA, and neonatal death in a limited-resource setting. The likelihood of an abnormal FHR is magnified with labor complications.

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Introduction

Each year, intrapartum hypoxia is estimated to account for about 2 million perinatal deaths worldwide, including intrapartum stillbirths and early neonatal deaths, with 98–99% of the burden in low- and middle-income countries [1–3]. An additional 1 million of the surviving infants develop neurocognitive problems such as cerebral palsy and learning difficulties [4]. The incidence of intrapartum-related stillbirths and neonatal deaths has remained essentially unchanged over the past 15 years despite efforts to intervene and meet Millennium Development Goal 4 [2, 3, 5].

The goal of fetal heart rate (FHR) monitoring is the early detection of a hypoxic fetus which should trigger appropriate and timely response/s to reverse the processes resulting in organ injury and death. Cardiotocography is the 'gold standard' for identifying fetuses at high risk in high-resource settings [6], but this device is neither available nor feasible in limited-resource settings where the burden is highest [7]. Intermittent FHR monitoring with a fetal acoustic stethoscope is the most frequent method in these areas, but evidence concerning reliability and efficacy is almost nonexistent [8, 9]. Indeed, there has only been one randomised trial comparing the effectiveness of different methods of FHR monitoring in a low-resource country [10].

In a recent series on stillbirths, the presence of skilled care at birth coupled with emergency obstetric care were identified as two major components to reduce the number of stillbirths globally. Interestingly, the necessity or importance of FHR monitoring to detect the babies at highest risk for either intrapartum stillbirths or neonatal death was not addressed [11, 12].

We hypothesized that an abnormal FHR, routinely detected using a fetal stethoscope, would identify the fetus at highest risk for intrapartum death/fresh stillbirth (FSB), birth asphyxia (BA), the need for face mask ventilation (FMV) and/or special care, and neonatal death within 24 h postpartum. The study objectives were to determine whether the detection of FHR abnormalities is associated with BA, an increased likelihood for neonatal resuscitation, early neonatal morbidity or death, and stillbirths.

Methods

This is an ongoing descriptive observational study initiated in November of 2009 at Haydom Lutheran Hospital, a rural referral hospital in Northern Tanzania. Haydom Lutheran Hospital provides comprehensive emergency obstetric care and basic emergency newborn care to a population of approximately 500,000 people, while the greater reference area covers about 2 million people [13]. Midwives largely conduct deliveries with doctors on call 24 h. FHR during labor is routinely monitored by an attending midwife using a fetal stethoscope.

Research assistants/observers are continuously present in the labor ward. The observers work in three shifts over 24 h. Three observers cover each shift; two are always located in the delivery room or in the theater; one in the adjacent neonatal area. Altogether 14 local women have been trained to observe the health care workers performance related to the deliveries and the newborns. Observations are timed using a stop watch. The findings are recorded on a data collection form and include labor information and FHR categorized as normal, abnormal, absent, or not measured; neonatal characteristics and interventions in the delivery room; and perinatal outcome (normal, admitted neonatal area, death within 24 h, or stillbirths; Appendix 1). The research assistants also review the partograms that are filled out by the birth attendants. The frequency of FHR monitoring is not recorded; therefore, the categorization of FHR is based on multiple measurements throughout labor. Abnormal is classified as one or more FHR measurement/s <120 or >160 beats/min.

GA was based on self-report of the last menstrual period and distance from symphysis pubis to fundus (on admission). Normal-term GA at Haydom Lutheran Hospital is routinely defined as 36 weeks. Thus, prematurity was defined as a GA <36 weeks. BA was defined as a 5-min Apgar score <7. Normal outcome was defined as survival >24 h without any detected difficulties. Intrapartum death/FSB was defined as an Apgar score of 0 at both 1 and 5 min with intact skin and suspected death during labor/delivery. Antepartum death/macerated stillbirth was defined as an Apgar score of 0 at both 1 and 5 min with macerated skin and suspected death before the start of labor.

Data Management at Haydom Lutheran Hospital

The research assistants are supervised and retrained by the local research manager (E.M.) who reviews the data collection forms on a daily basis for quality control issues including missing information or potential errors. The data are double entered in EpiData 3.1 by two different people. For this report the data collection was from November 2009 through December 2011.

Statistical Analysis

Analysis was performed using Statistical Package for Social Sciences 17. Descriptive statistics were used to present data as means ± SD unless otherwise stated. χ^2 calculations and independent-sample t tests were utilised to compare different subpopulations. The significant associated dependent categorical variables were identified after multiple logistic modelling (logistic regression with forward and backward selection). Notably each dependent variable was subjected to multiple logistic modelling. OR, 95% CI, and p values were also determined. The categorical covariates were entered as follows: pregnancy complications (yes or no), maternal infections (yes or no), GA (<36 or ≥36 weeks), birth weight (≤2,500 or >2,500 g), fetal presentation (abnormal or normal), labor complications (yes or no), and FHR (abnormal or normal). Estimates of specificity and predictive values were calculated using 'VassarStats' Clinical Calculator 1.

Table 1. Perinatal outcomes at 24 h after birth defined as normal, admitted to a neonatal area, dead, FSB, and macerated stillbirth (MSB), and associated population description

Population descriptors	Normal 9,870 (96.1)	Admitted 33 (0.3)	Death 89 (0.9)	FSB 159 (1.5)	MSB 120 (1.2)
Antenatal information					
Antenatal care visit	9,817 (99.5)	32 (97.0)	89 (100)	156 (98.1)	119 (99.2)
Pregnancy complication	64 (0.6)[a]	3 (9.1)[a]	3 (3.4)[a]	12 (7.9)[a]	18 (15.0)[a]
Neonatal characteristics					
Birth weight, g	3,137 ± 482[b]	2,902 ± 608[b]	2,662 ± 812[b]	2,919 ± 740[b]	–[c]
GA, weeks	36.5 ± 1.4[d]	35.5 ± 2.5	35.0 ± 3.0	36.0 ± 2.6	34.9 ± 3.1[d]
5-min Apgar score <7	28 (0.3)[e]	5 (15.2)[e]	36 (40.4)[e]	0	0
Resuscitation					
Stimulation	1,472 (14.9)[f]	24 (72.7)[f]	73 (82.0)[f]	25 (15.7)	0
Suction	1,319 (13.4)[f]	23 (69.7)[f]	73 (82.0)[f]	27 (17.0)	0
FMV	578 (5.9)[f]	20 (60.6)[f]	70 (78.7)[f]	27 (17.0)	0

Values given are n (%) or mean ± SD.

[a] Self-reported pregnancy complication were more frequent among mothers of babies who died ($p = 0.002$), those who remained admitted ($p \leq 0.0005$), FSB ($p \leq 0.0005$), and MSB ($p \leq 0.0005$) compared to normal infants.

[b] The birth weight of infants who died, remained admitted, or FSB was significantly less than of normal infants ($p \leq 0.0005$).

[c] Due to cultural tradition MSB are not weighted at the hospital.

[d] MSB were of lesser GA than normal babies ($p \leq 0.0005$).

[e] Infants who died and those admitted to the neonatal area were more likely to receive an Apgar score <7 at 5 min compared to infants with a normal outcome ($p \leq 0.0005$).

[f] Infants who died and those admitted to the neonatal area were more likely to receive stimulation, suction, and/or FMV as compared to infants with a normal outcome ($p \leq 0.0005$).

Ethical Considerations

The National Institute for Medical Research in Tanzania has approved this ongoing study.

The Regional Committee for Medical and Health Research Ethics, Western Norway considers the project (reference No. 2009/302) to be an evaluation program among certified health care workers. Formal approval from Norwegian ethical committee is thus not required. Informed consent was not obtained.

Results

The patient population included all infants (n = 10,271) born during the time period. Of these, 9,888 were singletons, 190 were of a twin set and 3 of a triplet set. Perinatal outcome by 24 h postpartum with associated population description is presented in table 1. Specifically, the death rate was 9 per 1,000 births and the FSB rate was 15 per 1,000 births. Sixty-nine infants (0.7%) had an Apgar score <7 at 5 min. Stimulation and/or suction was attempted in 1,603 cases (15.6%) and resuscitation including FMV in 695 infants (6.8%) because of failure to initiate spontaneous respirations with stimulation and/or suction. Duration of FMV was significantly longer in babies with FHR abnormalities versus normal FHR, i.e. 13 ± 21 versus 6 ± 13 min ($p = 0.006$).

The frequencies of the different perinatal outcomes, related labor complications, and mode of delivery are shown in table 2. Abnormal fetal presentation, labor complications, assisted breech delivery, vacuum extraction, and caesarean section (CS) were significantly more frequent in infants with adverse outcome (i.e. death, admission to the neonatal area, and FSB) compared to normal infants. The macerated stillbirths were not included in the analysis due to suspected death before onset of labor.

FHR and Associated Outcomes

The FHR was recorded as normal in 9,649 cases (94%), abnormal in 279 (2.7%), not detected in 200 (1.9%), and not measured in 143 (1.4%; fig. 1). Approximately 38% (59/154) of the FSB (with FHR recordings) had a normal or abnormal FHR record; the remainder had no detectable FHR (fig. 1). An undetected FHR predicted a FSB with an OR of 1,983 (95% CI: 922–4,264; $p \leq 0.0005$), a specificity of 0.99 (95% CI: 0.998–0.999), and a probability of 0.92 (95% CI: 0.85–0.96). Conversely, the probability of an alive baby with an undetected FHR was 0.08 (95% CI: 0.04–0.15).

A CS was performed in 1,271 women (12.4%) including 1,019 of 9,649 cases (10.6%) with a normal FHR and

Table 2. Perinatal outcomes at 24 h after birth defined as normal, admitted to a neonatal area, dead, FSB, and macerated stillbirth (MSB), and associated labor complications and mode of delivery

Characteristic	Normal 9,870 (96.1)	Admitted 33 (0.3)	Death 89 (0.9)	FSB 159 (1.5)	MSB 120 (1.2)
Abnormal presentation	571 (5.8)	6 (18.2)[a]	17 (19.1)[a]	41 (25.8)[a]	33 (27.5)
Labor complications	1,308 (13.3)	19 (57.6)[b]	39 (43.8)[b]	57 (35.8)[b]	23 (19.2)
Mode of delivery					
Spontaneous vaginal	8,474 (86.0)	14 (42.4)	48 (53.9)	97 (61.0)	92 (76.7)
Assisted breech	155 (1.6)	3 (9.1)[c]	5 (5.6)[c]	11 (6.9)[c]	13 (10.8)
CS	1,164 (11.8)	13 (39.4)[c]	35 (39.3)[c]	45 (28.3)[c]	14 (11.7)
Vacuum extraction	77 (0.8)	3 (9.1)[c]	1 (1.1)[c]	6 (3.8)[c]	1 (0.8)

Values given are n (%).

[a] There was a higher frequency of abnormal fetal presentation (noncephalic) among babies with abnormal outcome (i.e. admitted or dead at 24 h, or FSB) compared to normal outcome ($p \leq 0.0005$).

[b] Labor complications were more frequent in babies with abnormal compared to normal outcome ($p \leq 0.0005$).

[c] Assisted breech delivery, CS, and vacuum extraction were more common among babies with abnormal compared to normal outcome ($p \leq 0.0005$).

212 of 279 (76.0%) cases with an abnormal FHR ($p \leq 0.0005$; fig. 2). An abnormal outcome (i.e. admitted or death at 24 h, and FSB) was more likely when CS was performed because of an abnormal versus normal FHR, i.e. 30 of 212 (14%) versus 36 of 1,019 (3.5%; OR = 4.5; 95% CI: 2.7–7.5; $p \leq 0.0005$). In 67 of the 279 (24.0%) cases with an abnormal FHR, the infants were delivered vaginally (fig. 2). An abnormal outcome was 56 times more likely (OR = 56.7; 95% CI: 32.9–97.9; $p \leq 0.0005$) in those infants with abnormal FHR, i.e. 24 of 67 infants (35.8%) as compared to 88 of 8,630 infants (1.0%) with a normal FHR delivered vaginally. Finally, a FHR was not detected in the remaining 40 of 1,271 infants who underwent a CS (fig. 2). The stillbirth rate in this group was 95% (38 of 40 cases).

Table 3 summarises the significant associated relationships between the dependent variables and associated factors. The nonsignificant associated factors that were included in the modelling are not presented in the table. An abnormal FHR during labor was associated with labor complications (OR = 31.4; 95% CI: 23.1–42.8; $p \leq 0.0005$). An abnormal FHR in turn was associated with the need for FMV (OR = 7.8; 95% CI: 5.9–10.1; $p \leq 0.0005$), a 5-min Apgar score <7 (OR = 21.7; 95% CI: 12.7–37.0; $p \leq 0.0005$), neonatal death (OR = 9.9; 95% CI: 5.6–17.5; $p \leq 0.0005$), continued admission (OR = 3.0; 95% CI: 1.2–7.8; $p \leq 0.0005$), and FSB (OR = 35.0; 95% CI: 20.3–61.4; $p \leq 0.0005$).

Discussion

This prospective observational report demonstrates for the first time the value of routinely performed intermittent FHR monitoring during labor using a fetal stethoscope for the detection of the fetus at risk for FMV, BA, early neonatal death or morbidity, and FSB in a limited-resource setting. This supports the well-established thesis that an abnormal FHR is an important indicator of fetal compromise. Moreover, the findings indicate a significant association between an abnormal FHR and labor complications.

Many of the intrapartum-related deaths in this report were associated with labor complications and potentially preventable with targeted obstetric interventions. There were several babies with abnormal FHR and abnormal outcome delivered vaginally, who might have benefited from a more expedited delivery. Clearly the impact of FHR monitoring is dependent upon several factors including correct interpretation of an abnormal finding, decision-making coupled with appropriate communication, and timely effective interventions [6, 9]. On the other hand, almost 75% of the babies that either died or were admitted to the neonatal area had a normal FHR record. Several factors may have influenced this observation, including the inability to perform measurements correctly and as often as recommended [14], as well as different causes of deaths [15].

An undetected FHR was noted in nearly 2% of the records and was a powerful predictor of a subsequent stillbirth. Importantly, 5 infants with an undetected FHR had

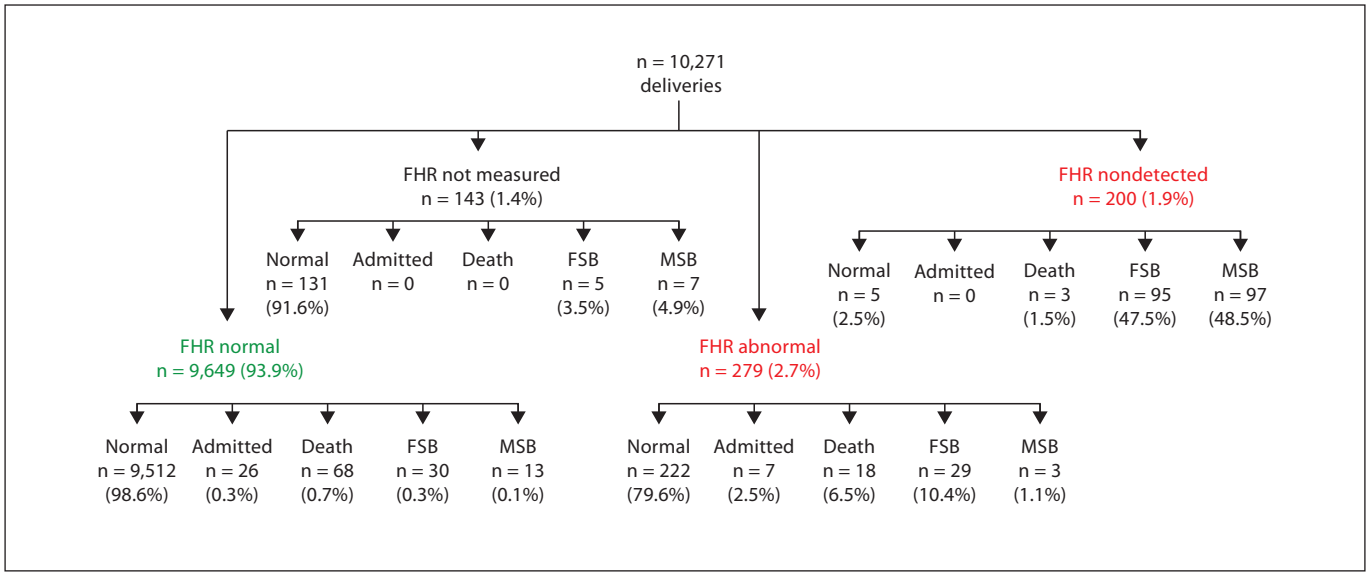

Fig. 1. Relationship of FHR recordings and perinatal outcomes at 24 h after birth. MSB = Macerated stillbirth.

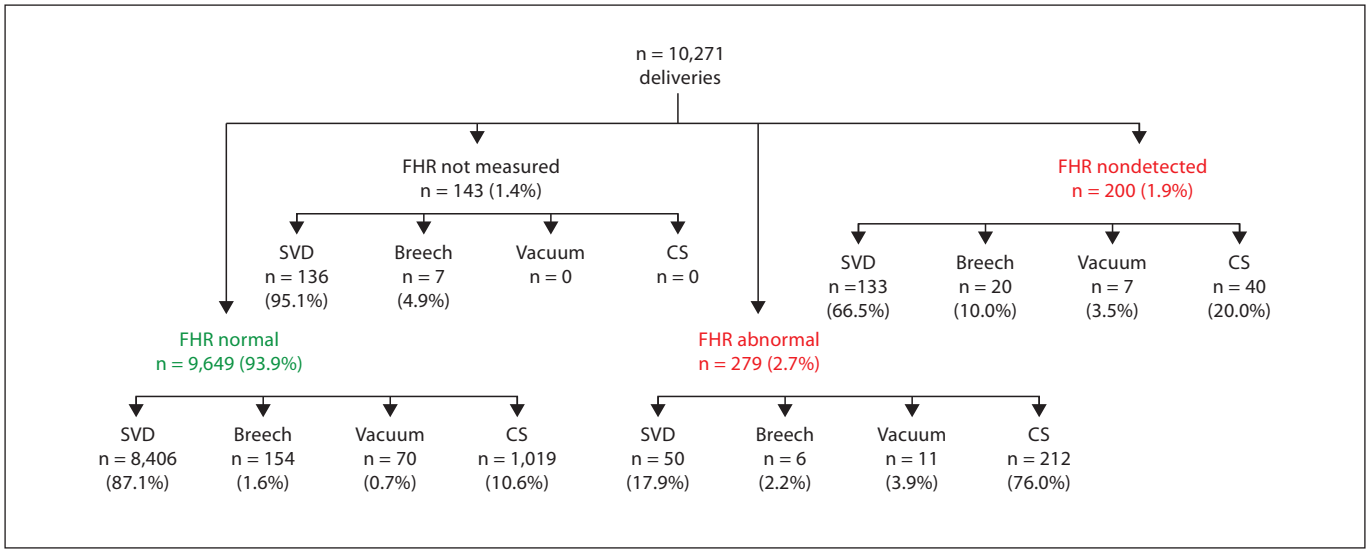

Fig. 2. Relationship of FHR recordings and mode of delivery. SVD: Spontaneous vaginal delivery.

a normal outcome, which indicate the potential of false positives for fetal death when using the fetal stethoscope, and maybe an explanation for why several CS were performed with an absent FHR. Conversely, over one third of the FSB had either an abnormal or normal FHR. This indicates an unnecessarily high FSB rate, and we can only speculate that infrequent auscultations, uncertainty around the findings, and/or delay in interventions are potential reasons. No specific reasons were noted for not monitoring the FHR in 143 cases. One factor can be that a single midwife takes care of many delivering women simultaneously, due to limited human resources. Finally, the FHR was recorded as normal or abnormal in 14 macerated stillbirths, may be due to difficulty in distinguishing FHR from maternal heart rate when using the fetal stethoscope.

Table 3. Dependent variables with significant associated risk factors, OR, 95% CI, and p values following multiple logistic modelling

Dependent categorical variable	Associated factors	OR	95% CI	p value
Abnormal FHR (vs. normal)	labor complications	31.4	23.1–42.8	≤0.0005
	GA <36 weeks	2.3	1.4–3.9	0.002
Nondetected FHR (vs. normal)	pregnancy complications	10.4	5.9–18.2	≤0.0005
	GA <36 weeks	6.9	4.7–1.2	≤0.0005
	abnormal fetal presentation	4.9	3.5–7.0	≤0.0005
CS (vs. not)	abnormal FHR	26.8	20.2–35.5	≤0.0005
Need for FMV (vs. not)	abnormal FHR	7.8	5.9–10.1	≤0.0005
	birth weight <2,500 g	1.6	1.3–2.1	≤0.0005
	GA <36 weeks	2.0	1.4–3.0	0.001
Need for stimulation/suction (no FMV) (vs. not)	labor complications	2.4	2.0–2.8	≤0.0005
	birth weight <2,500 g	1.3	1.1–1.7	0.013
Apgar score 5 min < 7 (vs. ≥ 7)	abnormal FHR	21.7	12.7–37.0	≤0.0005
	GA <36 weeks	4.2	1.9–9.3	≤0.0005
Neonatal death within 24 h (vs. normal)	abnormal FHR	9.9	5.6–17.5	≤0.0005
	birth weight <2,500 g	4.2	2.3–7.4	≤0.0005
	GA <36 weeks	3.9	2.0–7.8	≤0.0005
Admitted neonatal area at 24 h (vs. normal)	pregnancy complications	7.5	2.1–27.8	0.002
	labor complication	6.0	2.8–13.0	≤0.0005
	abnormal FHR	3.0	1.2–7.8	0.023
	birth weight <2,500 g	3.0	1.3–6.7	0.007
FSB (vs. normal)	abnormal FHR	35.0	20.3–60.4	≤0.0005
	pregnancy complications	6.0	1.7–21.0	0.005
	abnormal fetal presentation	2.3	1.1–4.5	0.021
Macerated stillbirths (vs. normal)	pregnancy complications	11.7	6.1–22.3	≤0.0005
	GA <36 weeks	12.2	7.8–19.1	≤0.0005
	maternal infection	3.7	1.9–6.9	≤0.0005

There are several limitations to this study. First, an observational study limits interpretation of whether an alternative obstetrical management strategy would have altered neonatal outcomes. Second, an abnormal FHR was broadly defined. Third, the duration of an abnormal FHR, the frequency of FHR monitoring, and the provider response to an abnormal tracing was not part of the data retrieval. Fourth, the presence of observers might have affected the staff.

The Pinard stethoscope is reported to be difficult to use, time consuming, and often painful for the mother [7, 16]; and several shortcomings are demonstrated in this study. An alternative technique is the hand-held Doppler ultrasound that is considered to cause less pain, be easier to handle, and be more reliable [7, 10, 16]. The superiority of the Doppler technique over the Pinard stethoscope for the detection of abnormal FHR and improved neonatal outcomes has been shown in one study [10]. The authors concluded almost two decades ago that 'Doppler ultrasound monitoring should be promoted in developing countries where electronic monitoring is not feasible'. Despite this recommendation, there has been no advancement in FHR monitoring technology in low-resource countries. The current Doppler technology is rarely available because of cost and the need for batteries or electricity [8, 16], and the lack of attention towards promoting intermittent FHR monitoring in recent publications remains puzzling [11, 12, 17].

This report demonstrates the predictive value of intermittently detected FHR abnormalities, and thus shows how early identification of the fetus at increased risk can be a critical catalyst to reduce perinatal mortality and morbidity in low-resourced settings. A global priority should be to develop and study noninvasive Doppler ultrasound devices that are robust and affordable, do not require electricity, permit more reliable measures, and are easy to use during labor by providers extending down to the community level. The early detection of FHR ab-

normalities should alert the (single) provider to seek obstetrical assistance locally or refer the mother to more advanced obstetrical care (if possible) in time. Furthermore, the (single) provider should identify a helper prior to delivery, prepare for newborn resuscitation, and draw attention towards stabilizing the compromised baby upon delivery before managing the mother.

This approach coupled with the 'Golden Minute®' concept adopted by the 'Helping Babies Breathe' program [18, 19] should help low-income countries accelerate towards meeting Millennium Development Goal 4 goals by 2015.

Conclusions

An abnormal FHR, routinely detected using a fetal stethoscope, is associated with FSB, increased need for neonatal FMV, BA, and early neonatal death in a limited-resource setting. An absent FHR is strongly associated with FSB. Thus, a global priority should be to develop and study the potential role of novel Doppler devices. A downstream consequence may be a reduction of perinatal morbidity and mortality by accelerating delivery as well as anticipating the need for neonatal resuscitation.

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Appendix 1

Information Recorded on the Data Collection Form

Antenatal information	
Antenatal care	Yes or no
Pregnancy complications	Yes or no
Maternal infections	Non, uterine, malaria, HIV, sepsis, or other
Labor information	
Fetal presentation	Cephalic, breech, shoulder dystocia, transverse, or other
FHR	Normal: 120–160 beats/min; abnormal: <120 or >160 beats/min; nondetected, or not measured
Mode of delivery	Spontaneous vaginal delivery, CS, assisted breech delivery, and vacuum extraction
Labor complication	Prolonged labor, obstructed labor, preeclampsia, eclampsia, uterine rupture, hemorrhage, cord prolapse
Neonatal information	
Transitional newborn adaption	Time interval (s) from birth to initiation of spontaneous respirations and cord clamping
Gender	Male or female
Birth weight	Grams
GA	Weeks
Apgar scores	1 and 5 min
Interventions in the delivering room	Stimulation, suction ± FMV with a self-inflating bag, and time interval (s) to initiation of FMV
Specific observations	Newborn heart rate present or not, time interval (s) from initiation of FMV to the onset of spontaneous breathing or death
Perinatal outcome at 24 h postpartum	
Normal	Survival > 24 h without any detected difficulties
Admitted	Designated neonatal area
Death	
Stillbirth	Macerated = antepartum or fresh = intrapartum

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