Open Peer Review on Qeios

Ensuring Fetal Well-being in Oman: Advocating Optimal Fetal Monitoring for Sustainable Maternal and Child Health

Asma Al Alawi[1], Nihal Al Riyami[1], Samir Al-Adawi[1]

1 Sultan Qaboos University

Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.

Abstract

Regular foetal monitoring during pregnancy is essential to assess the well-being of the foetus and, where necessary, to take steps to protect the health of the mother and the foetus. We summarise the best practices in foetal monitoring with emphasis on cardiotocography (CTG) and explain how the optimal use of CTG aligns with the subgoal 'good health and well-being' (SDG 3) in the 2030 Sustainable Development Goals of the United Nations (SDG). Prioritising child and maternal health in countries in the global south such as Oman is necessary due to relatively high birth rates. Inadequate foetal monitoring during pregnancy, especially during labour and delivery, puts many newborns at avoidable health risks. The home message for the present discourse is that the demographic trend in the global South and its aspiration to achieve the goal of the SDG, the CTG, have the potential to emerge as a critical tool in promoting the well-being of the emerging generation, thus contributing significantly to the overarching objective of the SDG of fostering good health and well-being for all.

Asma Al Alawi[1], **Nihal Al Riyami**[2], & **Samir Al Adawi**[2,*]

[1] *Department of Obstetrics and Gynecology, College of Medicine and Health Sciences, Sultan Qaboos University, Muscat 123, Oman*

[2] *Department of Behavioural Medicine, College of Medicine and Health Sciences, Sultan Qaboos University, Muscat 123, Oman*

[a]ORCID iD: 0009-0006-9960-8949

[b]ORCID iD: 0000-0003-0925-1052

[c]ORCID iD: 0000-0002-9858-5582

[*]Corresponding Author:

Samir Al-Adawi

Department of Behavioural Medicine,

College of Medicine & Health Sciences,

Sultan Qaboos University

Al Khoudh 123, Muscat, Oman

Email: adawi@squ.edu.om

Keywords: foetal monitoring, cardiotocography, pregnancy outcome, labour, obstetrics, SDG, Oman.

Introduction

The United Nations established the Sustainable Development Goals (SDGs) in 2016, which comprise 17 global goals as part of the 2030 Agenda for Sustainable Development. These goals are intended to address a variety of global challenges and promote a more sustainable and equitable world (United Nations, 2017). Although the SDGs cover a wide range of issues, including poverty, hunger, education, gender equality, and environmental sustainability, they are also indirectly related to health including 'good health and well-being' (SDG 3).

Oman, a country on the Arabian Peninsula with a population of four million, has been a great achiever in achieving the SDGs, especially in the field of health care. Over five decades Oman has transformed its nearly non-existent public healthcare system into one of the most efficient ones in the world (Beaudevin, Gaudillière & Gradmann, 2023). This is reflected in the country's health statistics that rival those of industrialised countries, including a high life expectancy of 78.58 years and low infant and maternal mortality rates. Most Omani women deliver in government-run hospitals. Although fertility has fallen steeply from > 7 in the 1980s to an estimated 2.548 in 2024 and is expected to fall further, it is still higher than the global fertility rate of 2.3. Such a relatively high birth rate calls for careful foetal and maternal health during pregnancy, especially near delivery. Fortunately, infrastructure and expertise are available for optimal foetal health monitoring; the question is whether these are being optimally utilised.

Foetal monitoring in Oman is a comprehensive effort aimed at ensuring the well-being of expectant mothers and their unborn children. Central to this initiative are antenatal education services, which serve as invaluable resources for pregnant women. These services empower them with the knowledge necessary to make informed decisions throughout their pregnancy journey, prepare adequately for labour, and minimise the risks associated with perinatal complications and fatalities (AlDughaishi, Seshan, & Matua, 2023).

The Ministry of Health in Oman places significant emphasis on providing effective antenatal education that goes beyond merely understanding physiological changes during pregnancy. Instead, the focus is on fostering safe pregnancy experiences, labour, childbirth, and postnatal transitions to prevent complications for both mother and foetus (AlDughaishi, Seshan & Matua, 2023).

During labour, healthcare providers utilise foetal surveillance techniques such as ST analysis of foetal electrocardiography (ECG) to monitor the well-being of the foetus. This facilitates timely interventions and enhances outcomes by furnishing valuable information (Kazmi, Radfer & Khan, 2011). Additionally, the Ministry of Health of Oman has formulated guidelines

and standardised documentation to ensure the provision of quality maternal and child health services. These guidelines underscore the importance of close monitoring and risk assessment during pregnancy and delivery to mitigate adverse outcomes (Ministry of Health, 2016).

In Oman, a dedicated effort has been made to improve foetal monitoring by setting up a centralised office. The National Pregnancy and Childbirth Guidelines have devised protocols for foetal monitoring during labour, highlighting the need to identify women at high risk for complications during the intrapartum period (Ministry of Health, 2010). Continuous electronic monitoring of the foetus during labour is recommended in such cases. For healthy women with low-risk pregnancies, intermittent auscultation is preferred, with repetition every three hours if the CTG on admission shows a normal trace. Criteria for transitioning from intermittent to continuous foetal monitoring have also been outlined. These include a baseline fetal heart rate that falls below 110 or exceeds 160 beats per minute during auscultation, the presence of decelerations detected in the CTG trace, or the development of any intrapartum risk factors such as maternal hypertension, antepartum haemorrhage, prematurity, meconium-stained amniotic fluid, prolonged membrane rupture, induction of labour, and increased labour.

The Ministry of Health in Oman provides universal free healthcare coverage, which is available to all Omani citizens and non-Omani government employees. Healthcare services in Oman are structured in three tiers: primary, secondary, and tertiary. At the primary level, services are provided through regional health centres and local hospitals, while regional hospitals constitute the secondary care level. The tertiary care level is represented by four national hospitals located primarily in Muscat, the capital of Oman. The Oman healthcare system aims to protect the well-being of expectant mothers. The Ministry of Health in conjunction with other social services stipulates mandatory antenatal care to optimise maternal and neonatal health outcomes. The objective is to provide comprehensive antenatal care to reduce perinatal and maternal mortality rates across the country. In particular, Oman has witnessed a decrease in maternal mortality rates from 22 per 100,000 live births in 1995 to 15.7 in 2022. Similarly, infant mortality and stillbirth rates have decreased from 20 to 8.8 and 11.8 to 6.9 per 1000 live births, respectively, during the same period. (Annual Health Report, 2022).

Antenatal registration, or antenatal reservation, is a crucial initial step in the process, ideally occurring within the first 13 weeks of gestation at the parent health centre. Upon registration, expectant mothers receive a 'green card' containing information, medical history, and initial investigations, including analysis of blood groups, serology evaluation, hemoglobin levels, and a first-trimester ultrasound (Annual Health Report, 2022). In addition, comprehensive health education is provided on topics such as breastfeeding and mental health during these visits. The risk assessment is performed at each prenatal visit and is updated in the Maternal Health Record (Annual Health Report, 2022). Women who have conditions outlined in the Level 1 pregnancy and childbirth management guidelines (Ministry of Health, 2016) are considered at high risk and require specialised care. Those classified as very high risk, such as people with cardiac disease, diabetes, hypertension, or hemoglobinopathies such as sickle cell disease and thalassemia, are referred to tertiary care institutions for specialised treatment and management.

Several studies show that availability and, for that matter, the absence of accurate interpretation and management of fetal monitoring may increase the prevalence of newborns with hypoxic brain injuries (Berglund, Grunewald, Pettersson, &

Cnattingius, 2008; Andreasen, Backe &, Oian, 2014; Alfirevic, Devane, Gyte & Cuthbert, 2017). Prenatal hypoxia, which refers to a decrease in oxygen supply to the foetus, has been shown to cause structural and functional changes in the brain, affecting neuronal functions and increasing the risk of cognitive, emotional and social deficits (Jain, Samycia, Elmrayed & Fenton, 2024).

Wordsworth's famous line 'The child is the father of the man' encapsulates the ancient understanding that our childhood experiences and attitudes profoundly affect who we become as adults. In the 1980s, Barker (Wang, Zeng, Liu & Sun, 2021) extended this by his hypothesis 'foetal origins of adult disease' (FOAD), implying that chronic adult diseases originate from adverse stimuli in early foetal development. Indeed, emerging evidence appears to suggest that some chronic diseases of the body and the mind may have prenatal associations (Jain, Samycia, Elmrayed & Fenton, 2024).

Limited epidemiological surveys in the Global South, including Oman, indicate that the region is vulnerable to the 'double sword' of communicable and non-communicable diseases (Asogwa et al., 2022). At this juncture, it remains premature to unequivocally attribute the predominant manifestation of the amorphous phenotype, characterised by cognitive, emotional, and social deficits, solely to prenatal events. However, it is imperative to acknowledge the potential influence of prenatal factors on the development of such deficits. The adverse impact of these factors can encompass a spectrum of negative consequences, ranging from increased dependency and increased utilisation of healthcare to the onset of disability. Therefore, while caution is warranted in assigning causality, considering prenatal events in this context has significant relevance to understanding and addressing the multiple challenges associated with the amorphous phenotype. Therefore, the dominant baby boom in the global south requires these countries to prioritise foetal monitoring.

The discernible trend of declining birth rates, evident even in regions such as the global South, including Oman, signifies a notable demographic shift. However, despite this anticipated downturn, birth rates persist at levels considered unsustainable. This poses a looming challenge, particularly in contexts like Oman, where resources are limited, relying heavily on revenues from a volatile hydrocarbon market and service industries. The imminent birth rate suggests a significant demand for foetal monitoring services, putting strain on already limited resources within the health system. To mitigate possible consequences, it becomes imperative to equip healthcare professionals with enhanced knowledge and interpretative skills in foetal monitoring. By addressing these capacity gaps, healthcare providers can strive to optimise outcomes for mothers and foetuses, thus contributing to the overarching goal of improving quality of life and well-being, as outlined in the Sustainable Development Goals (SDGs) that are set to be achieved by 2030. As such, investing in the advancement of foetal monitoring practices aligns with the global broader aspiration for sustainable development and improved healthcare outcomes.

Therefore, this discourse seeks to shed light on the science of the interpretation of foetal cardiotocographs (CTG) for healthcare professionals. The following paragraph will start by giving a background on intrapartum foetal monitoring and move on to the general principles of CTG, intermittent versus continuous auscultation, and the characteristics and interpretation of CTG according to the FIGO Intrapartum Foetal Monitoring Expert Consensus (2015). The goal is to provide obstetricians, midwives, and other providers of maternity services with the knowledge and skills necessary to accurately interpret the results of CTG, increase their awareness of possible complications, and encourage proactive

measures. These efforts contribute to the advancement of healthcare care delivery in alignment with the Sustainable Development Goal.

Background of Intrapartum Foetal Monitoring

Auscultation of foetal heart tones began in the early 19th century, and by the late 19th century, clinical criteria for intrapartum foetal distress were already established based on foetal heart rate patterns and other indicators. Intermittent auscultation of the foetal heart during labour became common practice in the first half of the twentieth century, at a time when advances in obstetrics focused on improving maternal outcomes. Research on electronic devices to monitor foetal heart rate began in the 1950s, and a commercially viable model was introduced in the United States in 1968 (Ayres-de-Campos, 2018). This led to a rapid evolution of increasingly capable foetal monitors that could continuously or intermittently assess foetal status, including heart rate during labour and delivery. There was also a concurrent proliferation in research on the benefits of intrapartum foetal monitoring (Bailey 2009). . Over time, advances in technology have led to the development of more sophisticated foetal monitoring equipment, including internal foetal scalp electrodes and intrauterine pressure catheters, allowing for a more accurate and detailed evaluation of foetal well-being. Modern cardiotocographs (CTGs) are capable of continuously monitoring multiple parameters, including foetal heart rate and uterine activity, and providing real-time feedback on foetal status, including signs of hypoxia.

The increasing dependence on intrapartum foetal monitoring has significantly influenced modern obstetric and childbirth practices. This has led to criticism of its high false positive output rates, leading to an increase in premature interventions, such as unnecessary cesarean deliveries. The benefits of continuous foetal monitoring compared to intermittent monitoring are also questioned in improving neonatal outcomes.

In the following paragraphs, electronic fetal monitoring using cardiotocography (CTG) will be considered, with particular references to the general principles of CTG, intermittent versus continuous auscultation, and finally to the characteristics and interpretation of CTG. Foetal pulse oximetry, an alternative technique, is not the subject of this discussion.

This discourse will use the guidelines and standards developed by the American College of Obstetricians and Gynecologists (ACOG) and the Royal College of Obstetricians and Gynecologists (RCOG) [Chandraharan, 2023]. Regarding the use of CTG, *the* views of the *FIGO Intrapartum Fetal Monitoring Expert Consensus (*2015) will be taken for guidance. In recent years, there has been a shift towards incorporating evidence-based practice into intrapartum fetal monitoring. This involves the use of a combination of clinical judgment, maternal-fetal evaluation, and the interpretation of fetal monitoring data to make informed decisions about labor management and interventions. The multimodal approach will be recapitulated when the context arises.

General Principles of CTG

CTG plays a crucial role in ensuring the health and well-being of both the mother and the developing foetus (Xiao, Lu, Liu, Zeng & Bai, 2022), especially during the birth process. It is crucial to moderate the dominance of technology through

personalized care during labour. A skilled caregiver can help transform a CTG session into a holistic experience that promotes understanding and empowerment throughout the birthing process. Maintaining transparency and eye contact when discussing CTG findings with the mother is likely to help her feel more actively involved in the experience. The care provided should not rigidly follow fixed recommendations but rather be sculpted to fit the unique contours of the mother's needs. Care should be tailored to factors such as contraction dynamics and antenatal and intrapartum risk profiles. This approach weaves a tapestry of care that is adjusted to the specific needs of both mother and child. The presence and participation of the husband/birth companion and their participation in the decision-making process can be a valuable source of support and enhance their shared experience and confidence. The successful management of these delicate matters depends a lot on the expertise, humanity, and patience of the caregiver. Developing these qualities and expressing them even under pressure should be constantly emphasised during the training process and included in daily briefings because each well-managed birth event is also a family bonding event.

Interpreting the CTG findings is a complex process that requires a holistic perspective, taking into account the evolving clinical situation. Therefore, it is crucial to combine the insights of CTG with the clinical narrative. In summary, the essence of CTG transcends mere monitoring; it embodies a narrative of care, in which dialogue, personalised considerations, and holistic interpretation converge to guide both mother and child and the present birth companion, through the challenge of labour into the miracle of new life and renewed togetherness.

Continuous vs*. intermittent auscultation during labour*

In intermittent auscultation, the foetal heart rate is monitored at regular intervals using a handheld Doppler ultrasound device or a fetoscope (Martis, Emilia, Nurdiati & Brown, 2017). Typically, this involves listening to the foetal heartbeat every few minutes (Eg. 15–30 min) during the active phase of labour and more frequently during the second stage or 'pushing' (Martis, Emilia, Nurdiati, & Brown, 2017). The advantages of intermittent auscultation include its non-invasiveness that allows more maternal movement. It may also reduce the likelihood of unnecessary medical interventions (Lewis, Downe, & FIGO Intrapartum Fetal Monitoring Expert Consensus Panel, 2015), leading to a more natural birth experience. Its drawbacks include the possibility of missing rapid changes in fetal status. Intermittent auscultation also needs skilled users to accurately interpret the fetal heart rate patterns. In addition, intermittent auscultation may not be suitable for high-risk pregnancies or prolonged labor.

The continuous electronic fetal monitoring technique involves placing two belts around the mother's abdomen. One belt contains a transducer to monitor fetal heart rate, while the other measures uterine contractions (Panelli, Teplick, McCarthy, & Hebert, 2014). The data are displayed on a monitor and recorded. Among its obvious advantages is that continuous monitoring of foetal heart rate and uterine contractions enables the machine to detect subtle changes in foetal well-being immediately, which makes it especially suitable for high-risk pregnancies or prolonged labour. Regarding the disadvantage of intermittent auscultation, there is evidence that it can increase the probability of interventions such as cesarean sections or instrumental deliveries due to interpretation errors or false alarms (Sandmire & DeMott, 1995). Second, intermittent auscultation limits maternal mobility, since the woman can be confined to bed or tied to the monitoring equipment.

The choice between intermittent auscultation and continuous electronic monitoring of the foetus depends on various factors, including the risk status of pregnancy, maternal preferences, labour progress, and the availability of skilled healthcare providers. Existing guidelines including ***FIGO consensus guidelines on intrapartum foetal monitoring: Cardiotocography*** (https://obgyn.onlinelibrary.wiley.com/doi/10.1016/j.ijgo.2015.06.020), ***Foetal Heart Monitoring*** (https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/fetal-heart-monitoring); Indications for Outpatient Antenatal Foetal Surveillance (https://www.acog.org/clinical/clinical-guidance/committee-opinion/articles/2021/06/indications-for-outpatient-antenatal-fetal-surveillance); Intrapartum Foetal Monitoring (Arnold & Gawrys, 2020); (Kauffmann & Silberman, 2023) provide recommendations on when each method is appropriate based on these factors (Lewis, Downe, & FIGO Intrapartum Foetal Monitoring Expert Consensus Panel, 2015; Patey et al., 2017; Kauffmann & Silberman, 2023).

Features and Interpretation of CTG

According to Francis et al. (2023), the analysis of CTG involves evaluating the different characteristics of the tracings, with fetal decelerations (DEC) being the most important, as they can indicate fetal distress. DECs are classified according to their duration and appearance of uterine contractions as prolonged, early, late, and variable, each of which is related to a specific state of foetal health. The 2016 National Institute of Clinical Excellence; by Pinas & Chandraharan (NICE 2016) describe the specific characteristics of CTG. Machine learning has demonstrated the potential to classify abnormal CTG, allowing automated interpretation (Bailey, 2009).

The Advanced Life Support in Obstetrics (ALSO) curriculum has developed a helpful mnemonic called DR C BRAVADO to help healthcare providers interpret and understand the results of CTG readings, and easily communicate with each other, leading to better care for pregnant women. In this mnemonic, DR stands for *defined risk*, C stands for *contraction frequency in 10 minutes*, Bra stands for *baseline rate*, V stands for *variability,* A stands for *accelerations,* D stands for *accelerations,* and O stands for general classification. These factors are explained as follows:

1. **DR for *defining risk.*** This indicates that the continuous CTG trace is interpreted in combination with each foetus' clinical risk status (low, medium, or high). For example, a pre-term, or otherwise high-risk infant would be expected to have relatively low resilience to the stress of birthing, which may require a change from intermittent auscultation to continuous CTG monitoring. High-risk mothers, such as those highlighted in Table 1, can have a higher risk of complications during labour, in turn increasing the risk to the foetus, which calls for closer monitoring of the mother-child dyad.
2. ***C* for *contractions.*** This indicates the duration and frequency of contractions measured using an electronic foetal monitor using an intrauterine pressure catheter (IUPC) or an external pressure transducer. Regular strong contractions will help advance labor. There is an indication that too many contractions can cause maternal and fetal complications, including the need for an emergency cesarean section. Contractions are classified according to their frequency as white (occurring ≥ 5 times in 10 minutes), and amber (≥ 5 times in 10 minutes). There are riskier types of contractions, such as those lasting two minutes or more, and can cause changes in fetal heart rate. In case of unexpected

deceleration, it is important to assess it and correlate its timing with contractions (Francis et al., 2023).

3. ***BRA* for *baseline rate*** of the fetal heart, which is usually between 110 and 160 beats per minute (BPM). A baseline outside of this range can signal potential problems and require further evaluation. It is identified by choosing the mean fetal heart rate, excluding accelerations and decelerations within 10 minutes on the CTG trace, and when the fetal heart is stable. To assess changes in baseline fetal heart rate, check previous CTG traces or foetal heart rate recordings for comparison. Categories: white (110-116 beats per minute), amber (elevations in the baseline fetal heart rate by 20 beats per minute or more from the onset of labor or within the past hour of review or 100–109 beats per minute, or if it is not possible to identify the baseline) and red (< 100 or > 160 beats per minute). An elevation in baseline fetal heart rate could indicate the onset of chorioamnionitis or hypoxia. (Francis et al., 2023).
4. **V for *variability.*** Assess fetal heart rate variability by observing small fluctuations occurring at 3 to 5 cycles per minute. Calculate the variance in beats per minute within a one-minute segment, excluding decelerations and accelerations. Categories variability as white (5-25 bpm), amber (less than 5 bpm for 30-50 minutes or more than 25 bpm for up to 10 minutes), or red (less than 5 bpm for more than 50 minutes or more than 25 bpm for more than 10 minutes), or sinusoidal pattern). Decreased variability may result from hypoxia, asthma, prior cerebral injury, infection, or drug use (Francis et al., 2023). Increased variability, known as the saltatory pattern, may indicate fetal autonomic instability or active autonomic system during hypoxia/acidosis (Thellesen et al., 2017). The sinusoidal pattern, with a smooth undulating signal, suggests severe fetal anemia or acute fetal hypoxia, among other conditions (Thellesen et al., 2017). Note: If there is no variability, cautiously expedite delivery, as it is concerning. Occasionally reduced variability is normal, especially during quiescent periods (Francis et al., 2023).
5. **A for *acceleration.*** This aims to alert the clinician to an abrupt increase in fetal heart rate, lasting 15 seconds or more, with an increase of 15 beats per minute or more. Accelerations that align with fetal movements are an indication of a healthy fetus without hypoxia or acidosis. Such movements can be used to assess the neurological response before 32 weeks of gestation, although their amplitude and frequency may be lower with 10 seconds and 10 beats per minute of amplitude. Although the absence of accelerations in a normal intrapartum CTG is of uncertain significance, it is unlikely to suggest hypoxia or acidosis. Accelerations that occur simultaneously with uterine contractions, particularly in the second stage of labour, may indicate a possible error in the recording of maternal heart rate, as the foetal heart rate most often decelerates with a contraction, while the maternal heart rate generally increases. (Francis et al., 2023).
6. **D for *decelerations*,** indicating an abrupt decrease in the fetal heart rate by more than 15 beats per minute below baseline lasting 15 seconds or more. Decelerations can be classified as early, variable, or late. Early decelerations are shallow, and brief and correspond to contractions caused by compression of the head of the fetus, which does not indicate fetal hypoxia / acidosis. Variable decelerations show a V-shaped pattern, often associated with umbilical cord compression, which is generally not indicative of significant fetal hypoxia/acidosis unless certain criteria are met. Late decelerations have a slow onset/return to baseline and reduced variability, indicating a response to fetal hypoxemia. They can also be classified as white, amber, or red depending on characteristics and duration. As variable decelerations without alarming characteristics often arise from cord compression, the mother should be encouraged to change positions or move during labour.
7. **O for *overall classification.*** Interpretation of the CTG trace is consistent at the extreme ends of the foetus monitor

strip range. For example, a normal baseline rate accompanied by accelerations or moderate variability indicates the absence of foetal acidemia. However, bradycardia, lack of variability and accelerations, and the presence of recurrent late or variable decelerations can indicate the current or imminent appearance of asphyxia. According to the NICE guidelines, the CTG traces are classified into three categories, white, amber, or red depending on the evaluation of each of the four characteristics (contractions, baseline, variability, and decelerations). If all four features are white, then it is considered normal. However, if any of the features shows up as amber, then it is considered suspicious. If two or more features are amber, or any feature is red, it is considered pathological (see Table 2). (Francis et al., 2023). Management will be determined by assessing the risk of hypoxia and the ability to deliver quickly if necessary. If the CTG trace shows abnormalities, interventions can be used, such as changing positions, providing maternal oxygen, and administering intravenous fluids. Amnioinfusion for recurrent deep variable decelerations showed a reduction in total caesarean delivery. If CTG consistently shows abnormal traces despite initial management, the possibility of accelerated delivery (either by operative vaginal delivery or cesarean delivery) should be considered (Ayres-de-Campos et al., 2015).

In conclusion, monitoring of monitoring in obstetric care embodies the principles of SDG3 by prioritizing the health and well-being of mothers and newborns. Through personalized care, effective communication, and holistic interpretation of monitoring data, CTG helps navigate the complexities of labor, ensuring safe outcomes for both mother and child, thus contributing to the overarching goal of promoting health and well-being for all.

Table 1. *Risk factors indicating the conversion from intermittent auscultation to Continuous Electronic Fetal Monitoring (O'Heney et al., 2022)*

Maternal	Fetal
Previous caesarean birth or other full-thickness uterine scar	Non-cephalic presentation (including breech, transverse, oblique and cord), including while a decision is made about mode of birth
Any hypertensive disorder needing medication	Fetal growth restriction (estimated fetal weight below the 3rd centile)
Prolonged ruptured membranes	Small for gestational age (estimated fetal weight below 10th centile) with other high-risk features such as abnormal Doppler scan results, reduced liquor volume, or reduced growth velocity.
Any vaginal blood loss other than a show	Advanced gestational age (more than 42+0 weeks at the beginning of established labor)
Any vaginal blood loss other than a show	Anhydramnios or polyhydramnios
Suspected chorioamnionitis or maternal sepsis	Reduced fetal movements 24 hours before the onset of regular contractions
Pre-existing diabetes (type 1 or type 2) and gestational diabetes that requires medication	

Table 2. *2015 revised FIGO guidelines on intrapartum fetal monitoring (Ayres-de-Campos et al., 2015)*

	Normal	Suspicious	Pathological
Baseline	110-160 bpm	Lacking at least one characteristic of normality but without pathological features.	< 100 bpm
Variability	5-25 bpm		Reduced variability. Increased variability. Sinusoidal pattern.
Decelerations	No repetitive* decelerations		Repetitive* late or prolonged decelerations for > 30 min (or > 20 min if there is reduced variability). Deceleration > 5 min
Interpretation	No hypoxia/acidosis	Low probability of hypoxia/acidosis	High probability of hypoxia/acidosis
Clinical Management	No intervention is necessary to improve the state of foetal oxygenation.	Action to correct reversible causes if identified, close monitoring, or adjunctive methods	Immediate action to correct reversible causes, adjunctive methods, or if this is not possible, accelerate delivery. In acute situations immediate assistance is essential. delivery should be accomplished;

Discussion

The present discussion advances the view that, although rarely acknowledged, CTG monitoring in obstetric care aligns with the principles of the Sustainable Development Goal 3 (SDG3) of the United Nations for 2030 by prioritizing the health and well-being of mothers and newborns. This is especially relevant to countries of the Global South with higher fertility rates, which includes relatively prosperous countries such as Oman. In these countries the population structure is pyramidal.

The Global South is also in its ‘second epidemiological transition', where ‘lifestyle’ diseases are the main threat. In the West, this phase started at least a century ago. The pace of technological changes was gradual and occurred over several generations, giving successive generations plenty of coping time. The global South, however, is passing through its second epidemiological transition phase in a world of enormous technological changes and globalisation. Cheap fast food, lack of exercise, exposure to environmental pollution, etc., affect the health of pregnant women, which could also affect their foetuses. This has resulted in a rising tide of cognitive, emotional, and social deficits that make a significant part of people incapable of thriving in the new world order.

Although there are likely to be complex mechanisms that lead to these cognitive, emotional and social deficits, the present discourse limits itself to the need to monitor foetal heartbeat and uterine contractions during pregnancy and labour. Foetal rhythm abnormalities, including irregular fetal heart rates, occur in up to 2% of pregnancies (Hornberger & Sahn, 2007). Studies have suggested that persistent foetal distress has the dire consequence of triggering hypoxic brain injuries that significantly contribute to the development of cognitive, emotional, and social deficits (DiPietro et al., 2007).

The relevance of electronic fetal monitoring lies in its potential to contribute to several goals within SDG 3. Goal SDG 3.1 aims to reduce maternal mortality. Foetal monitoring can help identify foetal distress during labour, allowing timely

interventions that can prevent complications that lead to maternal mortality. SDG3 also aims to end preventable deaths among newborns for which electronic fetal monitoring plays a crucial role. SDG 3.8 focuses on universal health coverage, including essential quality health services and protection against financial risks. Access to electronic fetal monitoring services ensures that pregnant women receive the necessary monitoring during labor, which contributes to a safer childbirth experience. Again, SGG 3) aims to strengthen the capacity of all countries to detect, reduce risk, and manage national and global health risks. Universal adoption of electronic fetal monitoring reduces maternal and fetal health risks in the short term and also reduces the long-term impact of fetal distress on the individual and society.

The future trajectory of electronic fetal monitoring holds promising prospects, with advances poised to revolutionize the field. An area of notable potential lies in the integration of artificial intelligence (AI) and machine learning algorithms into fetal monitoring systems. By harnessing the power of AI, these systems can offer enhanced capabilities for analyzing and interpreting fetal heart rate patterns and uterine contractions, leading to more accurate assessments of fetal well-being. Initiatives are already underway to utilize emerging AI in the field of fetal monitoring (Aeberhard et al, 2024). In addition, the incorporation of wearable technology into EFM devices presents another avenue for advancement. Wearable sensors and monitors could provide continuous foetal monitoring outside of traditional clinical settings, offering expectant mothers greater flexibility and convenience while ensuring constant vigilance over foetal health (Malani et al., 2023). Furthermore, the convergence of EFM with telemedicine technologies holds immense promise for remote monitoring and consultation. This could be particularly impactful in rural or underserved areas, where access to specialised obstetric care may be limited. Telemedicine-enabled EFM platforms can facilitate real-time transmission of data to healthcare providers, enabling timely interventions and improving maternal and foetal outcomes. In summary, the future evolution of electronic fetal monitoring is expected to benefit significantly from advances in AI, wearable technology, and telemedicine. By embracing these innovations, EFM systems can become more sophisticated, accessible, and effective in protecting foetal health and promoting positive pregnancy outcomes.

A famous book called "The Ghost in the Machine" by Arthur Koestler (1967) explores the challenge of using reductionists and interpretations to understand complex issues such as the status of the foetus. The idea encapsulated in the writing of Arthur Koestler can also have implications for fetal monitoring. Human eyes and clinical estute should not be relegated. Furthermore, while foetus behaviour has been shown to adhere to particular development patterns dictated by genetic factors, epigenetic mechanisms should not be overlooked. In foetal development, the epigenetic principle plays a crucial role in orchestrating various processes that govern growth, differentiation, and maturation. Throughout prenatal development, epigenetic mechanisms regulate gene expression patterns in response to environmental signals, thus shaping the development and functioning of the foetus. Environmental signals could be factors such as diet, stress, and exposure to toxins, which can influence fetal development. These environmental influences can alter epigenetic marks on the foetus's genome, potentially affecting gene expression patterns and contributing to long-term health outcomes. Therefore, in principle, in the context of epigenetic mechanisms, the field of foetal monitoring should operate within the biopsychosocial approach. This holistic perspective acknowledges that the health and development of the foetus are shaped by a complex interplay of biological processes, the psychological state of the mother, and social determinants of health. Within this context, in addition, the field of foetus development would require clinical acumen that is shaped by

biopsychosocial, and there is also the entry of culture. This means blind adherence to standardisation and norms from, say, the global north, should be critically evaluated before applying them in the mosaic society of the global south. Thus, it is necessary to scrutinise the validity, predictability, and specificity of emerging electronic foetus monitoring.

In summary, the review has highlighted the critical role of fetal monitoring in obstetric care. This undertaking has direct implications for the preservation of future citizens' well-being, which, in turn, would help align the global south with the SDG 3 agenda of promoting good health and well-being for all by prioritising the health and well-being of mothers and newborns through personalised care, effective communication and holistic interpretation of monitoring data.

Conclusions

Electronic fetal monitoring of fetal status during pregnancy and labor using cardiotocography (CTG) is crucial to ensure the health and well-being of both the mother and the fetus. Effective use of CTG is a holistic process that includes technical expertise, personalised care, effective communication, and interpretation of the output data. The CTG aligns with the United Nations Sustainable Development Goal 3 (SDG 3) for 2030 by reducing maternal mortality, preventing newborn deaths, ensuring universal health coverage, and strengthening healthcare systems. In countries in the global south that have relatively high birthrates, such as Oman, CTG plays an important role in safeguarding the well-being of the emerging generation, contributing to SDG 3's objectives of promoting good health and well-being for all.

Statements and Declarations

Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.

References

- Aeberhard, J. L., Radan, A. P., Soltani, R. A., Strahm, K. M., Schneider, S., Carrié, A., Lemay, M., Krauss, J., Delgado-Gonzalo, R., & Surbek, D. (2024). Introducing Artificial Intelligence in Interpretation of Foetal Cardiotocography: Medical Dataset Curation and Preliminary Coding-An Interdisciplinary Project. Methods and protocols, 7(1), 5. https://doi.org/10.3390/mps7010005
- Al-Adawi S, Al-Sibani N, Al-Harthi L, Shetty M, Valentina J, Al Sadoon M (2022). The Frequency and Correlates of Mental Health Problems among Khaliji Students in post-secondary education. In, Masood Zangeneh, Mona Nouroozifar & Priscilla Chou (Editors), Post-Secondary Education Student Mental Health: A Global Perspective. Toronto: Concurrent Disorders Society Press.
- AlDughaishi, M. Y. K., Seshan, V., & Matua, G. A. (2023). Antenatal Education Services in Oman: A Descriptive Qualitative Inquiry of Healthcare Provider's Perspective. SAGE open nursing, 9, 23779608231167820. https://doi.org/10.1177/23779608231167820

- Alfirevic Z, Devane D, Gyte GM, Cuthbert A. Continuous cardiotocography (CTG) as a form of electronic fetal monitoring (EFM) for fetal evaluation during labor. Cochrane Database Syst Rev. 2017 Feb 3;2(2):CD006066. doi: 10.1002/14651858.CD006066.pub3.
- Al-Saadoon M, Al-Adawi M, Al-Adawi S. Sociocultural constraints in protecting child rights in a society in transition: a review and synthesis from Oman. Child indicators research. 2021 Feb;14(1):239-67.
- Andreasen S, Backe B, Oian P. Claims for compensation after alleged birth asphyxia: a nationwide study covering 15 years. Acta Obstet Gynecol Scand. 2014;93:152–158.
- Annual Health Report (2022). Department Studies and Planning of General Directorate, Health of Ministry, Oman. https://www.moh.gov.om/documents/274609/7264771/Annual+Health+Report+2022/47623227-57f9-d9b7-372b-f16d8af6d91f
- Arnold, J. J., & Gawrys, B. L. (2020). Intrapartum Fetal Monitoring. American Family Physician, 102(3), 158–167.
- Asogwa, O. A., Boateng, D., Marzà-Florensa, A., Peters, S., Levitt, N., van Olmen, J., & Klipstein-Grobusch, K. (2022). Multimorbidity of non-communicable diseases in low-income and middle-income countries: a systematic review and meta-analysis. BMJ open, 12(1), e049133. https://doi.org/10.1136/bmjopen-2021-049133.
- Ayres-de-Campos D, Spong CY, Chandraharan E. FIGO consensus guidelines on intrapartum fetal monitoring: Cardiotocography. International Journal of Gynecology & Obstetrics. 2015;131(1), 13–24. https://doi.org/10.1016/j.ijgo.2015.06.020.
- Ayres-de-Campos, D. (2018) 'Electronic fetal monitoring or cardiotocography, 50 years later: What's in a name?', American Journal of Obstetrics and Gynecology, 218(6), pp. 545–546. doi:10.1016/j.ajog.2018.03.011.
- Ayres-de-Campos, D., Arulkumaran, S., & FIGO Intrapartum Fetal Monitoring Expert Consensus Panel (2015). FIGO consensus guidelines on intrapartum fetal monitoring: Introduction. International Journal of Gynecology and Obstetrics: the official organ of the International Federation of Gynecology and Obstetrics, 131(1), 3–4. https://doi.org/10.1016/j.ijgo.2015.06.017.
- Bailey RE. Intrapartum Fetal Monitoring. Am Fam Physician. 2009;80(12):1388-1396, https://www.aafp.org/pubs/afp/issues/2009/1215/p1388.html.
- Beaudevin, C., Gaudillière, J. P., & Gradmann, C. (2023). The local roots of 'health for all': Primary health care in practices, 1950s–2000s. Social science & medicine, 319, 115321. https://www.macrotrends.net/countries/OMN/oman/fertility-rate.
- Berglund, S., Grunewald, C., Pettersson, H., & Cnattingius, S. (2008). Severe asphyxia due to delivery-related malpractice in Sweden 1990-2005. BJOG: an international journal of obstetrics and gynaecology, 115(3), 316–323. https://doi.org/10.1111/j.1471-0528.2007.01602.x.
- Bhartiya V, Sharma R, Kumar A, Srivastava H. Admission cardiotocography: A predictor of neonatal outcome. J Obstet Gynaecol India 2016;66(Supp l1):321-9.
- Blix E, Maude R, Hals E, Kisa S, Karlsen E, Nohr EA, et al., Intermittent auscultation fetal monitoring during labour: a systematic scoping review to identify methods, effects, and accuracy. PLoS One. 2019 Jul 10;14(7):e0219573. doi: 10.1371/journal.pone.0219573.
- Byford S, Weaver E, Anstey C. Has the incidence of hypoxic-ischaemic encephalopathy in Queensland been reduced

with improved education in fetal surveillance monitoring? Aust N Z J Obstet Gynaecol. 2014;54(4):348-353. doi: 10.1111/ajo.12200.

- Chandraharan E. Updated NICE Cardiotocograph (CTG) guideline: Is it suspicious or pathological?. J Clin Med Surgery. 2023; 3(2): 1129.
- DiPietro JA, Bornstein MH, Hahn CS, Costigan K, Achy-Brou A. Fetal heart rate and variability: stability and prediction to developmental outcomes in early childhood. Child Dev. 2007 Nov-Dec;78(6):1788-98. doi: 10.1111/j.1467-8624.2007.01099.x. PMID: 17988321; PMCID: PMC2267766.
- DiPietro JA, Bornstein MH, Hahn CS, Costigan K, Achy-Brou A. Fetal heart rate and variability: stability and prediction to developmental outcomes in early childhood. Child Dev. 2007 Nov-Dec;78(6):1788-98. doi: 10.1111/j.1467-8624.2007.01099.x. PMID: 17988321; PMCID: PMC2267766.
- Draycott T, Sibanda T, Owen L, Akande V, Winter C, Reading S, et al. Does training in obstetric emergencies improve neonatal outcome? BJOG. 2006;113(2):177-182. doi: 10.1111/j.1471-0528.2006.00800.x.
- Evans, M. I., Britt, D. W., Evans, S. M., & Devoe, L. D. (2022). Changing Perspectives of Electronic Fetal Monitoring. Reproductive sciences (Thousand Oaks, Calif.), 29(6), 1874–1894. https://doi.org/10.1007/s43032-021-00749-2.
- Francis F, Luz S, Wu H, Townsend R, Stock SS. Machine Learning to Classify Cardiotocography for Fetal Hypoxia Detection. Annu Int Conf IEEE Eng Med Biol Soc. 2023 Jul;2023:1-4. doi: 10.1109/EMBC40787.2023.10340803.
- Gültekin-Zootzmann B. (1975). The history of monitoring the human fetus. Journal of Perinatal Medicine, 3(3), 135–144. https://doi.org/10.1515/jpme.1975.3.3.135.
- Hornberger LK, Sahn DJ. Rhythm abnormalities of the fetus. Heart. 2007 Oct;93(10):1294-300. doi: 10.1136/hrt.2005.069369. PMID: 17890709; PMCID: PMC2000955.
- Hove, L. D., Bock, J., Christoffersen, J. K., & Hedegaard, M. (2008). Analysis of 127 peripartum hypoxic brain injuries from closed claims registered by the Danish Patient Insurance Association. Acta obstetricia et gynecologica Scandinavica, 87(1), 72–75. https://doi.org/10.1080/00016340701797567.
- Jain, S., Samycia, L., Elmrayed, S., & Fenton, T. R. (2024). Does the evidence support in utero influences on later health and disease? A systematic review of highly cited Barker studies on developmental origins. Journal of perinatology: official journal of the California Perinatal Association, 10.1038/s41372-024-01889-4. Advance online publication. https://doi.org/10.1038/s41372-024-01889-4.
- Jepsen I, Blix E, Cooke H, Adrian SW, Maude R. The overuse of intrapartum cardiotocography (CTG) for low-risk women: An actor-network theory analysis of data from focus groups. Women and Birth. 2022;35(6), 593–601. doi.org/10.1016/j.wombi.2022.01.003.
- Kauffmann, T., & Silberman, M. (2023). Fetal Monitoring. In StatPearls [Internet]. StatPearls Publishing.
- Kazmi, T., Radfer, F., & Khan, S. (2011). ST Analysis of the Fetal ECG, as an Adjunct to Fetal Heart Rate Monitoring in Labour: A Review. Oman medical journal, 26(6), 459–460. https://doi.org/10.5001/omj.2011.118.
- Lewis, D., Downe, S., & FIGO Intrapartum Fetal Monitoring Expert Consensus Panel (2015). FIGO consensus guidelines on intrapartum fetal monitoring: Intermittent auscultation. International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics, 131(1), 9–12. https://doi.org/10.1016/j.ijgo.2015.06.019.

- Malani, S. N., 4th, Shrivastava, D., & Raka, M. S. (2023). A Comprehensive Review of the Role of Artificial Intelligence in Obstetrics and Gynecology. Cureus, 15(2), e34891. https://doi.org/10.7759/cureus.34891
- Martis, R., Emilia, O., Nurdiati, D. S., & Brown, J. (2017). Intermittent auscultation (IA) of fetal heart rate in labour for fetal well-being. The Cochrane database of systematic reviews, 2(2), CD008680. https://doi.org/10.1002/14651858.CD008680.pub2.
- Millde-Luthander C, Källen K, Nyström ME, Hogberg U, Hakansson S, Harenstam K, et al. Results from the National Perinatal Patient Safety Program in Sweden: the challenge of evaluation. Acta Obstet Gynecol Scand. 2016;95(5):596-603. doi: 10.1111/aogs.12873.
- Miller, S., Abalos, E., Chamillard, M., Ciapponi, A., Colaci, D., Comandé, D., Diaz, V., Geller, S., Hanson, C., Langer, A., Manuelli, V., Millar, K., Morhason-Bello, I., Castro, C. P., Pileggi, V. N., Robinson, N., Skaer, M., Souza, J. P., Vogel, J. P., & Althabe, F. (2016). Beyond too little, too late and too much, too soon: a pathway towards evidence-based, respectful maternity care worldwide. Lancet (London, England), 388(10056), 2176–2192. https://doi.org/10.1016/S0140-6736(16)31472-6.
- Ministry of Health (2010). Pregnancy & Childbirth Management Guidelines: Level- 2: A Guide for Nurses, Midwives and Doctors (1st Edition).
- Ministry of Health (2016). Pregnancy & Childbirth Management Guidelines: Level- 1: A Guide for Nurses, Midwives and Doctors (2rd Edition). www.moh.gov.om/documents/272928/4017900/ANC%2BLevel%2B1%2B2nd%2Bedition.pdf/2faec81b-46b3-7071-5d5f-3a4a676089aa.
- Ministry of Health (2018) Healthcare in Oman-The Nation's Progress in Health and Well-Being. https://sustainableoman.com/wp-content/uploads/2021/04/Good-Health-and-Well-Being.
- Ministry of Health Annual Health Report (2022). https://www.moh.gov.om/documents/274609/7264771/Annual+Health+Report+2022/47623227-57f9-d9b7-372b-f16d8af6d91f).
- Mohan M, Ramawat J, La Monica G, Jayaram P, Fattah SA, Learmont J, et al. Electronic intrapartum fetal monitoring: a systematic review of international clinical practice guidelines. AJOG Glob Rep. 2021 Mar 6;1(2):100008. doi: 10.1016/j.xagr.2021.100008.
- Mohan, M., Ramawat, J., La Monica, G., Jayaram, P., Fattah, S. A., Learmont, J., Bryan, C., Zaoui, S., Pullattayil, A. K., Konje, J., & Lindow, S. (2021). Electronic intrapartum fetal monitoring: a systematic review of international clinical practice guidelines. AJOG global reports, 1(2), 100008. https://doi.org/10.1016/j.xagr.2021.100008.
- O'Heney J, McAllister S, Maresh M, Blott M. Fetal monitoring in labour: summary and update of NICE guidance. BMJ. 2022;379:o2854. https://doi.org/10.1136/bmj.o2854.
- Panelli, D., Teplick, F., McCarthy, M., & Hebert, S. (2014). Comparing methods to secure external fetal-monitoring devices. MCN. The American journal of maternal child nursing, 39(1), 41–49. https://doi.org/10.1097/NMC.0b013e3182a8de72.
- Patey, A. M., Curran, J. A., Sprague, A. E., Francis, J. J., Driedger, S. M., Légaré, F., Lemyre, L., Pomey, M. A., Grimshaw, J. M., & Canada Prime Plus team (2017). Intermittent auscultation versus continuous fetal monitoring:

exploring factors that influence birthing unit nurses' fetal surveillance practice using theoretical domains framework. BMC pregnancy and childbirth, 17(1), 320. https://doi.org/10.1186/s12884-017-1517-z.

- Pehrson C, Sorensen JL, Amer-Wåhlin I. Evaluation and impact of cardiotocography training programmes: a systematic review. BJOG. 2011;118(8):926-935. doi: 10.1111/j.1471-0528.2011.03021.x.
- Pinas, A., & Chandraharan, E. (2016). Continuous cardiotocography during labour: Analysis, classification and management. Best practice & research. Clinical obstetrics & gynaecology, 30, 33–47. https://doi.org/10.1016/j.bpobgyn.2015.03.022.
- Prabha S, Jha K. Role of admission cardiotocography in predicting perinatal outcome in low risk obstetric population. Int J Med Res Prof. 2017;3:369-72.
- Rosset, I. K., Lindahl, K., Blix, E., & Kaasen, A. (2020). Recommendations for intrapartum fetal monitoring are not followed in low-risk women: A study from two Norwegian birth units. Sexual & reproductive healthcare: official journal of the Swedish Association of Midwives, 26, 100552. https://doi.org/10.1016/j.srhc.2020.100552.
- Sandmire, H. F., & DeMott, R. K. (1995). Auscultation of the fetal heart presents advantages over electronic monitoring. Wisconsin medical journal, 94(12), 661–663.
- Santo S, Ayres-deCampos D, Costa-Santos C, Schnettler W, Ugwumadu A, Da Graca LM, et al. Agreement and accuracy using the FIGO, ACOG and NICE cardiotocography interpretation guidelines. Acta Obstet Gynecol Scand 2017;96:166-75.
- Singh SK, Kumar R, Agarwal A, Tyagi A, Bisht SS. Intrapartum cardiotocographic monitoring and its correlation with neonatal outcome. J Family Med Prim Care. 2022 Nov;11(11):7398-7405. doi: 10.4103/jfmpc.jfmpc_1525_22.
- Thellesen L, Sorensen JL, Hedegaard M, Rosthoej S, Colov NP, Andersen KS, et al. Cardiotocography interpretation skills and the association with size of maternity unit, years of obstetric work experience and healthcare professional background: a national cross-sectional study. Acta Obstet Gynecol Scand. 2017 Sep;96(9):1075-1083. doi: 10.1111/aogs.13171.
- Ugwumadu A, Steer P, Parer B, et al. Time to optimise and enforce training in interpretation of intrapartum cardiotocograph. BJOG. 2016;123(6):866-869.
- United Nations (2017) Resolution adopted by the General Assembly on 6 July 2017, Work of the Statistical Commission related to the 2030 Agenda for Sustainable Development (A/RES/71/313 Archived 28 November 2020 at the Wayback Machine.
- Wang, B., Zeng, H., Liu, J., & Sun, M. (2021). Effects of Prenatal Hypoxia on Nervous System Development and Related Diseases. Frontiers in neuroscience, 15, 755554. https://doi.org/10.3389/fnins.2021.755554
- Xiao Y, Lu Y, Liu M, Zeng R, Bai J. A deep feature fusion network for fetal state assessment. Front Physiol. 2022 Nov 30;13:969052. doi: 10.3389/fphys.2022.969052.