Available online at www.rajournals.in

RA JOURNAL OF APPLIED RESEARCH

ISSN: 2394-6709

DOI:10.47191/rajar/v11i3.10

Volume: 11 Issue: 03 March-2025

International Open Access

Impact Factor- 8.553

Page no.- 155-161

The Mechanism and Interpretation of Fetal Non Stress Test and Cardiotocography

I Gde Sastra Winata[1], Prayascita Mahendrata[2], Marchindy Paul Adrian Haning[3], Jessica Nathalia[4]

[1,3,4] Department of Obstetrics and Gynecology, Faculty of Medicine, Udayana University, Indonesia

[2]Department of Obstetrics and Gynecology, Bali Mandara General Hospital, Indonesia

ARTICLE INFO	ABSTRACT
Published Online: **17 March 2025** Corresponding Author: **I Gde Sastra Winata**	Understanding fetal heart rate monitoring is essential for ensuring the health of the developing child during pregnancy and labor. Healthcare professionals rely on this monitoring to detect any irregularities or changes in the fetal heart rate, which can indicate fetal distress or compromise. Monitoring methods such as the nonstress test (NST) and cardiotocography (CTG) play a vital role in assessing fetal well-being, providing critical information about the fetus's health. NST is a non-invasive procedure that monitors fetal heart rate in response to movements. NST helps determine if the fetus is receiving sufficient oxygen and is free from distress. CTG, also known as electronic fetal monitoring, is a more comprehensive method that continuously records both fetal heart rate and uterine contractions. CTG is crucial in labor monitoring, offering real-time data that aids in the assessment of fetal well-being and the identification of potential issues such as hypoxia or abnormal labor patterns. Both NST and CTG play integral roles in ensuring optimal fetal health during pregnancy and labor. By providing valuable data on fetal heart rate responses, these monitoring techniques enable healthcare providers to make informed decisions, enhance the management of high-risk pregnancies, and improve overall outcomes.

KEYWORDS: Fetal heart rate, Fetal Non-Stress Test, Cardiotocography

I. INTRODUCTION

Monitoring the fetal heart rate is crucial for assessing the health and well-being of the developing child during pregnancy and labor. Healthcare professionals use it to identify any irregularities or changes in the fetal heart rate that can indicate fetal distress or compromise.[1] Fetal heart rate monitoring is primarily used to assess the fetus's oxygen intake, track the fetal heart rate during contractions, and identify any abnormalities or changes in the heart rate rhythm. Typically, fetal heart rates range from 110 to 160 beats per minute for a normal reading. Deviations from this range, such as bradycardia (slow heart rate) and tachycardia (rapid heart rate), could indicate potential problems such as insufficient oxygen delivery or fetal distress.[2]

Fetal heart rate monitoring methods, such as the nonstress test (NST) and cardiotocography (CTG), play a vital role in assessing fetal well-being during pregnancy and labor. These methods provide critical information about the fetus's health by tracking heart rate patterns and responses to uterine contractions.[3] The NST measures the fetal heart rate in response to movement and is a non-invasive test that takes 20 to 40 minutes and is usually carried out after 28 weeks of pregnancy. Sensors placed on the mother's belly track the fetus's heart rate continuously throughout the test, and the results are classified as reactive (showing a healthy response) or nonreactive (which may require further investigation) based on the occurrence of heart rate accelerations in response to fetal movements.[4]

CTG, an electronic fetal monitoring method, enables the continuous recording of fetal heart rate and uterine contractions. It provides real-time assessment of fetal heart rate patterns and their correlation with contractions, aiding in the identification of signs of fetal distress during labor.[5] Both the NST and CTG are essential for determining possible problems with fetal oxygenation and general health. When abnormal patterns are detected using these monitoring techniques, additional testing or interventions, such as a biophysical profile or prompt delivery, may be required. These methods enable prompt interventions that can significantly improve outcomes for the mother and the fetus by providing insightful information about fetal health.[6]

By understanding the workings and interpretation of NST and CTG in fetal heart rate monitoring, healthcare providers can make more informed decisions to ensure the safety and well-being of both the mother and the fetus during labor. Therefore, this article was written to find out more about the mechanisms and interpretation of NST and CTG in FHR monitoring.

II. NON STRESS TEST (NST)

A. Definition

NST is a prenatal screening method employed to evaluate fetal well-being through the monitoring of fetal heart rate (FHR) in response to fetal movements. This non-invasive assessment is predominantly utilized in the third trimester of pregnancy to ensure the adequate oxygen supply to the fetus and to ascertain its well-being.[7] It yields crucial information that aids healthcare professionals in making informed decisions regarding the management of pregnancy and labor. The NST aims to evaluate fetal heart rate patterns and their correlation with fetal movements. Its primary objectives include assessing fetal well- being, particularly in determining fetal health and distress by observing FHR responses to movements, monitoring high-risk pregnancies to identify potential complications associated with conditions such as preeclampsia, diabetes, or growth restrictions, and evaluating overdue pregnancies to ensure fetal health post the due date or when decreased fetal movements raise concerns.[8]

B. Advantages and Disandvantages

The benefits of utilizing NST are as follows[9, 10]:

1. Non-Invasive Nature: NST is a wholly non-invasive procedure that entails the application of external sensors on the mother’s abdomen without the need for any internal instruments or procedures, thereby minimizing risk and discomfort.
2. Safety for Both Mother and Baby: The procedure is considered exceptionally safe for both the mother and the fetus as it does not involve medications or invasive techniques and can be performed as a component of routine prenatal care.
3. Real-Time Monitoring: NST offers immediate feedback on the fetal heart rate, enabling healthcare providers to promptly evaluate the well-being of the fetus, providing valuable real-time data to facilitate timely clinical decisions.
4. Simplicity of the Procedure: NST is a straightforward and easy procedure that generally necessitates minimal preparation and can be conducted in an outpatient setting, ensuring convenience for both patients and healthcare providers.
5. Applicability in High-Risk Pregnancies: This procedure is particularly advantageous for monitoring high-risk pregnancies, such as those complicated by preeclampsia, diabetes, or fetal growth restriction, aiding in the early detection of potential issues and assisting in the timely management of these conditions
6. Minimal Special Preparation Required: Typically, the procedure does not demand any special preparation from the patient, rendering it accessible and easily integrable into regular prenatal care.

NST also has some disadvantages[9, 10]:

1. False-Negative Results: NST may yield false-negative results, particularly when the fetus is in a state of rest or minimal movement, leading to a non-reactive outcome despite the fetus being healthy. Confirmation of fetal well-being may require further testing.
2. Limited Information: While NST offers insights into fetal heart rate in relation to movements, it lacks comprehensive data on other facets of fetal health, uterine contractions, or fetal position.
3. Potential for Maternal Discomfort: Some women may experience mild and temporary discomfort from the sensors or maintaining a specific position during the test, which can be bothersome for some individuals.
4. Interpretation Challenges: Interpretation of NST results, especially in non-reactive cases, can be challenging, potentially causing unwarranted anxiety for expectant mothers and necessitating supplementary diagnostic procedures.
5. Dependency on Fetal Activity: The accuracy of NST is contingent on fetal activity, where insufficient movement or the fetal sleep cycle during the test can impact results, potentially leading to a non-reactive outcome.
6. Potential for Follow-Up Tests: Non-reactive NST results may warrant additional testing, such as a biophysical profile or a stress test, resulting in heightened medical visits and increased anxiety for the mother.

C. Tools and Equipment

The Fetal Non-Stress Test (NST) relies on specific tools and equipment designed to monitor and evaluate the fetal heart rate in response to fetal movements. Here is an overview of the primary tools and equipment used in conducting an NST[10, 11]:

1. Fetal Heart Rate Monitor
   A fetal heart rate monitor is central to an NST. It typically consists of a Doppler ultrasound transducer or an electronic fetal monitor. The monitor detects and records the fetal heart rate using ultrasound waves. It measures the frequency and variability of the heartbeats to assess fetal well-being. There are two types of fetal heart rate monitors: a Doppler ultrasound transducer, often used in outpatient settings for NSTs, and an Electronic Fetal Monitor (EFM), which provides continuous fetal heart rate monitoring and can also measure uterine contractions.
2. Tocodynamometer (Toco)
   A tocodynamometer is a pressure-sensitive device used to detect and record uterine contractions. While primarily used in labor to monitor contractions, it can be part of an NST setup to ensure that uterine activity is accounted for, although not always necessary if the

focus is solely on fetal heart rate. It is placed on the abdomen to measure the tension or pressure exerted by uterine contractions.

3. Electrodes and Sensors
   Electrodes or sensors are attached to the mother’s abdomen to collect data from the fetal heart rate monitor and the tocodynamometer. They ensure accurate transmission of fetal heart rate and uterine contraction data to the monitoring equipment. There are two types of electrodes and sensors: external sensors (non-invasive sensors that attach to the mother’s skin using belts or straps) and internal electrodes (used less frequently, which are inserted into the uterus to directly measure fetal heart rate and contractions, usually in more complex cases).
4. Fetal Heart Rate Strips (Printouts)
   These are graphical representations of the fetal heart rate data recorded during the NST. They provide a visual record of the fetal heart rate patterns, accelerations, and decelerations. This printout is used by healthcare providers to analyze and interpret the results of the test.
5. NST Monitoring Software
   Modern fetal monitoring systems often include software that aids in the analysis and interpretation of the NST data. The software can analyze patterns in fetal heart rate variability, generate reports, and help identify whether the NST is reactive or non-reactive. It may include alarms for abnormal patterns, automated reports, and integration with electronic health records (EHR).
6. Patient Comfort Aids
   Tools and devices to ensure the comfort of the pregnant patient during the NST include cushions or support pillows to help the patient maintain a comfortable position during the test.

D. *Mechanism*

The Fetal Non-Stress Test (NST) is a vital procedure for monitoring fetal well-being through the assessment of fetal heart rate (FHR) response to movements. Below is a comprehensive guide on conducting the NST[9, 12]:

1. Patient Preparation:
   a) Positioning: Position the pregnant woman in a semi-reclining or lateral position to ensure comfort and avoid potential compression of major blood vessels.
   b) Clothing: Ensure that the patient is dressed in loose-fitting clothing to facilitate easy access to the abdomen.
2. Equipment Preparation:
   a) Fetal Heart Rate Monitor: Prepare and calibrate the monitor correctly.
   b) Tocodynamometer (if used): Set up the tocodynamometer for detecting uterine contractions.
   c) Sensor Placement: Fetal Heart Rate Sensor: Position the fetal heart rate monitor on the patient’s abdomen, typically close to where the fetal heartbeat is best detected, often in the upper part of the abdomen where the fetal back is located. Secure it using an elastic belt or strap to secure the sensor and ensure consistent skin contact.
   d) Tocodynamometer (if used):
   Position the tocodynamometer on the lower part of the abdomen, if applicable, to measure uterine contractions. Secure it with a belt or strap, ensuring a snug fit without being too tight.
3. Conducting the Test
   a) Initial Setup: turn on the fetal heart rate monitor and adjust settings as required and ensure proper alignment of the sensors and clear readings.
   b) Monitoring
   The NST typically lasts between 20 to 40 minutes. Encourage the mother to record fetal movements or consume a cold drink to stimulate fetal activity. Continuously monitor the fetal heart rate and ensure the sensors remain in place throughout the test.
   c) Data Collection and Analysis:
   Record the fetal heart rate and the mother is asked to press a button each time she feels the baby move. The fetal heart rate is then recorded in response to these movements. A normal response is an increase in fetal heart rate by at least 15 beats per minute within 30 seconds of fetal movement. Display real-time data on a monitor and produce a cardiotocogram (CTG) or fetal heart rate strip.
   d) Analysis:
   There’s 2 type of NST analysis, reactive NST and non-reactive NST.
4. Post-Test Procedure:
   a) Sensor Removal
   Gently remove the sensors and any belts or straps from the patient's abdomen and ensure the patient's comfort and address any inquiries or concerns.
   b) Interpreting Results
   Review the fetal heart rate strip or cardiotocogram with the healthcare provider for result interpretation and discuss findings with the patient, explaining whether the NST was reactive or non-reactive and the potential next steps.

E. *Interpretation*

To evaluate fetal well-being, an NST printout, also known as a cardiotocogram (CTG), is analysed to interpret the fetal heart rate (FHR) and uterine contractions over time. The layout of the NST printout contains three axis: the horizontal axis (time), representing the duration of the test and allowing tracking of FHR changes; the vertical axis (FHR), measured in beats per minute (bpm) to observe FHR fluctuations and patterns.[12]

Baseline heart rate is crucial, with a normal range of 110 to 160 bpm over a 10-minute period being reassuring. Tachycardia (consistently above 160 bpm) may indicate fetal distress, while bradycardia (consistently below 110 bpm) may signal fetal distress or oxygenation issues. Assessing heart rate variability is important, with normal moderate variability (6-25 bpm) indicating a healthy, well-oxygenated fetus. Decreased variability may suggest fetal distress, sedation, or sleep cycles, while absent variability can be concerning and indicate significant fetal distress. Temporary increases in FHR of at least 15 bpm above the baseline, lasting for at least 15 seconds, are known as accelerations. A normal pattern involves at least two accelerations within a 20-minute period, resulting in a reactive NST and indicating good fetal health. Decelerations are also assessed.[11, 13] Early decelerations are gradual decreases in FHR that start and end with contractions and are typically benign. Variable decelerations are abrupt decreases in FHR related to umbilical cord compression and may require further evaluation. Late decelerations occur after the peak of a contraction and can indicate uteroplacental insufficiency, necessitating additional investigation. The overall patterns of NST are categorized as reactive NST (characterized by a normal baseline FHR, moderate variability, and at least two accelerations), non-reactive NST (lacking accelerations and abnormal variability, usually requiring further assessment), and equivocal NST (results that are not clearly reactive or non-reactive may necessitate repeat testing or additional diagnostic procedures to clarify fetal well-being).[8, 9, 13]

III. CARDIOTOCOGRAPHY

A. *Definition*

Cardiotocography (CTG) is a diagnostic tool used to monitor the fetal heart rate and uterine contractions during labor and delivery. It provides real-time data on how the fetus is coping with the stress of labor and helps in identifying potential problems. CTG helps evaluate how well the fetus is handling labor by monitoring heart rate patterns and the impact of contractions. It also can identify signs of fetal distress, such as abnormal heart rate patterns, which may indicate issues like reduced oxygen supply or other complications.[7, 14]

B. *Advantages and Disadvantages*

Cardiotocography (CTG) is a method used for monitoring fetal well-being during pregnancy and labor. It offers the advantage of early detection of fetal distress, particularly in high-risk pregnancies involving maternal or fetal medical conditions. CTG also aids in guiding delivery decisions and enhancing monitoring during labor.[7, 15]

However, CTG has limitations, including restricting the mother's mobility and potentially leading to complex and challenging interpretations of fetal heart rate patterns. Continuous CTG monitoring may also result in a higher rate of interventions without a corresponding improvement in perinatal outcomes.[16] While CTG can reduce neonatal seizures, it does not significantly impact rates of cerebral palsy or perinatal mortality. Insufficient evidence supports the claim that continuous CTG significantly improves fetal outcomes compared to intermittent monitoring methods, suggesting that continuous data from CTG does not necessarily translate into better health outcomes for the fetus.[16, 17]

C. *Tools*

The integration of Cardiotocography (CTG) and Non-Stress Test (NST) tools is crucial for fetal monitoring. These tools serve different purposes and are utilized in different contexts. The main components and tools used in CTG[14, 18]:

1. External Fetal Monitors: This includes the ultrasound transducer, which uses ultrasound waves to detect the fetal heart rate. It is positioned on the mother’s abdomen, providing real-time heart rate information. Additionally, the tocodynamometer measures uterine contractions by detecting changes in abdominal pressure during contractions.
2. Internal Fetal Monitors: In certain cases, a fetal scalp electrode is used for more accurate fetal heart rate monitoring. It involves attaching a small electrode to the fetal scalp through the cervix. Moreover, the use of an Intrauterine Pressure Catheter (IUPC) inserted into the uterus measures the precise strength of uterine contractions, offering a more accurate measurement compared to the external tocodynamometer.
3. CTG Machines: These machines integrate both the ultrasound transducer and tocodynamometer. They display and record fetal heart rate and uterine contraction data on a screen. Some systems also feature digital storage and analysis capabilities.
4. Software and Digital Tools: Modern CTG systems are equipped with software for data analysis, providing graphical representations and alerts for abnormal readings. This software aids in interpreting complex patterns and trends in fetal heart rate and contractions. Additionally, CTG data can be integrated into electronic health records for improved documentation and accessibility.

D. *Mechanism*

1. Preparation[18]
   a) Patient Positioning: The mother is typically positioned in lateral recumbent, half-sitting, and upright positions. It is important to avoid the maternal supine recumbent position as it can lead to aortocaval compression by the pregnant uterus, which can impact placental perfusion and fetal oxygenation.
   b) Gel Application: A conductive gel is applied to the mother’s abdomen to enhance the transmission of sound waves for the ultrasound transducer.
2. Monitoring Components[19, 20]
   a) External Monitoring

This method utilizes ultrasound waves to detect the fetal heart rate. The transducer emits high-frequency sound waves that bounce off the moving fetal heart. The reflected waves are then converted into electrical signals to produce a real-time fetal heart rate graph. The transducer is typically placed on the mother’s abdomen, usually over the fetal back where the heart rate is best detected. Tocodynamometer is used to measure uterine contractions by detecting changes in abdominal pressure caused by uterine contractions. It converts these pressure changes into electrical signals and is placed on the abdomen over the area where contractions are most palpable.

b) Internal Monitoring (used if external monitoring is insufficient)

Internal monitoring involves the use of a fetal scalp electrode, which provides a more accurate measurement of fetal heart rate. A small electrode is attached to the fetal scalp through the cervix to directly measure the electrical activity of the fetal heart. Additionally, internal monitoring can utilize an Intrauterine Pressure Catheter (IUPC) to measure the strength and duration of uterine contractions. A catheter is inserted into the uterus through the cervix and connected to a pressure transducer to measure intrauterine pressure directly. It is inserted through the cervix into the amniotic sac.

3. Signal Recording[21]

The data from both transducers is recorded on a paper strip known as a cardiotocograph (CTG) or displayed graphically on a monitor. This provides a continuous record of fetal heart rate and uterine contractions.

E. Interpretation

CTG analysis begins with assessing basic CTG features: baseline, variability, accelerations, decelerations, and contractions, followed by overall CTG classification.[7, 22]

1. Baseline

The mean level of the most horizontally oriented and least oscillating segments in fetal heart rate (FHR) is determined within 10-minute intervals and expressed in beats per minute (bpm). The baseline value may vary between consecutive 10-minute segments. In cases where FHR signals are unstable, it may be necessary to review previous segments and/or assess longer time periods to establish the baseline, particularly during the second stage of labor and when identifying the fetal behavioral state of active wakefulness. This is important as it can lead to inaccurately high baseline estimations.[19, 20, 22]

Normal baseline is a value between 110 and 160 bpm. Tachycardia is defined as a baseline heart rate above 160 beats per minute lasting for more than 10 minutes. Conditions that can cause tachycardia include maternal pyrexia, the use of epidural analgesics, the initial stage of fetal hypoxemia, and the administration of beta-agonist drugs such as terbutaline, salbutamol, ritodrine, and fenoterol, as well as fetal arrhythmias. On the other hand, bradycardia is characterized by a baseline heart rate below 110 beats per minute lasting for more than 10 minutes. Maternal hypothermia, the administration of beta-blocker drugs, and fetal arrhythmias are among the conditions that can lead to bradycardia. [19, 20, 22]

2. Variability

The term "variability" refers to the fluctuations in the FHR (fetal heart rate) signal, assessed as the average bandwidth amplitude of the signal in 1-minute intervals. Normal variability is indicated by a bandwidth amplitude of 5–25 bpm. Reduced variability is described as a bandwidth amplitude below 5 bpm for more than 50 minutes in baseline segments or for more than 3 minutes during decelerations. Decreased variability can stem from hypoxia/acidosis in the central nervous system, which results in diminished sympathetic and parasympathetic activity. It may also be linked to preexisting cerebral injury, infection, administration of central nervous system depressants, or parasympathetic blockers. Increased variability, termed a "saltatory pattern," is characterized by a width value surpassing 25 bpm that persists for over 30 minutes and is believed to be caused by fetal autonomic instability or an overactive autonomic system.[18, 20, 22]

3. Accelerations

Sudden increases in fetal heart rate that reach their peak in less than 30 seconds, are more than 15 beats per minute above the baseline, and last for more than 15 seconds but less than 10 minutes are known as accelerations. Most accelerations coincide with fetal movements and reflect a responsive nervous system in the fetus, indicating absence of hypoxia or acidosis. Before 32 weeks of gestation, the intensity and frequency of accelerations may be reduced (10 seconds and 10 beats per minute in intensity). After 32-34 weeks, accelerations rarely occur during periods of deep sleep, which can last up to 50 minutes, as fetal behavioral states develop.[7, 20, 22]

4. Deceleration

When monitoring fetal heart rate, it's important to be aware of certain patterns. Early decelerations are typically shallow, short-lived, and coincide with contractions. Variable decelerations have a distinctive V shape, drop quickly, but then bounce back to the baseline with good variability. They can vary in size, shape, and their relationship to contractions. Late decelerations have a gradual onset and/or return to the baseline and/or reduced variability. Prolonged decelerations last for more than 3 minutes and may indicate hypoxemia. Any deceleration lasting over 5 minutes, with fetal heart rate maintained at less than 80 bpm and reduced variability, should prompt urgent intervention, as it's often associated with acute fetal hypoxia/acidosis.[22]

5. Contraction
   Bell-curved gentle rises in uterine activity are followed by similarly shaped decreases, lasting a total of 45 to 120 seconds. Tachysystole is when contractions occur too frequently, meaning more than five contractions in 10 minutes, in two consecutive 10-minute periods, or on average over a 30-minute period.[7, 22]
6. Overall CTG Classification[20, 22]
   a) Sinusoidal pattern
      A regular, smooth, wavelike signal, reminiscent of a sine wave, with a strength ranging from 5 to 15 beats per minute and a frequency of 3 to 5 cycles per minute. This pattern persists for over 30 minutes and is observed simultaneously with absent accelerations. Additionally, this pattern has been noted in cases of acute fetal hypoxia, infection, cardiac malformations, hydrocephalus, and gastroschisis.
   b) Pseudosinusoidal pattern
      A pattern that looks like the sinusoidal pattern, but with a more uneven "saw-tooth" appearance instead of the smooth sine-wave shape. It rarely lasts longer than 30 minutes and is characterized by normal patterns before and after. This pattern has been observed after the mother is given pain relief medication, and during times when the fetus is sucking or making other mouth movements.

The interpretation of cardiotocography (CTG) results includes three scenarios: a fetus without hypoxia or acidosis, a fetus with a low likelihood of hypoxia or acidosis, and a fetus with a high probability of hypoxia or acidosis.[22] In cases where there is no fetal hypoxia or acidosis, no intervention is needed. When there is a low probability of hypoxia or acidosis, it is important to address any reversible causes and closely monitor the fetus or use additional methods to assess fetal oxygenation. If there is a high probability of hypoxia or acidosis, immediate action is necessary to address any reversible causes, use additional techniques to evaluate fetal oxygenation, or expedite delivery if needed. In urgent scenarios such as cord prolapse, uterine rupture, or placental abruption, immediate delivery is crucial.[7, 19, 22]

IV. CONCLUSION

NST nad CTG are methods used to monitor fetal health, but they have different purposes and applications. CTG is used for continuous monitoring during labor and to identify signs of fetal distress, while the NST is a screening test used in the third trimester to assess fetal well-being. CTG involves simultaneous monitoring of fetal heart rate and uterine contractions, whereas the NST measures fetal heart rate in response to maternal perception of fetal movements. CTG records are analyzed for multiple features related to fetal heart rate and uterine activity, whereas the NST focuses on the presence of accelerations in response to fetal movements. NST is often used as a routine screening in high-risk pregnancies or when there are concerns about fetal health outside of labor, whereas CTG is more commonly used during labor to closely monitor fetal and uterine conditions.

REFERENCES

1. Monson M, Heuser C, Einerson BD, et al. Evaluation of an external fetal electrocardiogram monitoring system: a randomized controlled trial. *Am J Obstet Gynecol* 2020; 223: 244.e1-244.e12.
2. Romano M. A Comprehensive Review of Techniques for Processing and Analyzing Fetal Heart Rate Signals Alfonso. *Sensors* 2021; 21: 1–32.
3. Enabudoso E. Contemporary Obstetrics and Gynecology for Developing Countries: eSecond Edition. In: *Electronic fetal monitoring*, pp. 159–173.
4. Singhania AT, Jahagirdar S, Junghare P, et al. Role of Admission Test NST and Its Outcome in Pregnancy. *Int J Heal Allied Sci*; 12. Epub ahead of print 2024. DOI: 10.55691/2278-344x.1068.
5. David AL, Spencer RN. Clinical Assessment of Fetal Well-Being and Fetal Safety Indicators. *J Clin Pharmacol* 2022; 62: S67–S78.
6. Kauffmann T, Silberman M. Fetal Monitoring. Treasure Island (FL), 2023.
7. Grivell RM, Alfirevic Z, Gyte GML, et al. Antenatal cardiotocography for fetal assessment. *Cochrane Database Syst Rev* 2015; 2015: 1–39.
8. Umana OD, Vadakekut ES, Siccardi MA. Antenatal Fetal Surveillance. Treasure Island (FL), 2024.
9. Rezaee Moradali M, Pazhohan A, Zareipour M, et al. Effectiveness of Non Stress Test on Fetal, Neonatal and Maternal Outcomes to Prevent Chronic Consequences in Delivery Health Centers. *Jundishapur J Chronic Dis Care* 2020; 9: 1–6.
10. Deshmukh S, Choudhary A, Jungari M, et al. Study of non-stress test as a screening tool in low risk pregnancies at term gestation. *Indian J Forensic Med Toxicol* 2020; 14: 7126–7131.
11. American College of Obstetricians and Gynecologists. Antepartum Fetal Surveillance. *Obstet Gynecol* 2021; 137: e116–e127.
12. Patange RP, Patil SS, Shah PD, et al. Non-stress test in high-risk pregnancy. *Int J Curr Res Rev* 2020; 12: 112–117.
13. Lear CA, Westgate JA, Ugwumadu A, et al. Understanding Fetal Heart Rate Patterns That May Predict Antenatal and Intrapartum Neural Injury. *Semin Pediatr Neurol* 2018; 28: 3–16.
14. Ben M'Barek I, Jauvion G, Ceccaldi PF. Computerized cardiotocography analysis during labor – A state-of-the-art review. *Acta Obstet Gynecol Scand* 2023; 102: 130–137.
15. Alfirevic Z, Devane D, Gyte GML, et al. Continuous cardiotocography (CTG) as a form of electronic fetal

monitoring (EFM) for fetal assessment during labour. *Cochrane Database Syst Rev*; 2017. Epub ahead of print 2017.
DOI: 10.1002/14651858.CD006066.pub3.

16. Jepsen I, Blix E, Cooke H, et al. 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: 593–601.
17. Deng Y, Zhang Y, Zhou Z, et al. A lightweight fetal distress-assisted diagnosis model based on a cross-channel interactive attention mechanism. *Front Physiol* 2023; 14: 1–13.
18. Ribeiro M, Nunes I, Castro L, et al. Machine learning models based on clinical indices and cardiotocographic features for discriminating asphyxia fetuses—Porto retrospective intrapartum study. *Front Public Heal*; 11. Epub ahead of print 2023. DOI: 10.3389/fpubh.2023.1099263.
19. Spairani E, Steyde G, Tagliaferri S, et al. Fetal states identification in cardiotocographic tracings through discrete emissions multivariate hidden Markov models. *Comput Methods Programs Biomed* 2023; 240: 107736.
20. Ingemarsson I. Fetal monitoring during labor. *Neonatology* 2009; 95: 342–346.
21. Mendis L, Palaniswami M, Brownfoot F, et al. Computerised Cardiotocography Analysis for the Automated Detection of Fetal Compromise during Labour: A Review. *Bioengineering* 2023; 10: 1–28.
22. Ayres-De-Campos D, Spong CY, Chandraharan E. FIGO consensus guidelines on intrapartum fetal monitoring: Cardiotocography. *Int J Gynecol Obstet* 2015; 131: 13–24.