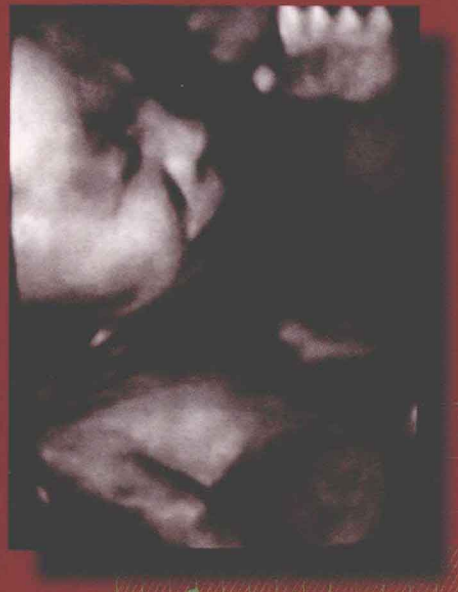
Fetal Monitoring Interpretation

Second Edition



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FETAL MONITORING INTERPRETATION

SECOND EDITION

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Production Services: Aptara, Inc.

530 Walnut Street
Philadelphia, PA 19106 USA
LWW.com

Printed in China

Library of Congress Cataloging-in-Publication Data
Cabaniss, Micki L.
Fetal monitoring interpretation / Micki L. Cabaniss, Michael G. Ross.—2nd ed.
p. ; cm.
Includes bibliographical references and index.
ISBN 13: 978-1-60831-381-5 (alk. paper)
ISBN 10: 1-60831-381-6
1. Fetal heart rate monitoring—Interpretation. I. Ross, Michael G. II. Title.
[DNLM: 1. Fetal Monitoring. WQ 209 C112f 2010]
RG628.3.H42C33 2010
618.3′207543—dc22 2009033138

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To our families and our patients, and to the clinicians who utilize
the fetal monitor
in the daily practice of medicine

Micki L. Cabaniss, MD
Michael G. Ross, MD, MPH

FOREWORD

The ubiquity of electronic fetal heart rate (FHR) monitoring in ante- and intrapartum monitoring in North America today stands in contrast to the paucity of epidemiologic evidence supporting its effectiveness. There are a number of reasons why this is so, and which I do not plan to cover, but it is clearly a widespread rebuttal of the numerous trials that have shown minimal or no benefit to FHR monitoring in improving newborn outcome. Most obstetricians now regret the fact that FHR monitoring was introduced and so widely accepted by health care providers before its benefits were demonstrated by clinical trials. But now, despite its widespread usage, it is important for clinical teachers and investigators to find evidence to support or reject its usage.

This book by Cabaniss and Ross shows the enormous literature that has developed around the subject and uses those publications, and I suspect the authors' own private opinions, to present recommendations for interpretation of most of the variant patterns that will be encountered in the antepartum or labor and delivery suite. Almost every page contains their suggestions and recommendations to apply to the various patterns. The presumed physiologic mechanism(s) behind the patterns are also described.

This is a treasure trove for anyone wanting to design studies to support or refute the proposals for management described herein. The propositions of the authors are based on the best available evidence, but in fact, so few of these proposals have been adequately proven that almost every statement on management serves as a hypothesis waiting to be rigidly tested.

Agreement on nomenclature has been widely promulgated since the 1997 National Institute of Child Health and Human Development Research Planning Workshop,[1] and revisited in 2008 with some additions, and the major clinical bodies such as the American College of Obstetricians and Gynecologists,[2] the Association of Women's Health Obstetrics and Neonatal Nurses,[3] and the Society for Maternal Fetal Medicine have accepted the definitions. The same is true, but to a lesser degree, about interpretation (i.e., the relationship between various patterns and fetal acidemia). When it comes to management recommendations, however, the major societies are hesitant to make proposals.[4] There appear to be a number of reasons for this,[5] but the end result is that management proposals, at least in U.S. fetal monitoring, are left to individual investigators to describe.[6] Clearly, these algorithms will need to be appropriately tested, but without a clearly stated proposed management framework, it will not be possible to do any testing.

The field of FHR monitoring is currently warming up considerably, with interest being shown by the National Institute of Child Health and Human Development, the Society for Maternal Fetal Medicine, the American College of Obstetricians and Gynecologists, and the Food and Drug Administration. Such multipronged approaches are sure to result in promulgation of more management theories, and recommendations will then be testable. Should this happen, the authors of this book will be content not only that they have provided a skeleton for tentative recommendations for management of FHR patterns based on the best available evidence, admittedly mostly Level III, but also in providing hypotheses that our young iconoclastic perinatologists will be able to investigate.

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PREFACE

Electronic fetal monitoring is a field of medicine that is advancing, yet the basics are timeless. It is advancing because it involves the rapidly changing world of technology. In addition, improvements in standardization of terminology bring promise of improved research leading to evidence that might enhance interpretation and interventions. However, the measurement that forms the foundation of fetal monitoring—the distance between two heart beats—has been utilized from the outset. Its precision is not easily superceded. Consequently, fetal monitoring interpretation maintains a significant degree of stability—it is a clinical tool that has not become outmoded in over four decades of use.

The first edition, a monograph, catalogued individual examples of fetal monitoring visual data, reporting published-to-date significance of the individual patterns and components of patterns. Case illustrations placed the visual finding in a clinical context, and labeled diagrams facilitated the associated teaching. Electronic fetal heart rate data in settings of fetal arrhythmias were correlated with electrocardiographic and echocardiographic data and were accompanied by teaching diagrams.

The second edition, coauthored with representation from both the east and west coasts, adds 20 new case illustrations, again supplemented by teaching diagrams. There are five added tracings—previously published in the medical literature—that are used by permission to present rare and unique patterns. The text is modernized, deleting items from the first edition that are outmoded by advancing knowledge and by improved technology while adding new information in the field. The text incorporates the changes in terminology recommended by the 2008 workshop jointly sponsored by the National Institute of Child Health and Human Development, the American College of Obstetricians and Gynecologists, and the Society for Maternal-Fetal Medicine. In addition to reorganization and updating of the material in the first edition, there are five new text sections.

- *Chapter 4:* Bedside assessment of the fetus is a dynamic process. Changes occur over time, influenced by a variety of factors including maternal health, pre-existing fetal health, gestation, medications, and anesthesia. This chapter looks at change over time.
- *Chapter 6:* The first edition focused on intrapartum monitoring. In this chapter, the second edition presents interpretation unique to the antepartum setting.
- *Chapter 7:* This chapter begins with a maternal or fetal condition or the fetal environment and addresses potential fetal heart rate patterns that might be associated.
- *Chapter 9:* Adjunctive methods of fetal assessment that might improve on the monitor heart rate data in inconclusive situations are reviewed in this chapter.
- *Chapter 10:* The final chapter looks at the role of the monitor in predicting or retrospectively assisting with the analysis of adverse neonatal outcomes and the future of the monitor in obstetrics.

In order to protect patient privacy, according to the Health Insurance Portability and Accountability Act regulations and/or to enhance teaching, clinical and visual data have occasionally been modified in the current edition.

ACKNOWLEDGMENTS

We are grateful to those individuals who helped with the many tasks required in compiling and formatting the information for this book.

At the Asheville office:

Lindy Gibson, who managed all behind-the-scenes activities involved in completing the book

Chris Dalton, Judith Rinaldi, Stephanie DeLoach, and Joy Eilers, who compiled the reference database

Twila Jefferson and Sundara Fawn, who created teaching sketches

Susan Pearce, who facilitated the development phase of the second edition

At the Torrance office:

Raphael Zawelski, who furnished technical support

Antonia Enriquez, who compiled the reference database

Bonnie Price and Ursula Perkins, who provided administrative support

We appreciate the gentle, skilled encouragement and assistance provided by the team at Lippincott Williams & Wilkins, particularly Kerry Barrett, Nicole Walz, and Ryan Shaw, and by the production team at Aptara.

We remain indebted to those who contributed to the first edition: Patricia C. Wagner, MSN, RNC; the late C. Daniel Cabaniss, MD; the late Robert C. Cefalo, MD, PhD; and Dimitri Karetnikov. Their prior work is reflected in the current edition.

CONTENTS

1 INTRODUCTION TO THE FETAL MONITOR

The electronic fetal monitor is a computer, a precision instrument. It is the only instrument with the capability of following the fetus one heartbeat at a time. The fetus who starts with adequate oxygenation for its brain and heart can be tracked through responses to changes in oxygen supplies, by the degree to which it uses compensatory measures to maintain healthy cellular function of critical organs. Were the fetus eventually unable to sustain such compensation, the monitor can demonstrate a transition to decompensation. This provision of information, continuously updated from the fetus with its dynamic changes, is facilitated by clinician recognition of patterns and their significance—information that directly relates to the very organ systems most associated with healthy survival. Individual examples of these patterns will be reviewed and fetal physiologic responses that explain the fetal heart patterns will be emphasized. As well, we will explore the history of the monitor's role in clinical medicine, its current usage, its limitations, and its place among the opportunities for future fetal assessment.

ROLE OF THE ELECTRONIC FETAL MONITOR

The electronic fetal monitor was developed during the 1960s following extensive research of many investigators, particularly that of Edward H. Hon and R. Caldeyro-Barcia.[1–3] The instrument began to appear for use in clinical settings in the 1970s, and shortly thereafter there were monitors in almost every labor and delivery unit in the United States and those of other countries throughout the world.[4–6] There have been predictions that fetal monitoring may soon become antiquated, yet it has persisted in clinical settings for decades with promise of many years of usage ahead, perhaps incorporating continued advances in technology.

Major criticism about the monitor has been directed at its introduction in patient care prior to what was considered adequate research to show its effectiveness.[7–9]

When the monitor came on the clinical scene, it was hoped that we would seldom have stillbirths in labor and seldom have babies who developed cerebral palsy, which at that time was believed to be largely caused by oxygen depletion during labor and delivery.[10] Initially, retrospective reports were published with small numbers of patients showing significant improvements in perinatal mortality and newborn outcomes.[11–14] However, these retrospective studies were confounded by the relative effects of other coincident clinical advances that improved fetal and neonatal outcome in the mid 1970s to mid 1980s. These included maternal transport, new subspecialized maternal and neonatal caregivers, and newborn intensive care units with accompanying new technology and treatments. Prospective multi-institutional studies followed, with large case numbers comparing electronic fetal monitoring with intermittent fetal heart auscultation of low- and high-risk patients.[15–21] Children were followed into school years, rather than studies stopping with the Apgar score or newborn survival. A frequent finding across the studies was the increase in cesarean section rates in monitored groups.[17,18,20,22,23] Although cesarean section rates were increasing at that time for reasons other than the monitor (e.g., increased fetal weight due to improved maternal nutrition, increased maternal prepregnancy weight and pregnancy weight gain), operative rates remained elevated among electronically monitored patients. Of surprise to clinicians, there has been little evidence of clinical benefit of electronic fetal monitoring,[23,24] with no evidence of a reduction in the rates of cerebral palsy[24–30] and limited evidence of a reduction in perinatal mortality,[23] although one study demonstrated a reduction in the incidence of neonatal seizures (1987). The studies themselves have been challenged as performed before resolving some of the issues that have limited the clinical understanding of asphyxia and the relationship to cerebral palsy.[31] We now know that a major reason for lack of impact on cerebral palsy rates is the evidence that only a small proportion of cerebral palsy is a result of fetal oxygen deprivation during labor.[32,33]

Consequently, proponents of intermittent fetal heart auscultation have suggested that electronic fetal monitoring should not be used for reasons including:

- Increased operative rate without a consequent reduction in cerebral palsy[34,35]
- Potential distraction from direct patient care and interaction
- Confinement of the mother to a bed because of the instrument
- Unwarranted lawsuits that may be fostered by monitor data[35]
- Risk of invasive technology of internal monitoring[36–38]
- Increased cost of obstetric care[35]

With all of these deterrents, why do we still have the monitor? Could it be that it is really beneficial yet the benefits are not easily examined with a research protocol? The use of the instrument has improved our understanding of underlying maternal-fetal-placental physiology.[39] Among individual cases, it is apparent that the monitor can detect impending fetal compromise as well as demonstrate resolution of compromise.[40] However, as has been suggested,[41] fetal heart rate monitoring may lack optimal specificity and positive predictive value for the recognition of fetal hypoxia, acidemia, or acidosis, even with "expert" interpretation.[42–45] Challenges of complex pattern recognition and interpretation by myriad practitioners further limit the ability of studies to demonstrate benefit when compared with intensive one-on-one nursing with intermittent auscultation.[46–53] Yet with diminishing nursing resources, the need for transmission of fetal heart rate information, and the desirability of documentation and

"evidence," this form of fetal assessment has risen to the most common obstetric procedure.[54,55] It is apparent that electronic fetal heart rate monitoring will remain.[56–59] However, it is only with proper knowledge of fetal heart rate patterns and the underlying fetal and maternal physiology, and with appropriate clinical recognition, interpretation, and decision-making, that the use of the fetal monitor will benefit both mother and fetus.[60–63] The goal of this text is to provide the clinician with the knowledge of maternal and fetal physiology, the established definitions of fetal heart rate assessment, and the pattern recognition skills to assess and appropriately react to the challenges of fetal heart rate changes during labor.

CLASSIFICATION/TERMINOLOGY

In the late 1990s, the need for an accepted terminology was recognized by the National Institute of Child Health and Human Development (NICHD). A multidisciplinary work group was convened and succeeded in developing a generally accepted standardization of definitions and terms.[64] A subsequent 2008 workshop jointly sponsored by the NICHD, the American College of Obstetricians and Gynecologists (ACOG), and the Society for Maternal-Fetal Medicine further clarified definitions and terminology.[65] This text uses the NICHD consensus-based terminology and definitions, although we will emphasize the opportunities for clinicians to go beyond those research-based parameters when appropriate.[66,67] The new terminology does not address clinical application nor is there evidence that use of the new terminology reduces adverse outcomes.[27]

Basic Review

The vertical scale of the fetal monitor tracing denotes beats per minute (bpm), and the horizontal scale is time elapsed. Each vertical solid line represents a minute in the system in use in the United States. The semisolid lines are 20 seconds, and the tiny vertical markers denote 10 seconds. Of note, European systems use 3 minutes per vertical solid lines, and many monitors are able to shift between the two modes. On the maternal portion, the horizontal scale has the same time representation as the fetal scale, and the vertical scale is measured in millimeters of mercury (or centimeters of water) to be used if there is an internal uterine monitor. It is just an arbitrary set of numbers when using an external monitor.

Fetal monitoring tracings are divided into two parts:

- **Fetal information:** Fetal heart rate is displayed on the upper part of the monitor or paper tracing. Fetal movement indicators may also be included.
- **Maternal information:** Uterine contractions are displayed on the lower part of the monitor or paper tracing. In addition, maternal heart rate may be displayed in the upper part.

The fetal heart information is divided into two key features:

- **Baseline information:** This is the level part of the heart rate data.
  - *Heart rate:* The placement on the scale tells us the **heart rate** of the fetus (110 to 160 bpm is a "normal" rate).
  - *Variability:* This refers to fluctuations in the heart rate produced by fetal response to its internal and external environment, governed by the autonomic nervous system.
- **Changes from the baseline**
  - *Accelerations:* There is upward trace deflection. Accelerations are a speeding up of the heart rate, which is a sympathetic nervous system or systemic catecholamine effect.
  - *Decelerations:* There is downward trace deflection. Decelerations are a slowing down of the heart rate, which is a parasympathetic effect.

Distinguishing Decelerations

There are three types of decelerations that are distinguished in clinical practice. In determining the kind of deceleration, assessing *shape*, not timing, is the first step.

- Uniform Decelerations: Uniform decelerations start slowly and return slowly with a bowl shape. They have the appearance of upside-down contractions, which is appropriate because it is the buildup of the contraction and the release of the contraction that actually induce the waveform of the deceleration. Timing is the second factor when analyzing uniform decelerations.
  - **Early deceleration:** Occurring with the contraction
  - **Late deceleration:** Occurring after the contraction is in process
- **Variable decelerations:** These are unique in their shape because of their abruptness. There are myriad appearances as well as timing.
- **Prolonged decelerations:** These are any decelerations that last more than 2 minutes, whether onset was abrupt or bowl shaped. Whether they begin in a pattern of late decelerations or variable decelerations or are isolated, if they last more than 2 minutes, they are termed *prolonged*.

National Institute of Child Health and Human Development Guidelines

In 1997, the NICHD Research Planning Workshop published recommendations for standardization of intrapartum electronic fetal monitoring terminology parameters.[64] In 2005, the ACOG presented an adaptation of the proposal in tabular form (Table 1).[54]

Terminology Issue

In addition to the specific rates and patterns of fetal heart tracings, the monitor tracings have been classified in overall assessment categories. During labor, tracings have been, in the past, interpreted as reassuring or nonreassuring, reflective of the general assessment of fetal well-being. Reassuring has been defined as a normal fetal baseline rate, the presence of variability, and the absence of a pattern of decelerations, which would signify potential fetal compromise. In the preterm infant, classic criteria of reassuring patterns may not be evident and the pattern referred to as "appropriate for gestational age." In contrast, nonreassuring has been defined as a pattern indicative of potential fetal compromise and may require one or more interventions for fetal assessment, potential improvement of fetal status, or steps toward delivery. *The fact that these definitions represent two extremes of heart rate patterns has led to much confusion and medical legal controversy.*

Most recently, a 2008 NICHD-sponsored workshop[65] revisited the 1997 workshop definitions and adopted the terminology of "Normal fetal heart rate (FHR) pattern, Abnormal FHR pattern, and Indeterminate FHR pattern."[66] The American College of Obstetrics and Gynecology endorsed these categories July, 2009.[68] The updated definitions

TABLE 1 DEFINITIONS OF FETAL HEART RATE PATTERNS

Pattern	Definition
Baseline	The mean FHR rounded to increments of 5 bpm during a 10-min segment, excluding: • Periodic or episodic changes • Periods of marked FHR variability (>25 bpm) • Segments of baseline that differ by >25 bpm The baseline must be for a minimum of 2 min in any 10-min segment.
Baseline variability	Fluctuations in the FHR of two cycles per min or greater Variability is visually quantitated as the amplitude of peak-to-trough bpm • Absent—amplitude range undetectable • Minimal—amplitude range detectable but ≤5 bpm or fewer • Moderate (normal)—amplitude range 6–25 bpm • Marked—amplitude range >25 bpm
Bradycardia	Baseline FHR <110 bpm
Tachycardia	Baseline FHR >160 bpm
Acceleration	A visually apparent abrupt increase (onset to peak in <30 sec) in the FHR from the most recently calculated baseline The duration of an acceleration is defined as the time from the initial change in FHR from the baseline to the return of the FHR to the baseline. At 32 weeks' gestation and beyond, an acceleration has an acme of ≥15 bpm or more above baseline, with a duration of ≥15 sec but <2 min. Before 32 weeks' gestation, an acceleration has an acme of ≥10 bpm above baseline, with a duration of ≥10 sec but <2 min Prolonged acceleration lasts ≥2 min but <10 min. If an acceleration lasts ≥10 min, it is a baseline change.
Early deceleration	In association with a uterine contraction, a visually apparent, gradual (onset to nadir ≥30 sec) decrease in FHR with return to baseline Nadir of the deceleration occurs at the same time as the peak of the contraction.
Late deceleration	In association with a uterine contraction, a visually apparent, gradual (onset to nadir ≥30 sec) decrease in FHR with return to baseline Onset, nadir, and recovery of the deceleration occur after the beginning, peak, and end of the contraction, respectively.
Variable deceleration	An abrupt (onset to nadir <30 sec), visually apparent decrease in the FHR below the baseline The decrease in FHR is ≥15 bpm, with a duration of ≥15 sec but <2 min.
Prolonged deceleration	Visually apparent decrease in the FHR below the baseline Deceleration is ≥15 bpm, lasting ≥2 min <10 min from onset to return to baseline.

bpm, beats per minute; FHR, fetal heart rate.
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and three-tiered interpretation system are discussed in this section and are referred to, when applicable, throughout the remainder of the text (Table 2).

The indeterminate tracing exhibits patterns that may deserve close observation or intrapartum therapeutic measures instead of delivery intervention.[69] The category includes patterns exhibited by well-oxygenated fetuses despite absence of "normal" features. In many such instances, the clinician might gain reassurance about the welfare of the fetus through the unique combination of features of the tracing specifically in the individual clinical context as well as through information gained from adjunctive testing.

Of further note, the term *reactive* addresses a single component of the electronic fetal monitoring tracing, the presence of accelerations, whereas the term *reassuring* or *normal* addresses a constellation of components, thus, a pattern. The term *reactive*, usually used in the antepartum setting (see Chapter 6), typically has implications regarding fetal oxygenation for a matter of days, whereas the term *reassuring* or *normal*, usually reserved for the intrapartum setting, may require periodic updating throughout the process of labor.

CLINICAL APPLICATION

Assessing Uterine Activity

All fetal monitoring interpretation is addressed in the context of each patient's unique clinical setting. Key to this is the presence or absence of uterine contractions. If present, understanding the nature of the uterine activity contributes to recognizing the significance of the fetal heart data. The altered environment during contractions with its temporary restriction of uteroplacental blood flow may be tolerated by the fetus with utilization of only basal oxygenation measures or may trigger the use of compensatory mechanisms to sustain adequate oxygenation. At times, the fetal responses may reflect a possible decompensation of such measures. The information reflected on the tracing may then guide the clinician in manipulation of the fetal environment for therapeutic intervention. Diminishing uterine activity may be a part of supportive measures to maximize blood flow and oxygenation. The assessment of uterine activity may guide assessment

TABLE 2 NICHD 2008 THREE-TIER FETAL HEART RATE INTERPRETATION SYSTEM

Normal FHR Pattern

A normal FHR tracing includes all of the following:

- Baseline rate: 110–160 bpm
- Baseline FHR variability: moderate
- Late or variable decelerations: absent
- Early decelerations: present or absent
- Accelerations: present or absent

Abnormal FHR Pattern

An abnormal FHR tracing includes either:

- Absent baseline FHR variability and any of the following:
  - Recurrent late decelerations
  - Recurrent variable decelerations
  - Bradycardia
- Sinusoidal pattern

Indeterminate FHR Pattern

An indeterminate FHR pattern includes all FHR tracings not categorized as normal or abnormal. These indeterminate patterns may represent an appreciable fraction of those encountered in clinical care. Examples of indeterminate FHR patterns include:

Baseline rate

- Bradycardia not accompanied by absent baseline variability
- Tachycardia
- Baseline FHR variability
- Minimal baseline variability
- Absent baseline variability not accompanied by recurrent decelerations
- Marked baseline variability

Accelerations

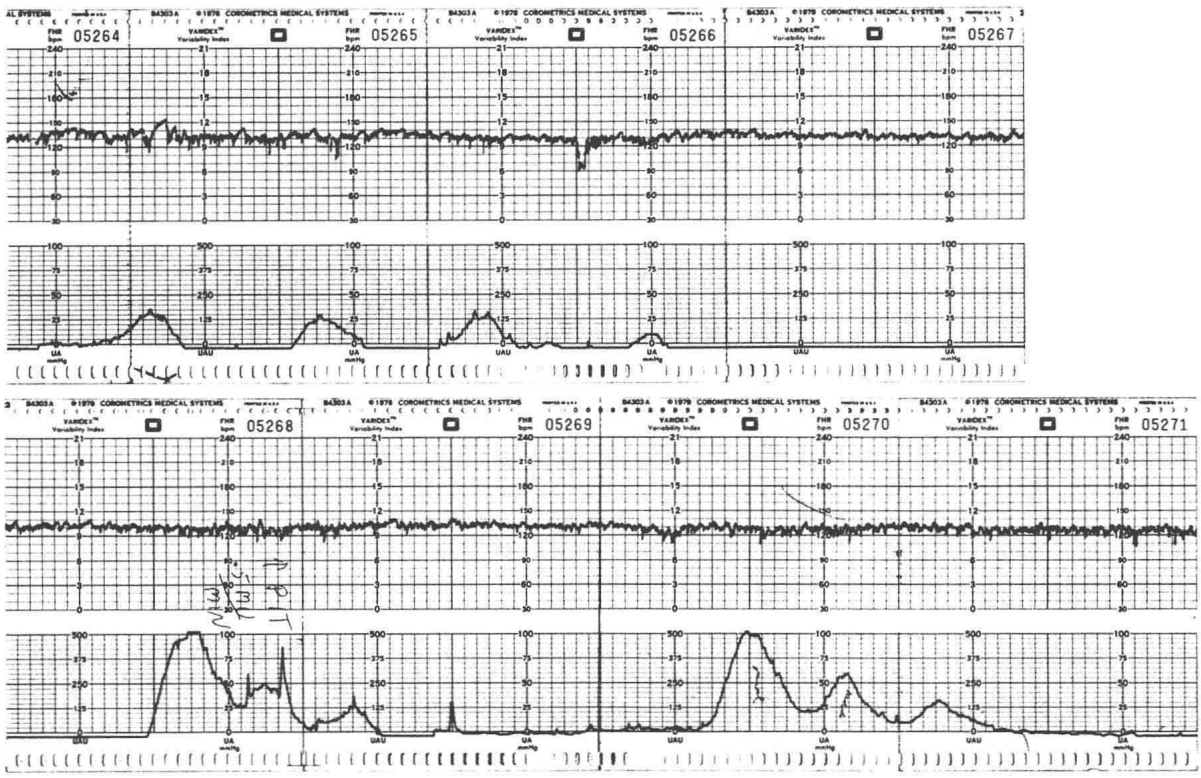
- Absence of induced accelerations after fetal stimulation
- Periodic or episodic decelerations
- Recurrent variable decelerations accompanied by minimal or moderate baseline variability
- Prolonged deceleration ≥2 but <10 min
- Recurrent late decelerations with moderate baseline variability
- Variable decelerations with other characteristics such as slow return to baseline, overshoots, or "shoulders."

NICHD, National Institute of Child Health and Human Development; FHR, fetal heart rate; bpm, beats per minute.
Reprinted from Macones GA, Hankins GD, Spong CY, Hauth J, Moore T. The 2008 National Institute of Child Health and Human Development workshop report on electronic fetal monitoring: update on definitions, interpretation, and research guidelines. Obstet Gynecol 2008;112:661–66, with permission.

of labor presence and progress as well as oxytocin induction and augmentation of labor.

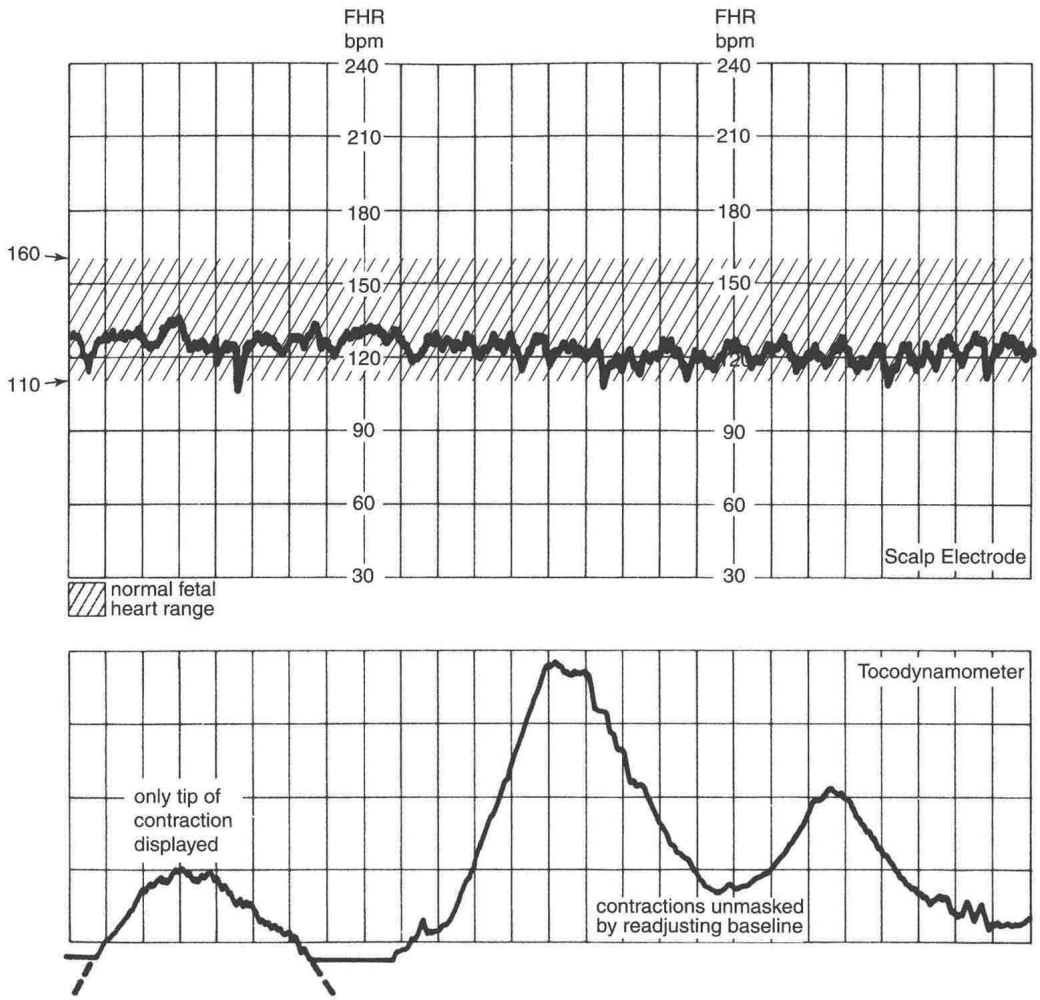
The external tocodynamometer records the uterine contraction waveform, frequency, and, to some degree of accuracy, the duration. It does not reflect the actual quantity of baseline tone or contraction amplitude. The baseline is arbitrarily adjusted by regulators on the fetal monitor and/or transducer.

The internal tocodynamometer (intrauterine pressure catheter [IUPC]) is designed to measure the actual internal uterine force. As is obvious, the IUPC requires rupture of chorioamniotic membranes for insertion. The information regarding uterine contraction intensity and basal tone may assist with diagnosis and management of labor disorders (see Chapter 5).



Case Interpretation

- **Baseline Information:** normal stable rate with moderate variability.
- **Periodic or Nonperiodic Changes:** single small acceleration, single "mild" variable deceleration.
- **Uterine Activity:** with the baseline uterine activity measured by a tocodynamometer set below zero, uterine contractions appear only every two to two and a half minutes, and oxytocin is increased; after placement of the baseline above zero, polysystolic contractions (in uterine "trigeminy") appear, which may have been masked previously.
- **Significance:** a well-oxygenated fetus is predicted, despite the dysfunctional uterine activity. Baseline adjustment improves the assessment of uterine activity for oxytocin regulation.
- **CASE OUTCOME:** Nineteen-year-old primigravida at 40 weeks' gestation delivered vaginally, with local anesthesia, a 9-pound, 9-ounce (4337 gram) male; Apgar score 9/9. The fetus was in a vertex presentation. A nuchal cord was present. The infant followed an uncomplicated newborn course.



Pattern Characteristic:
Decreased Uterine Activity—Artifact: Baseline Adjustment Effect

Predicting the Oxygenated Fetus

Patterns of the Basally Oxygenated Fetus

The fetal monitor is a highly sensitive indicator of good fetal oxygenation.[54] A normal fetal heart rate pattern has a 98% or better correlation with a fetus (were it to be delivered) that is nonhypoxic and nonacidotic.[70] There is a consensus about certain tracings that indicate a well-oxygenated fetus.

- Heart rate 110 to 160 bpm
- Moderate variability
- Accelerations
- Absence of features that have been associated with possible fetal decompensation

Because the presence of variability has an important place in assurance of fetal oxygenation (although its absence is not a consistent indicator of fetal jeopardy), it is important for the clinician to have an in-depth understanding of the capabilities and limitations of the electronic fetal monitor in delineating fetal heart rate variability. Variability is the irregularity of the heart rate produced by autonomic responses to a changing environment. It is demonstrated by changes from one heartbeat to the next (short term) and slower oscillations involving a complex of several beats (long term). The ACOG and NICHD are using a composite definition (Table 2), recognizing that the clinician views the two components as a unit. The range of change

over time has been given standardized quantitative parameters. Nevertheless, from a fetal health standpoint, the individual components have unique significance, and thus both will be discussed in this text. It is the beat-to-beat change that correlates most directly with lack of fetal acidosis. The modern external fetal monitor (utilizing autocorrelation's digital analysis of each heartbeat without averaging) is capable of reproducing beat-to-beat change to a degree of simulation of the internal monitor that allows adequate fetal assessment in the majority of circumstances.[71–73] However, it can never achieve the R wave to R wave precision of the scalp electrode–derived signal. Therefore, under conditions of markedly reduced short-term variability, it has the potential to enhance the appearance to a limited degree. Short-term variability is not easily quantitated. It involves a visual recognition of a jagged waveform superimposed on the long-term variability. It is therefore usually referred to as simply present or absent, although at least two to three beats of change are implied.

Under basal conditions, fetal oxygen is appropriately supplied by maternal blood oxygenation. Although the fetus survives under low oxygen tension (values following uncomplicated vaginal delivery: umbilical artery pO2, 18.0 +/– 6.2 mm Hg; umbilical vein pO2, 29.2 +/– 5.9 mm Hg),[74] it has several mechanisms that facilitate oxygen transfer within the placental intervillus space. The fetus has a high hematocrit (40% to 65% at term) permitting increased oxygen-carrying capacity. The presence of fetal hemoglobin (HbF) results in an increased hemoglobin saturation at lower oxygen levels. Finally, chemical mechanisms such as the Bohr and Haldane effects promote maternal to fetal oxygen transfer and fetal to maternal carbon dioxide transfer. The fetus, in addition, has a different blood flow than the child or adult with cardiac ventricles working in a series rather than a parallel circuit. Well-oxygenated blood coming from the umbilical vein to the inferior vena cava is preferentially shunted across the foramen ovale to the left atrium, left ventricle, and to the carotids supplying the cerebral circulation. In contrast, deoxygenated blood returning from the brain enters the right ventricle, crosses the ductus arteriosus, and, after mixing with better oxygenated aortic blood, supplies the fetal body and the fetal umbilical artery returning to the placenta.

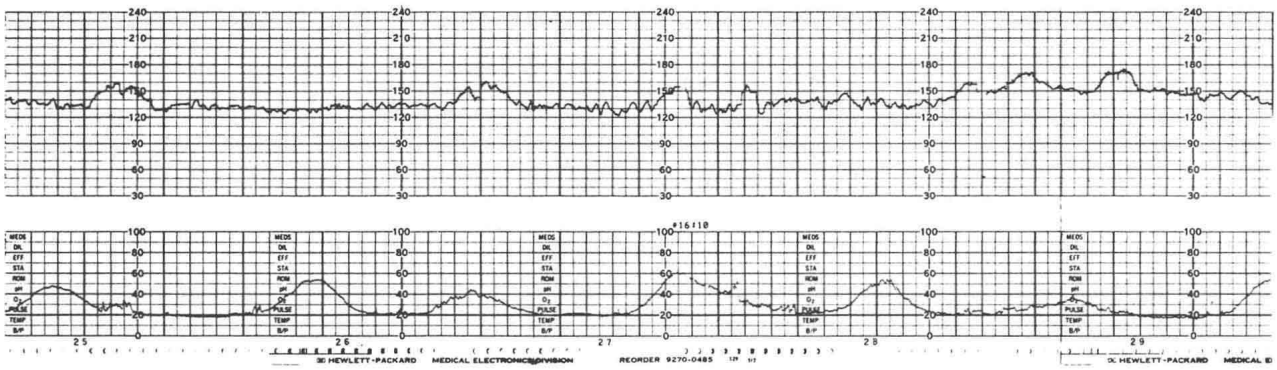
We will refer to fetal hypoxemia and hypoxia as a significant reduction in oxygen saturation or content in blood or in tissue, respectively. Generally, persistent oxygen saturations below 30% are believed to be insufficient for fetal oxygen requirements and might thus result in hypoxia-induced acidosis.[75] Similarly, as the normal fetus is slightly acidotic in utero (arterial pH ~7.35, arterial base deficit ~2 mmol/L), we will refer to an acidotic fetus as having a significant increase in base deficit. As a guide, one may consider a base deficit of 4 to 8 mmol/L as mild acidosis, 8 to 12 mmol/L as moderate acidosis, and >12 mmol/L as marked acidosis. There is no increase in the risk of acute hypoxia-induced neurologic effects until the base deficit exceeds 12 mmol/L.[76]

Routine intermittent maternal and fetal assessments throughout labor are appropriate for patients with a classic "normal" tracing when in a clinical setting without accompanying risk factors.[77–79]

In addition to this pattern, other fetal heart rate patterns that *may be* demonstrated in a well-oxygenated fetus might include:

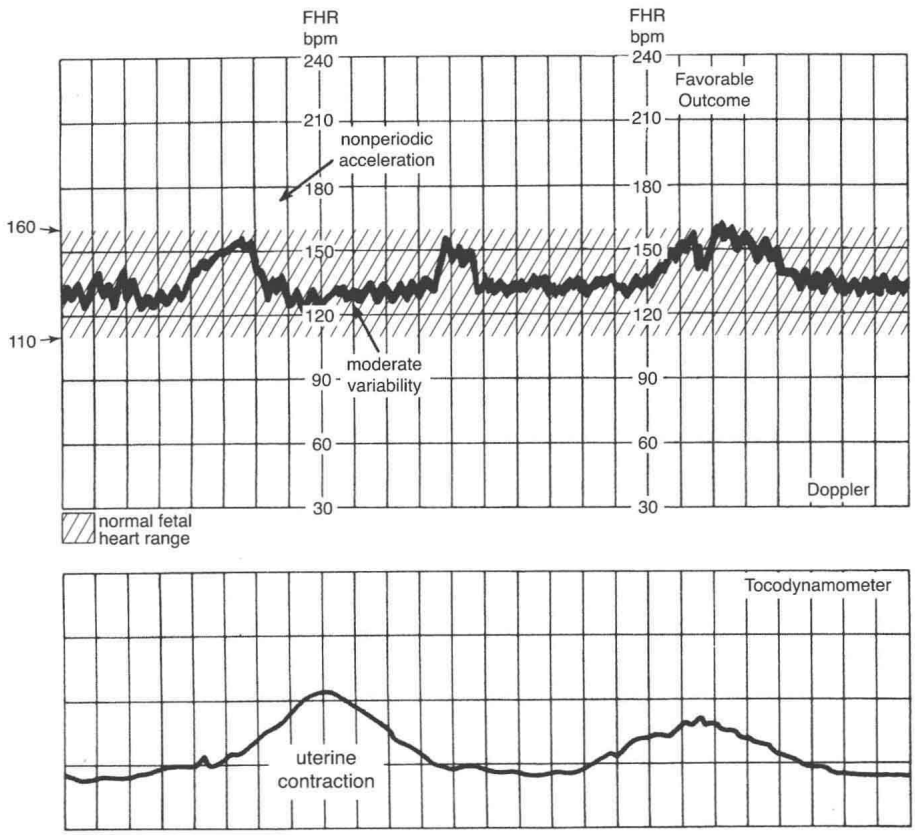
- Baseline bradycardia (with moderate variability and reactivity)
- Early decelerations
- Small V-shaped, once termed *mild-variable*, decelerations, when moderate variability persists
- Accelerations followed by brief decelerations (Lambda pattern)

These patterns display reflex responses to nonthreatening stimuli. These are also associated with good fetal outcome; however, tracings with these patterns warrant intermittent reassessment for transition to other less-reassuring patterns.



Case Interpretation

- **Baseline Information:** normal rate, moderate variability, stable baseline.
- **Periodic or Nonperiodic Changes:** nonperiodic uniform and variable accelerations.
- **Uterine Activity:** regular contractions with normal waveform, rare skewing.
- **Significance:** favorable immediate newborn outcome anticipated.
- **CASE OUTCOME:** Thirty-four-year-old gravida 2, para 1001, at 38 weeks' gestation, delivered vaginally with epidural anesthesia a living female, 7 pounds, 6 ounces (3345 grams); Apgar score 8/9. The newborn followed an uncomplicated newborn course.



Pattern Characteristic: **Normal, Well-oxygenated Fetus**

Identifying the Oxygenated Compensated Fetus

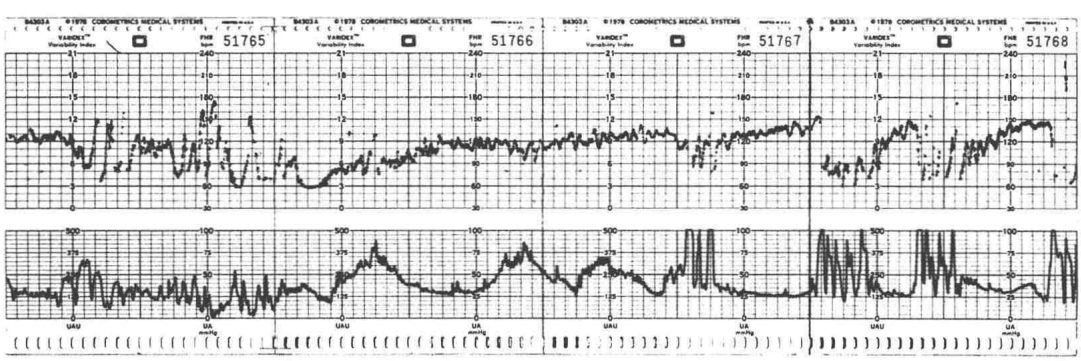
Compensated Patterns (See also Chapter 4)

Stress-compensated patterns are indicative of a fetus who is demonstrating healthy protective responses to such stimuli as hypoxemia, hypovolemia, and sinus node suppression. Such may be common events of normal labor.[80] Examples of compensatory mechanisms in response to stress are redistribution of blood flow, increased oxygen extraction at the placenta, increased or decreased heart rate, and escape rhythms.[81–86] Escape nodal or ventricular rhythms are unique lifesaving responses of the healthy fetus to abrupt reflex slowing of the heart.

Under most circumstances, an appropriate *baseline* variability with or without reactivity suggests a compensated intrapartum state.[87,88] It has been demonstrated that fetal pH values are nearly always nonacidotic under these circumstances.[89] However, further stress may deplete compensatory mechanisms. The challenge in the management of these patterns is to diminish present stresses while optimizing placental perfusion and fetal oxygenation. Measures that might be selected to do so include maternal oxygen administration, maternal repositioning, maternal hydration, discontinuation or reduction of oxytocin infusion, decreasing of maternal straining, tocolytic therapy, amnioinfusion, and reduction of maternal fever.[83,90–93] These therapeutic measures are individualized according to specific heart rate and uterine monitoring data as well as the clinical circumstances.[94,95] Fetal response varies with the basal condition and the nature and degree of the stressful stimulus.[96] It may also be appropriate, when possible, to minimize additional stress during subsequent labor and delivery.[90]

Stress-compensated patterns include:

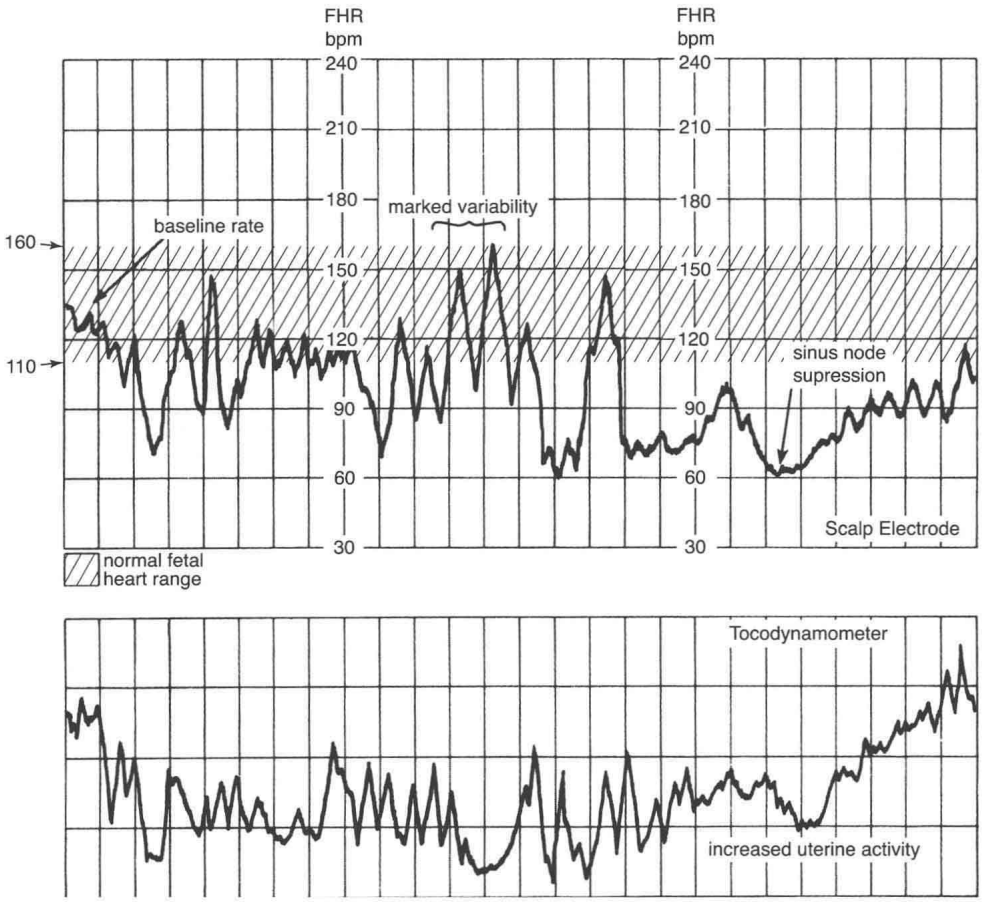
- Marked variability (i.e., saltatory pattern)
- Tachycardia with moderate variability
- Periodic accelerations and some patterns of marked or prolonged accelerations
- Late decelerations with moderate variability
- Classic "mild/moderate" variable decelerations or "marked" variable decelerations (without atypia). Refer to Chapter 2 for discussion of terminology regarding variable decelerations.
- Isolated prolonged decelerations with normal/full resolution
- Escape rhythms



Case Interpretation

- **Baseline Information:** normal rate, marked variability (formerly "salutatory" pattern), associated with decelerations in a mixed pattern.
- **Periodic or Nonperiodic Changes:** prolonged deceleration (7 minutes in duration) with full recovery, maintaining excellent variability throughout except for transient sinus node suppression, moderate variable decelerations with slow recovery during maternal straining, variability maintained throughout deceleration.
- **Uterine Activity:** frequent contractions without a resting interval. Maternal straining.
- **Significance:** stress of intact fetus probably secondary to hypoxemia produced by increased uterine activity.
- **CASE OUTCOME:** Nineteen-year-old gravida 2, para 0010, delivered at 42 weeks' gestation an 8-pound, $9^1/_2$-ounce (3898 gram) female from a vertex presentation with local anesthesia; Apgar score 9/9. The newborn followed an uncomplicated newborn course.

Pattern Characteristic: **Stress Pattern**



Guiding Delivery Timing of the Fetus with Progressive Stress Despite Intervention

When compensatory mechanisms are operating effectively, studies indicate that the vital organs of the fetus (e.g., heart, brain) are adequately oxygenated. However, with continued or worsening stress, fetal compensatory mechanisms may fail. Despite rerouting of oxygen and decrease in fetal oxygen consumption, if over time the oxygen supplies are not restored, the fetus converts to anaerobic metabolism as a survival mechanism.[97] Lactate levels rise and are very slowly cleared by the placenta, resulting in a fall in fetal pH and an increased base deficit.[98] Research demonstrates that there is a window of time during which the risk of asphyxial exposure could be predicted prior to actual decompensation.[99] It may be appropriate to consider delivery if the fetal status has not improved despite directed and comprehensive bedside intervention, especially if there is absent or diminishing variability, with an increasing baseline associated with late or prolonged decelerations.[99] It is important, however, that this pattern not be confused with the "rebound tachycardia" during the resolution of a prolonged deceleration (see Chapter 4).

Whether to continue assessment and expectant observation with intrapartum therapeutic measures or whether to facilitate steps toward a vaginal delivery or whether to perform an emergency or urgent cesarean section are individual judgments that cannot be directed by the fetal monitor alone.[96,100,101] Factors taken into account include:

- Fetal heart pattern and its change over time
- Fetal response to interventions
- Labor process and progress
- Gestation of the pregnancy
- Patient's parity
- Fetal size
- Underlying fetal and/or maternal problems

Each case is unique. There is no standard and no literature to delineate a single correct choice.