The Physiology of

Electronic Fetal Monitoring

Emily Hamilton, MD CM
SVP Clinical Research

PeriGen®

Featuring Emily Hamilton, MDCM
Senior Vice President of Clinical Research

An experienced obstetrician, Dr. Hamilton is currently an Adjunct Professor of Obstetrics and Gynecology at McGill University, as well as leading PeriGen's clinical research team.

Dr. Hamilton is the inventor of the PeriCALM advanced fetal monitoring system, holding 32 US and international patents for her research work. She is an internationally-known clinical thought leader on the use of technology to improve obstetric outcomes. She presents her research regularly at obstetric conferences and in peer-reviewed journals.

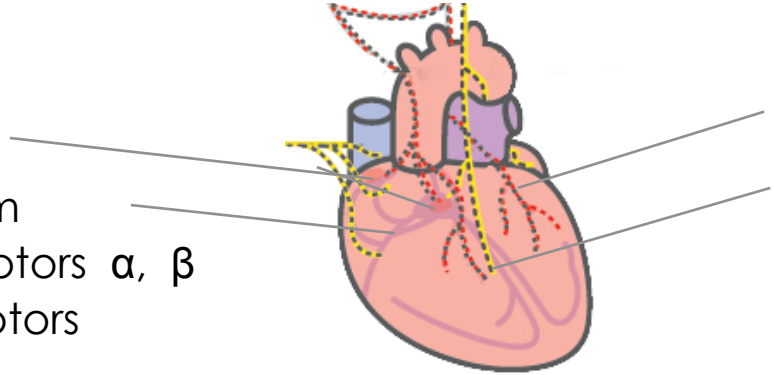
PeriGen®
Empowering Clinicians. Advancing Perinatal Systems.

1. Physiology of heart rate regulation
2. How scientists simulated labor stresses and determined deceleration mechanisms
3. Relevance to EFM usage in humans

PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Intrinsic

- Myocardium
- Pacemakers
- Conducting system
- Adrenergic Receptors α, β
- Cholinergic Receptors



Extrinsic

- Neuronal connections to
- Sympathetic
- Parasympathetic systems

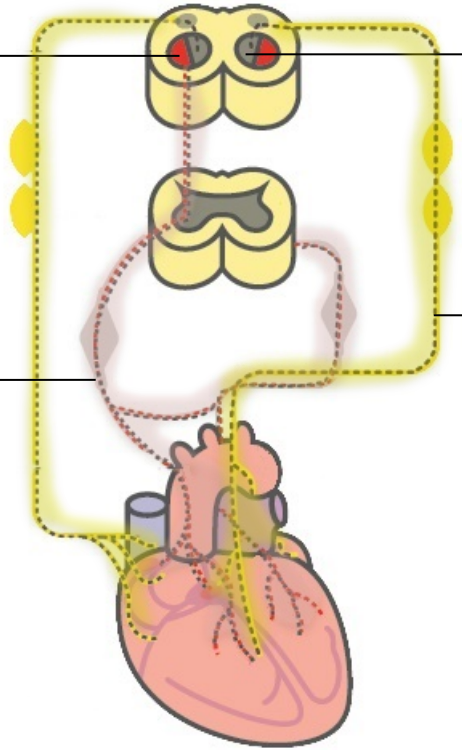
- Circulating catecholamines

PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Cardioregulatory Center

Cardioacceleratory Center

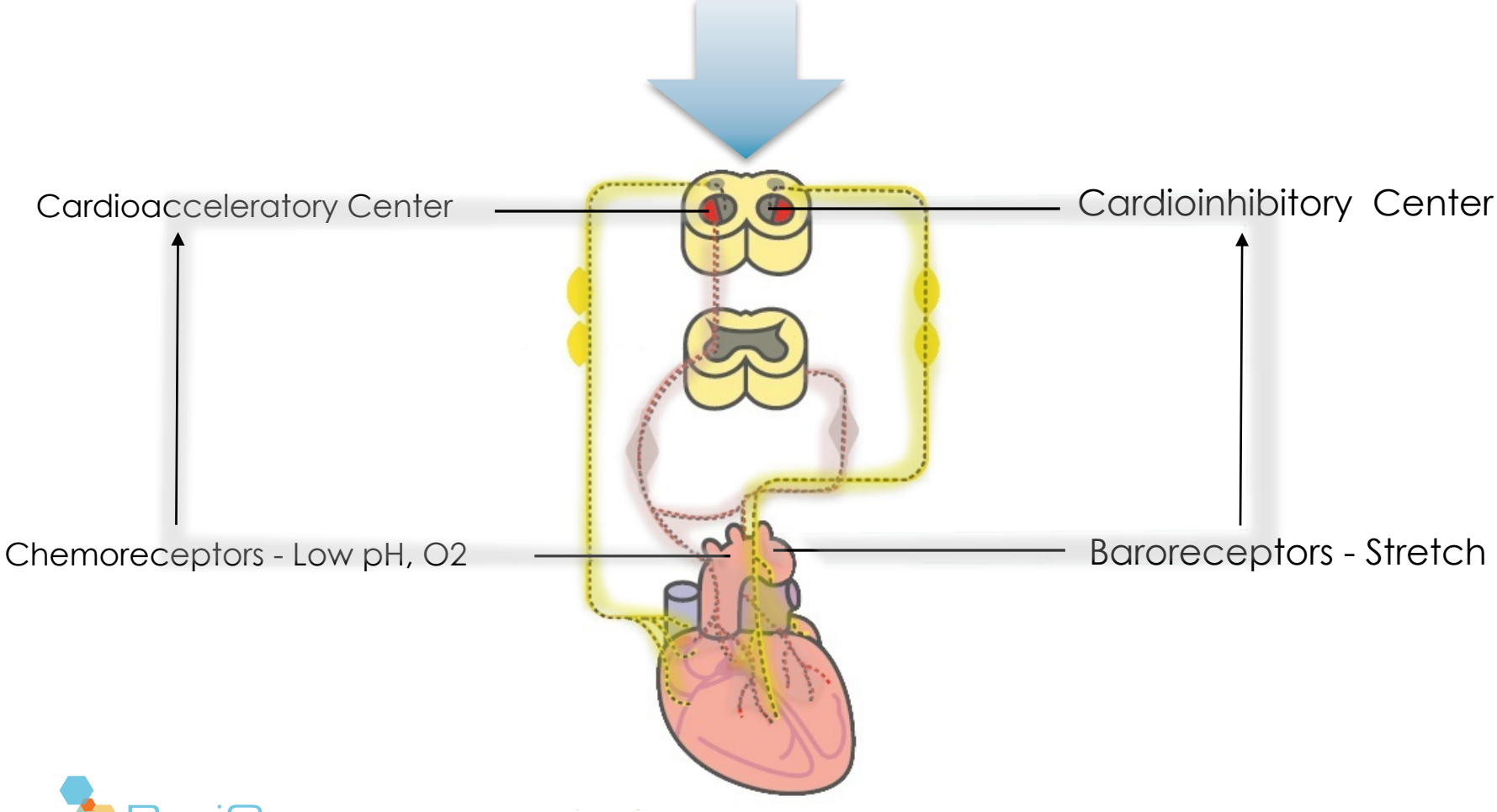
Cardioinhibitory Center



Parasympathetic (vagus)

Sympathetic

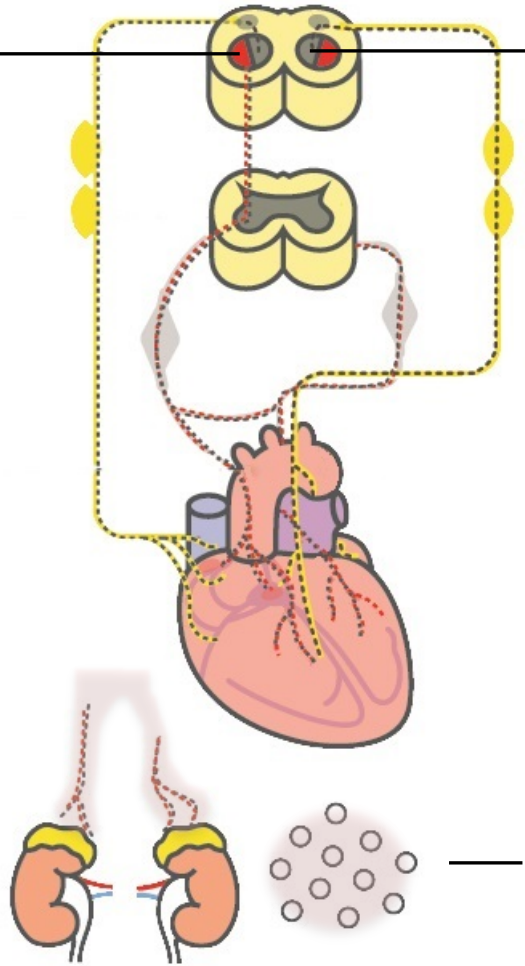
PeriGen
Empowering Clinicians. Advancing Perinatal Systems.



PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Cardioacceleratory Center

Cardioinhibitory Center



Circulating catecholamines

Vasomotor Center

- Autonomic control of dilation and constriction of peripheral vessels

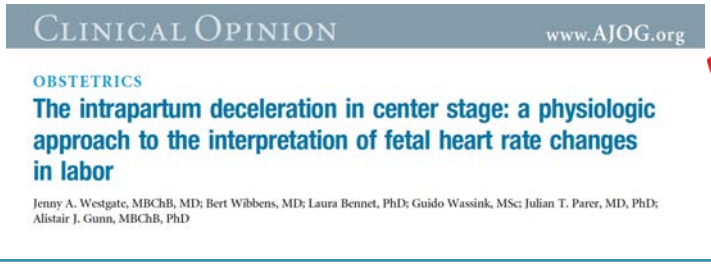
PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Fetal Heart Regulation

Mechanisms of late decelerations in the fetal heart rate.
A study with autonomic blocking agents in fetal lambs

C.B. Martin, Jr., J. de Haan *, B. van der Wildt, H.W. Jongsma, A. Dieleman and T.H.M. Arts

Department of Obstetrics and Gynecology, Catholic University and Sint Radboudziekenhuis, Nijmegen, The Netherlands



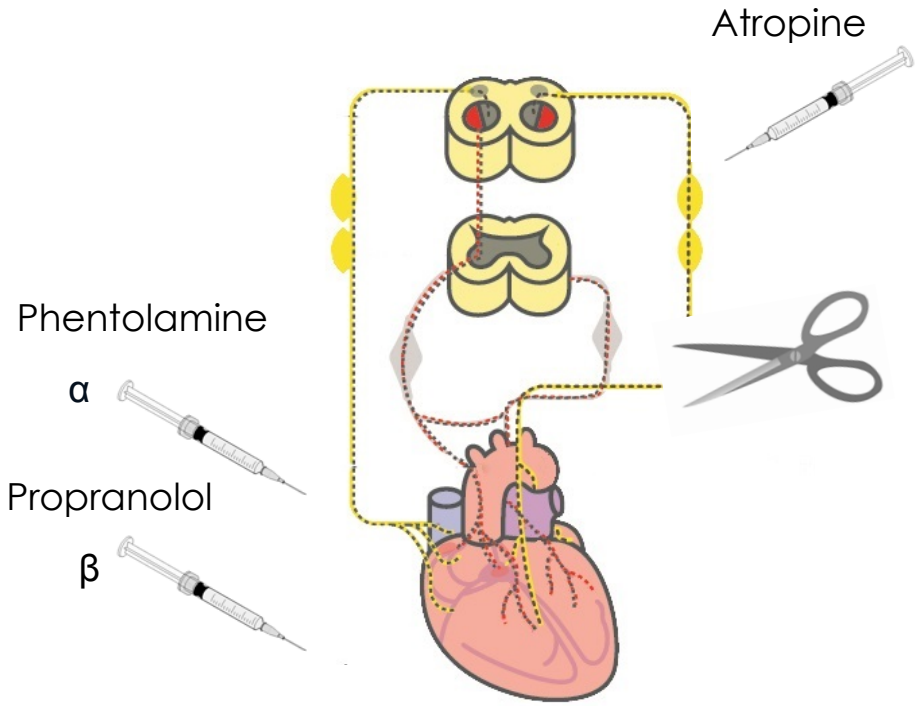
PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Animal Experimentation

1. Umbilical cord compression
   Mechanical devices to occlude the cord

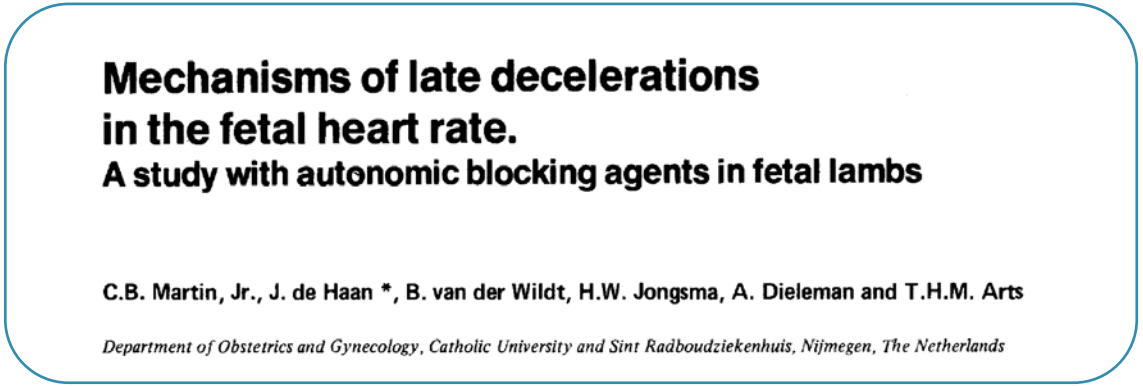
2. Uteroplacental insufficiency
   Compression of arteries outside the uterus

3. Implanted devices for BP, acid base status



PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Decelerations from Uteroplacental Dysfunction



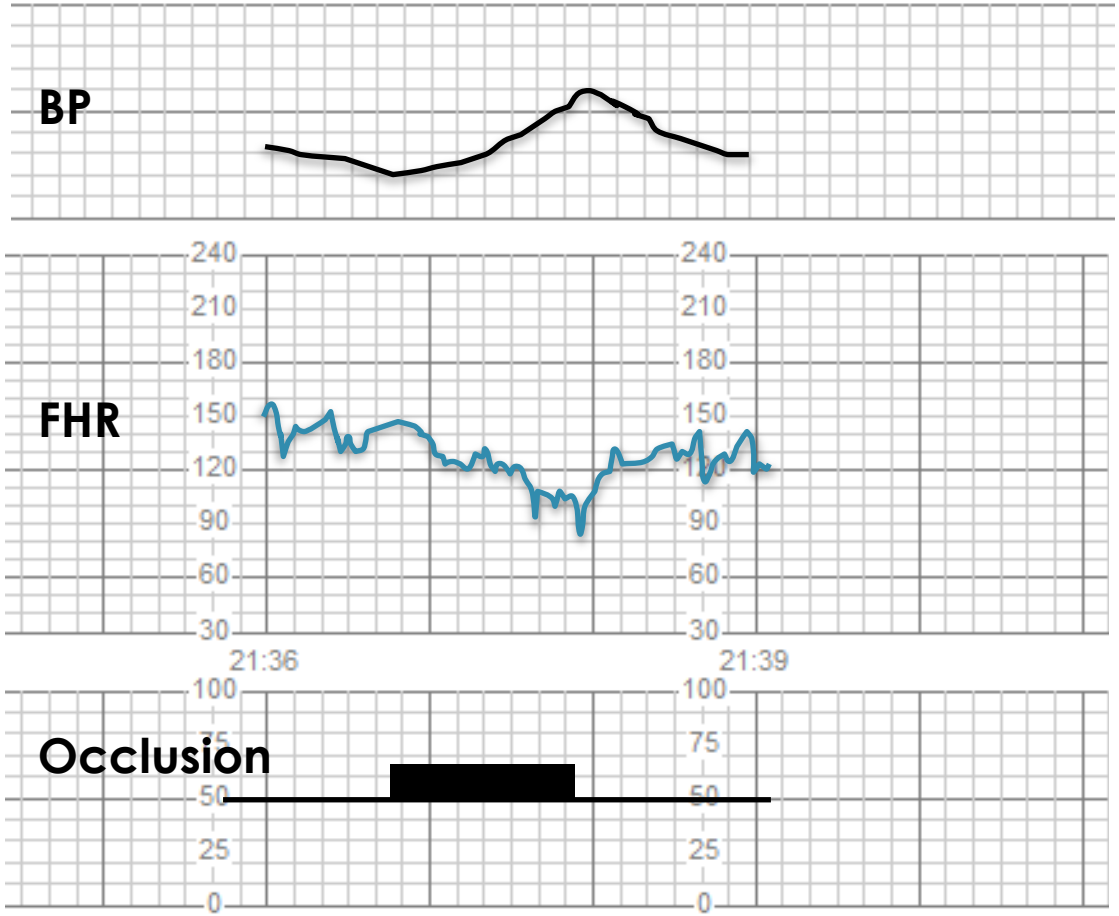
Mechanisms of late decelerations in the fetal heart rate.
A study with autonomic blocking agents in fetal lambs

C.B. Martin, Jr., J. de Haan *, B. van der Wildt, H.W. Jongsma, A. Dieleman and T.H.M. Arts

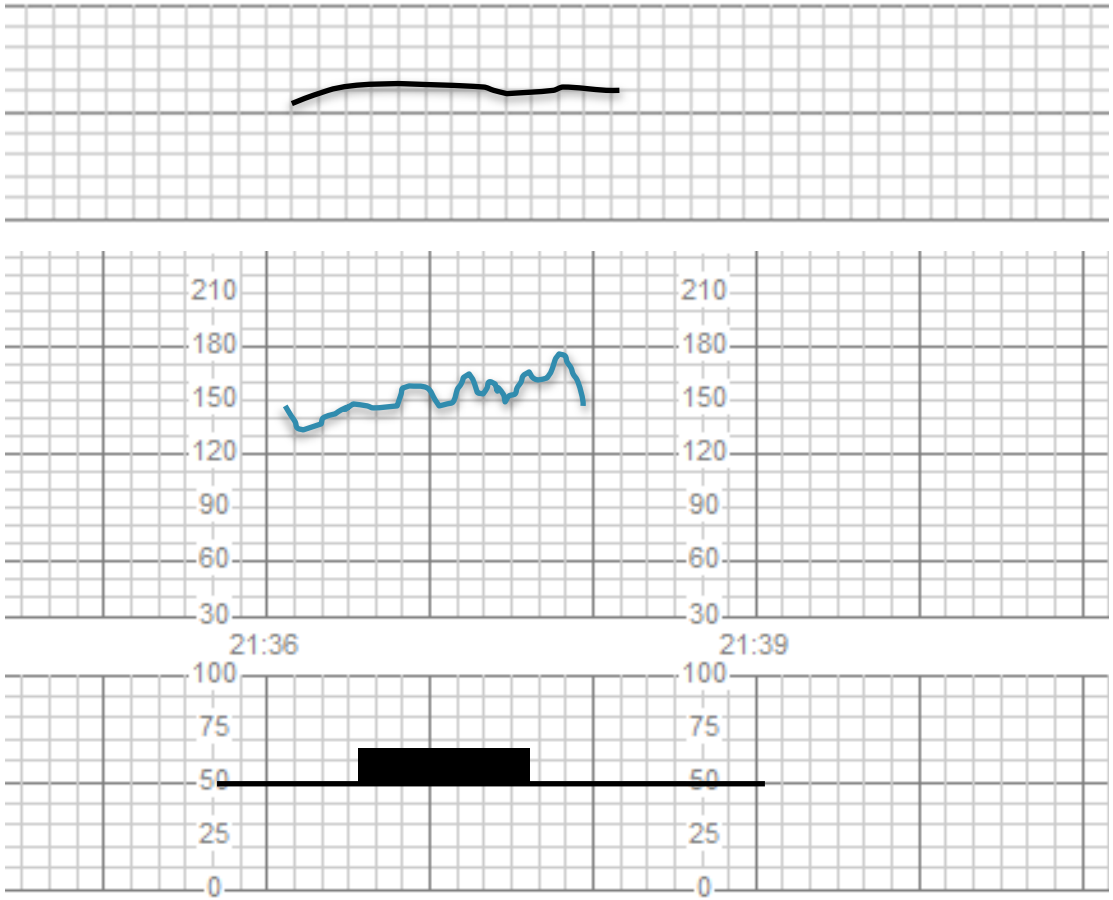
Department of Obstetrics and Gynecology, Catholic University and Sint Radboudziekenhuis, Nijmegen, The Netherlands

PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

pH 7.40 BE +1.3

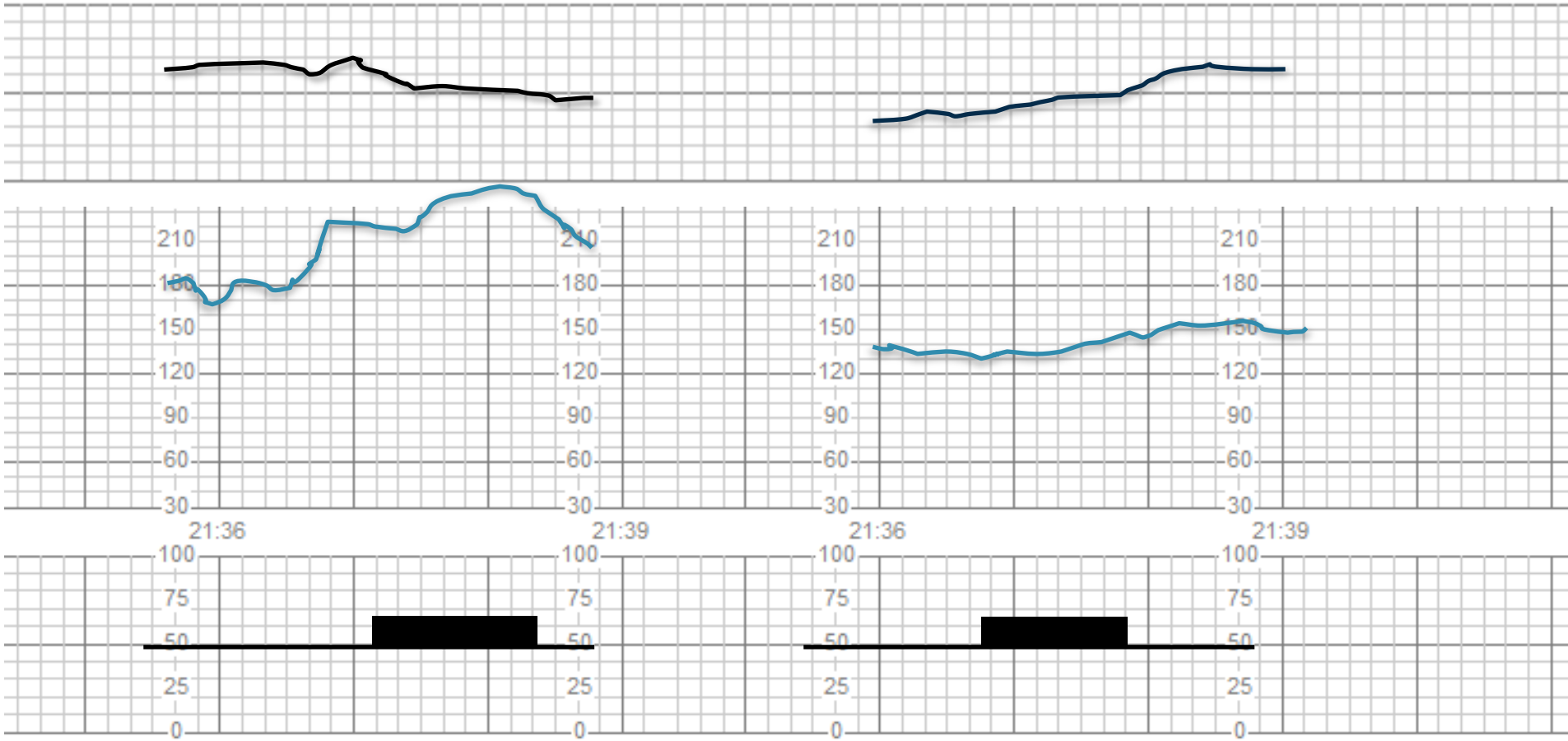

BP
FHR
240
210
180
150
120
90
60
30
21:36
21:39
Occlusion
100
75
50
25
0

Phentolamine pH7.35 BE -0.7

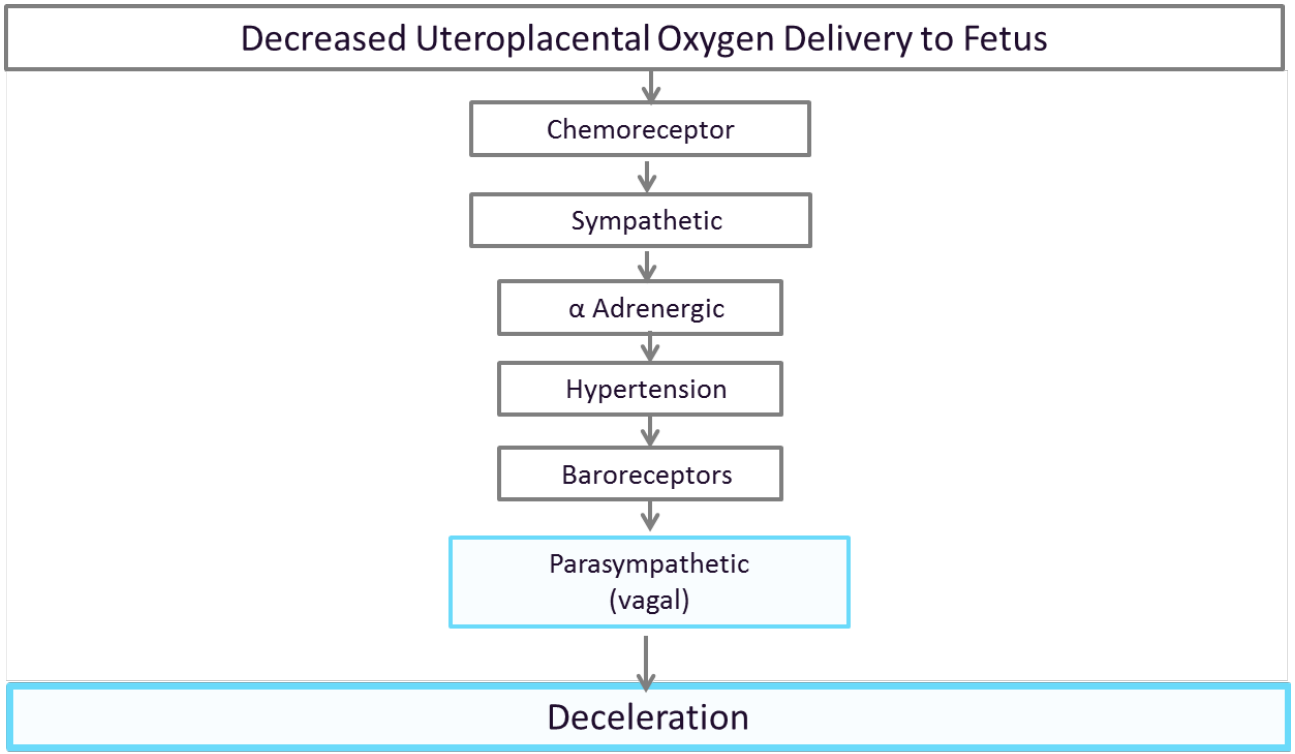


Phentolamine atropine
pH7.33 BE –4.8

Phentolamine atropine propranolol
pH7.33 BE –5.5



Physiological Mechanisms

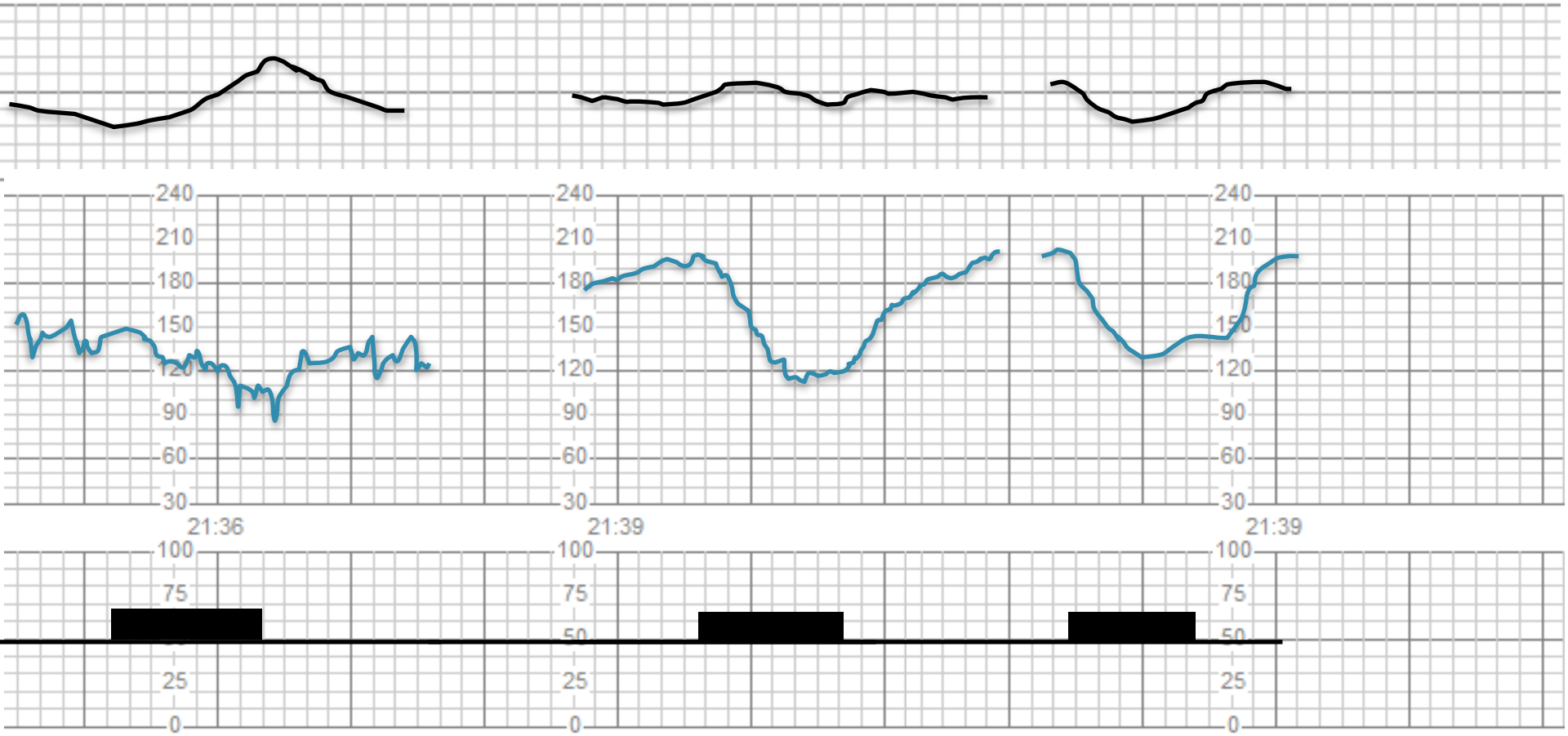


PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

pH 7.40 BE 1.3 I

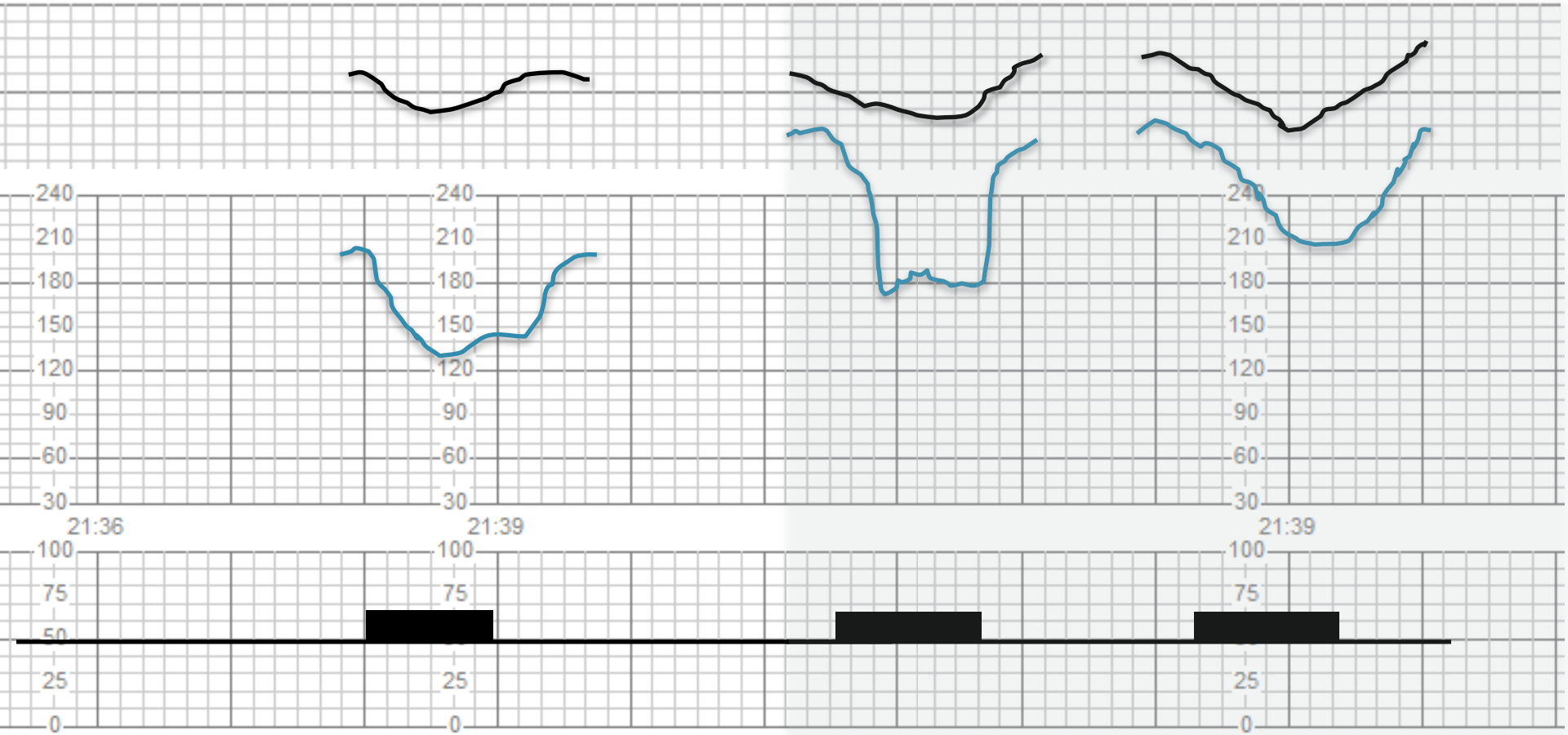
pH 7.14 BE -13.1

pH 6.96 BE -19.7

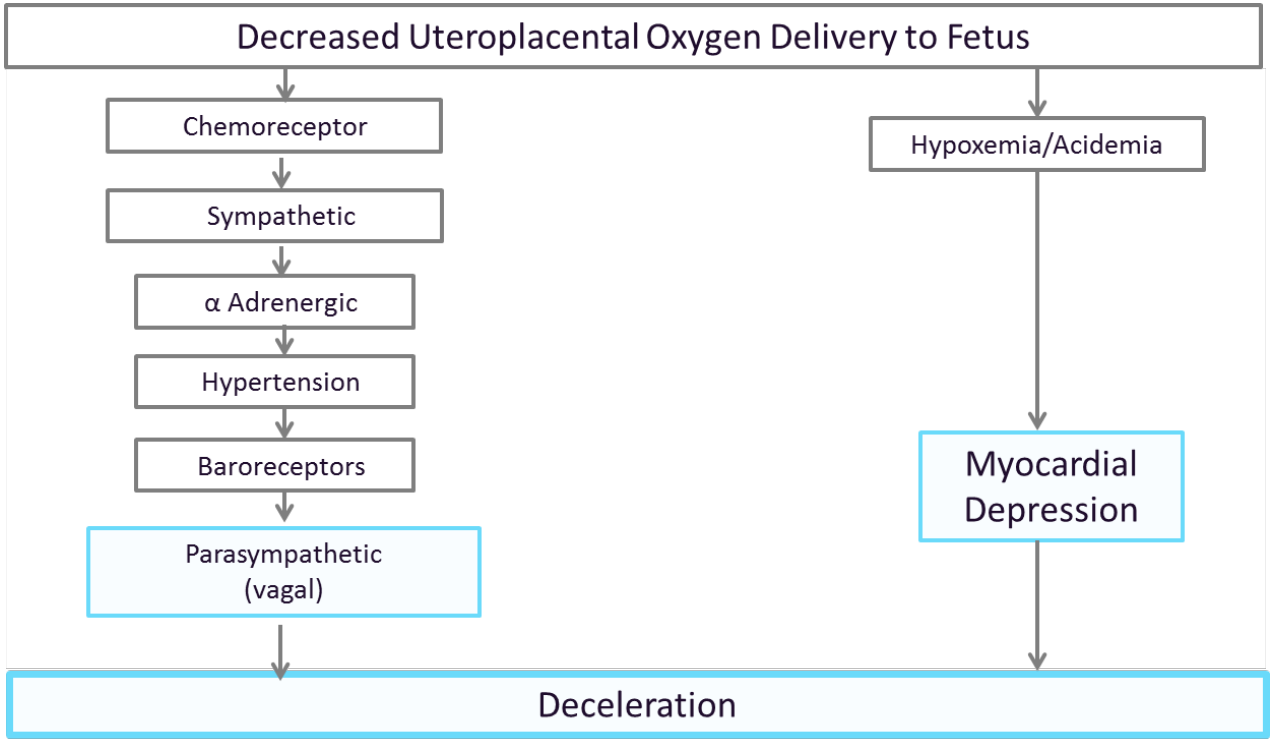


pH 6.96 BE -19.7

pH 6.96 BE -19.7
with Atropine



Physiological Mechanisms



PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Recurrent Lates
Incidence and Outcome

Low risk women **normal** tracing on admission

• Incidence of **sporadic** Lates	5.5%		1% pH<7.1
• With normal variability	5.4%		
• Incidence of **recurrent** Lates		1.8%	
• With normal variability		1.4%	10% → pH< 7.1
• With minimal/absent variability		0.36%	20% → pH< 7.1

With **low variability and recurrent Lates/PD on admission**

• Incidence	0.43%	**42%** → pH < 7.0
• Died or developed CP		**33%**

PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Unselected low-risk pregnancies and the effect of continuous intrapartum fetal heart rate monitoring on umbilical blood gases and cerebral palsy. Sameshima H, Ikenoue T, Ikeda T, Kamitomo M, Ibara S. Am J Obstet Gynecol. 2004 Jan;190(1):118-23.

Conclusions: Decelerations from Uteroplacental dysfunction “Late” deceleration

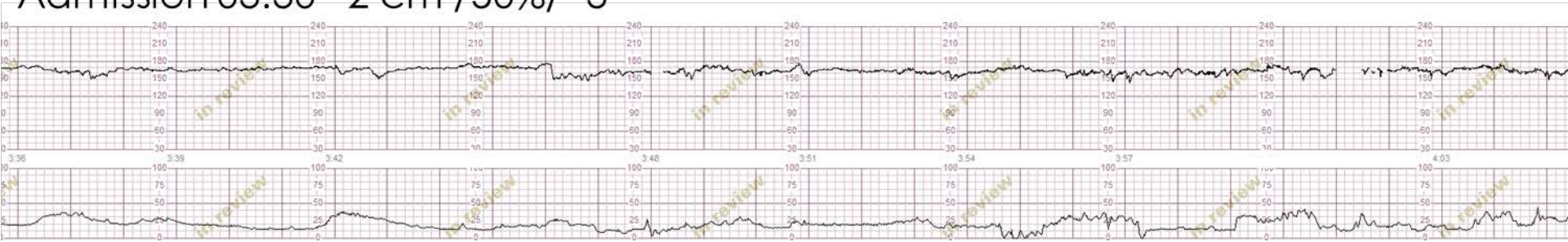
1. Uncommon pattern
2. Multiple pathways and shapes
3. Not all late decelerations indicate myocardial hypoxia or acidemia
4. Presence of very low variability with recurrent Lates on admission VERY concerning

PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

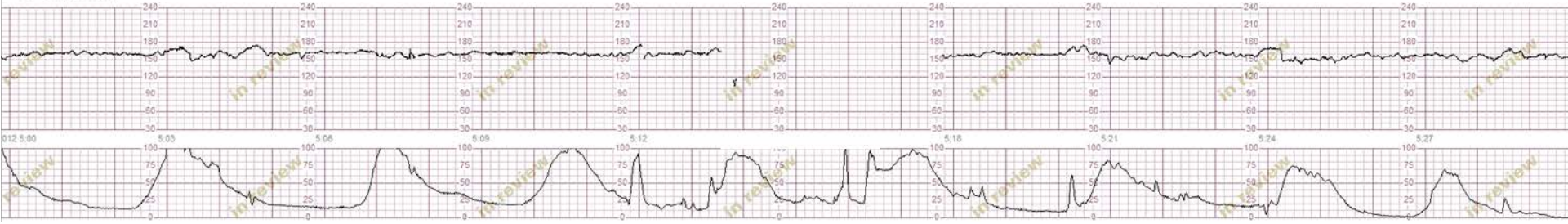
Case Presentation #1

- 25 year old P0 with an uncomplicated antenatal course, admitted in spontaneous labor at term.
- Delivered spontaneously 12 hrs later, a 3100 gram baby
  - No oxytocin, no meconium
  - Labor progression normal
- Would you deliver at point **1 or 2 or 3**

Admission 03:30 2 cm /50%/ -3

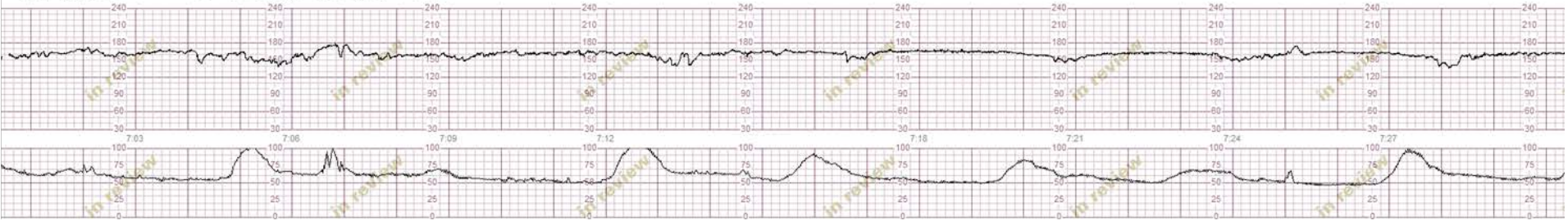


05:00

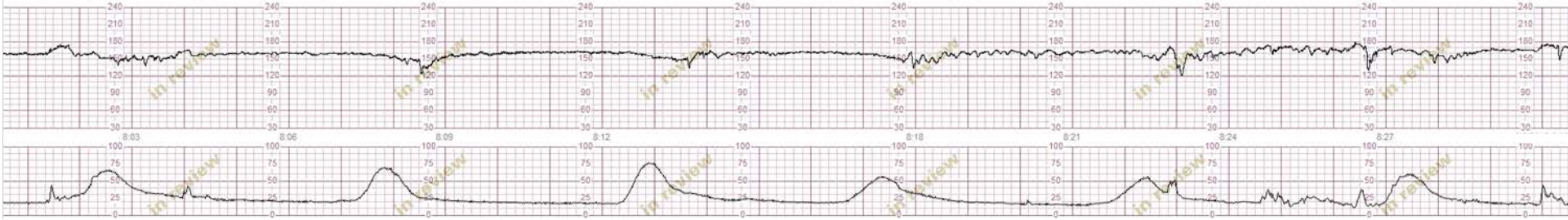


PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

07:00 3 cm/80%/-2

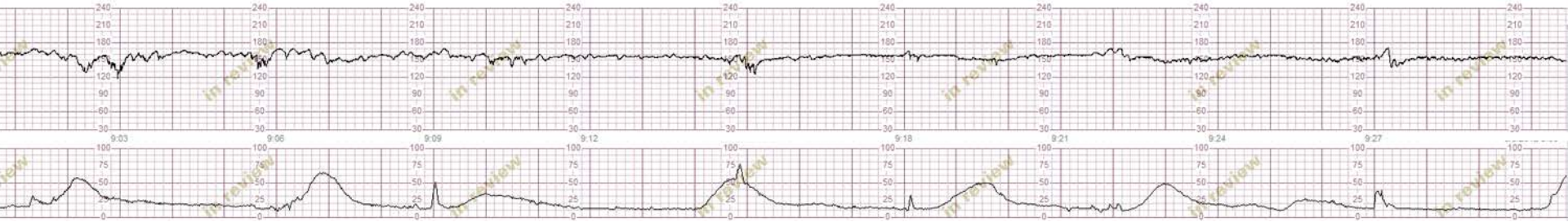


08:00

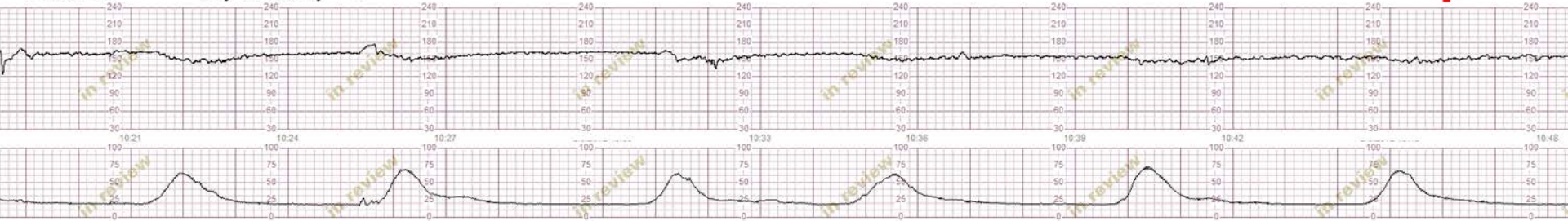


PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

09:00

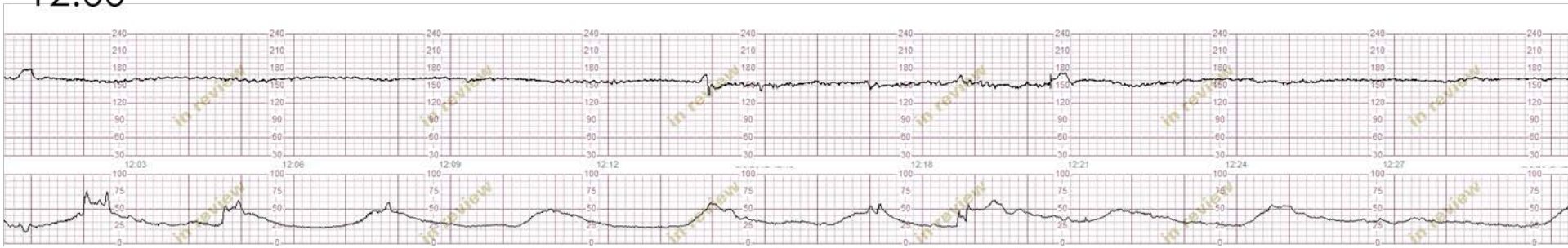


10:20 5/90%/-1 1

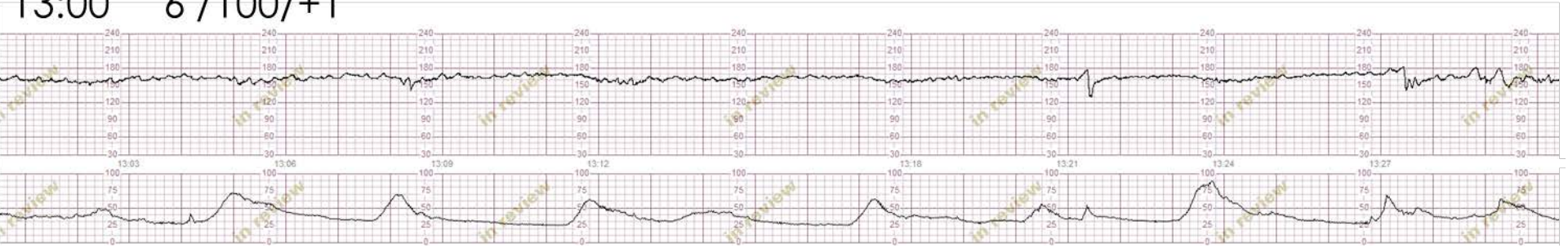


PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

12:00



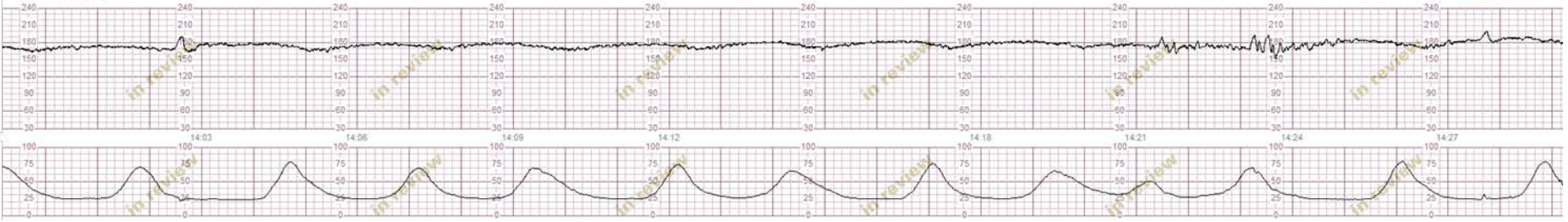
13:00 6 /100/+1



PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

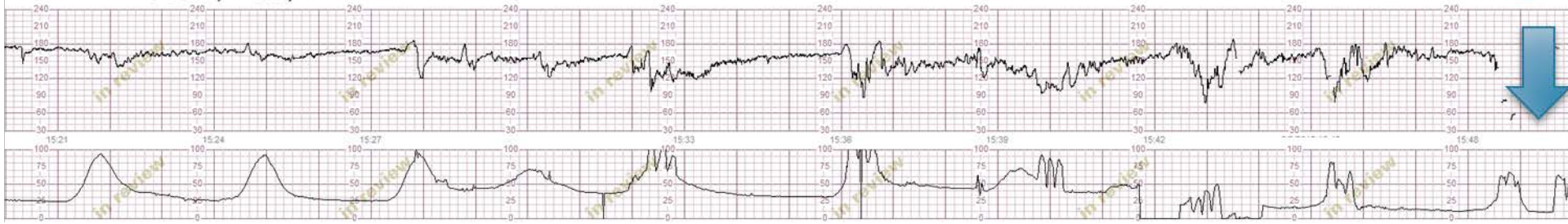
14:00

2



15:00 10cm/100/+1

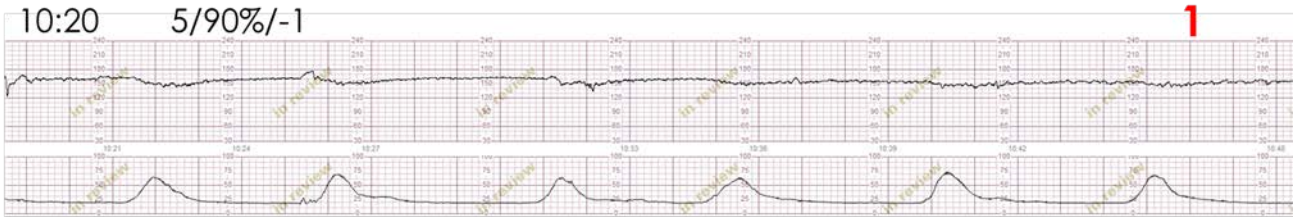
3

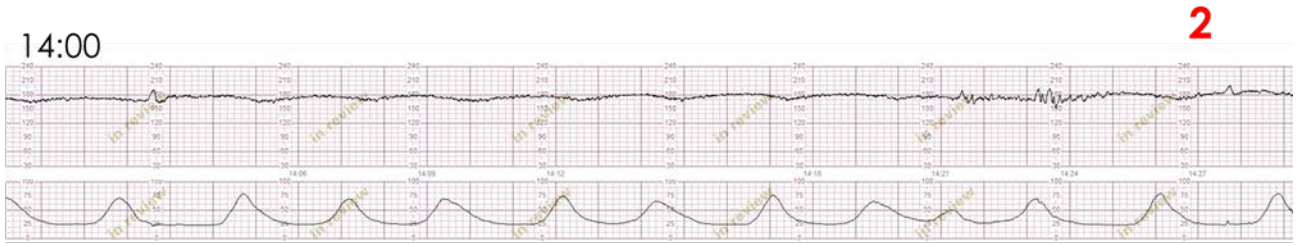


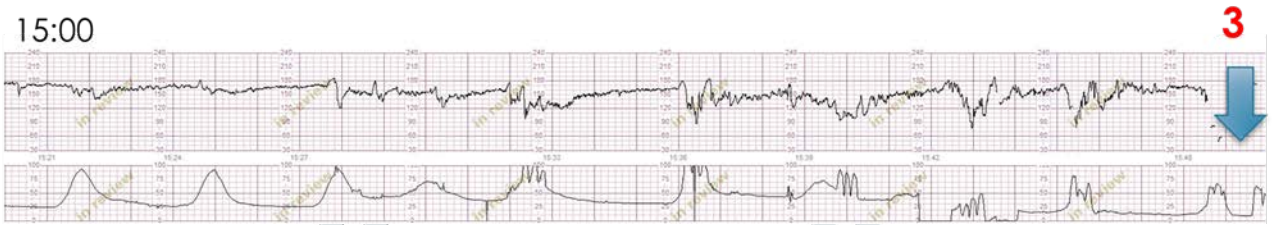
PeriGen

Empowering Clinicians. Advancing Perinatal Systems.

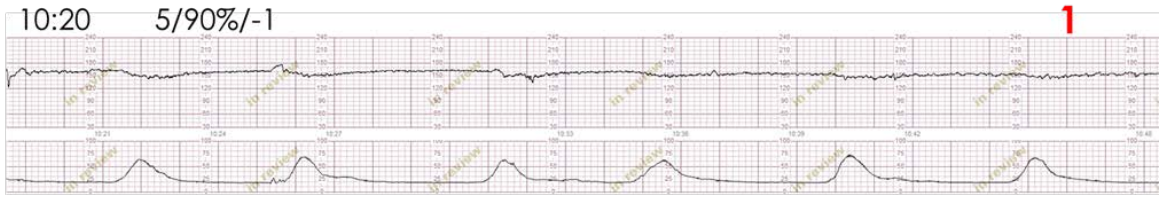
Delivery intervention recommended at point

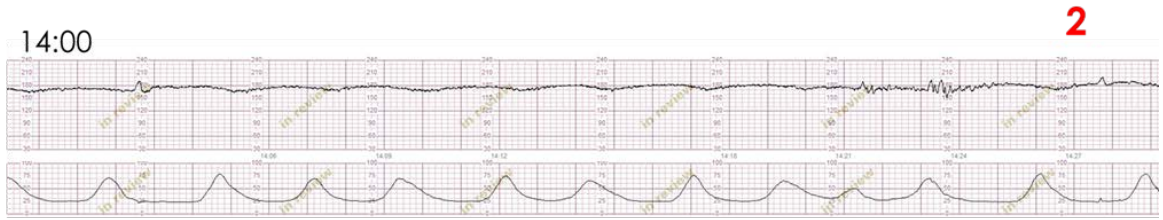


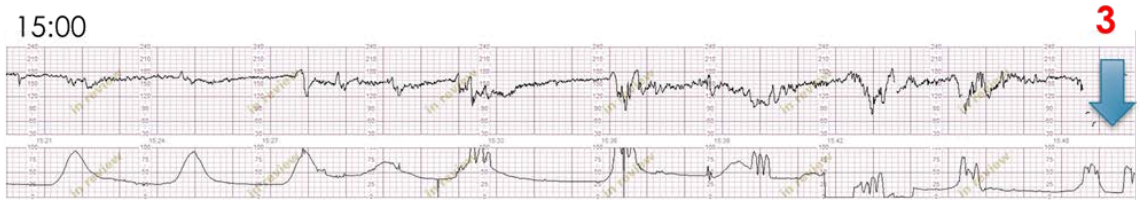




PeriGen
Empowering Clinicians. Advancing Perinatal Systems.







SVD, Apgar 8,9 pH 7.25 Base deficit 4 mmol/L

Case Presentation #2

G1P0

41+ weeks

Admitted in spontaneous labor

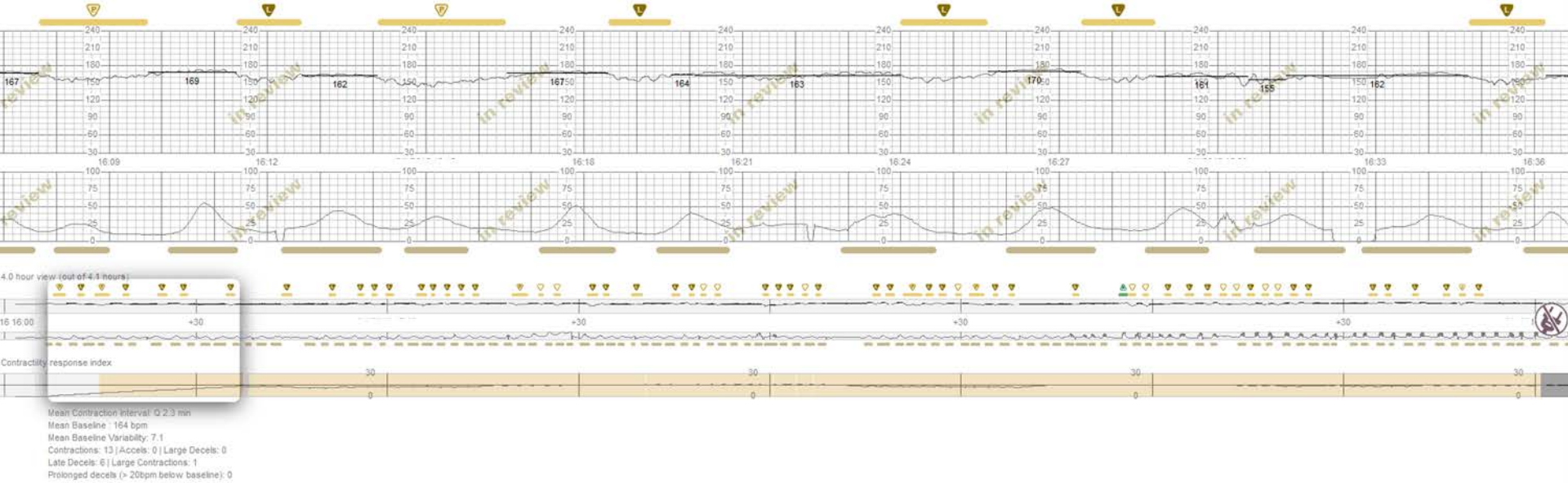
Spontaneous Delivery 4 hrs later, 3750 g

pH 6.91 BD 20.7

Apgars 3/6

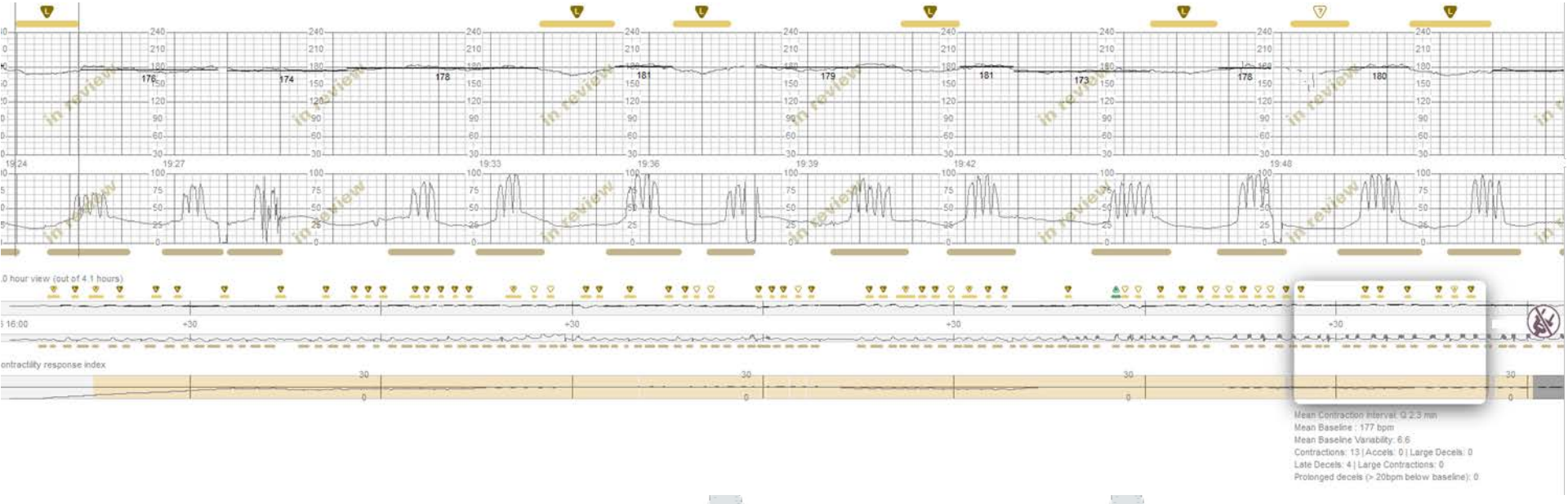
PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Tracing on Admission



PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Tracing minutes before vaginal delivery



PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

This tracing is highly concerning because of

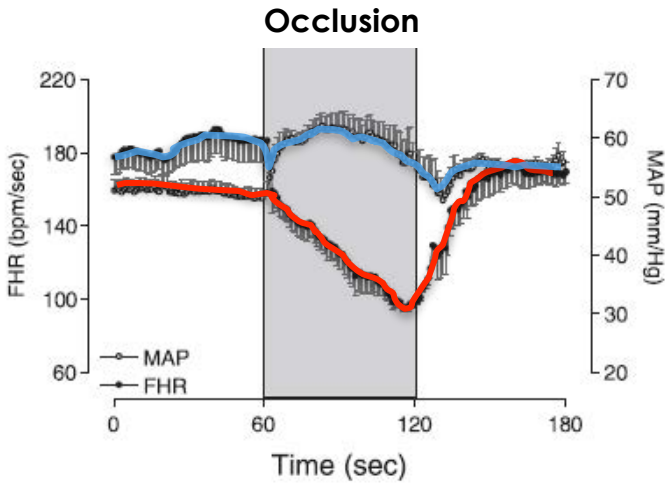
1. Abnormal EFM patterns on admission
2. Decelerations with almost every contraction
3. High and rising baseline with low baseline variability
4. Abnormalities persist for >4hrs
5. All of the above

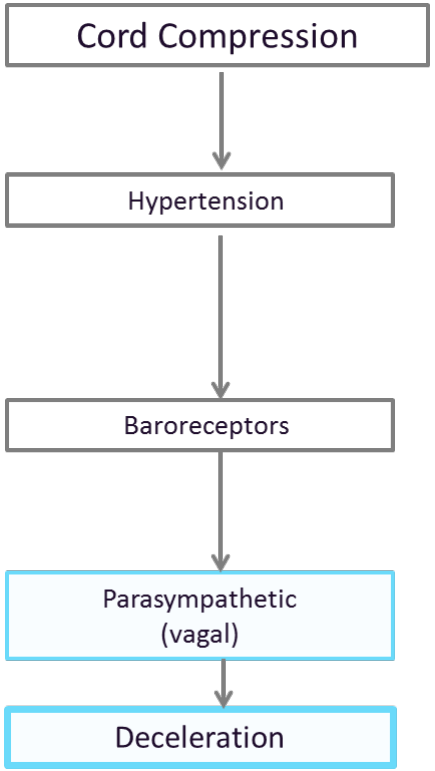
Decelerations From Umbilical Cord Compression

PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Cord Compression

Bennet L, Westgate JA, Liu YC, Wassink G, Gunn AJ. J Appl Physiol (1985). 2005





PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Repeated 1 min Cord Occlusion

Bennet L, Westgate JA, Liu YC, Wassink G, Gunn AJ. J Appl Physiol (1985). 2005

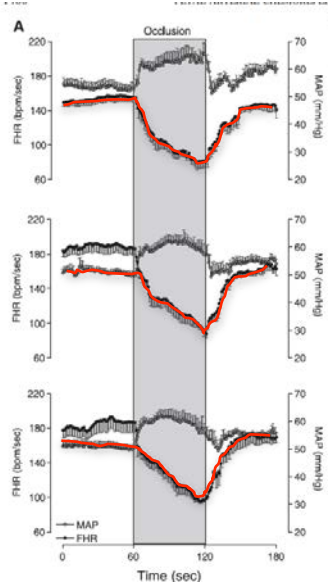
5 mins

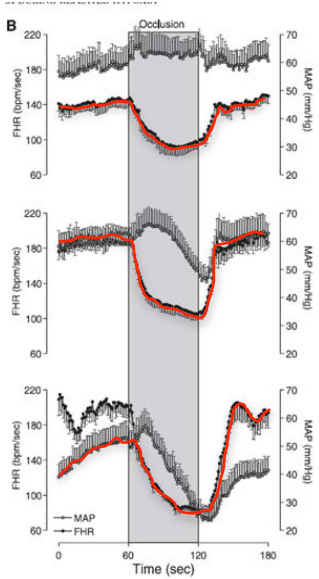
2.5 min

First 30 min

Mid 30 min

Last 30 min





pH	7.34	stable…	
BD	1.3	stable …	

pH	7.25	7.14	**6.92**
BD	3.3	13.6	**19.2**

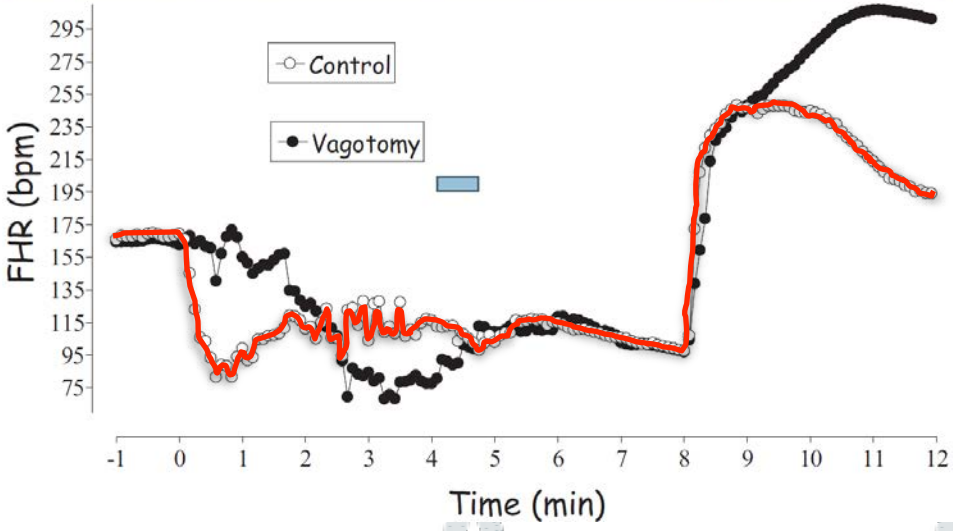
PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Non Vagal Component

Westgate JA, Wibbens B, Bennet L, Wassink G, Parer JT, Gunn AJ. Am J Obstet Gynecol. 2007

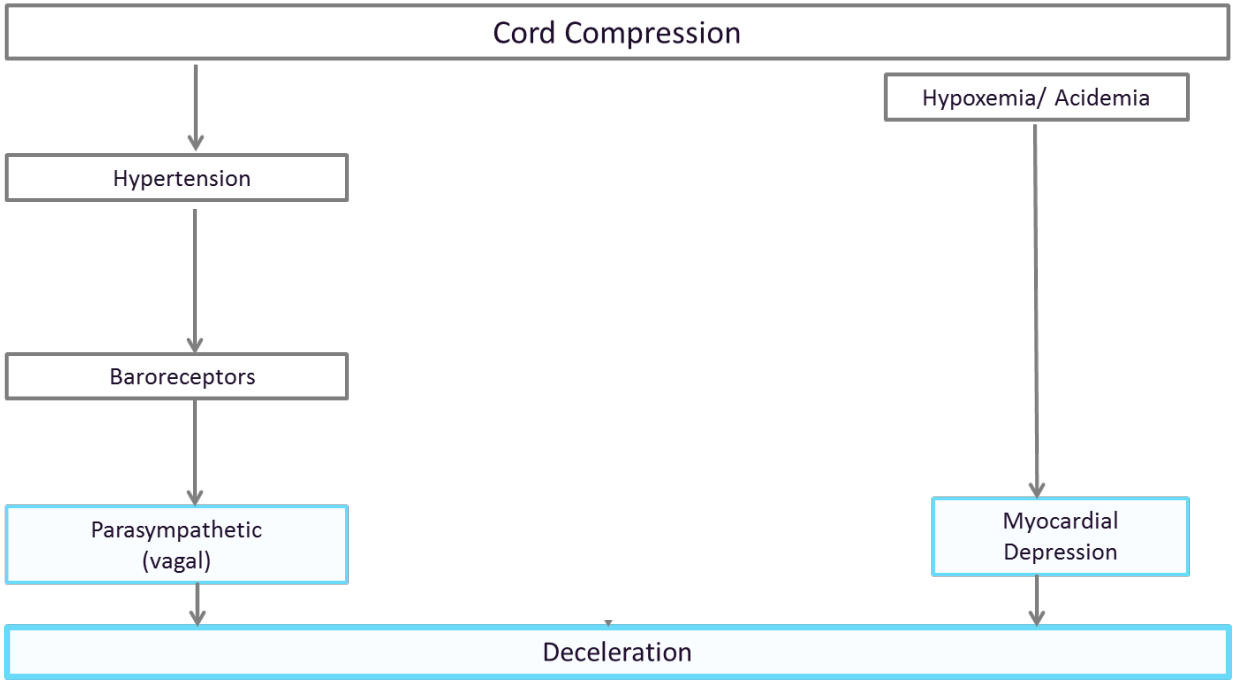
FIGURE 1

Examples show the contribution of the parasympathetic system to bradycardia during 8 minutes of severe asphyxia that was induced by complete occlusion of the umbilical cord in near-term sheep fetuses



PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Physiological Mechanisms



PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

Baseline Variability

1. **Heart**

   Myocardium and its pacemakers contribute to variability

2. **Central Nervous System**

   "Push Pull" effect of sympathetic and parasympathetic system

   Drugs, malformations, sleep

3. **Circulating catecholamines**

NICHD 2008 EFM Update Category I,II,III Defined

"Moderate FHR variability reliably predicts the absence of fetal acidemia at the time that it is observed."

How reliable ?

How much acidemia?

Experimental Hypoxemia Increases FHR Variability initially

	Animal	Intervention	Variability change
Ikenoue et al 1981	monkeys	hypoxemia	Increased
Dalton, Dawes et al 1977	sheep	hypoxemia	Increased
Murotsuki, Bocking et al 1997	IUGR sheep	hypoxemia	Initial increase in variability After 21 days of hypoxemia variability decreased by 20%
Martin 1979	Sheep	Hypogastric occulsion pH 6.96	Increased variability
Kozuma et al 1997	sheep	severe acidosis (mean pH 6.92)	Decreased in 2/3 Increased in in 1/3

PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

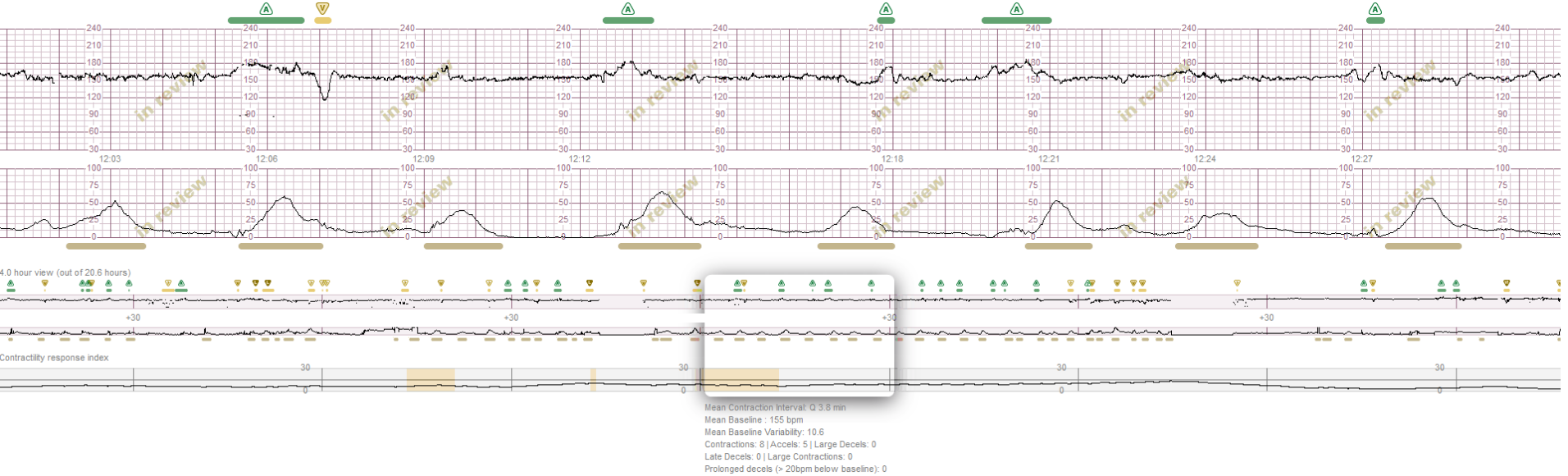
Low Variability in Humans

	Outcome	Number	With Low variability close to birth	Normal Variability
Samueloff 1994	pH <7.2	303	26%	74%
Cahill 2012	pH<7.1	57	9%	91%
Williams and Galarneau 2003	BD>12	36	42%	58%
Low 1999	BD>16	71	68%	32%
Williams and Galarneau 2003	BD>16	13	85%	15%

PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

G1 40+wks labor X 12.5Hrs 3600g baby

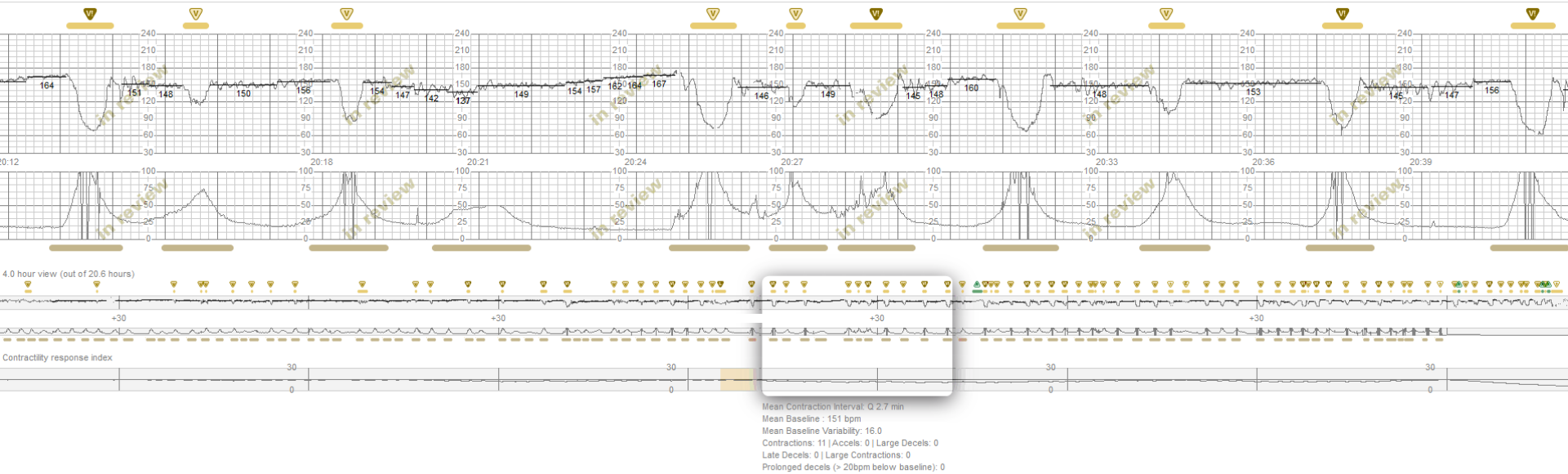
pH 6.89 BD 21.4 Apgar 3/5



PeriGen

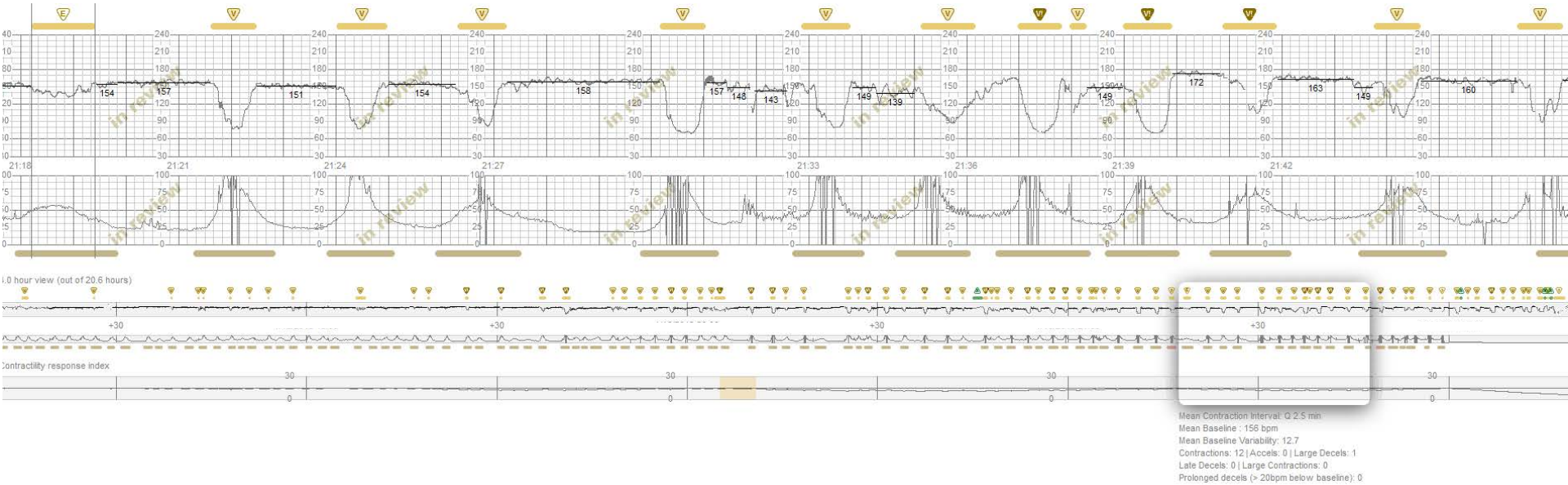
Empowering Clinicians. Advancing Perinatal Systems.

2.5 hours before birth



PeriGen
Empowering Clinicians. Advancing Perinatal Systems.

1 hour before birth

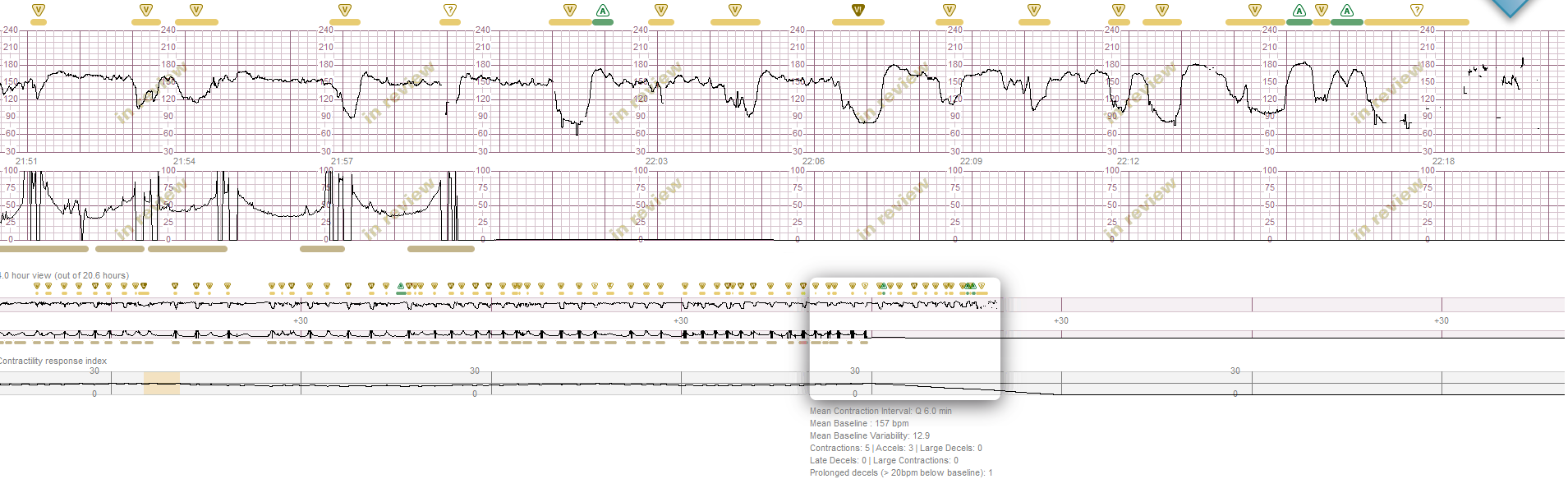


PeriGen

Empowering Clinicians. Advancing Perinatal Systems.

Last 30 minutes

pH 6.89 BD 21.4 Apgar 3/5



PeriGen

Empowering Clinicians. Advancing Perinatal Systems.

Baseline Variability

- Initial response to hypoxemia in experimental conditions is an increase in variability
- Low variability appears with advanced acidemia
- And /or with other “depressing” or “chronic ”central nervous system factors

SUMMARY

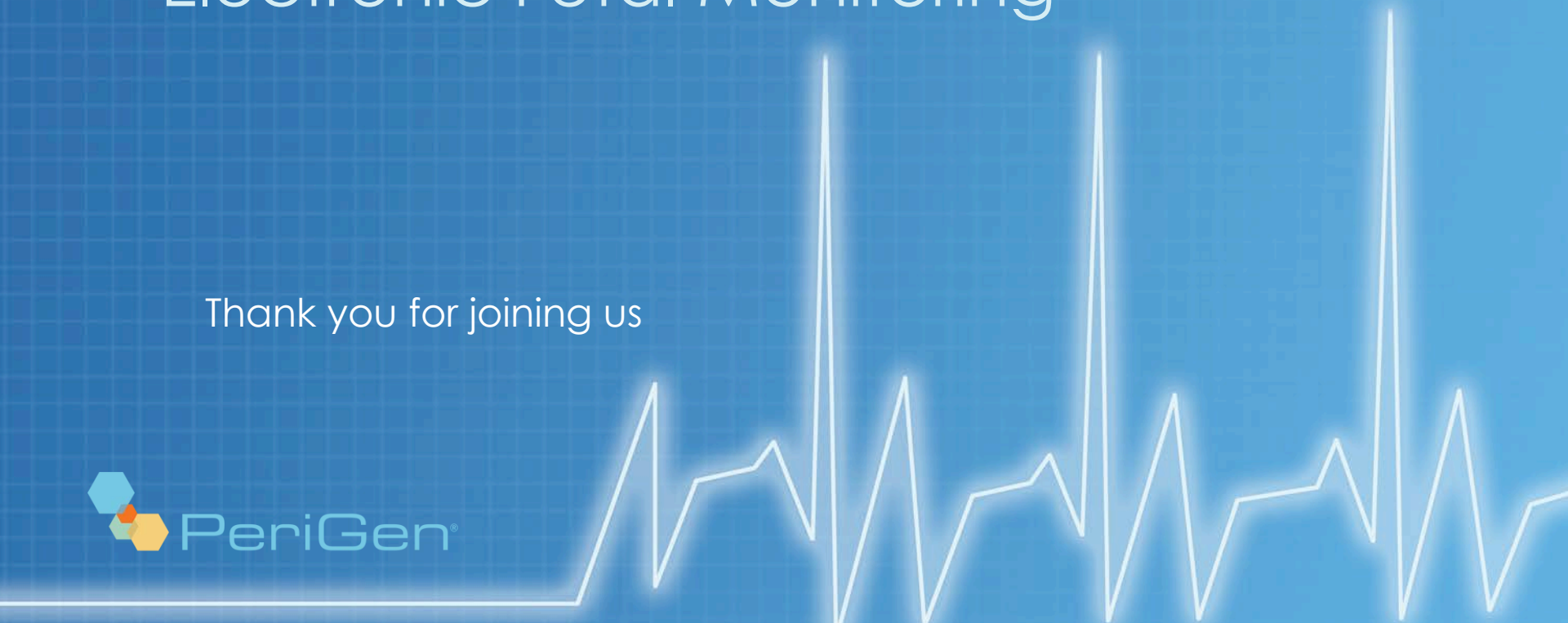
- EFM patterns are the result of many interacting physiological pathways that overlap and change in the presence of severe acidemia

- Important considerations for EFM interpretation
  1. Decelerations from uteroplacental insufficiency and cord compression share common physiological pathways
  2. Size, frequency of decelerations
  3. Duration of EFM problem and its progression
  4. Loss of baseline variability is a late change
  5. Underlying fetal tolerance and cause

The Physiology of

Electronic Fetal Monitoring

Thank you for joining us



PeriGen®