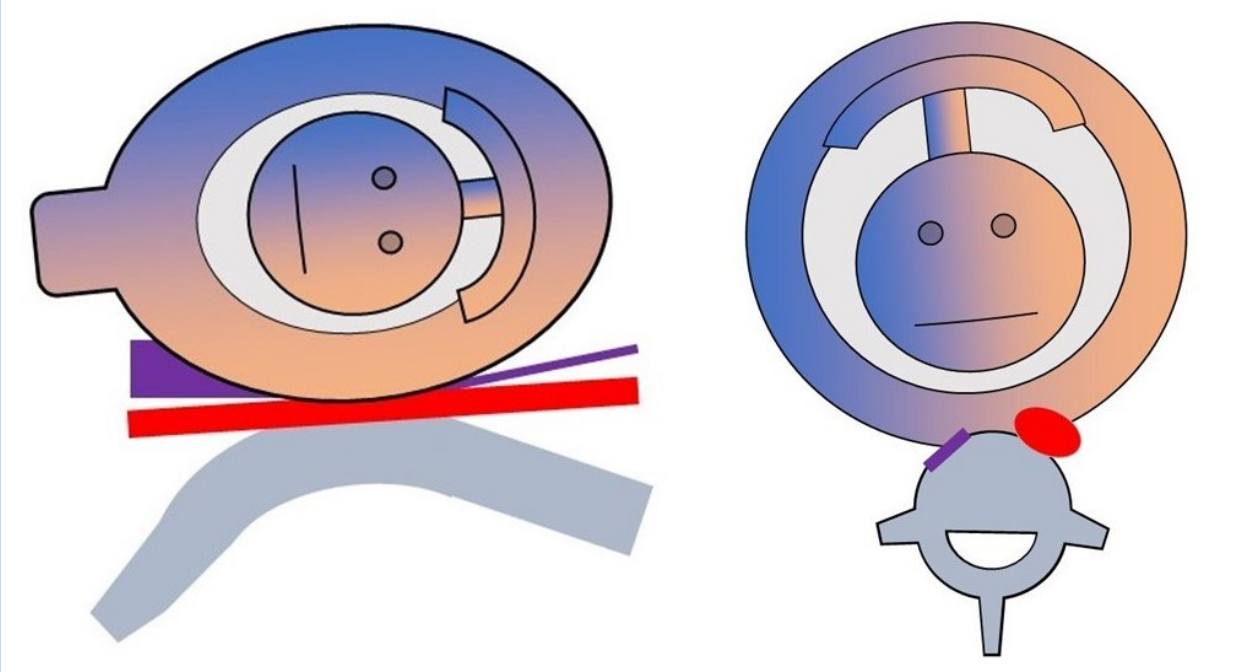


The value of measuring cardiac output during pregnancy

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Disclosures

None

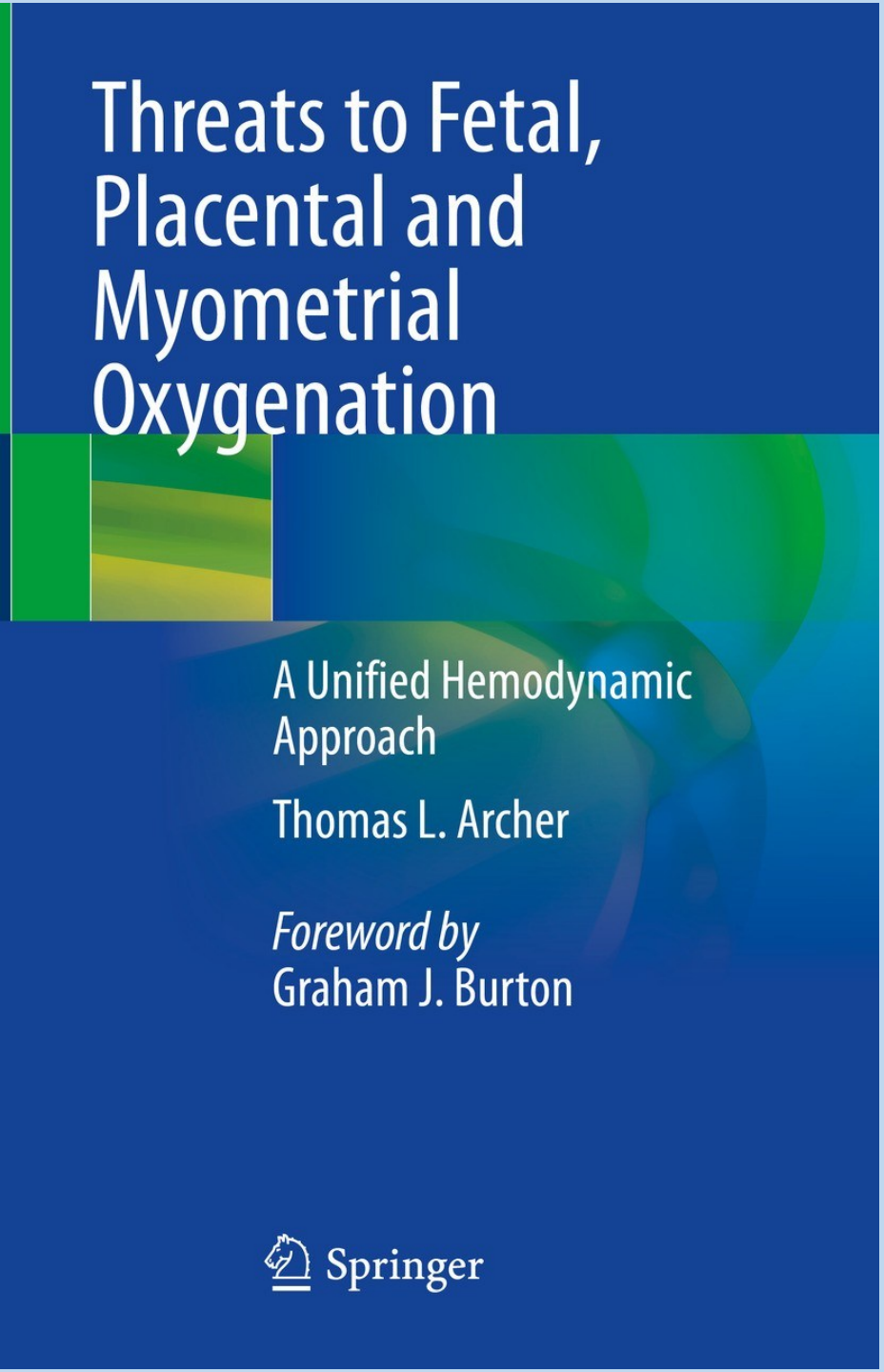
Starting off

For me, the use of electrical cardiometry to measure cardiac output during pregnancy has been a voyage of discovery and understanding

My purpose with this presentation is to awaken your curiosity and encourage new investigation.

A lot more research is needed to either prove or disprove the theories I am going to present.

I hope that some of you will feel inspired to undertake this research!



One purpose of measuring cardiac output during pregnancy is to protect the pregnant woman and her fetus from ***threats to fetal, placental and myometrial oxygenation.***

And that is the title of my second book!

Measurement and trending of cardiac output with electrical cardiometry

In our clinical practice and research with electrical cardiometry in pregnant patients, we relied solely upon the **trends** of cardiac output, since we considered that the absolute values were not reliable in obstetric patients. Despite this, we found that following cardiac output trends was extremely useful in patient care, and the conclusions of the majority of our publications are based solely on trends in cardiac output, rather than on absolute values.

Additionally, I have suggested improvements to increase the absolute accuracy of electrical cardiometry, but am unaware whether any of those suggestions have been incorporated into current devices.

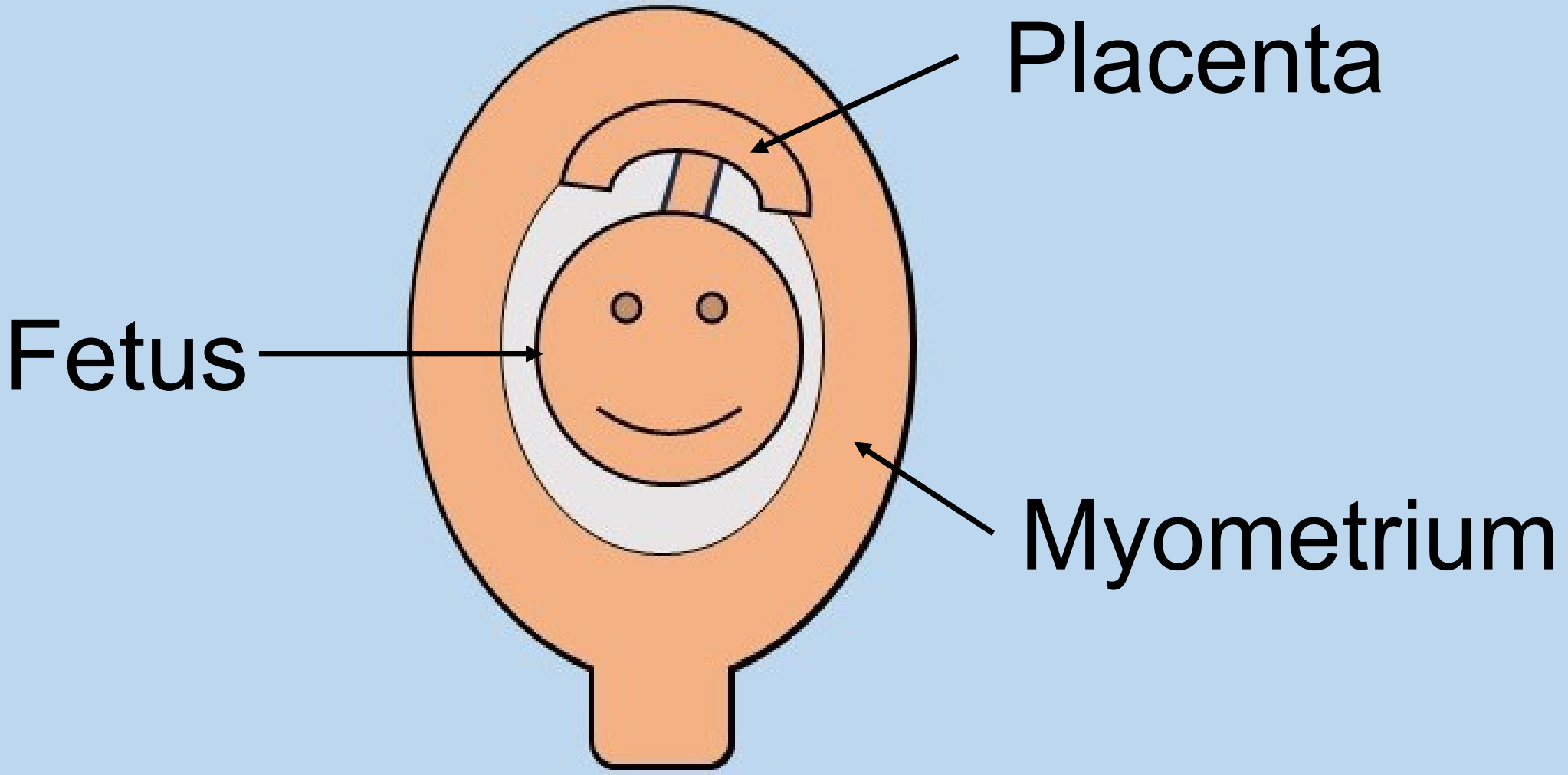
To understand cardiac output,
here is my cast of characters:

Pregnant woman

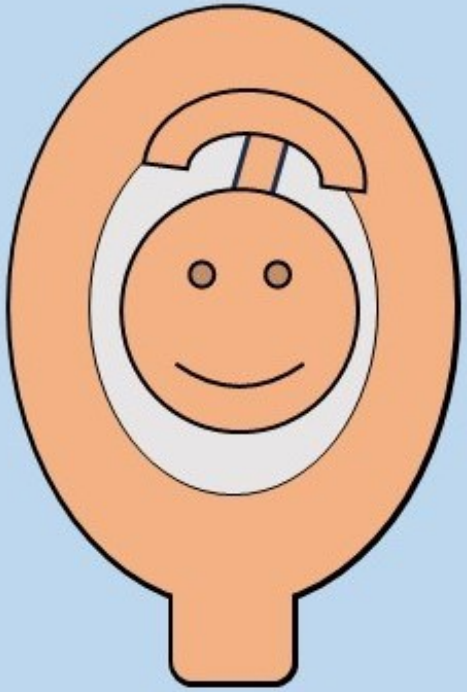


Comfortable, happy

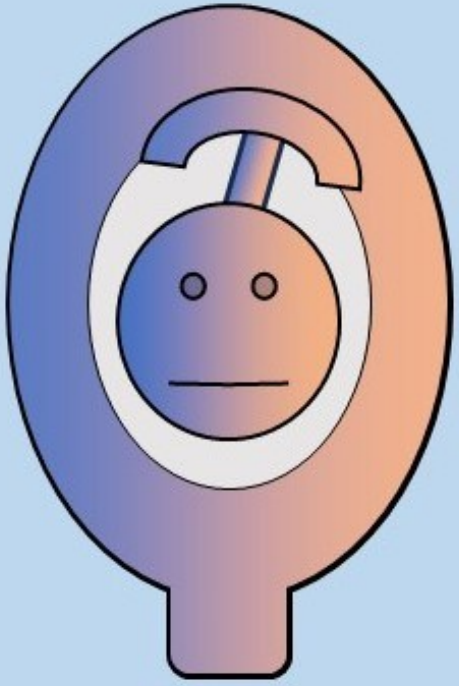
Anatomy lesson:
fetus, placenta and myometrium



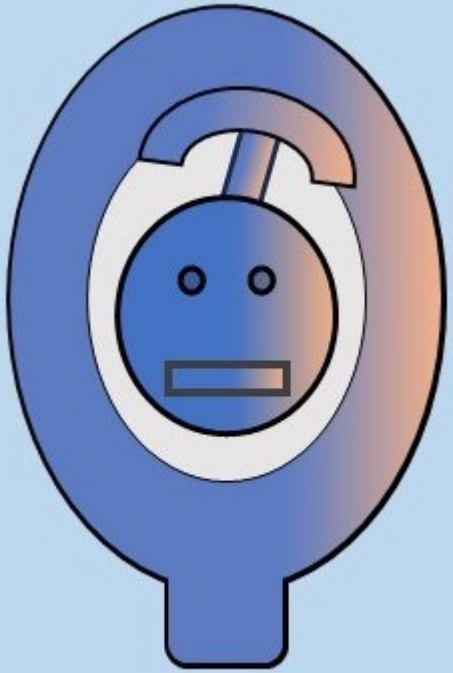
Oxygenation of fetus, placenta and myometrium



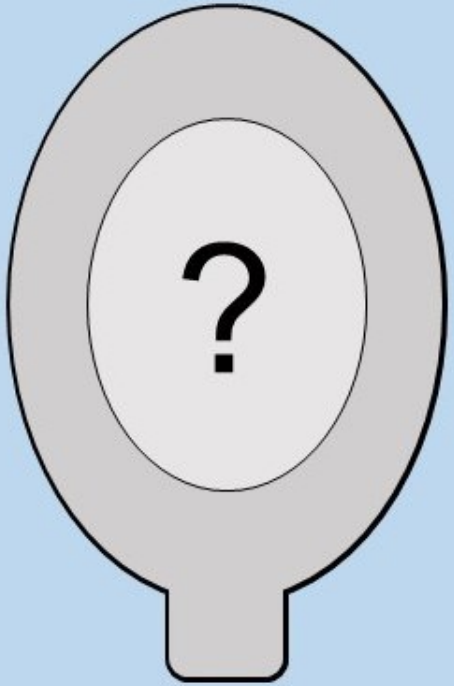
Good



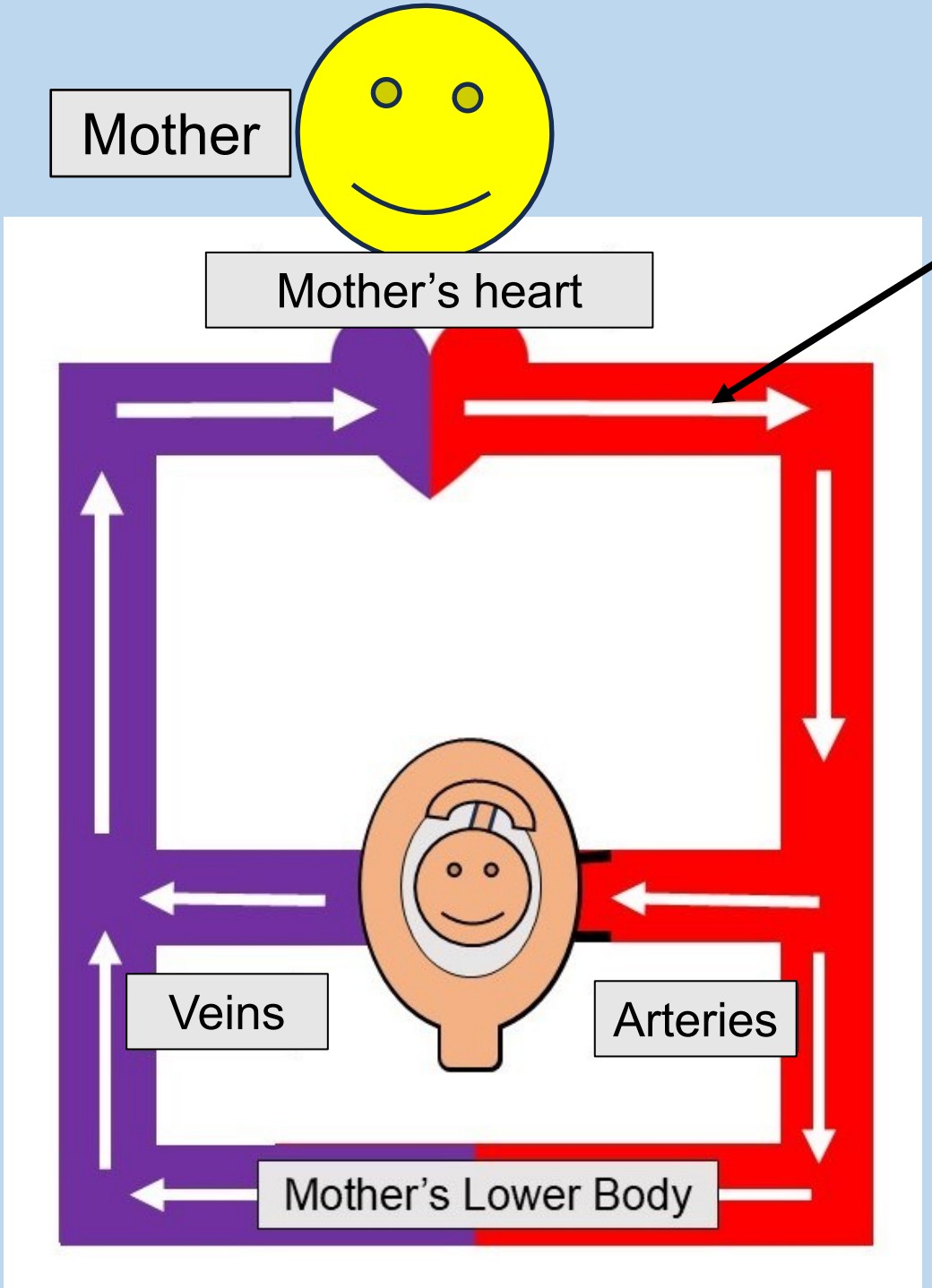
Precarious



Bad



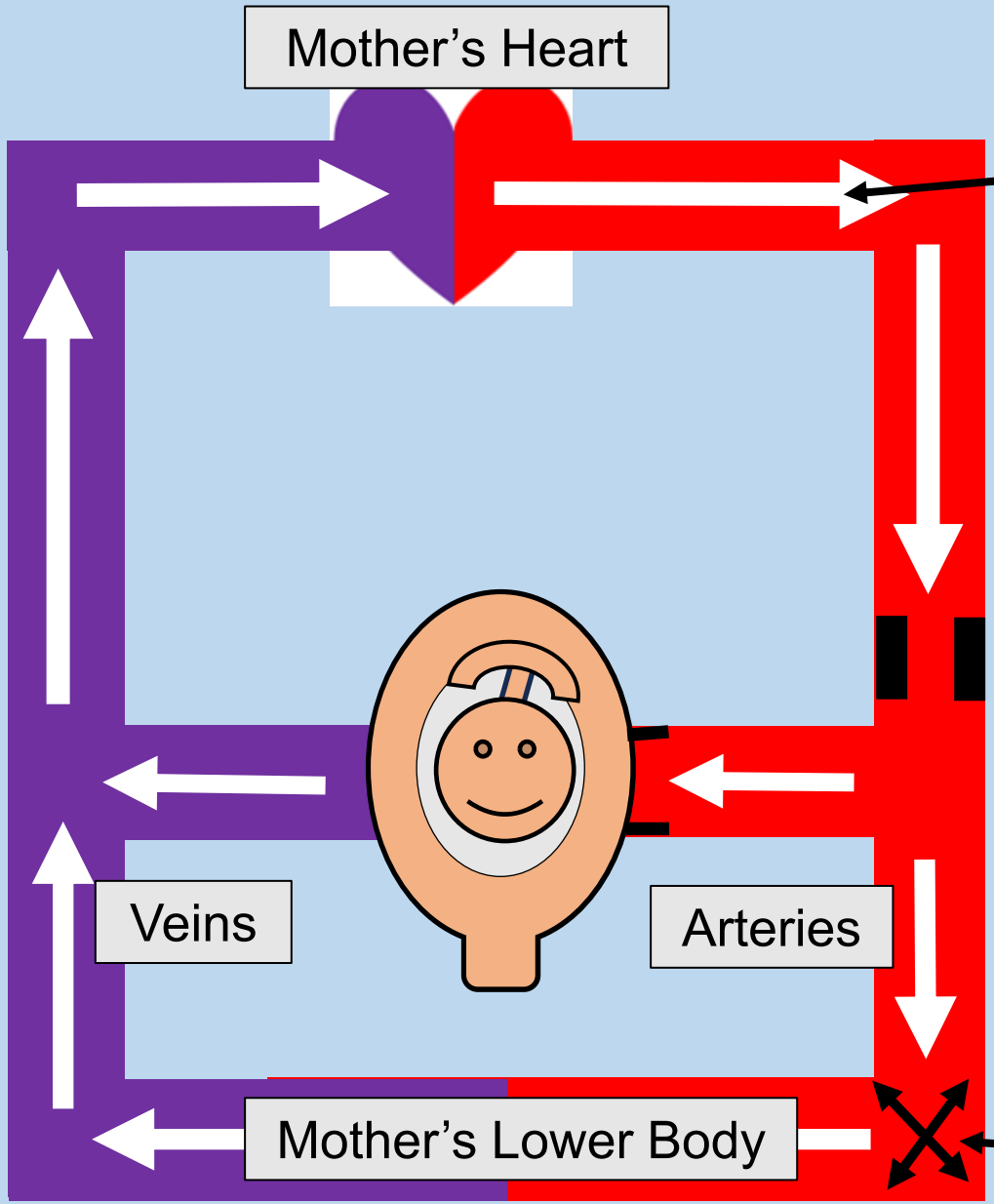
Unknown



Cardiac output (CO)

Total volume of blood pumped by the heart per minute.

Liters / minute



Cardiac output (CO)

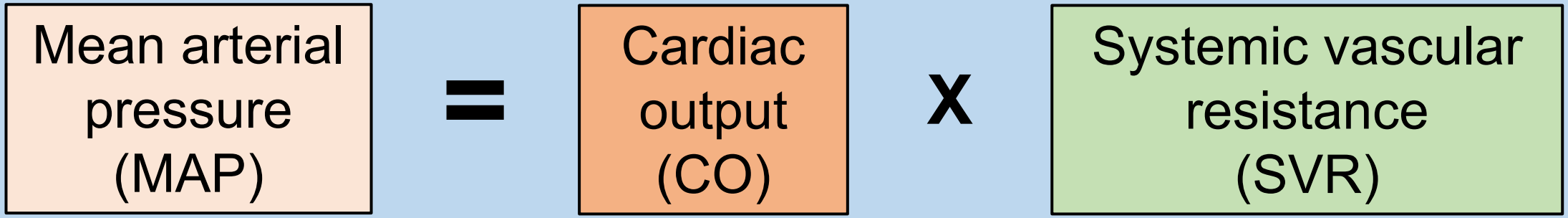
X

Systemic vascular resistance (SVR)

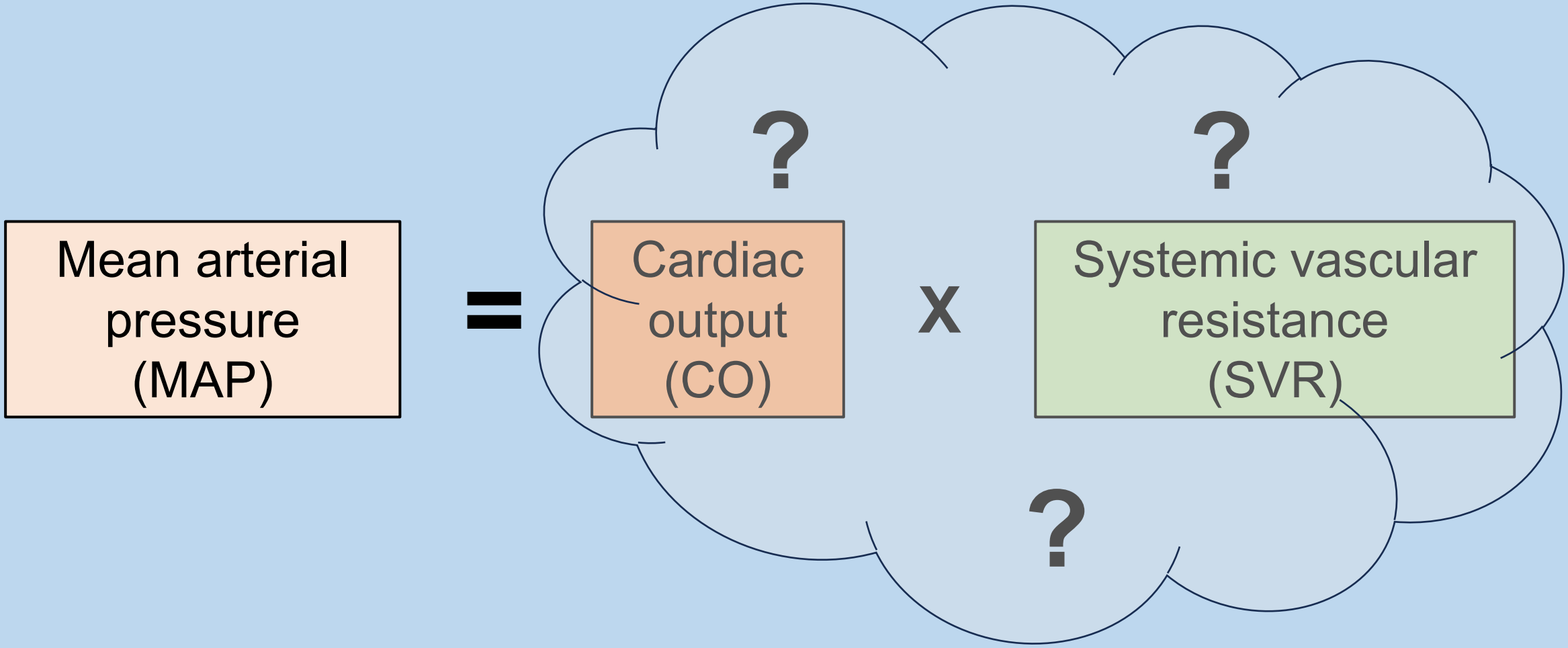
=

Mean arterial pressure (MAP)

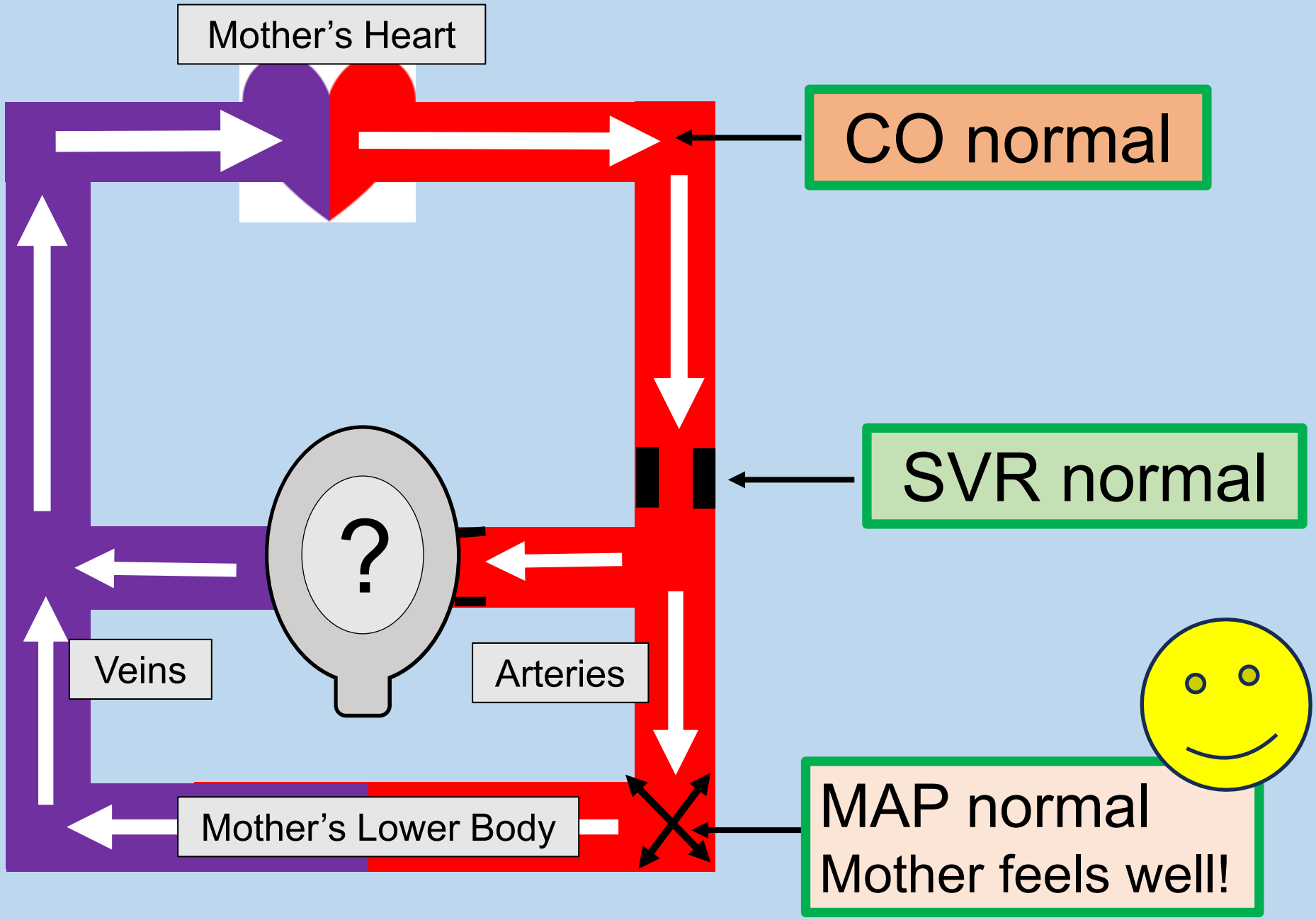
If we know cardiac output, we can understand the two components of arterial pressure.

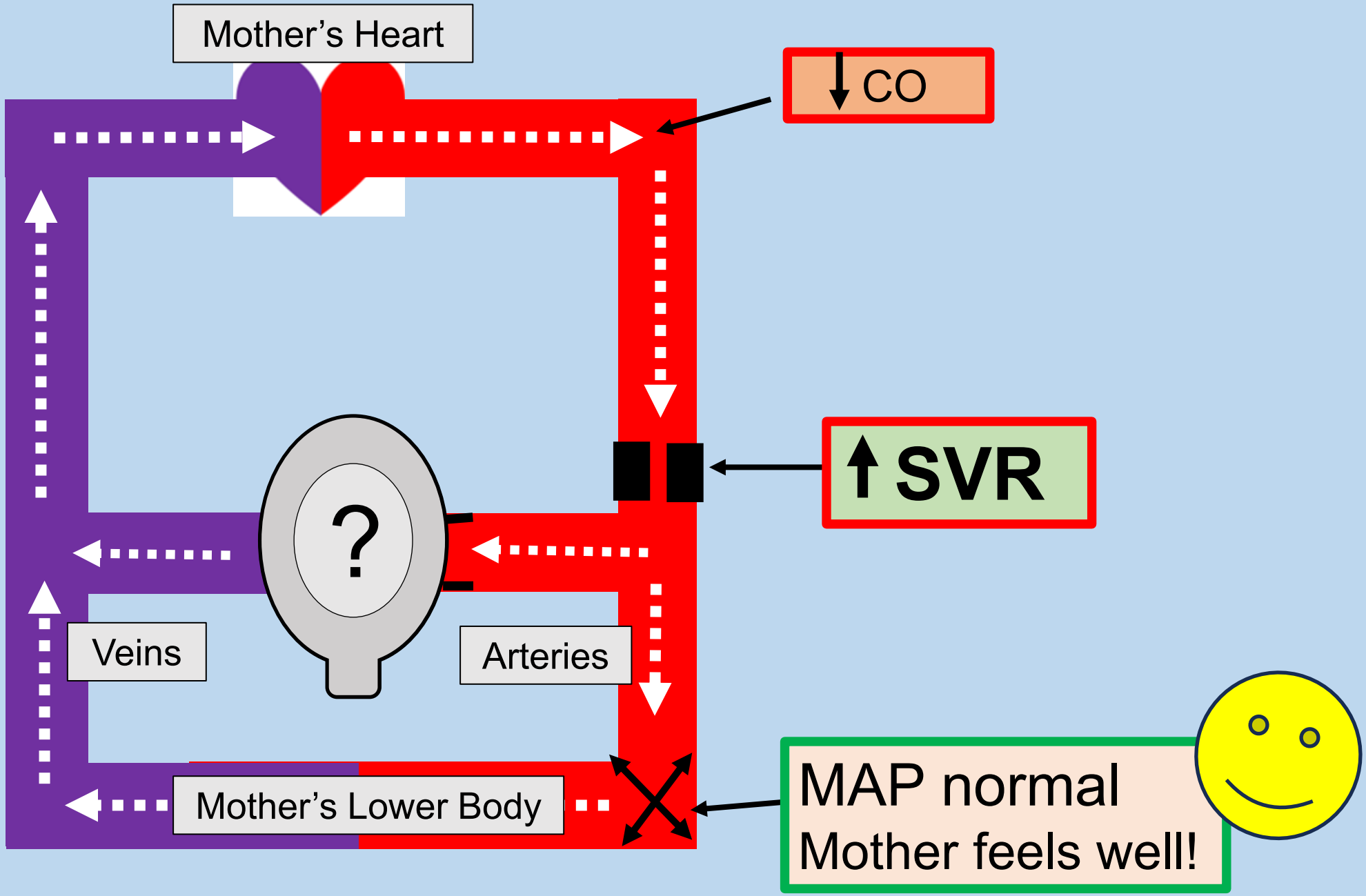


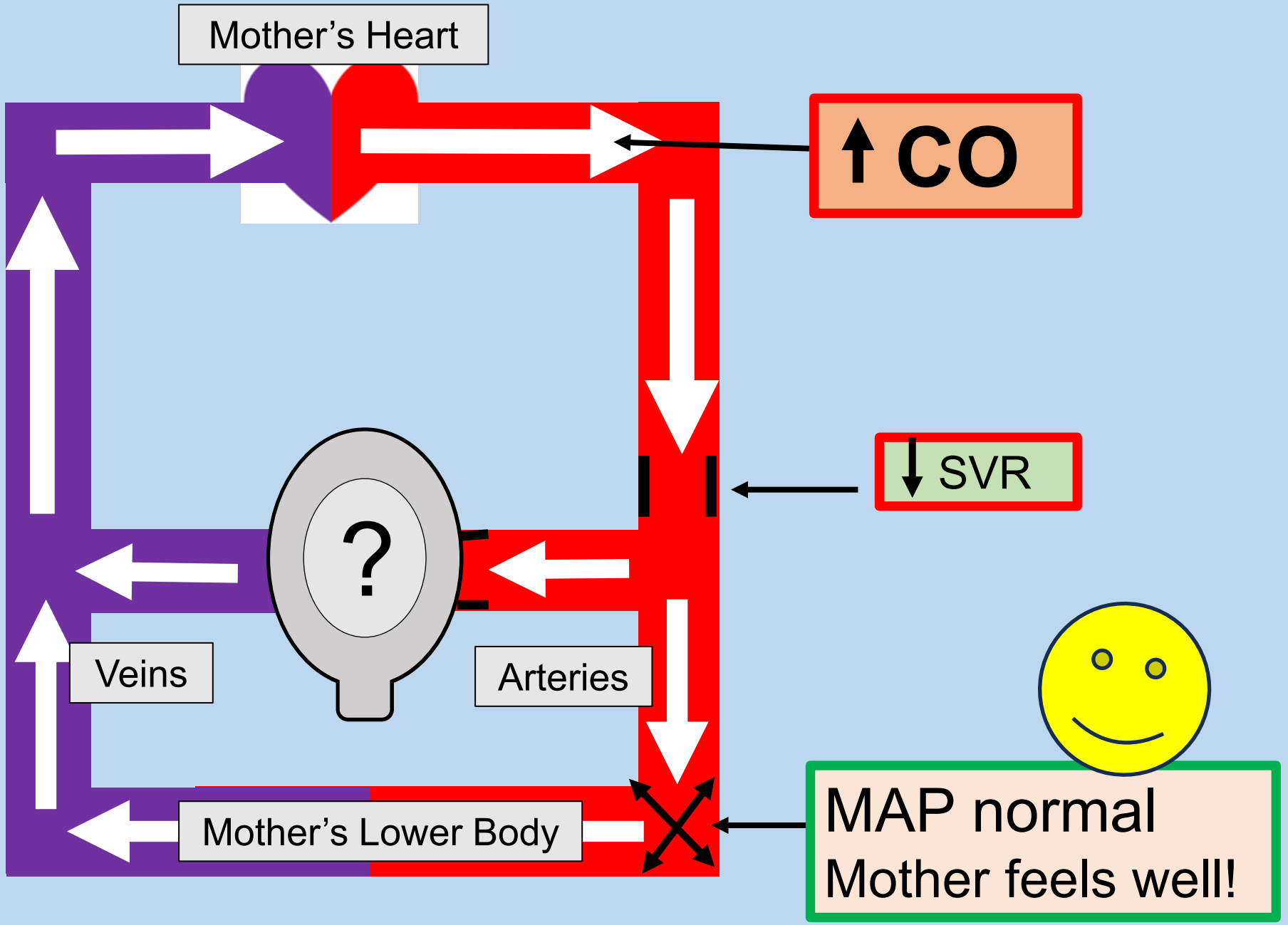
If we don’t know cardiac output, arterial pressure is a **mystery!**



The same arterial pressure can be associated with three very different hemodynamic situations


Mother's Heart
CO normal
SVR normal
?
Veins
Arteries
Mother's Lower Body
MAP normal
Mother feels well!

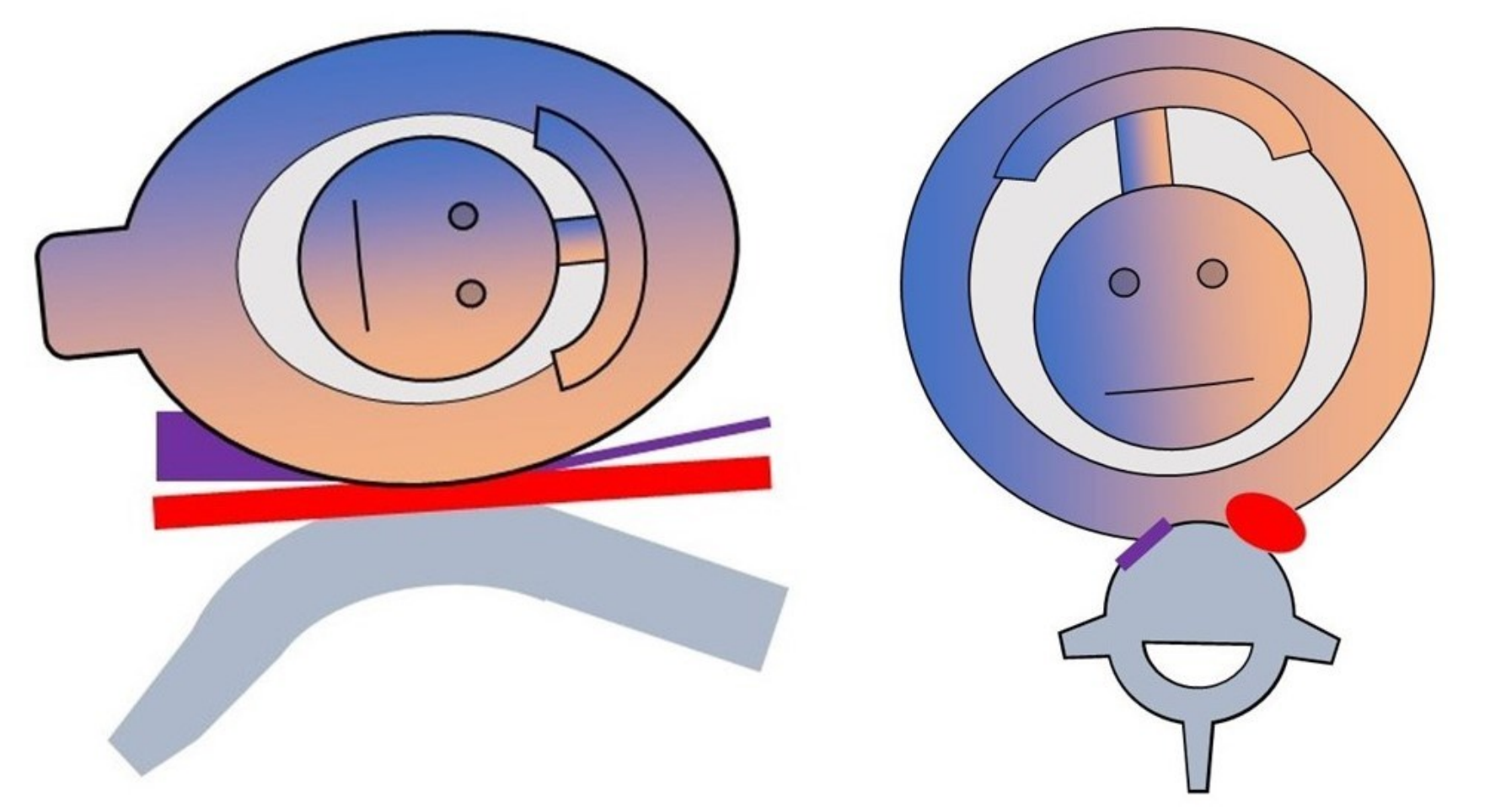

Mother's Heart
CO
SVR
?
Veins
Arteries
Mother's Lower Body
MAP normal
Mother feels well!


Mother's Heart
↑ CO
↓ SVR
?
Veins
Arteries
Mother's Lower Body
MAP normal
Mother feels well!

Maternal position therapy ("position therapy")

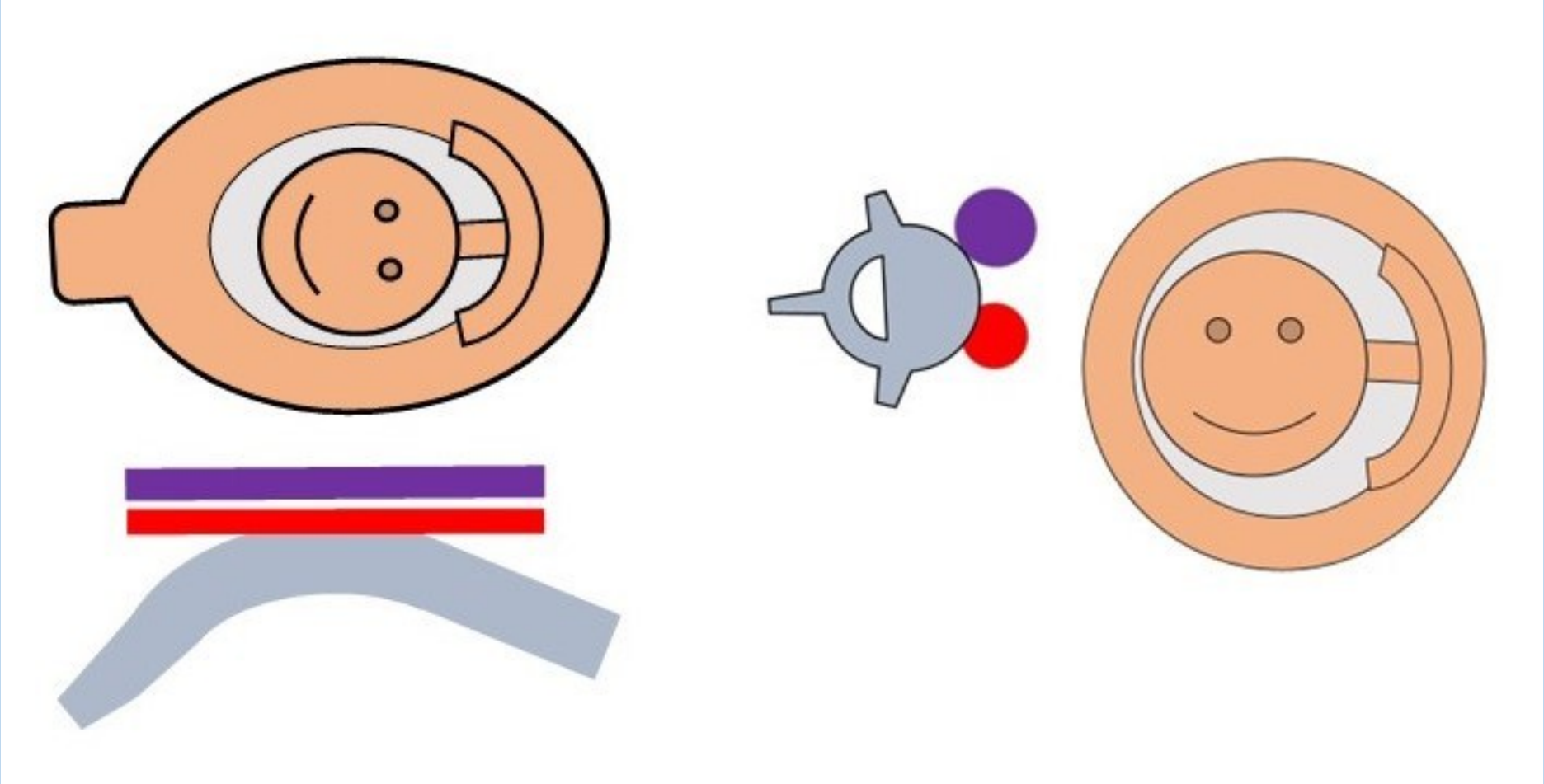
The use of the mother's body position to prevent or alleviate the obstruction of uterine venous return caused by positional compression of the inferior vena cava, by the uterus itself or by an obese abdominal wall

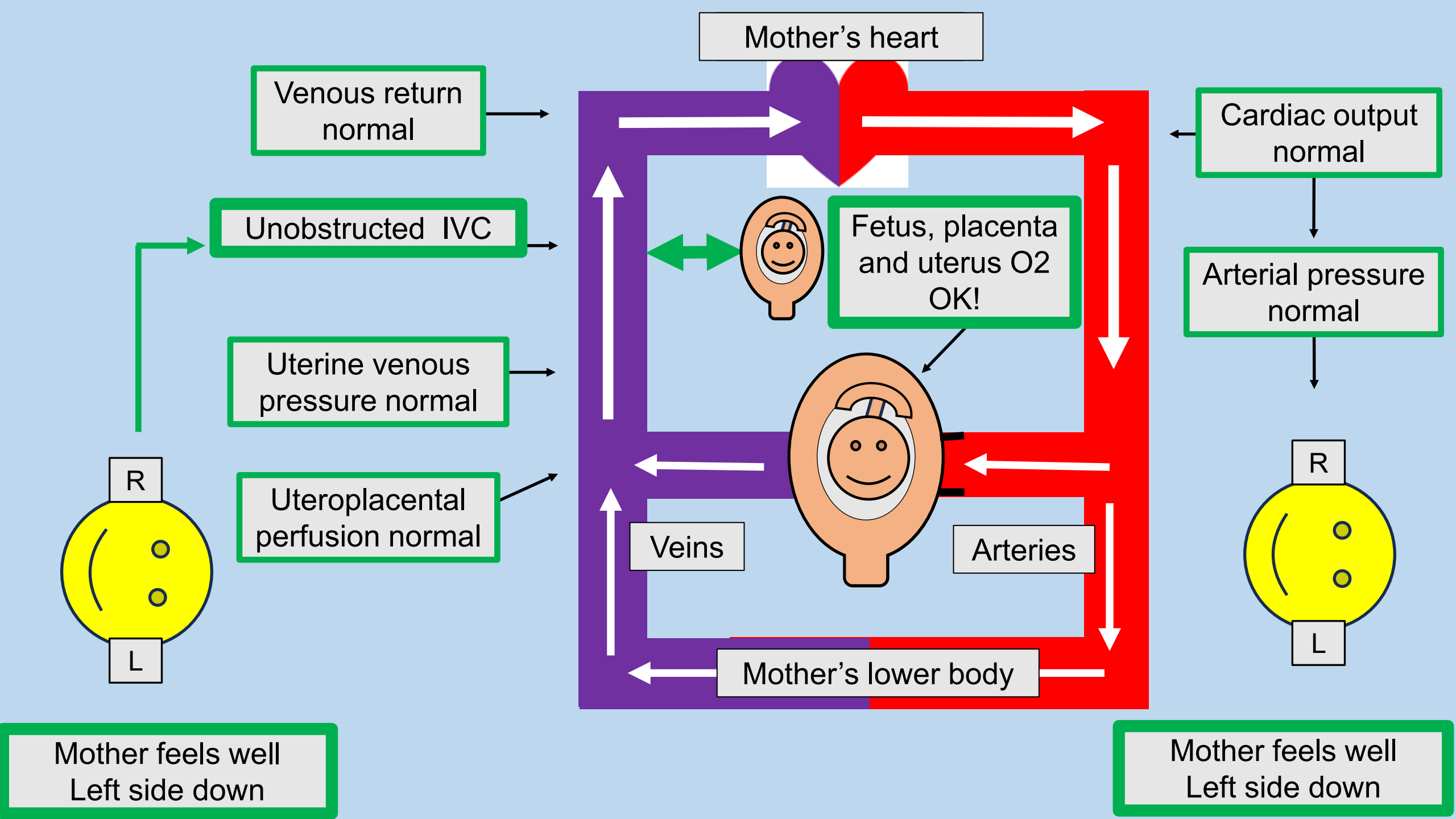
With “position therapy” we are trying to prevent the uterus from obstructing the veins that drain its own blood flow, like a **tourniquet!**



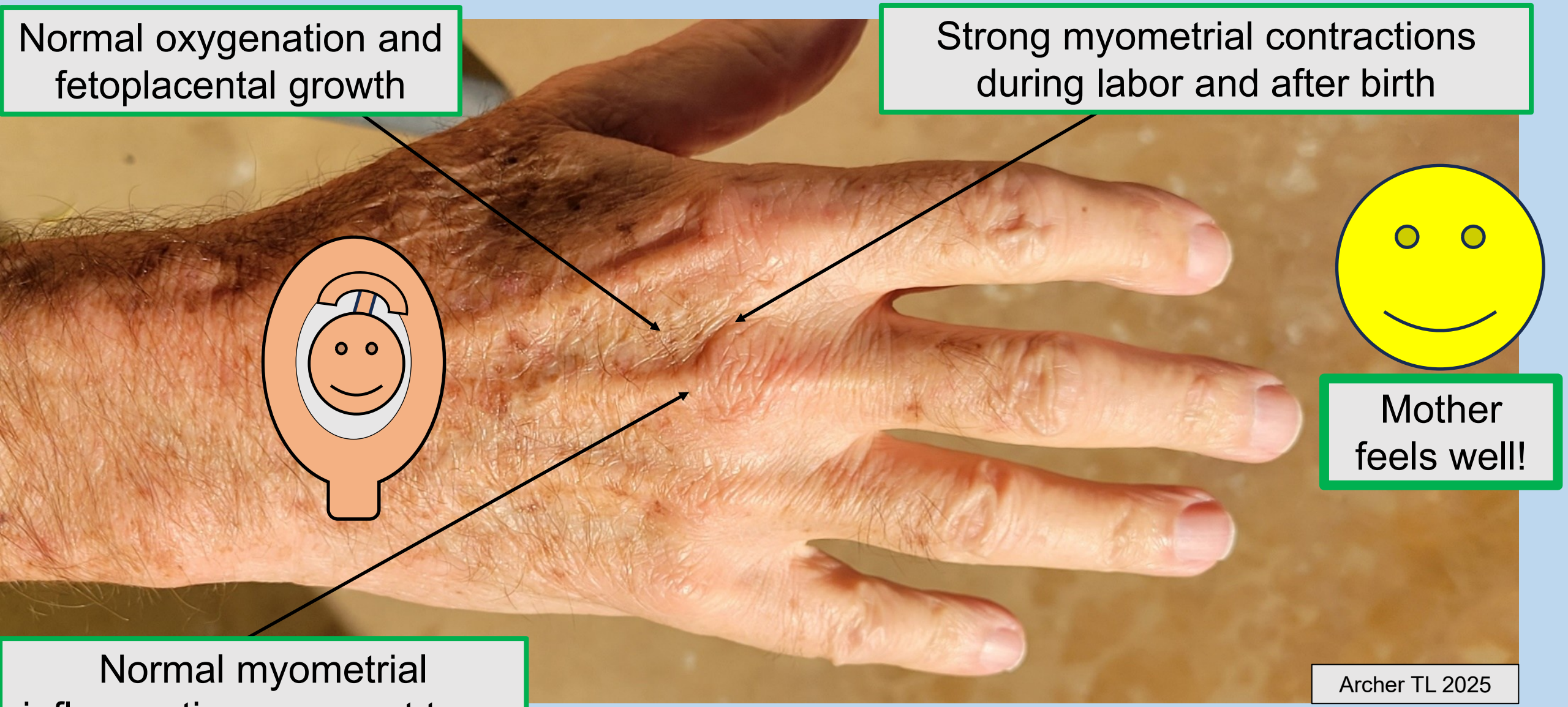
But let’s begin by looking at the **healthy uterine circulation--** in which unobstructed uterine venous return favors adequate fetal oxygenation.

With position therapy we prevent the uterus from obstructing its own venous return and thereby re-establish adequate oxygenation of the fetus, placenta and myometrium.



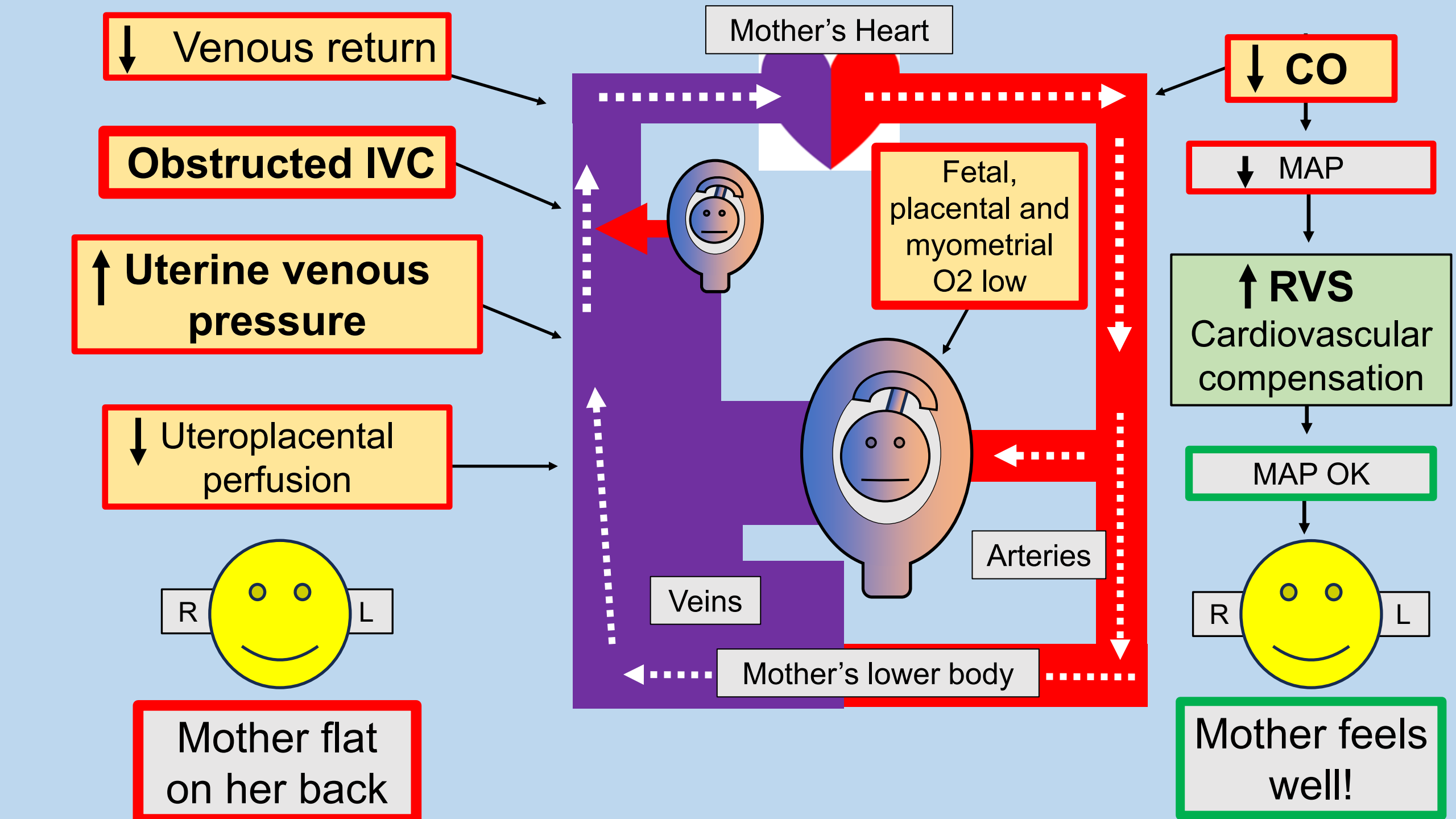

Mother's heart
Venous return normal
Unobstructed IVC
Uterine venous pressure normal
Uteroplacental perfusion normal
Fetus, placenta and uterus O2 OK!
Cardiac output normal
Arterial pressure normal
R
L
Veins
Arteries
Mother's lower body
R
L
Mother feels well
Left side down
Mother feels well
Left side down

My hand as a “uterus” **without venous obstruction:**

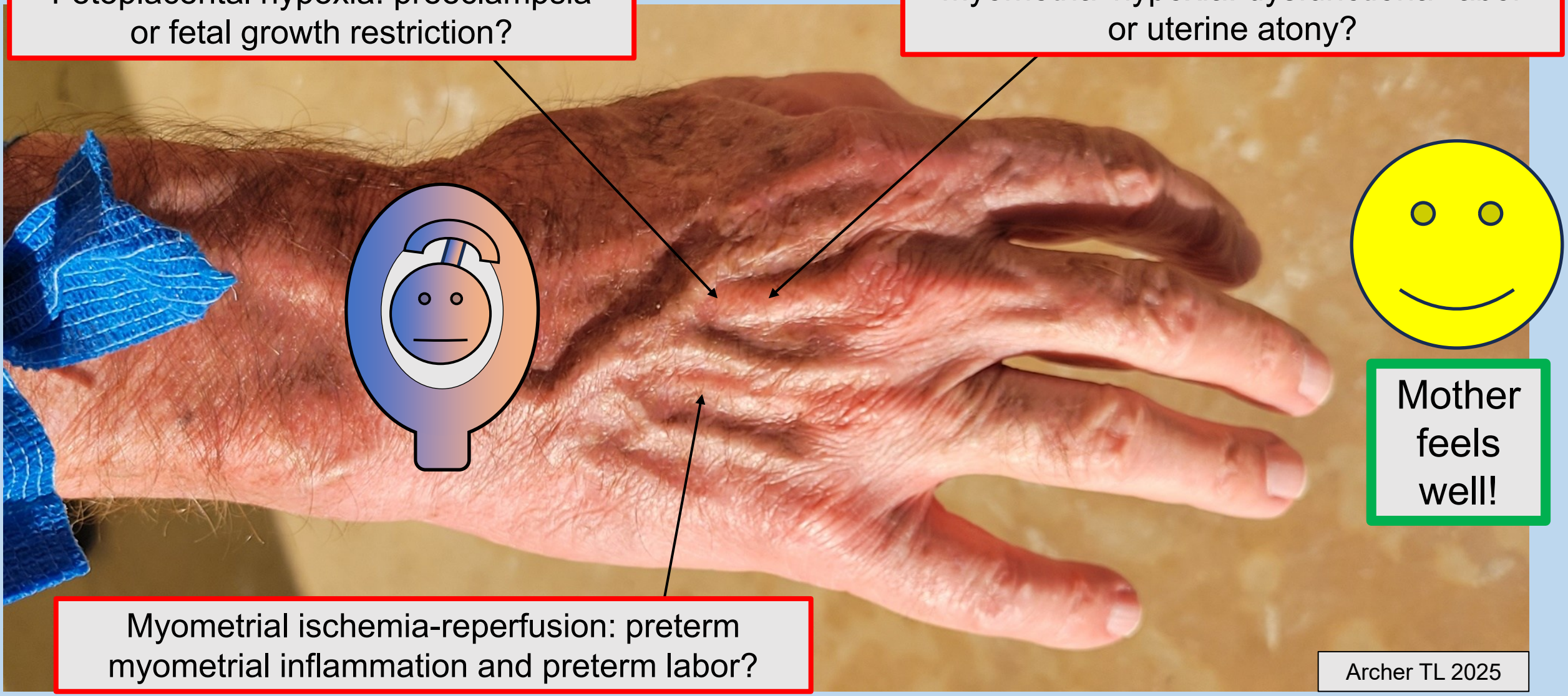


Now, let’s look at an **impaired uterine circulation:**

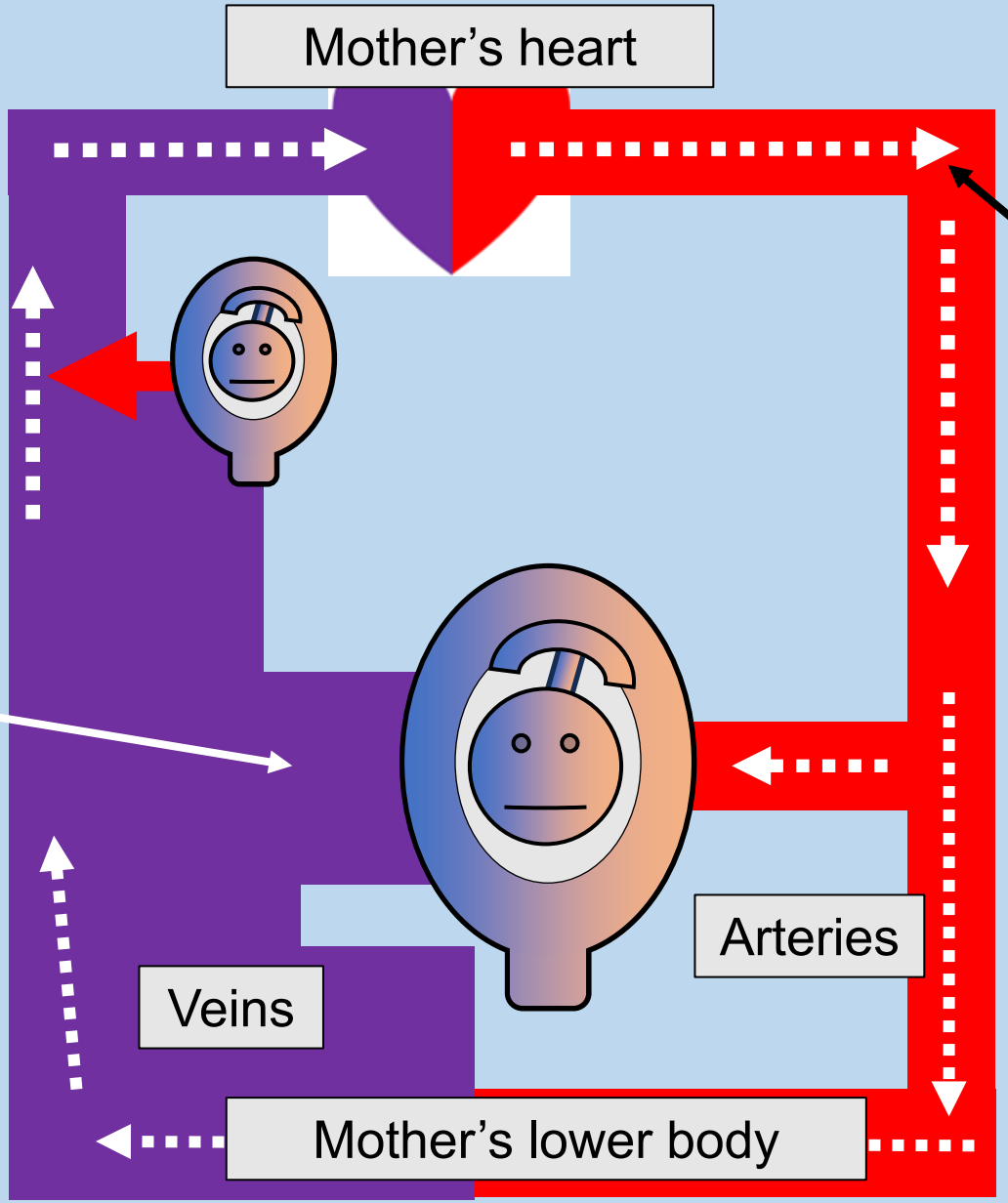
Obstruction of uterine venous return reduces fetal, placental and myometrial oxygen delivery.


↓ Venous return
Obstructed IVC
↑ Uterine venous pressure
↓ Uteroplacental perfusion
R
L
Mother flat on her back
Mother's Heart
Fetal, placental and myometrial O2 low
Arteries
Veins
Mother's lower body
↓ CO
↓ MAP
↑ RVS Cardiovascular compensation
MAP OK
R
L
Mother feels well!

My hand as a “uterus” **with venous obstruction:**



Obstruction of venous return causes **two threats:**

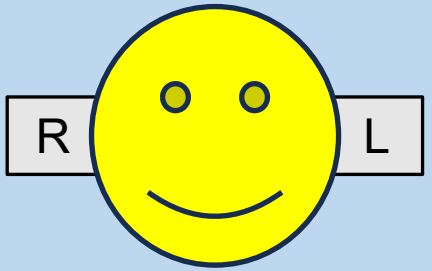


#1

↑ Uterine venous pressure

#2

↓ CO



Mother feels well!

Which of the two threats is more dangerous?

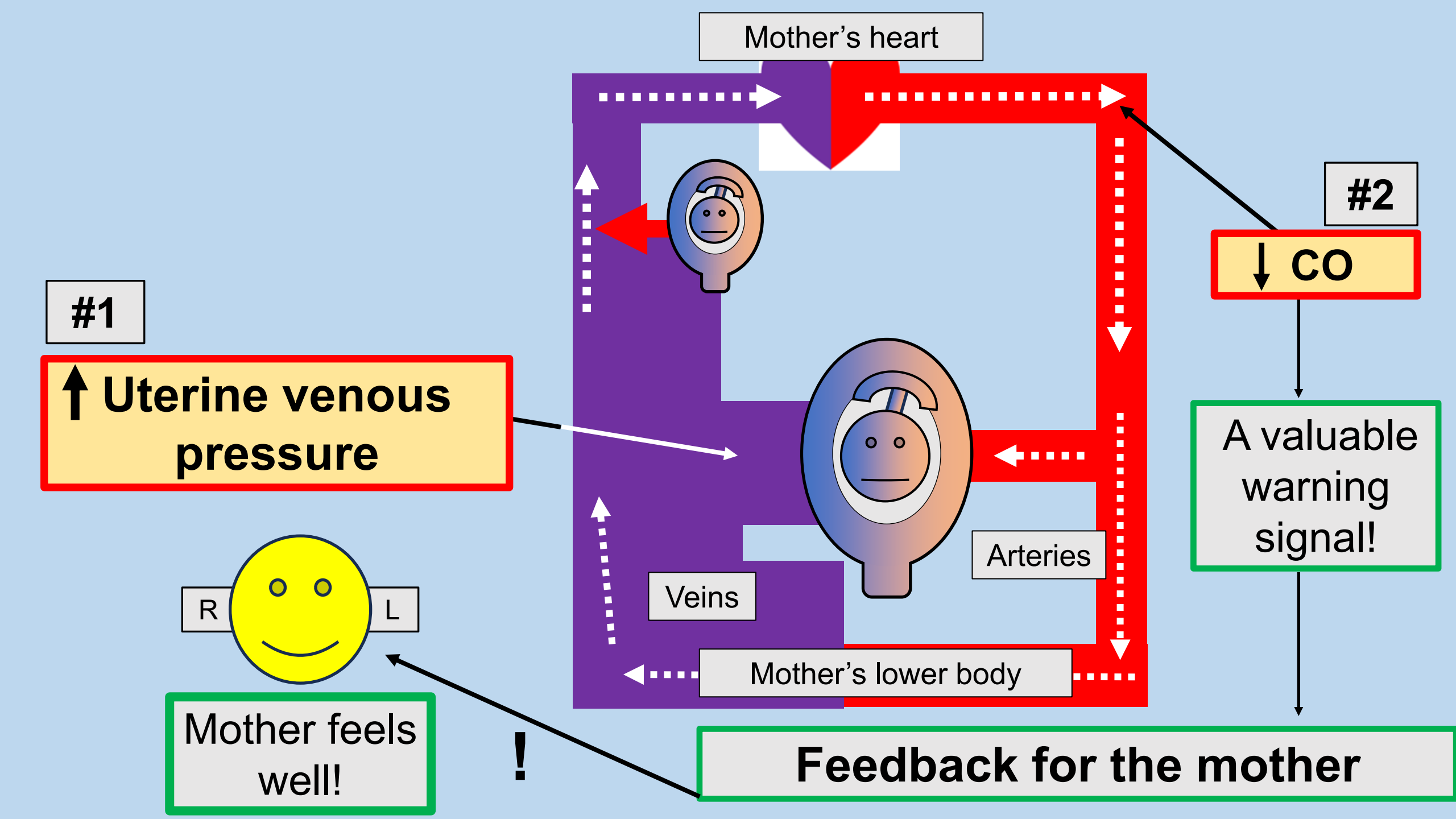
An important and subtle question:

Which of the two threats is more dangerous: the decrease in cardiac output or the increase in uterine venous pressure?

Although cardiac output– by itself-- is undoubtedly important in all patients, it is possible that during pregnancy a relatively small decrease in maternal cardiac output due to an unfavorable maternal positional is not as harmful to the fetus, placenta and myometrium as the increase in uterine venous pressure with which the decrease in cardiac output is associated.

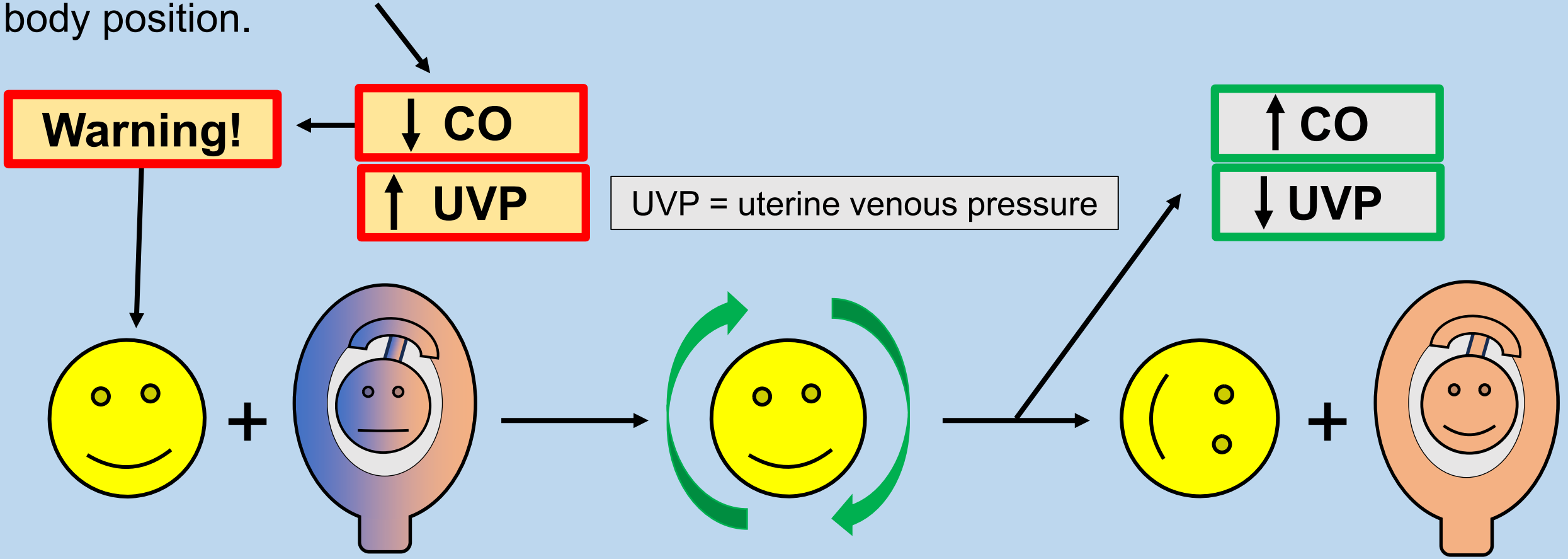
This somewhat surprising result might be true because the positional decrease in cardiac output is caused by an obstruction of the inferior vena cava which also obstructs uterine venous return and thereby increases uterine venous pressure– which, in turn, is the major cause of the dangerous reduction in uteroplacental perfusion and fetoplacental oxygenation!

For this reason, it is important to remember that reductions in maternal cardiac output due to unfavorable maternal positioning may serve as a warning signal regarding **a hemodynamic situation that is dangerous to the pregnancy for more than one hemodynamic reason!**


Mother's heart
#2
↓ CO
#1
↑ Uterine venous pressure
A valuable warning signal!
Arteries
Veins
Mother's lower body
R
L
Mother feels well!
!
Feedback for the mother

Cardiac output-guided maternal positioning:

A positional decrease in maternal cardiac output warns the mother to change her body position.



The concept of position therapy using cardiac output as an indicator may be applicable to both short- and long-term patient care.

Short-term use of cardiac output in obstetrics:

Observe effects and adjust dosage of medications.

Observe and use “autotransfusion waves”

Guide maternal positioning.

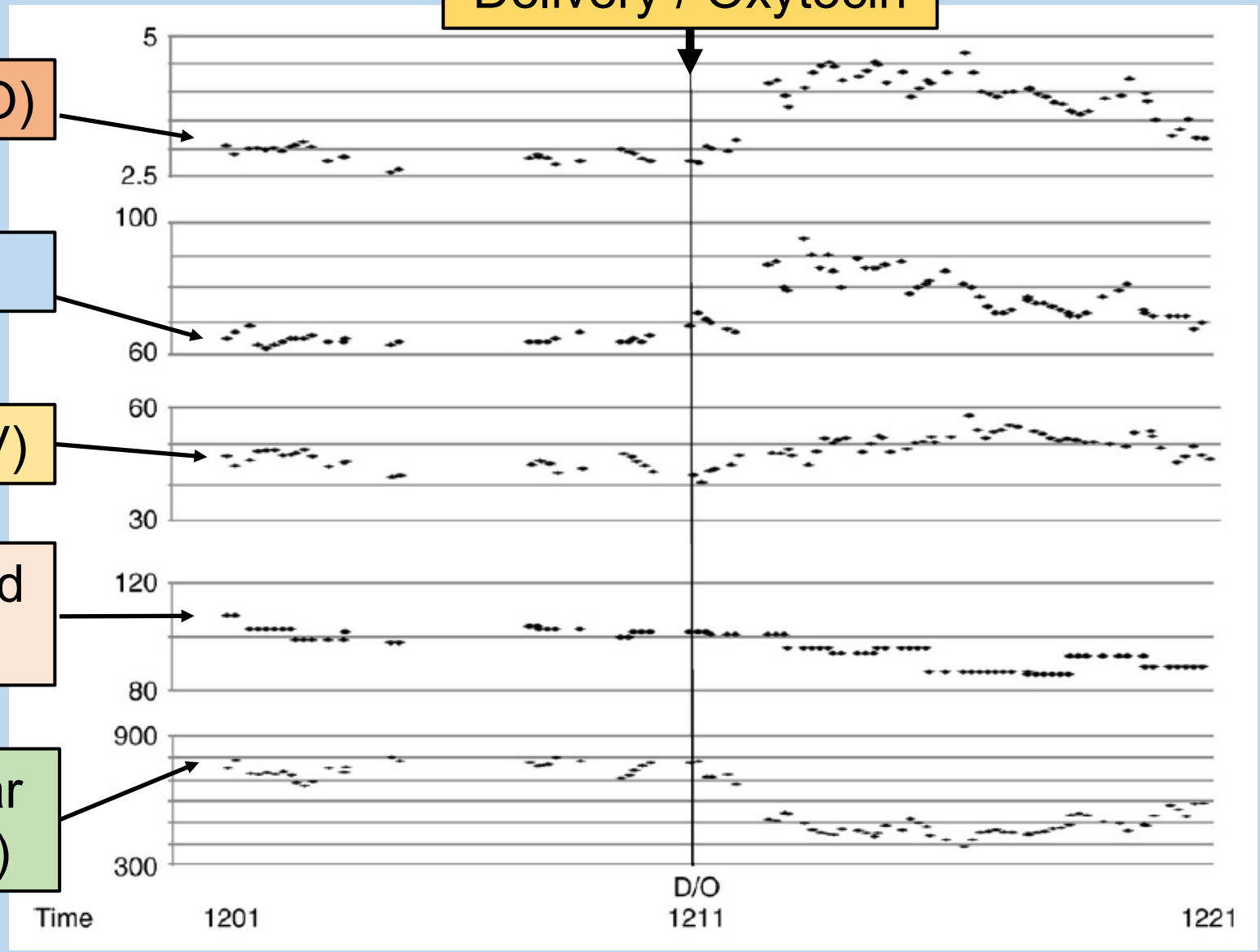
Prevent “fetal distress” during labor?

Prevent or treat dysfunctional labor?

Reduce cesarean delivery rate?

Observe effects and adjust dosage of medications.

Oxytocin at cesarean delivery



Cardiac output (CO)

Heart rate (HR)

Stroke volume (SV)

Mean arterial blood pressure (MAP)

Systemic vascular resistance (SVR)

↑ CO

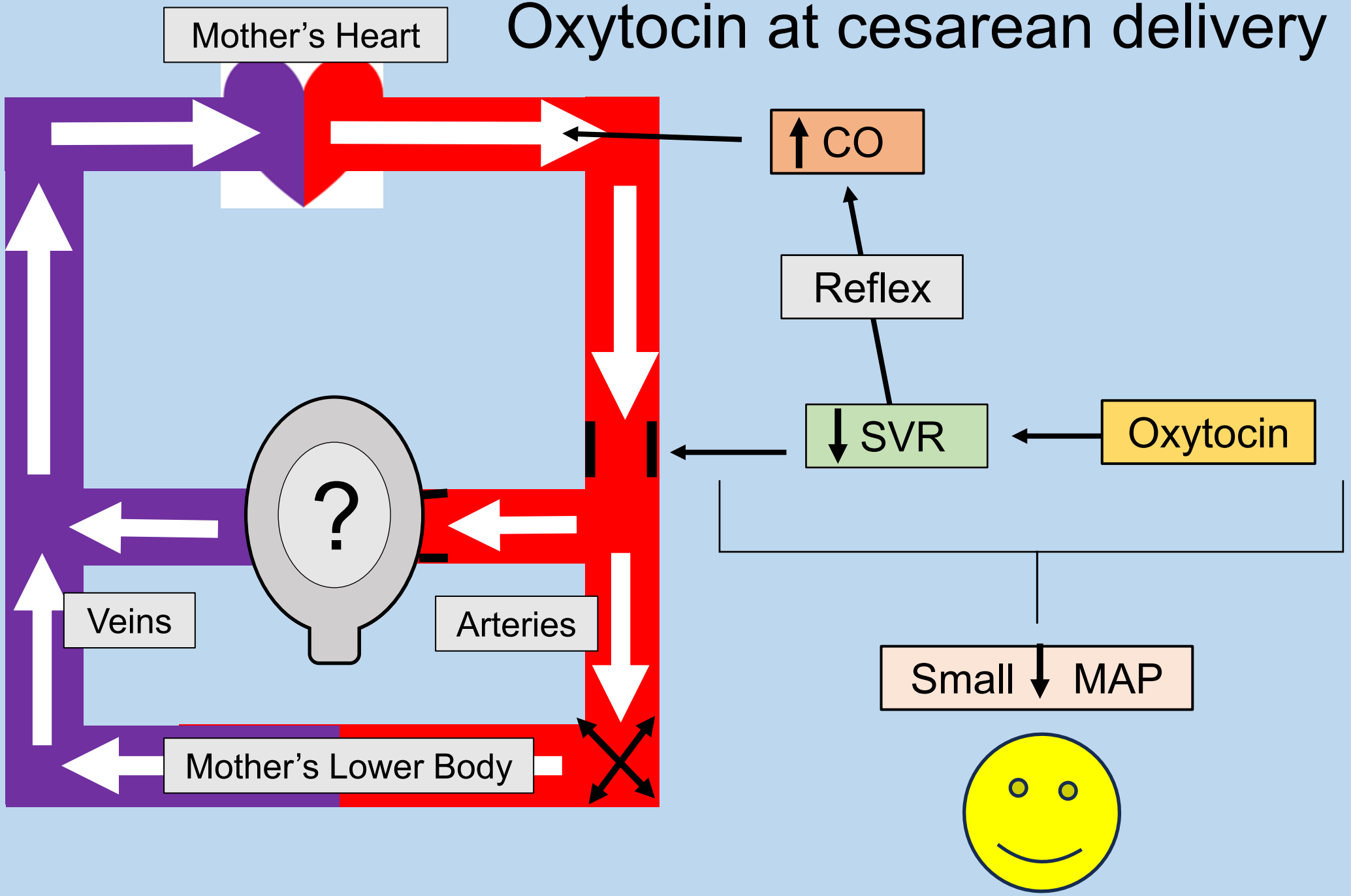
↑ HR

↑ SV

↓ MAP

↓ SVR

Oxytocin at cesarean delivery

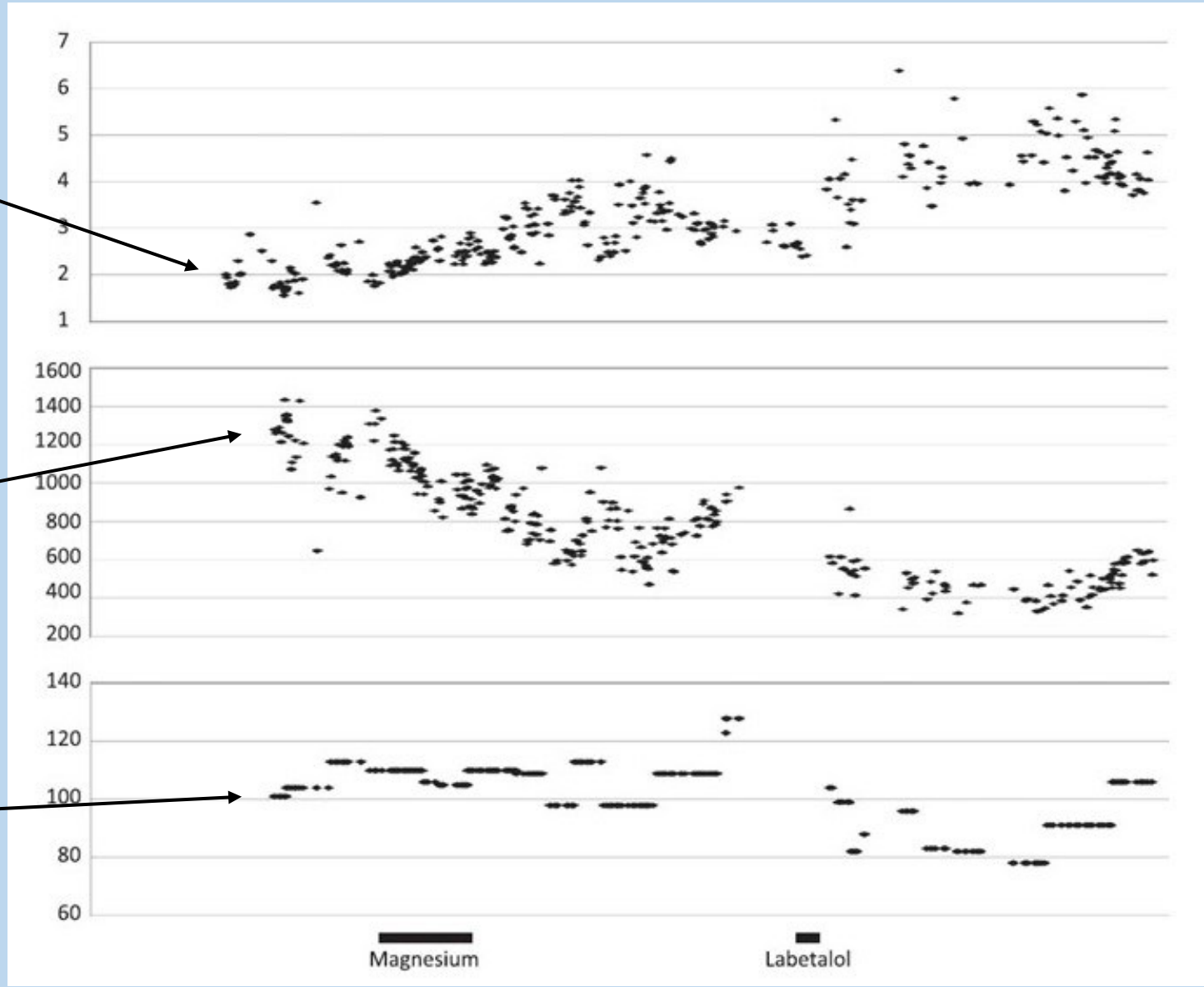


Preeclampsia, 27 weeks, treatment before induction of labor,

Cardiac output (CO)

Systemic vascular resistance (SVR)

Mean arterial pressure (MAP)



Magnesium

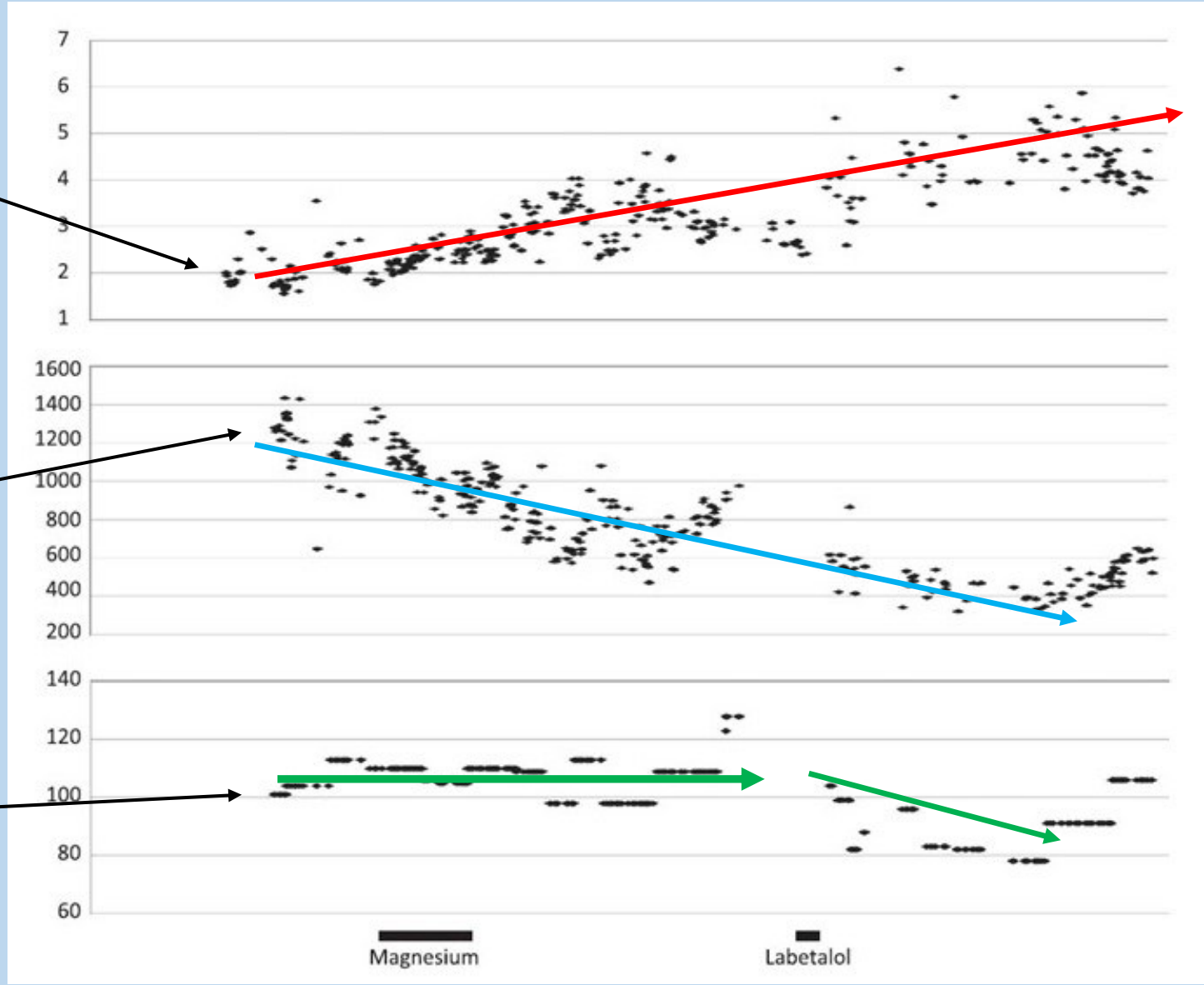
Labetalol

Preeclampsia, 27 weeks, treatment before induction of labor,

Cardiac output (CO)

Systemic vascular resistance (SVR)

Mean arterial pressure (MAP)



↑ CO

↓ SVR

MAP stable, then ↓

Magnesium

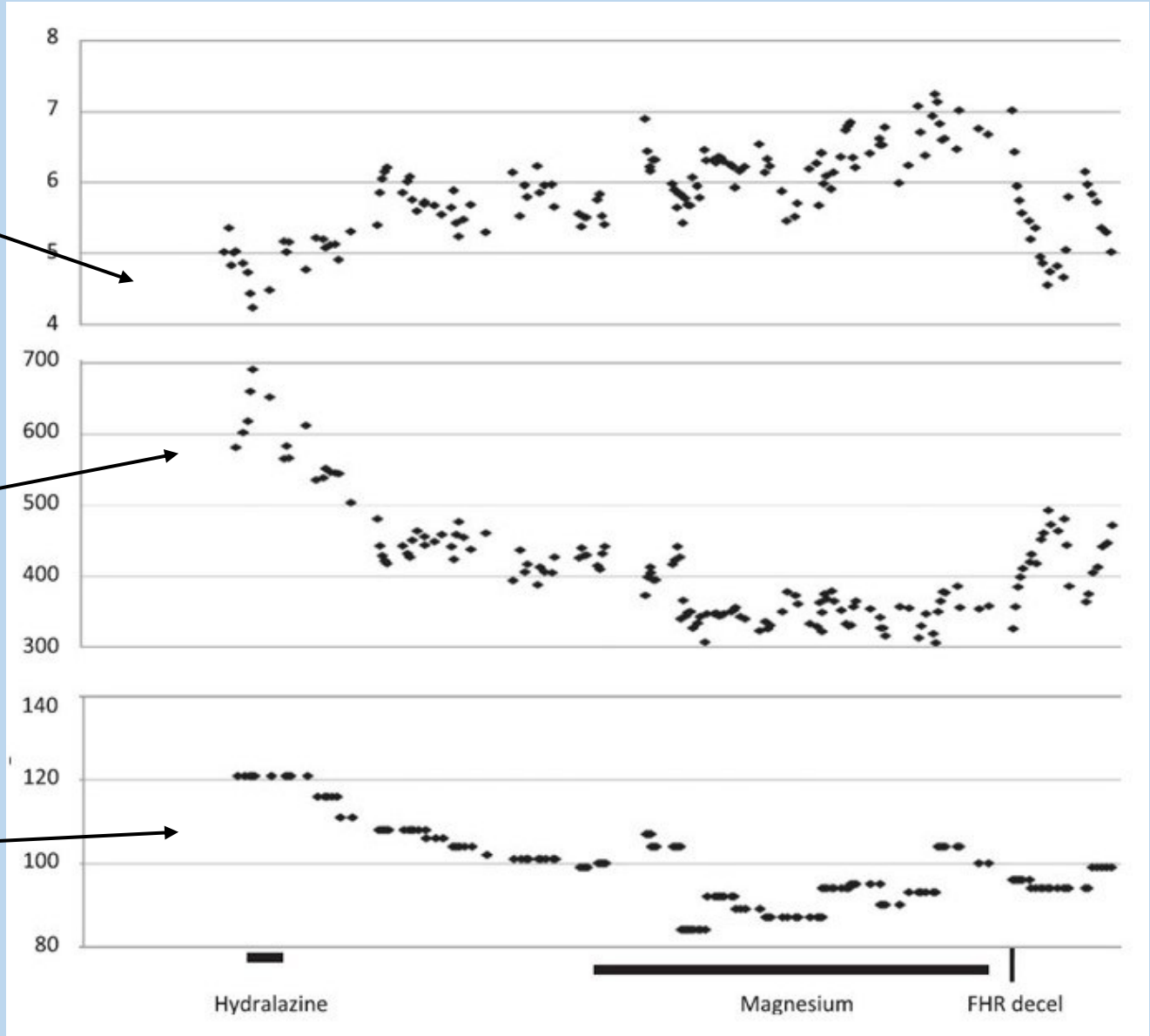
Labetalol

Preeclampsia, 29 weeks, treatment before induction of labor,

Cardiac output (CO)

Systemic vascular resistance (SVR)

Mean arterial pressure (MAP)



Hydralazine

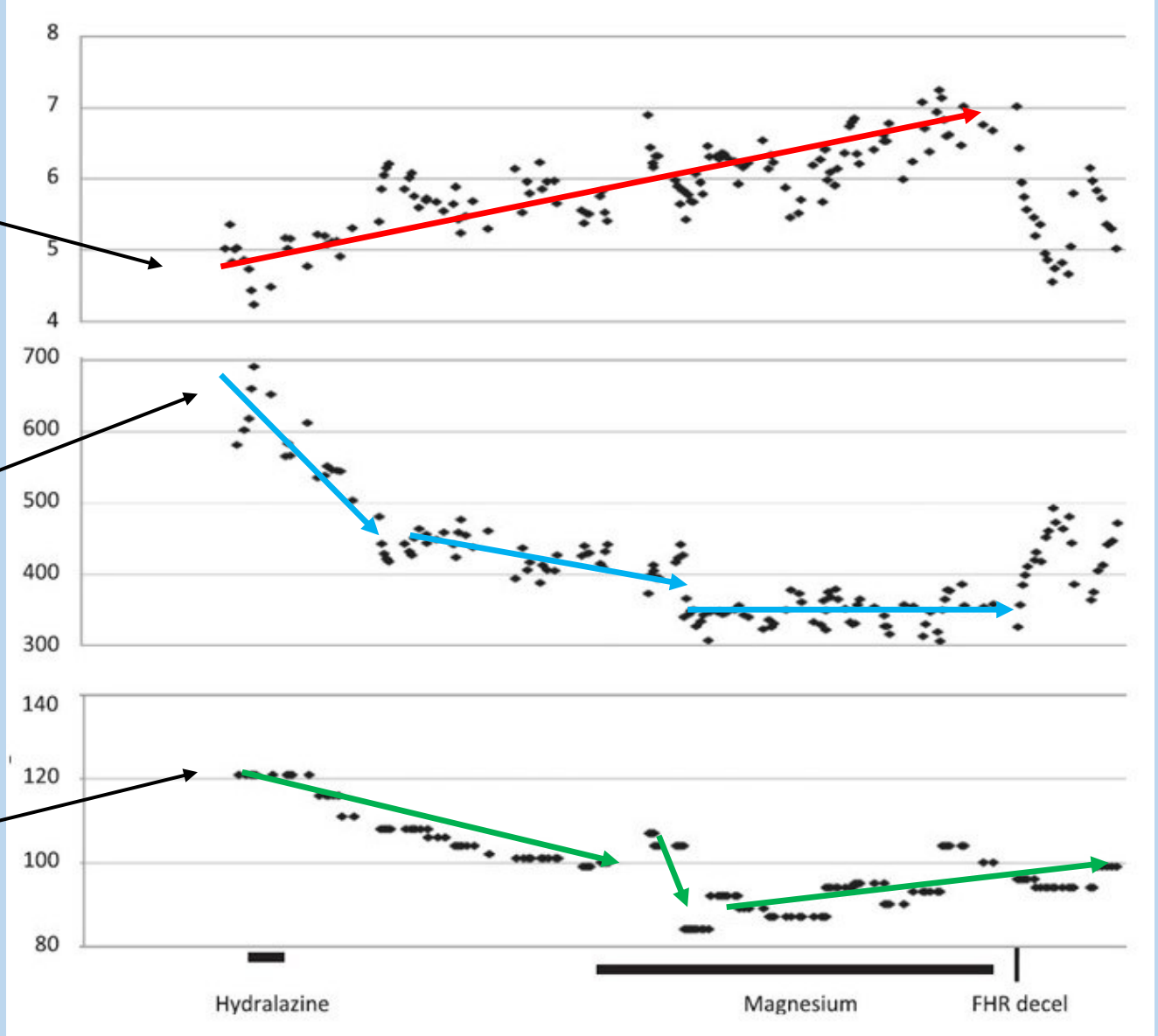
Magnesium

Preeclampsia, 29 weeks, treatment before induction of labor,

Cardiac output (CO)

Systemic vascular resistance (SVR)

Mean arterial pressure (MAP)



↑ CO

↓ SVR

↓ MAP, then stable

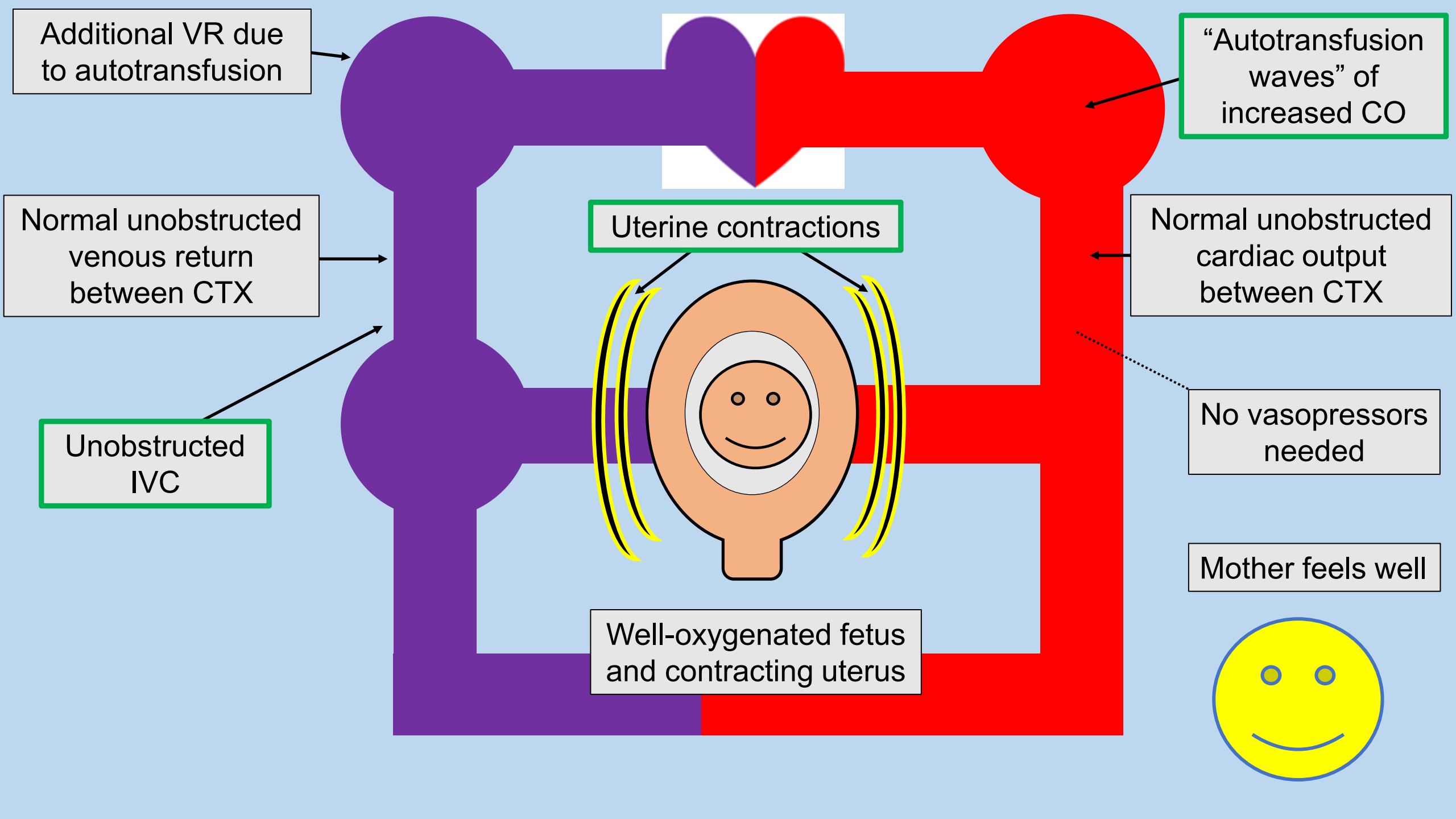
Hydralazine

Magnesium

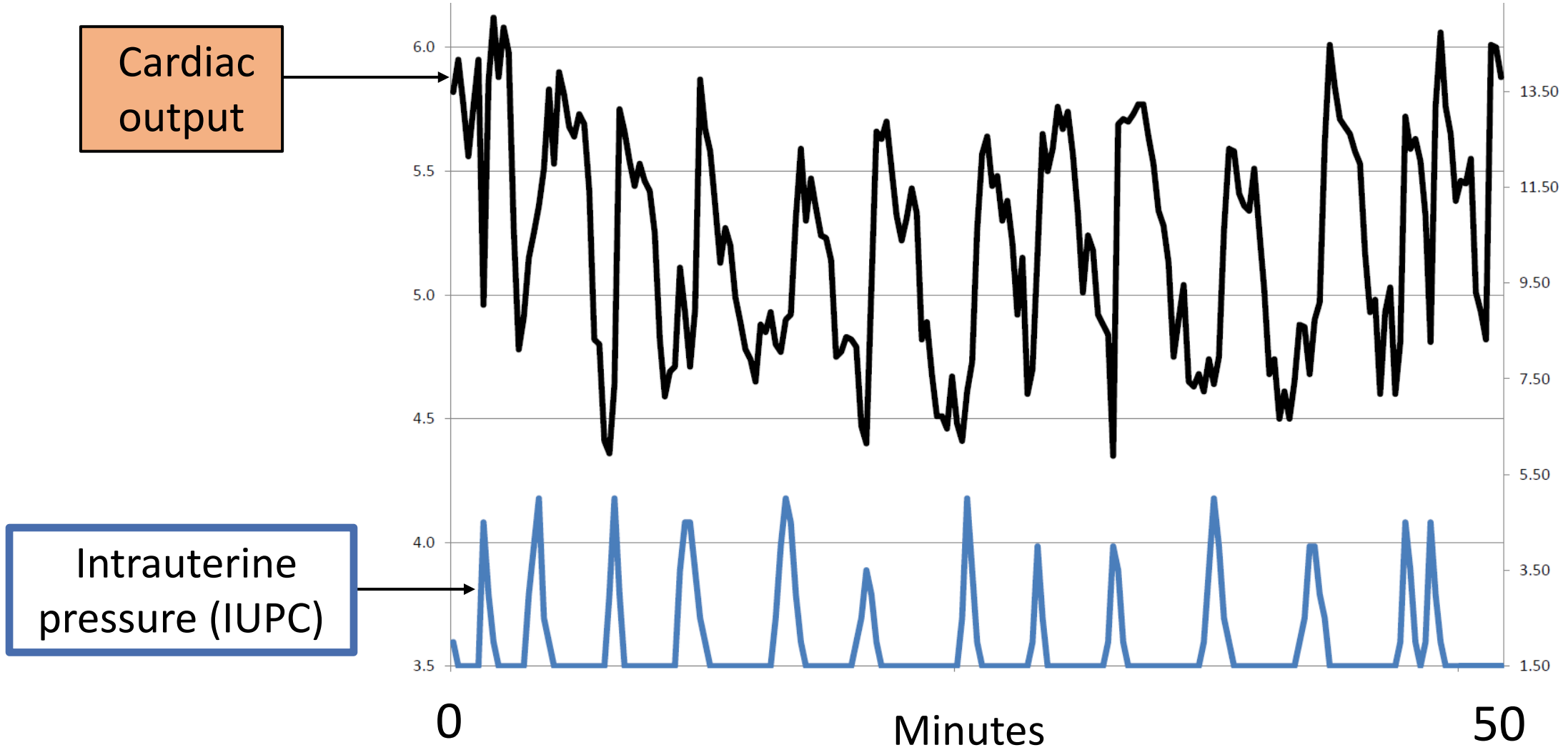
Detection of “autotransfusion waves” during labor

During labor, each contraction displaces blood from the uterine circulation towards the central maternal venous system (e.g. the IVC).

This **autotransfusion** transiently increases venous return (VR) and maternal cardiac output (CO), and I have used the term “autotransfusion waves” to describe these increases of CO as seen with electrical cardiometry.


Additional VR due to autotransfusion
“Autotransfusion waves” of increased CO
Normal unobstructed venous return between CTX
Uterine contractions
Normal unobstructed cardiac output between CTX
Unobstructed IVC
No vasopressors needed
Mother feels well
Well-oxygenated fetus and contracting uterus

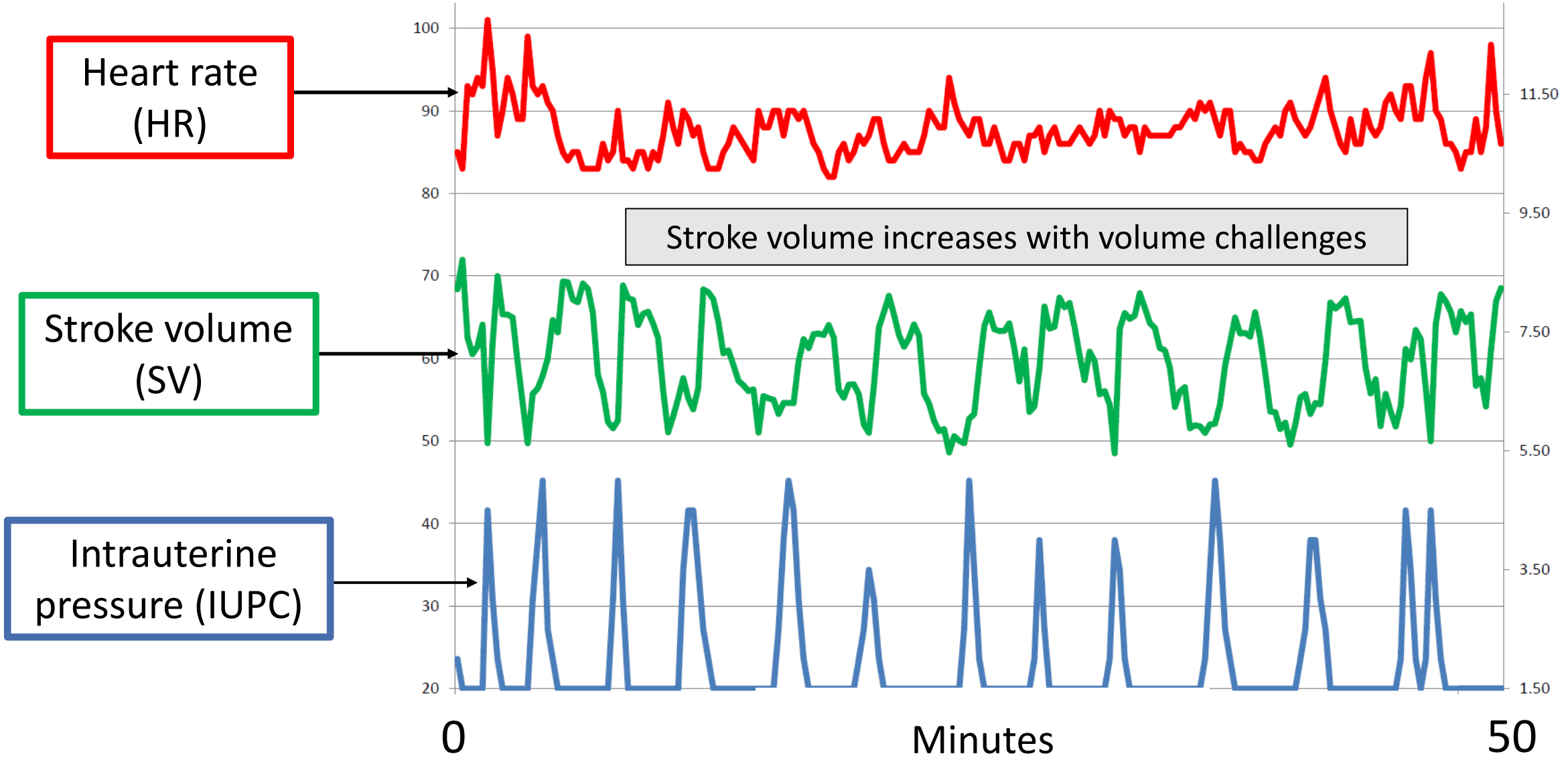
Pain-free normal labor with epidural, 3 cm cervical dilation. Peaks of cardiac output ("autotransfusion waves") follow peaks of intrauterine pressure by about 40 seconds.



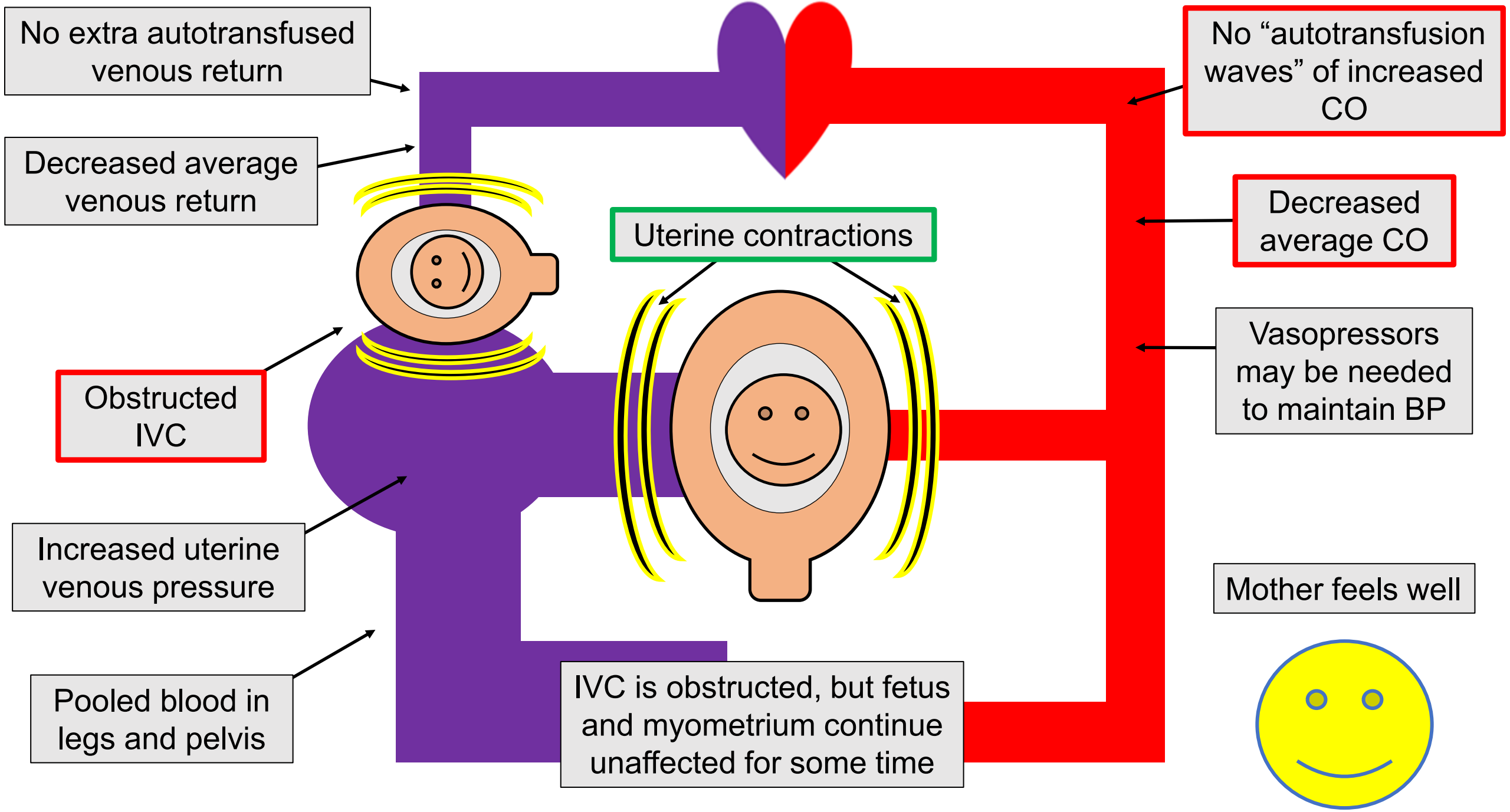
“Autotransfusion waves” and the “volume responsiveness” of the maternal circulation.

The observation of these “autotransfusion waves” can allow us to evaluate the “volume responsivenss” of the maternal circulation to a “volume challenge.” If the uterine venous drainage is free of obstruction, a uterine contraction presents the left ventricle with a bolus of blood, and in the next slide we see that that bolus of blood increases maternal stroke volume, showing that the maternal left ventricle is “volume responsive” at this time.

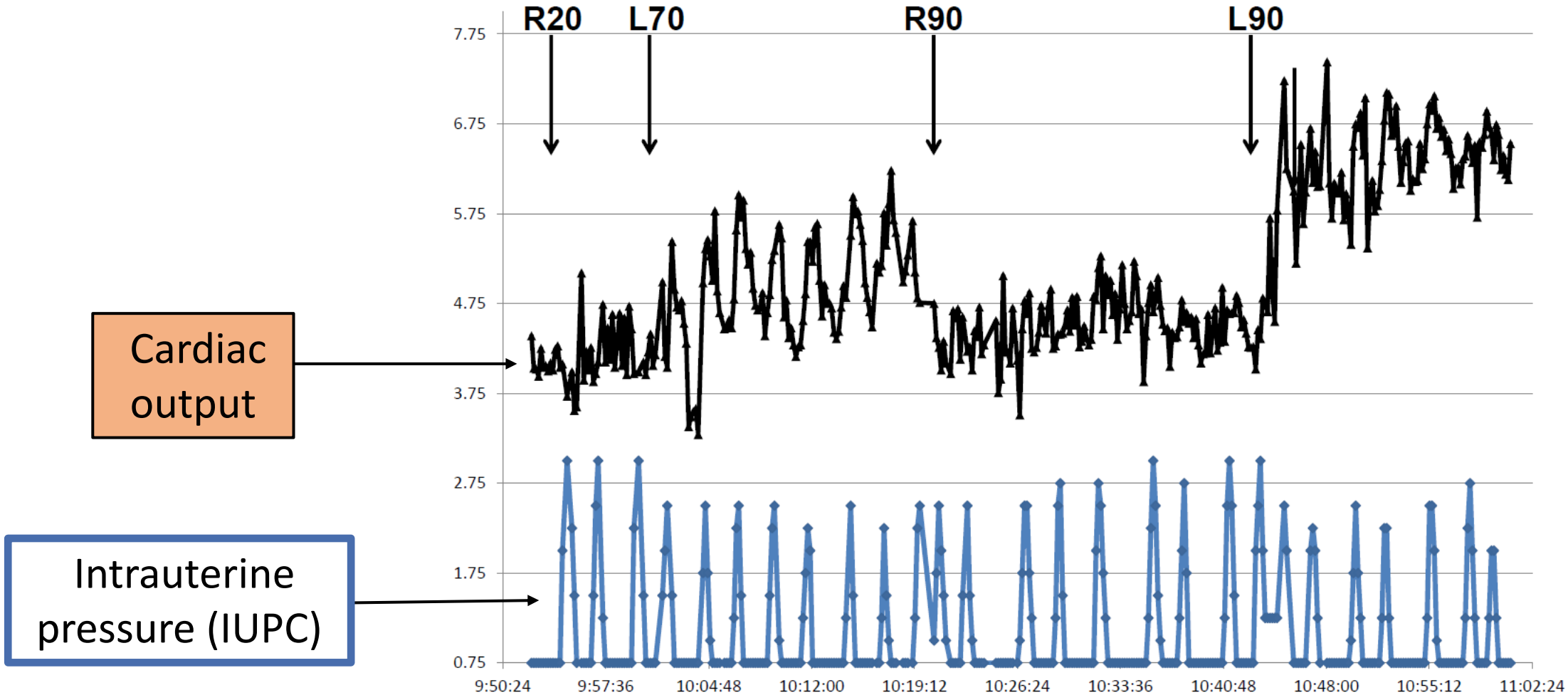
Same patient and time period as previous slide. Increases in cardiac output after uterine contractions are due to increased stroke volume.



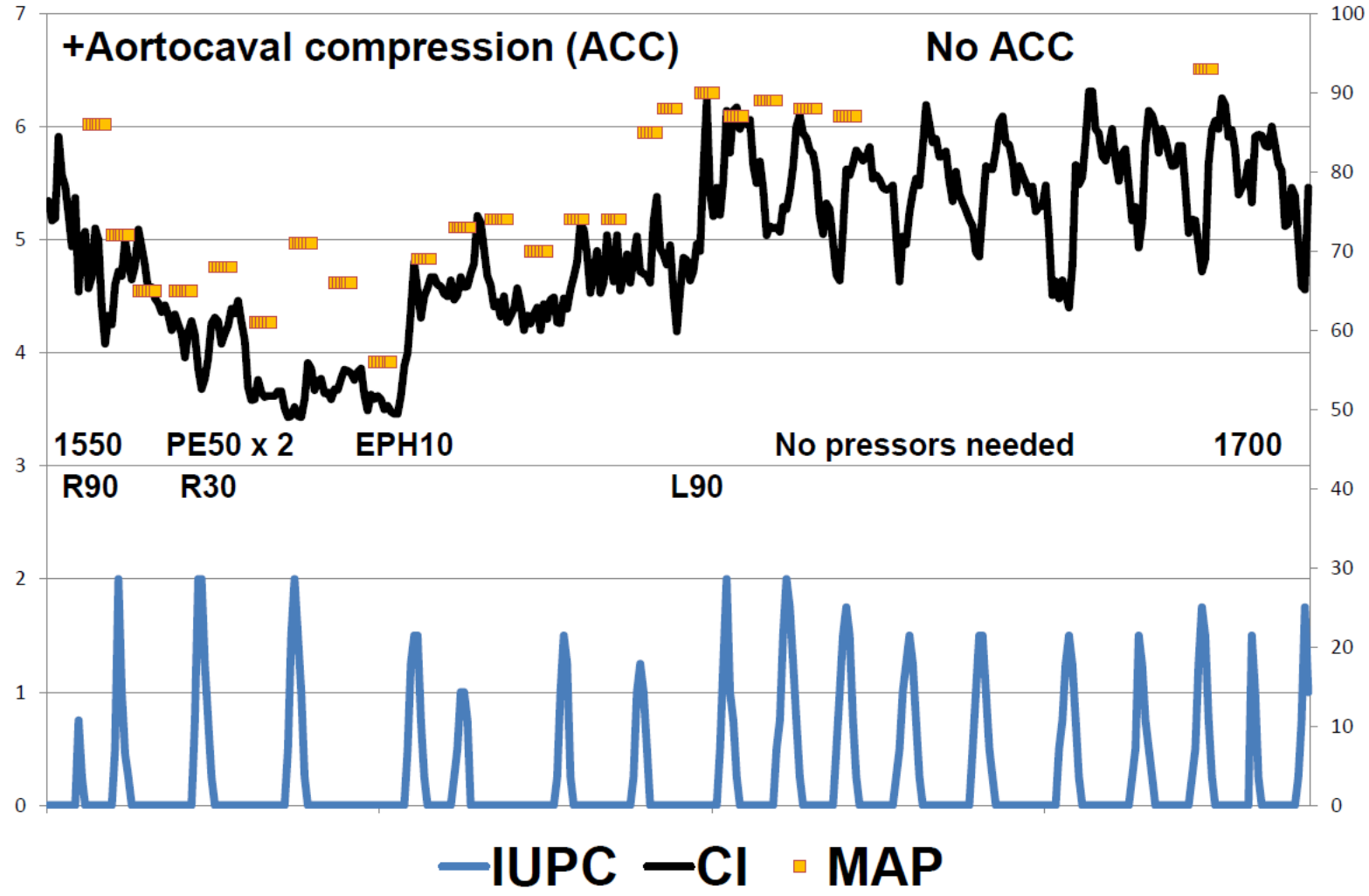
Use of autotransfusion waves to position pregnant woman during labor to avoid IVC obstruction

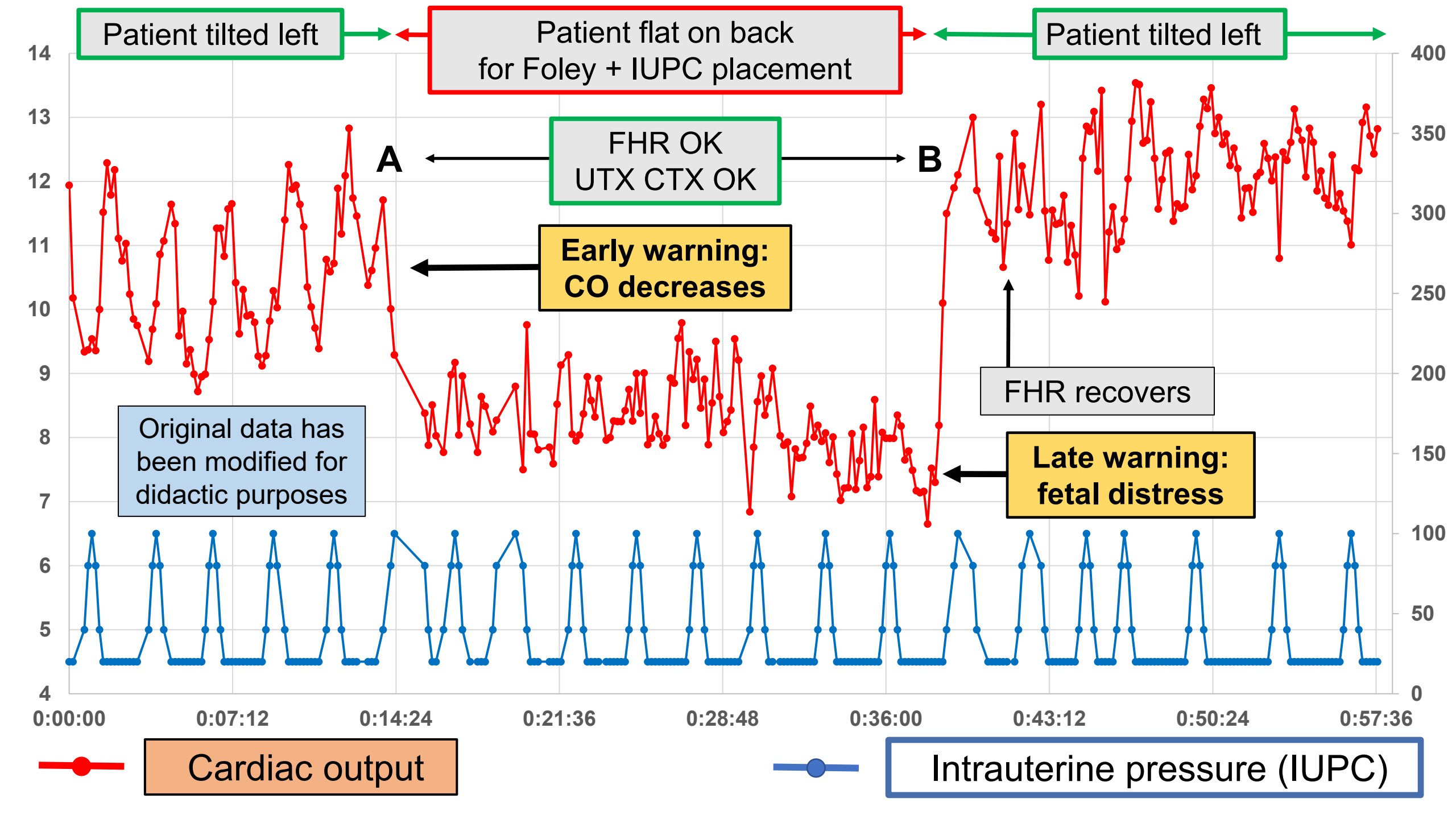

No extra autotransfused venous return
Decreased average venous return
Obstructed IVC
Increased uterine venous pressure
Pooled blood in legs and pelvis
Uterine contractions
IVC is obstructed, but fetus and myometrium continue unaffected for some time
No “autotransfusion waves” of increased CO
Decreased average CO
Vasopressors may be needed to maintain BP
Mother feels well

Patient in pain-free labor (epidural). The left side down positions are associated with higher cardiac output and the presence of “autotransfusion waves” occurring after each uterine contraction.



Patient 2, patient is comfortable after epidural placement. With right side down positions (R90 and R30), MAP and CI are low and pressors are needed to maintain MAP. After patient turns into full left lateral decubitus position (L90), MAP and CI increase and "autotransfusion waves" appear. PE50 = phenylephrine 50 mcgm, EPH10 = ephedrine 10 mg.




Patient tilted left
Patient flat on back
for Foley + IUPC placement
Patient tilted left
A
FHR OK
UTX CTX OK
B
Early warning:
CO decreases
Original data has
been modified for
didactic purposes
FHR recovers
Late warning:
fetal distress
14
13
12
11
10
9
8
7
6
5
4
400
350
300
250
200
150
100
50
0
0:00:00
0:07:12
0:14:24
0:21:36
0:28:48
0:36:00
0:43:12
0:50:24
0:57:36
Cardiac output
Intrauterine pressure (IUPC)

Long-term use of cardiac output in obstetrics:

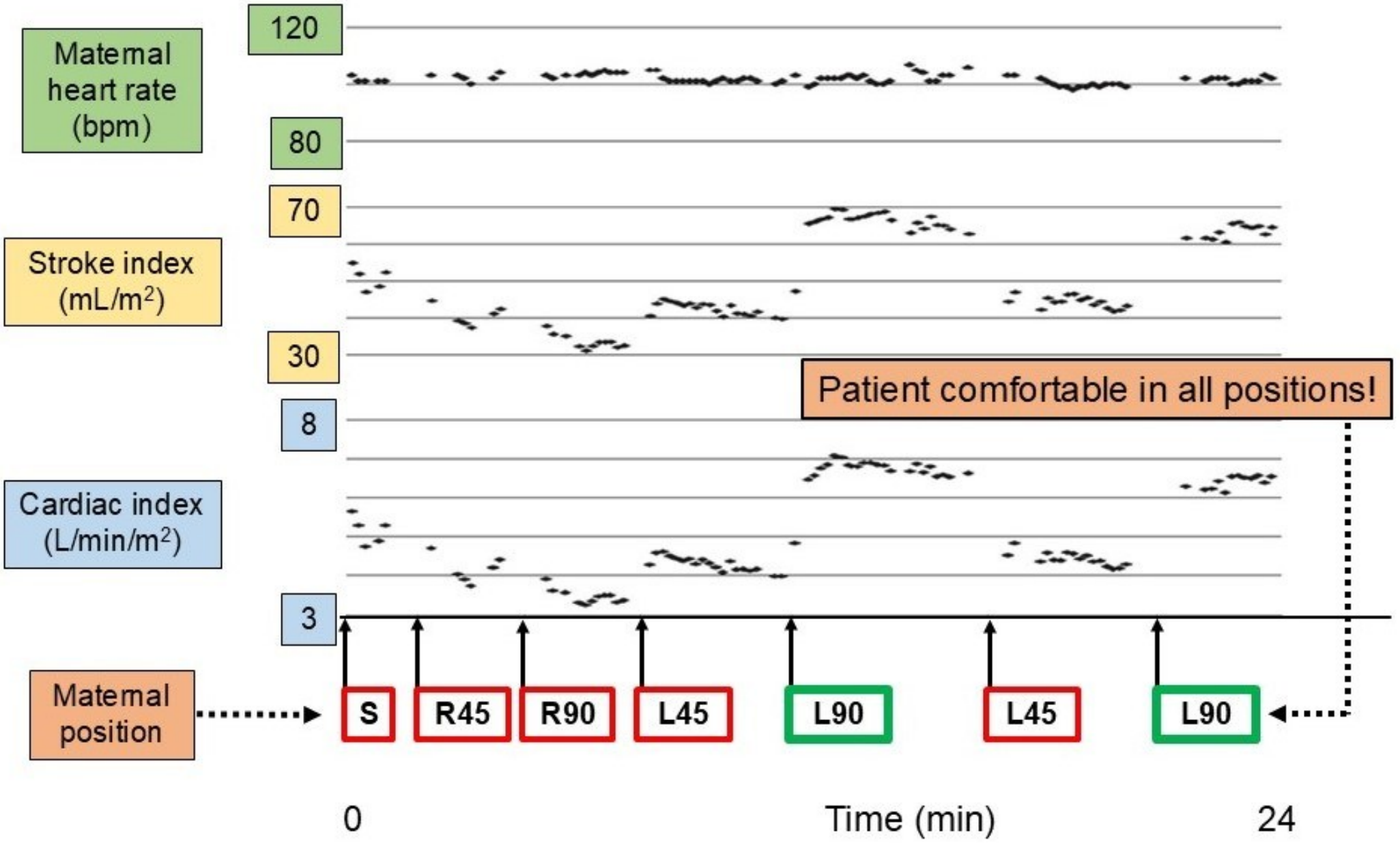
Guide maternal positioning during second half of pregnancy?

Prevent or mitigate fetal growth restriction?

Prevent or mitigate preeclampsia?

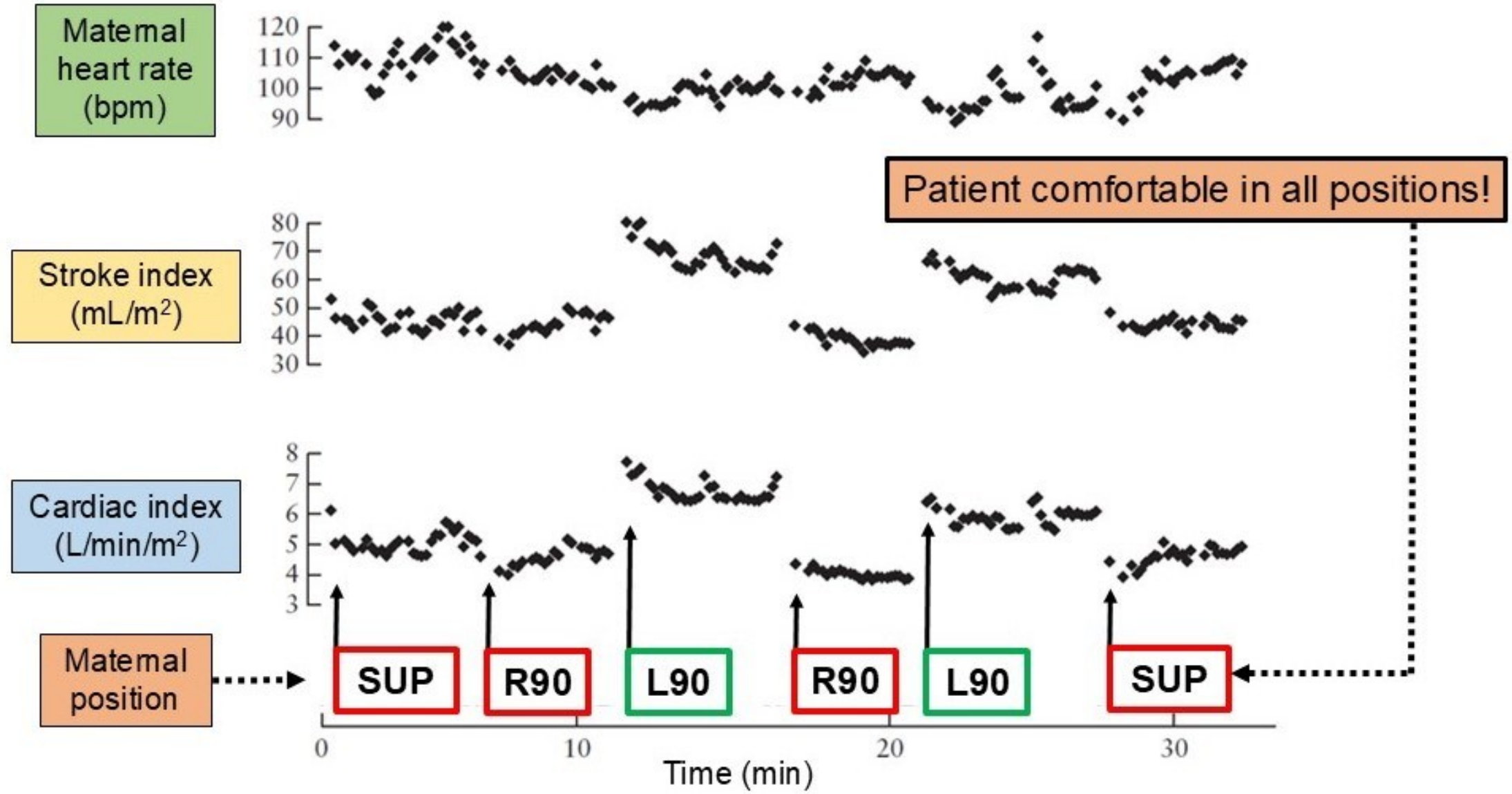
Prevent or reduce the risk of premature birth?

Positional maternal cardiac output in patient with ***fetal growth restriction*** (not in labor)



"Threats to Fetal, Placental and Myometrial Oxygenation: A Unified Hemodynamic Approach" Archer TL, 2024, Springer

Positional maternal cardiac output in patient admitted for ***preterm labor*** (not in labor)



"Threats to Fetal, Placental and Myometrial Oxygenation: A Unified Hemodynamic Approach" Archer TL, 2024, Springer

Summary

The value of measuring cardiac output during pregnancy:

Understand the determinants of arterial pressure, namely cardiac output and systemic vascular resistance.

Observe hemodynamic effects and adjust dosage of medications.

Cardiac output-guided maternal positioning:

Avoid obstruction of IVC and uterine venous return, in order to:

Keep uterine venous pressure low.

Promote adequate oxygenation of the fetus, placenta and myometrium.

Summary

The value of measuring cardiac output during pregnancy:

Much of what I have presented is still conceptual, theoretical and speculative, but I believe that there is sufficient evidence already to justify– or even demand– the continued exploration of the promising possibilities which the measurement of cardiac output during pregnancy offers us.

Thank you for your attention and your patience!

Contact information for Dr. Tom Archer:

Email: tarcher0727@hotmail.com

Website: www.pregnancyhemodynamics.com