2018학년도 1학기 산업수학 및 실습

A Mathematical Model of Fetal Heart Circulation

6조
201410335 국승호
201513208 양다은
201710285 김희정
201710304 정창해

Index

STEP. 1
Introduction

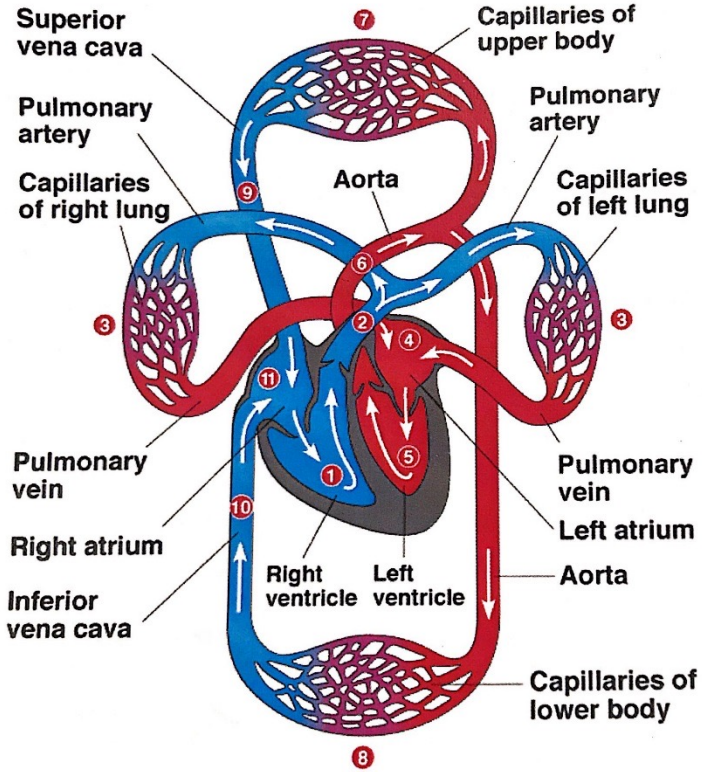
STEP. 2
Assumptions

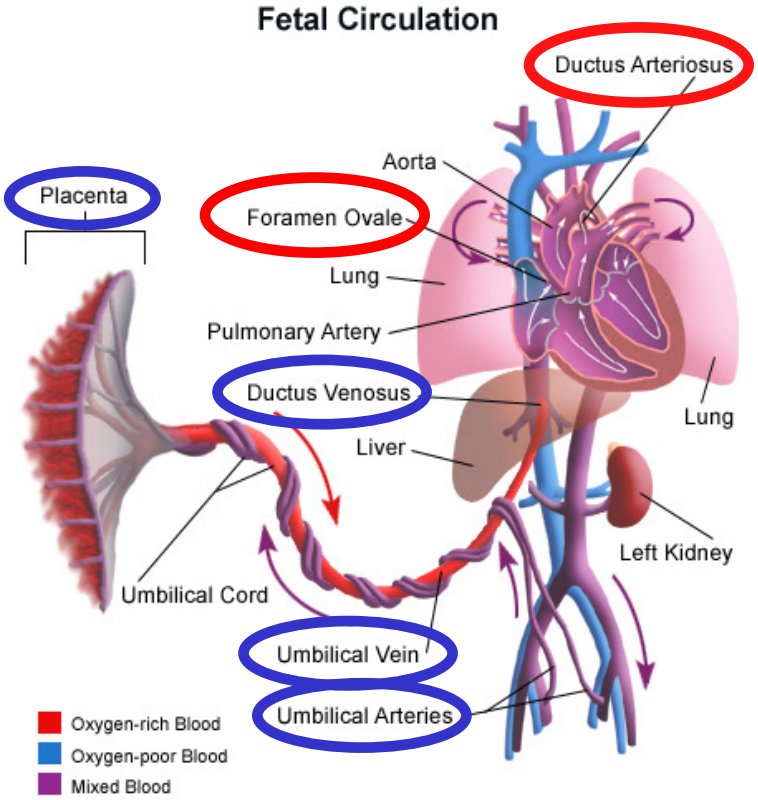
STEP. 3
Modeling
&
Analysis

STEP. 4
Results
&
Discussion

STEP. 5
References

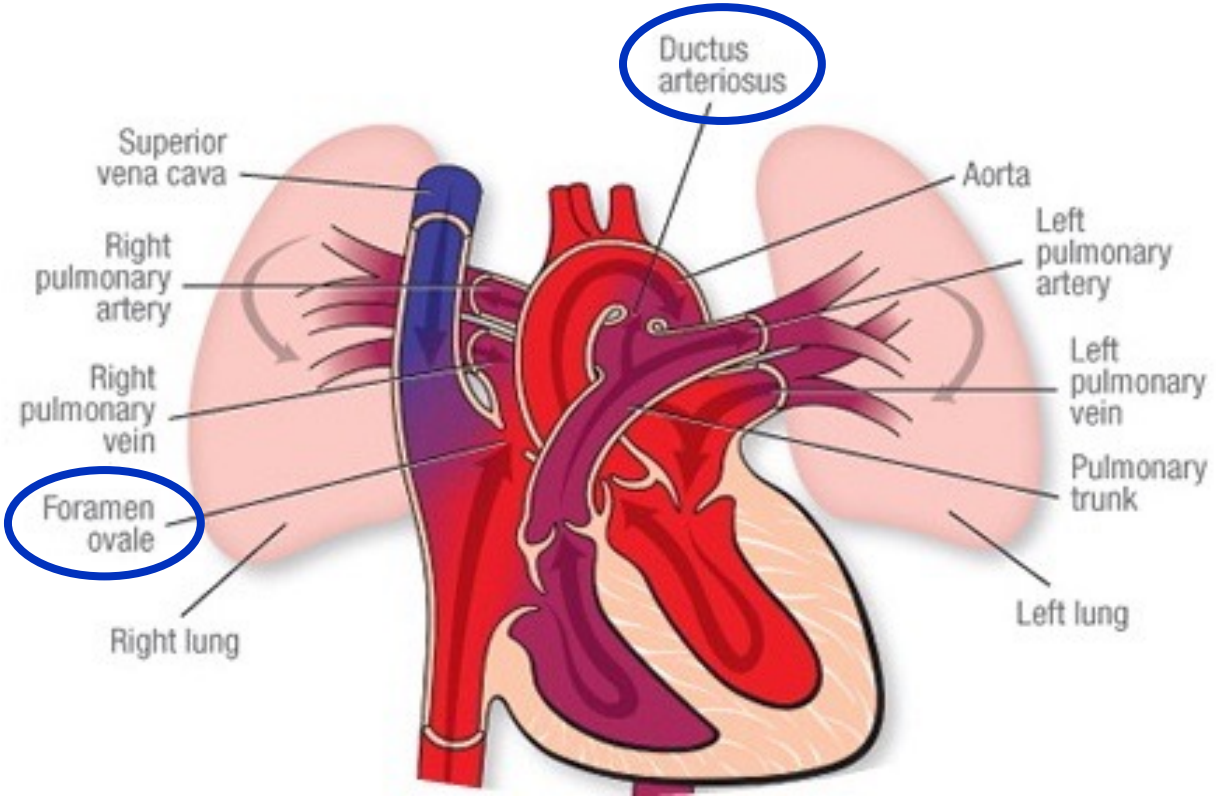
01 Introduction





출처 : Stanford Children's Health

01 Introduction



출처 : American Heart Association

02 Assumptions

- 태아는 3kg이고 임신 37~38주차 상태이다.
- 피의 흐름에 관해서는 ohm's law, volume conservation, compliance 3가지를 사용한다.
- 난원공을 통한 흐름은 우심방을 통하지 않고 바로 좌심방으로 가는 것으로 가정한다.
- 각 심방과 심실을 하나로 본다.
- 양과 인간의 태아의 심장 순환이 유사하다고 가정한다.

목표

→ **태아의 심장 순환 모델 구축.**

Compartments

- FPL : fetal-side placenta
- UV : umbilical vein
- IVC : inferior vena cava
- RA : right atrium
- LA : left atrium
- AA : ascending aorta
- SVC : superior vena cava
- PA : pulmonary artery
- DA : descending aorta
- UB : upper body
- LB : lower body
- BR : brain
- HE : liver
- IN : intestines
- MY : myocardium
- PV : pulmonary vein

참고 : F. J. Huikeshoven, I. D. Hope, G. G. Power, R. D. Gilbert and L. D. Longo. (1985)
Mathematical model of fetal circulation and oxygen delivery.

Parameters Compliance(ml/mmHg)

Parameter	값	Parameter	값
AA	0.07	LB	1.4
BR	0.6	MY	0.25
DA	0.14	PA	0.25
FPL	1.4	PV	0.25
HE	3.0	RA	1
IN	0.25	SVC	0.1
IVC	0.2	UB	0.9
LA	1	UV	0.3

출처 : F. J. Huikeshoven, I. D. Hope, G. G. Power, R. D. Gilbert and L. D. Longo. (1985)
Mathematical model of fetal circulation and oxygen delivery.

Parameters Resistance(mmHg·min/ml)

Parameter	값	Parameter	값
AA-BR	0.6	DA-IN	0.577
AA-DA	0.0067	DA-LB	0.144
AA-MY	0.6	FPL-UV	0.0091
AA-UB	0.125	HE-IVC	0.0086
BR-IVC	0.7	IN-HE	0.116
BR-SVC	0.08	IVC-LA	0.00357
DA-FPL	0.053	IVC-RA	0.00204
DA-HE	1.36	LB-IVC	0.0208

출처 : F. J. Huikeshoven, I. D. Hope, G. G. Power, R. D. Gilbert and L. D. Longo. (1985)
Mathematical model of fetal circulation and oxygen delivery.

Parameters Resistance(mmHg·min/ml)

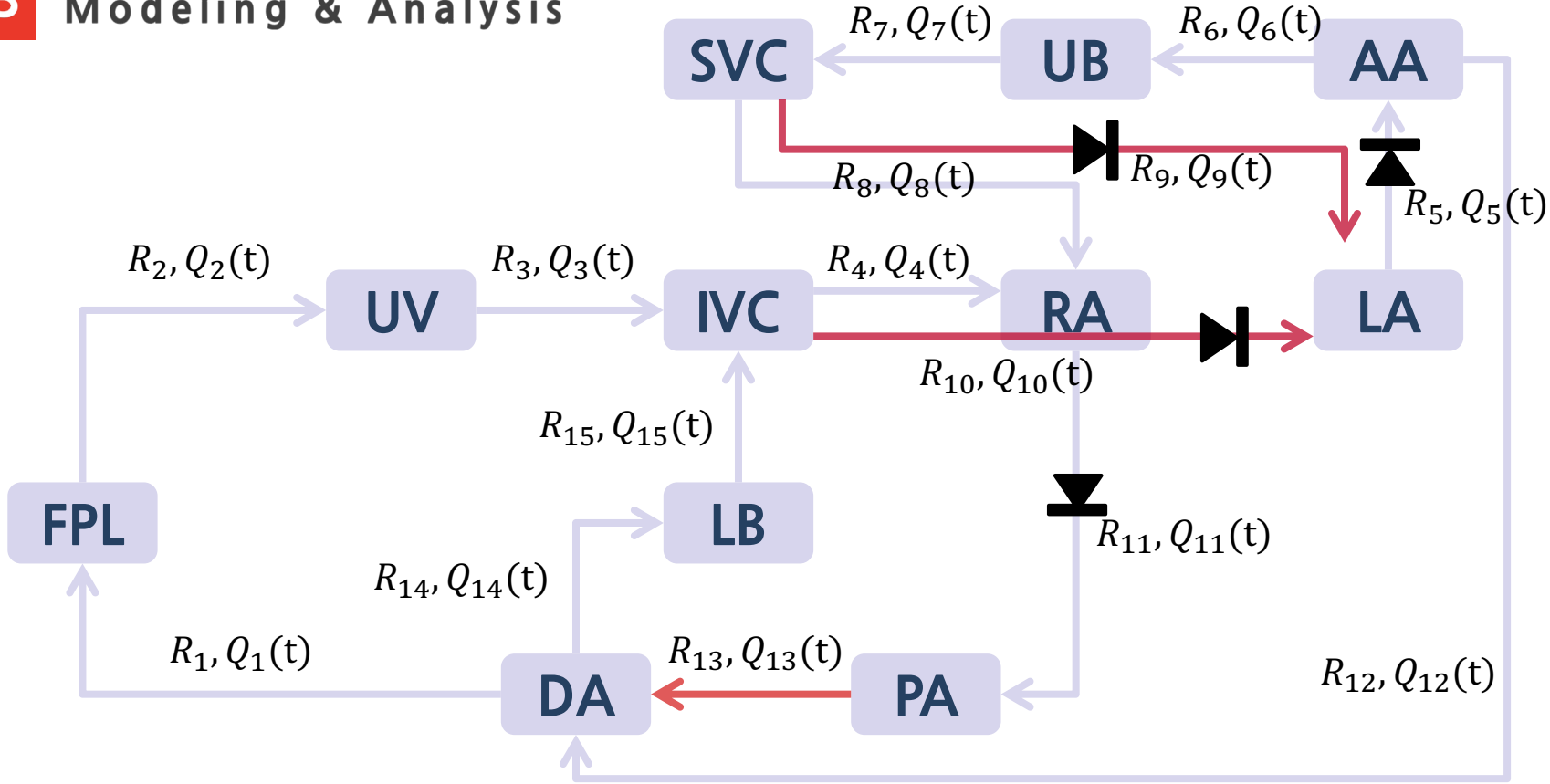
Parameter	값	Parameter	값
LB-SVC	0.15	UB-SVC	0.017
MY-RA	0.17	UV-HE	0.027
PA-DA	0.004	UV-IVC	0.0355
PA-PV	0.412	LA-AA	0.0813
PV-LA	0.122	RA-PA	0.0551
SVC-LA	0.04		
SVC-RA	0.0029		
UB-IVC	0.15		

출처 : F. J. Huikeshoven, I. D. Hope, G. G. Power, R. D. Gilbert and L. D. Longo. (1985)
Mathematical model of fetal circulation and oxygen delivery.

Parameters P(0)(mmHg)

Parameter	값	Parameter	값
AA	49.4	LB	10.0
BR	9.9	MY	14.1
DA	48.5	PA	51.6
FPL	20	PV	14.5
HE	8.1	RA	4.2
IN	14.9	SVC	5.1
IVC	5.1	UB	10.1
LA	3.6	UV	15.1

출처 : F. J. Huikeshoven, I. D. Hope, G. G. Power, R. D. Gilbert and L. D. Longo. (1985)
Mathematical model of fetal circulation and oxygen delivery.



참고 : F. J. Huikeshoven, I. D. Hope, G. G. Power, R. D. Gilbert and L. D. Longo. (1985)
Mathematical model of fetal circulation and oxygen delivery.

$$C = \frac{\Delta V}{\Delta P} = \frac{\frac{dV}{dt}}{\frac{dP}{dt}}$$

$$\Rightarrow \frac{dP}{dt} = \frac{1}{C}\frac{dV}{dt}$$

$$= \frac{1}{C}\left(Q_{in} - Q_{out} \right)$$

(tc<TS)

$$C = C_{Max}\left(\frac{C_{\min}}{C_{Max}}\right)^{\frac{1-e^{\frac{-tc}{\tau S}}}{1-e^{\frac{-TS}{\tau S}}}}$$

(tc≥TS)

$$C = C_{\min}\left(\frac{C_{Max}}{C_{\min}}\right)^{\frac{1-e^{\frac{-tc+TS}{\tau D}}}{1-e^{\frac{-T+TS}{\tau D}}}}$$

- TS : duration of systole
- τS : time constant during systole in LV.
- τD : time constant during diastole in LV.

출처 : Frank C. Hoppensteadt and Vharles S. Peskin.
Modeling and simulation in Medicine and the life sciences second edition

C4, C5(Max, min)

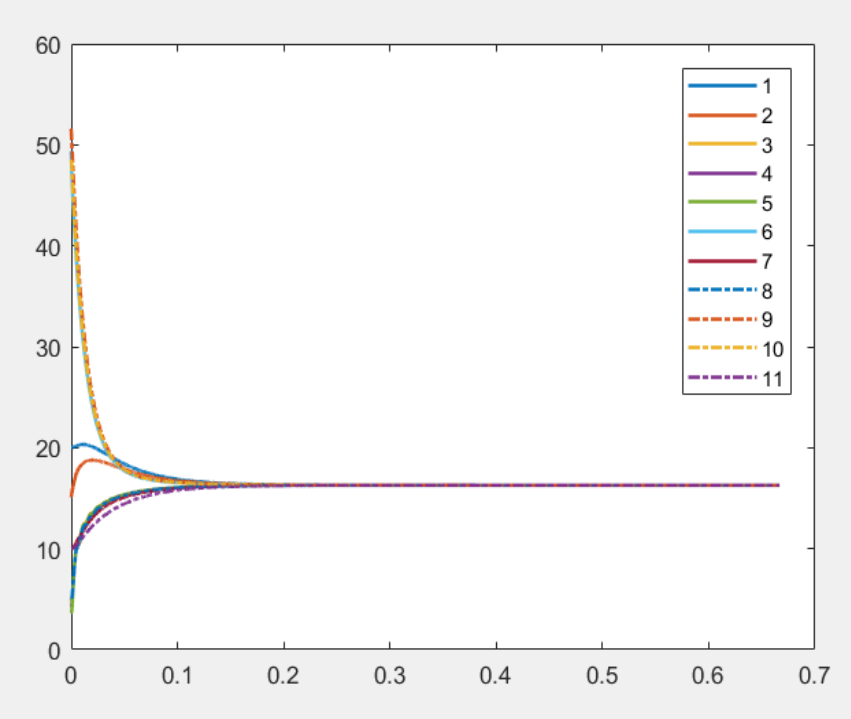
$$C(W) = C_0 \times W$$

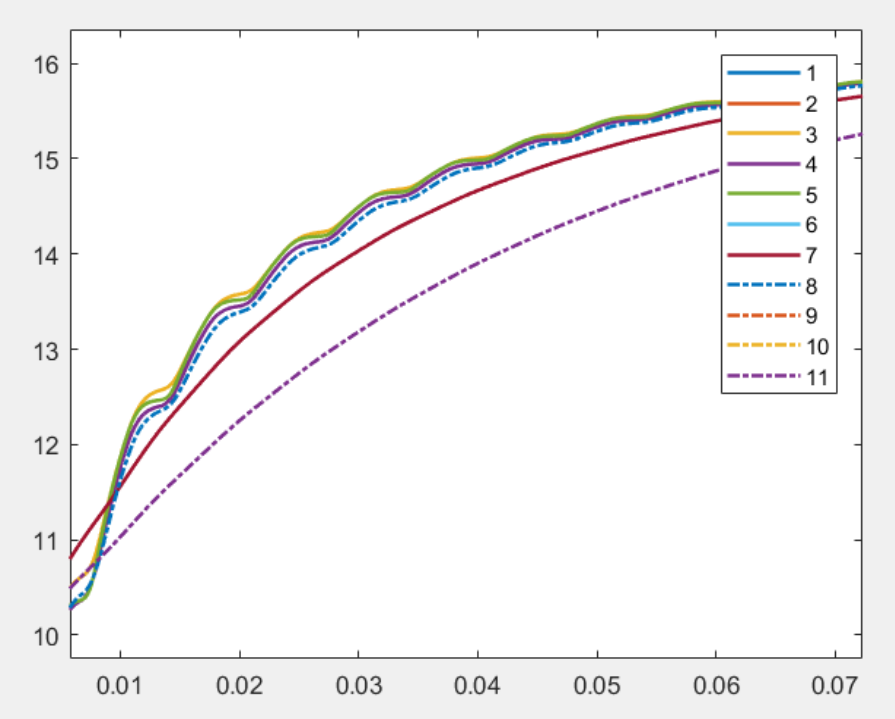
출처 : E. Jung. "*Optimal Cardiopulmonary Resuscitation Technique Depending on Body Size*". Applied Mathematics and Computation. (2012) pp.9615-9622

$$C_1 \frac{dP_1}{dt} = \frac{P_{10} - P_1}{R_1} - \frac{P_1 - P_2}{R_2}$$

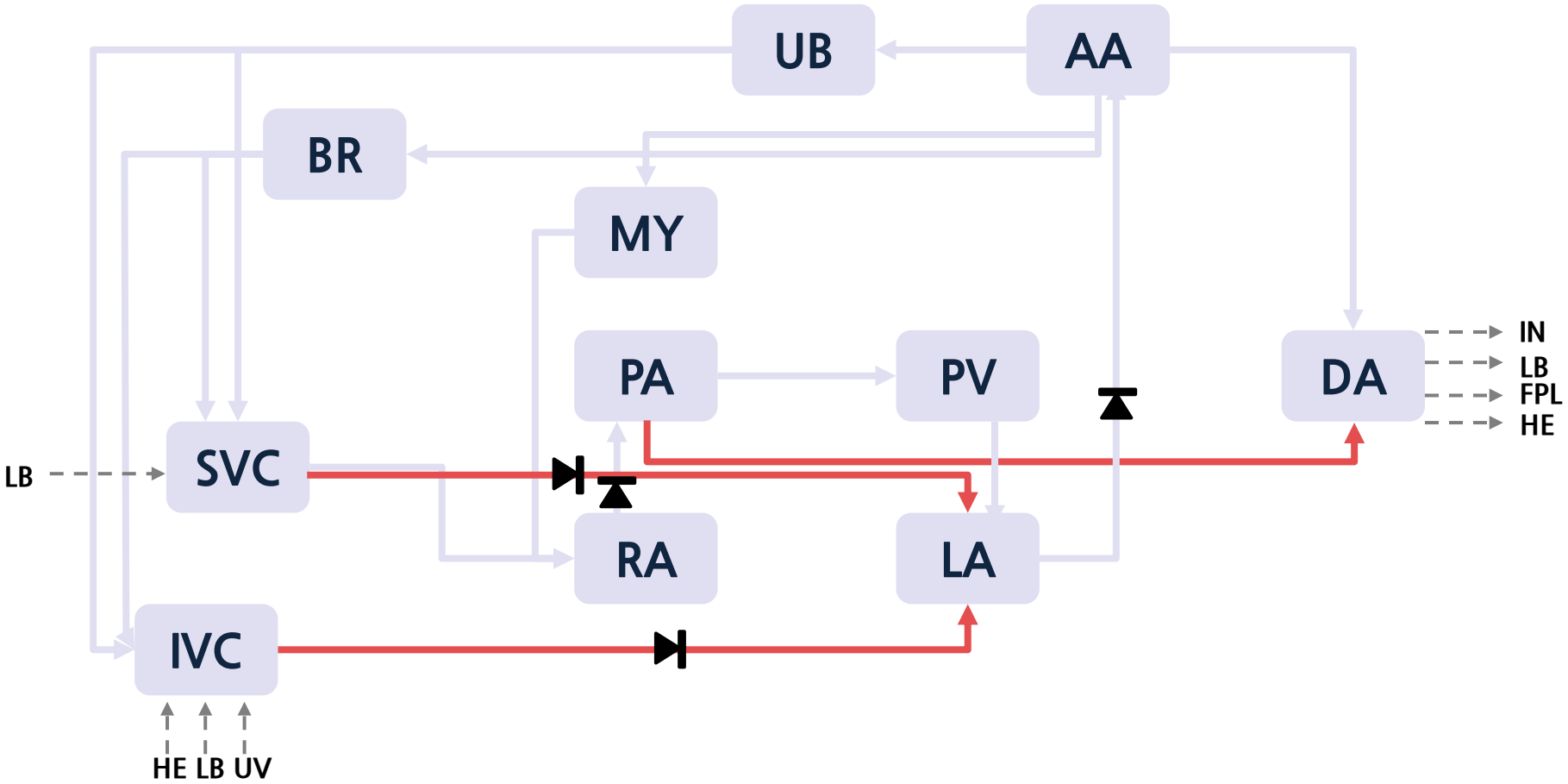
```
% dP1/dt
A(1,1) = C1 + dt *(1/R1 + 1/R2);
A(1,2) = -dt/R2;
A(1,3) = 0;
A(1,4) = 0;
A(1,5) = 0;
A(1,6) = 0;
A(1,7) = 0;
A(1,8) = 0;
A(1,9) = 0;
A(1,10) = -dt/R1;
A(1,11) = 0;
```

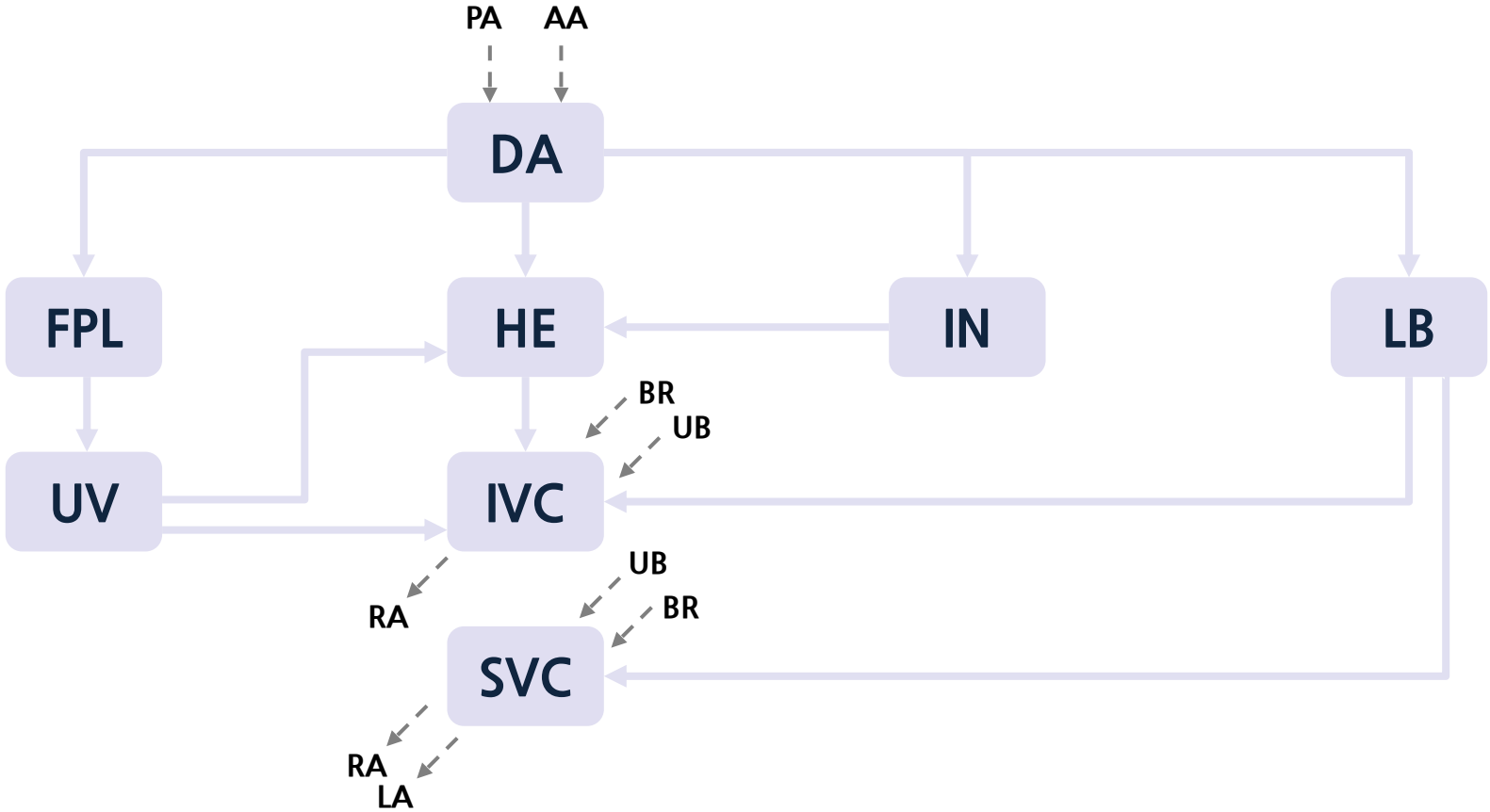
03 Modeling & Analysis





03 Modeling & Analysis





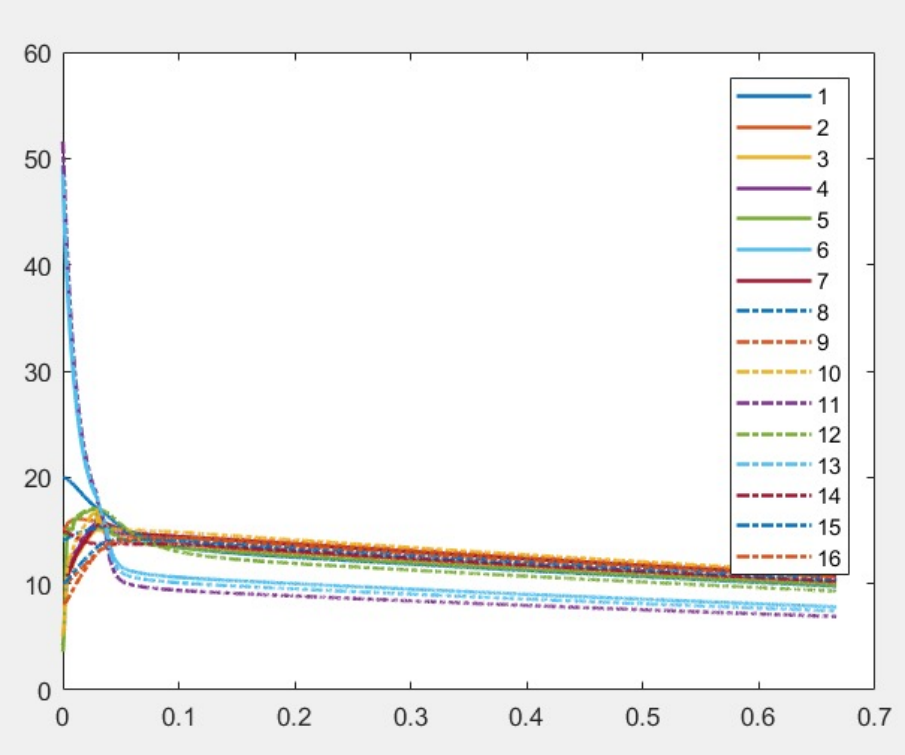
참고 : F. J. Huikeshoven, I. D. Hope, G. G. Power, R. D. Gilbert and L. D. Longo. (1985)
Mathematical model of fetal circulation and oxygen delivery.

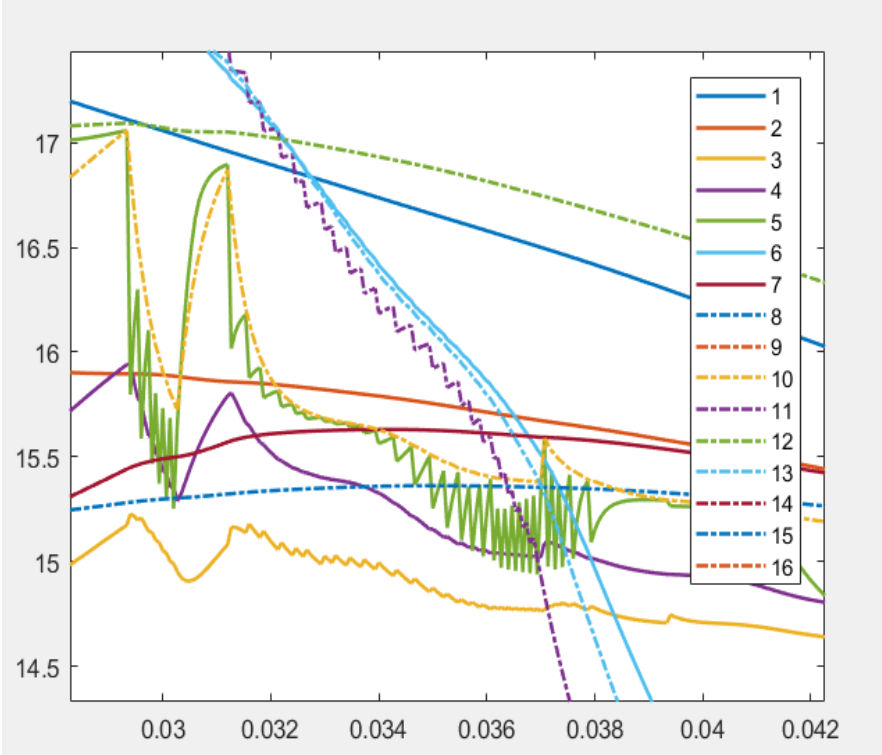
03 Modeling & Analysis

$$C_1 \frac{dP_1}{dt} = \frac{P_{13} - P_1}{R_{23}} - \frac{P_1 - P_2}{R_1}$$

```
% dP1/dt
A(1,1) = C1 + dt * (1/R23 + 1/R1);
A(1,2) = -dt/R1;
A(1,3) = 0;
A(1,4) = 0;
A(1,5) = 0;
A(1,6) = 0;
A(1,7) = 0;
A(1,8) = 0;
A(1,9) = 0;
A(1,10) = 0;
A(1,11) = 0;
A(1,12) = 0;
A(1,13) = -dt/R23;
A(1,14) = 0;
A(1,15) = 0;
A(1,16) = 0;
```

03 Modeling & Analysis





04 Results & Discussion

- Parameter가 steady state에서의 자료
- 자료 한계
- Compliance

05 References

- F. J. Huikeshoven, I. D. Hope, G. G. Power, R. D. Gilbert and L. D. Longo. (1985) *Mathematical model of fetal circulation and oxygen delivery*. Am J Physiol Regulatory Integrative Comp Physiol 249 : pp. 192-202.

- Frank C. Hoppensteadt and Vharles S. Peskin. (2001) *Modeling and simulation in Medicine and the life sciences second edition.* Springer-Verlag. p.46

- E. Jung. "*Optimal Cardiopulmonary Resuscitation Technique Depending on Body Size*". Applied Mathematics and Computation. (2012) pp.9615-9622

(이미지)
- Stanford Children's Health. "fetal circulatory system", http://www.stanfordchildrens.org/en/topic/default?id=blood-circulation-in-the-fetus-and-newborn-90-P02362 (2018. 6. 4)

- American Heart Association. "fetal circulation", http://www.heart.org/HEARTORG/Conditions/CongenitalHeartDefects/SymptomsDiagnosisofCongenitalHeartDefects/Fetal-Circulation_UCM_315674_Article.jsp#.WxpcN9Uza70 (2018. 6. 8)


Thank you!


Q & A