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Minimal Invasive Monitoring of Cardiac Output

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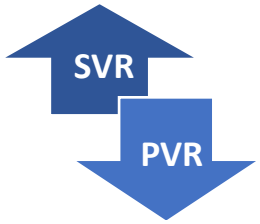
Introduction

- Transitional period: important physiologic changes in the circulatory system



Increase LV afterload

Decrease RV afterload
Increase LV preload

- Considerations in preterm infants:
  - *Impaired systolic and diastolic performance*
  - *Poor tolerance of increased afterload*
  - *Myocardium lacks adequate adrenergic innervation*
  - *Shunts (PDA; PFO)*

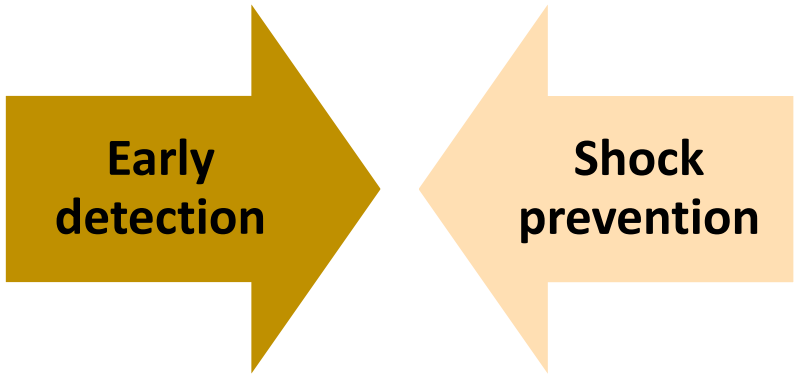
- Limitations of standard hemodynamic monitoring to determine tissue blood flow:
  - *"Normal blood pressure doesn't mean adequate cardiac output"*
  - *Late indicators and poor correlation with treatment response*

Introduction

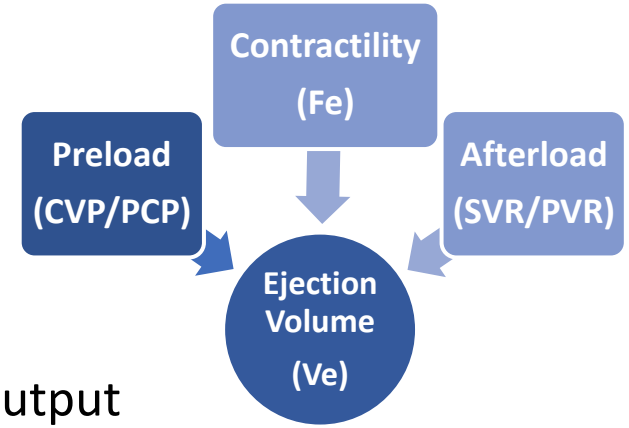
- Circulatory shock is an important cause of morbidity and mortality in patients submitted to intensive care units and an early diagnosis and treatment may be life-saving.

- A reliable tool for diagnosing and monitoring heart performance and vascular status is necessary:
  - Shock types
  - ¿Volume or drug support?
  - Monitoring treatment response

"Golden Rule" for hemodynamic therapy



Cardiac Output Monitoring



- To know each one of the parameters which contribute to the final cardiac output is very important in order to treat the leading etiology of hemodynamic instability.

LIMITATIONS	Patient size
	Risk volume overload
	Limited vascular access
	No reference parameters
	Shunts

REQUIREMENTS	Minimally invasive
	Continuous
	Monitor treatment changes
	Reproducible
	Efficient

Cardiac Output Monitoring

CoStatus®

(Transonic System)

Ultrasound Dilution Technology

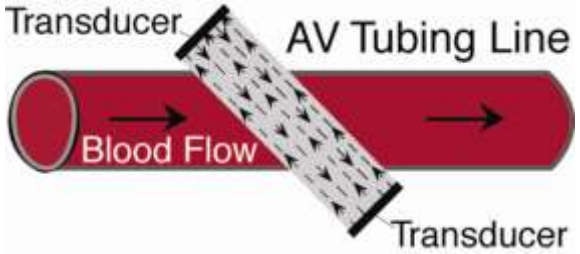
Aesculon®

(Osypka Medical)

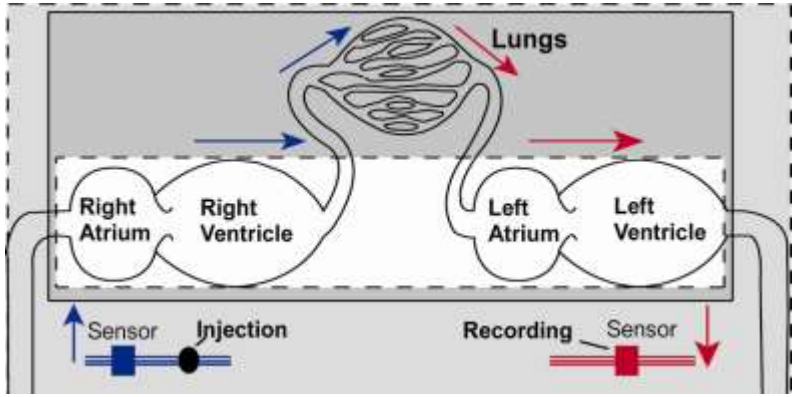
Electrical Velocimetry

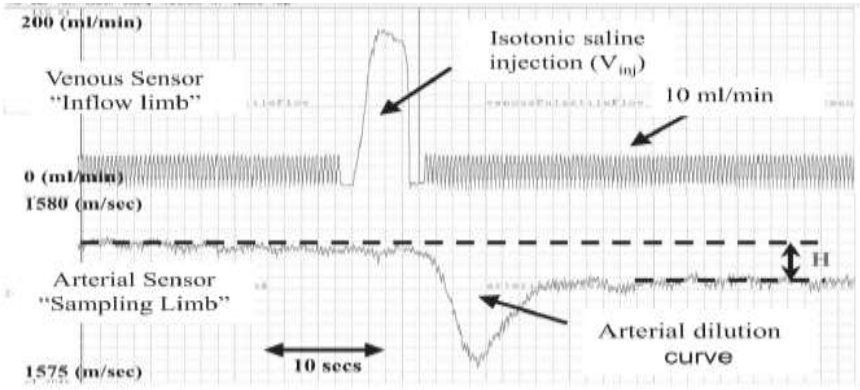
Ultrasound Dilution Technology

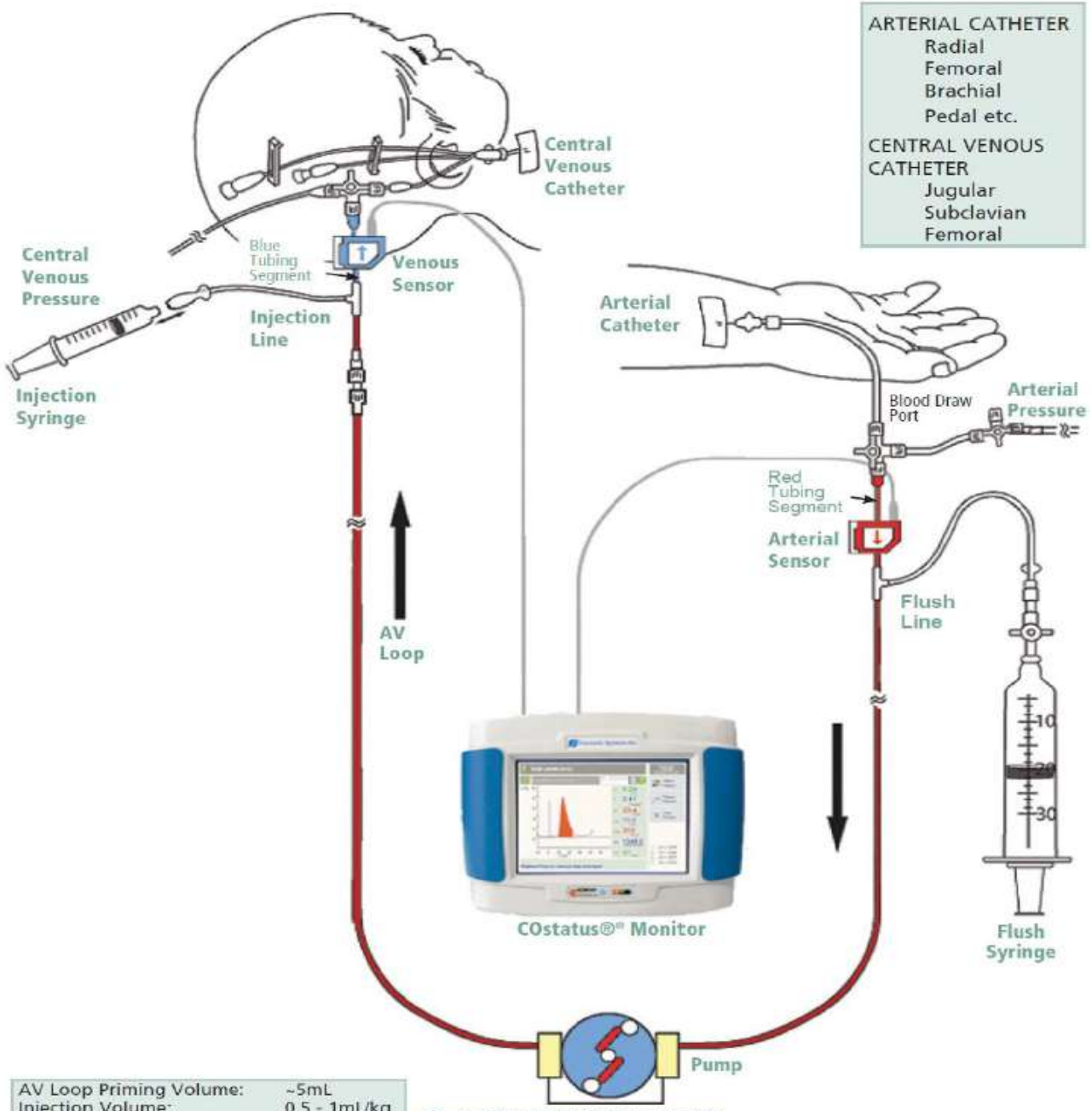
- Blood ultrasound velocity (1560-1585 m/seg):
  - Blood protein concentration
  - Temperature
  - Plasmatic ion concentration



- Injection of body temperature isotonic saline (ultrasound velocity of saline is 1533 m/sec) into the AV loop decreases blood ultrasound velocity, producing dilution curves



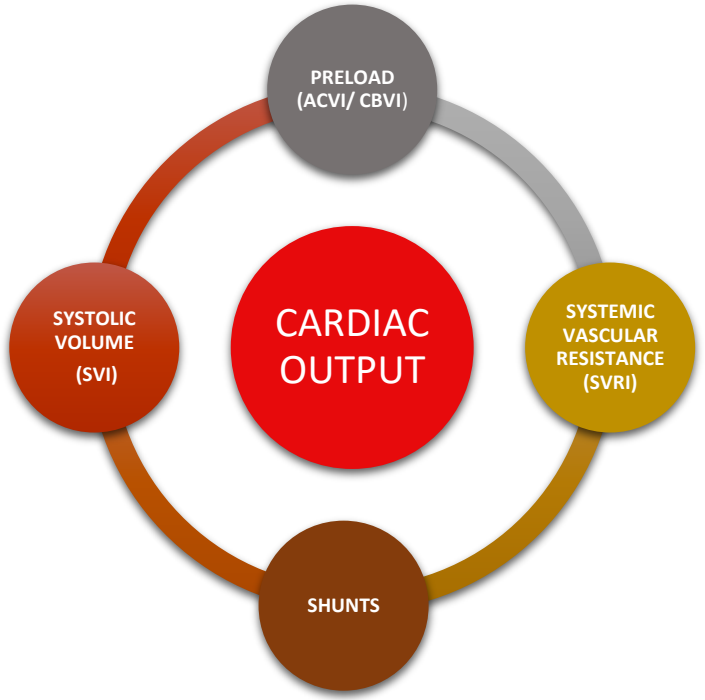


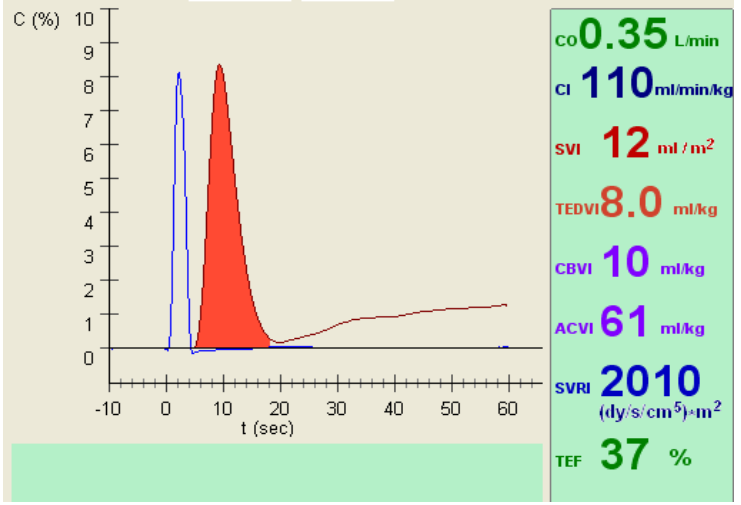


AV Loop Priming Volume:	~5mL
Injection Volume:	0.5 - 1mL/kg
Maximum Volume:	30mL
Pump Rate:	8-12mL/min
Measurement Time:	5 - 8 min

Fig. 1: Schematic of AV Loop with connections to the patient's existing arterial and CV catheters.

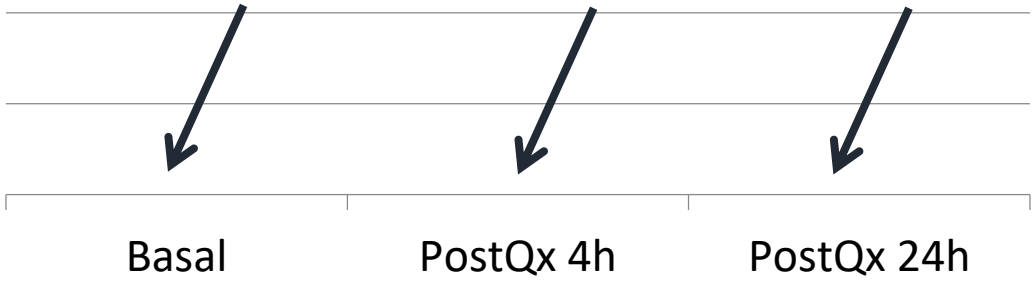
transonic
THE MEASURE OF BETTER RESULTS





Ultrasound Dilution Technology

Cardiac Output Monitoring in Congenital Cardiac Disease



Number of measurements in each period: x3
Injection volume per measure: 1ml/kg

Echocardiography
NIRS monitoring
Arterial and venous gasometry

Early Stage Low Cardiac Output Detection

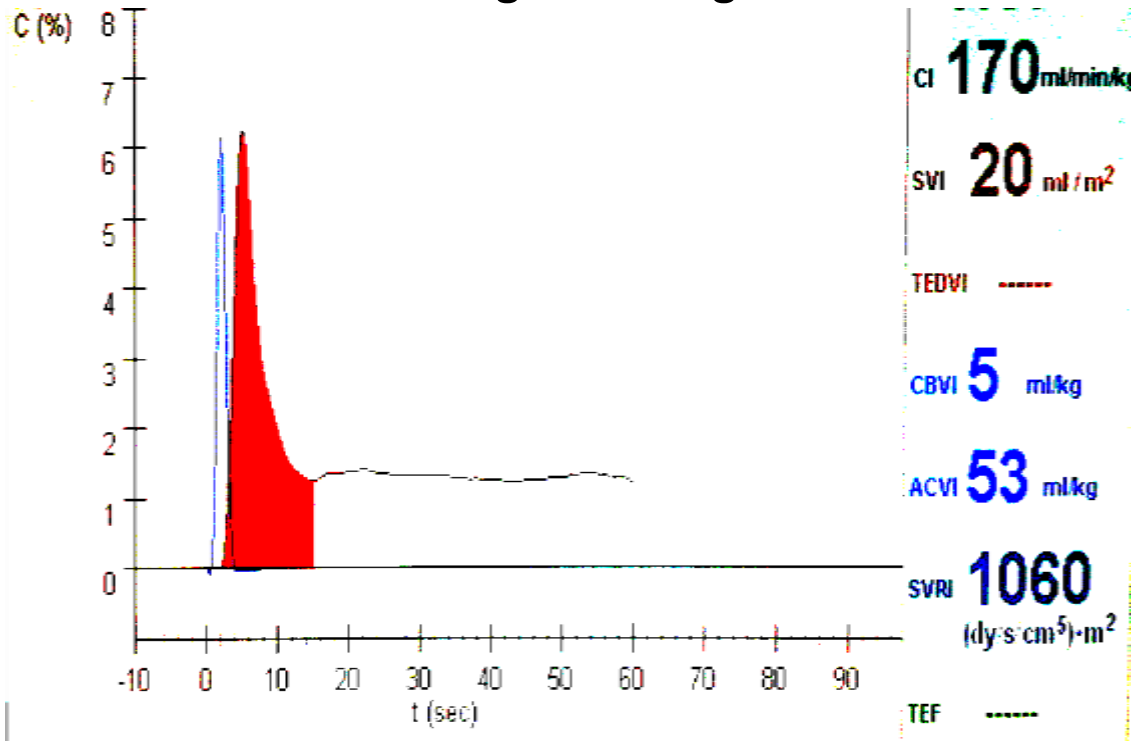
Therapeutic Strategy Volume vs Inotropics

Monitoring Treatment Changes

Shunts Detection

Case 1

- Term neonate. Weight: 3300 gr



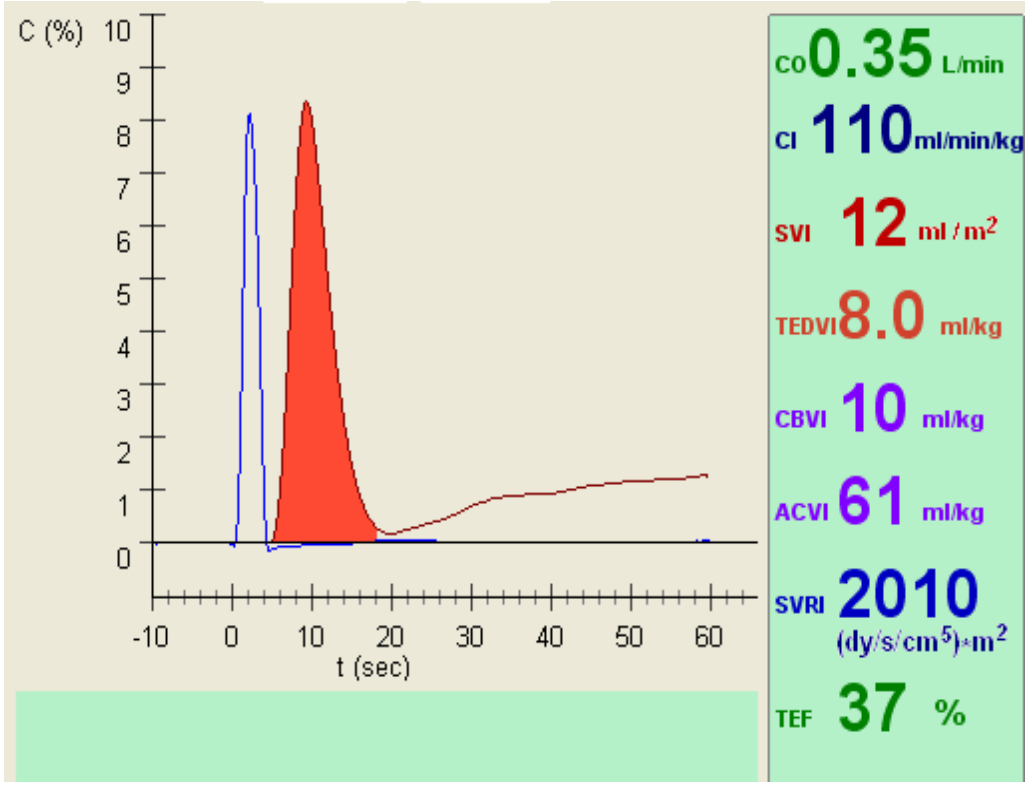
PRESURGICAL SITUATION	
BP	62/39 mmHg
HR	133 lpm
CVP	6 mmHg
$SatO_2$	81%
Lactate	1,6 mmol/L
OER	27
rSO_{2c}	72

POST- SURGICAL SITUATION

- Dopamine 5 µg/kg/min
  Milrinone 0.7 µg/kg/min
- Mechanical Ventilation (FiO_2 0.4)

- Echocardiography: no residual lesions.
  Normal biventricular function

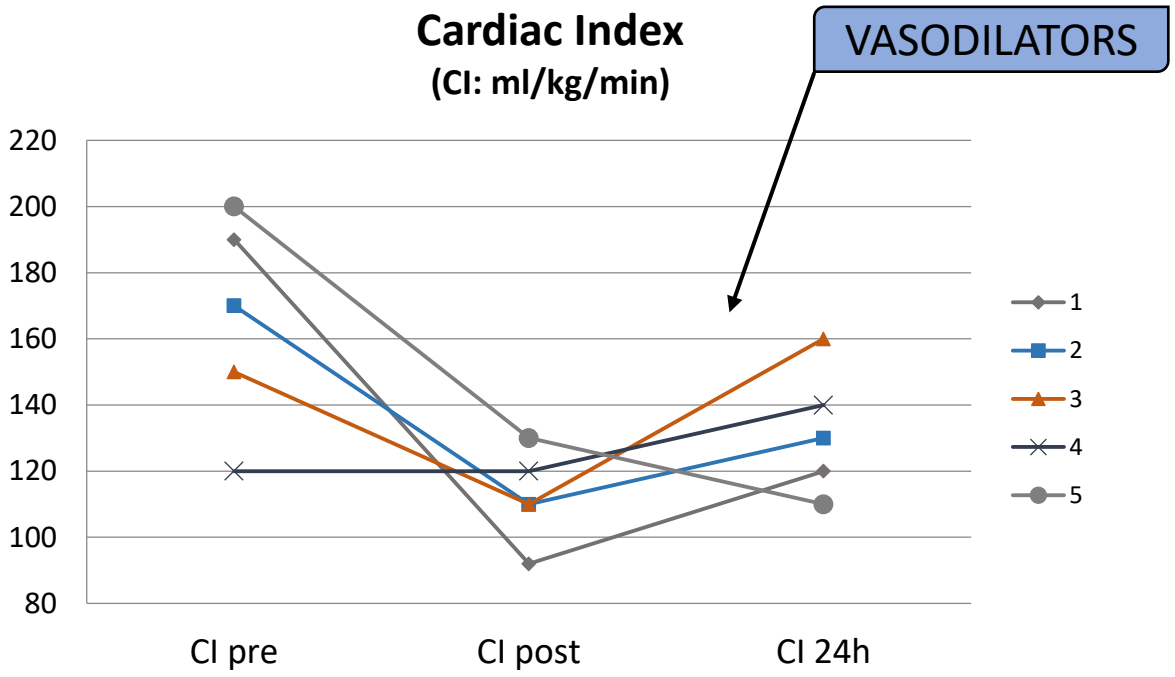
BP	61/41 mmHg
HR	140 lpm
CVP	4 mmHg
$SatO_2$	97 %
Lactate	1,1 mmol/L
OER	27
rSO_{2c}	70

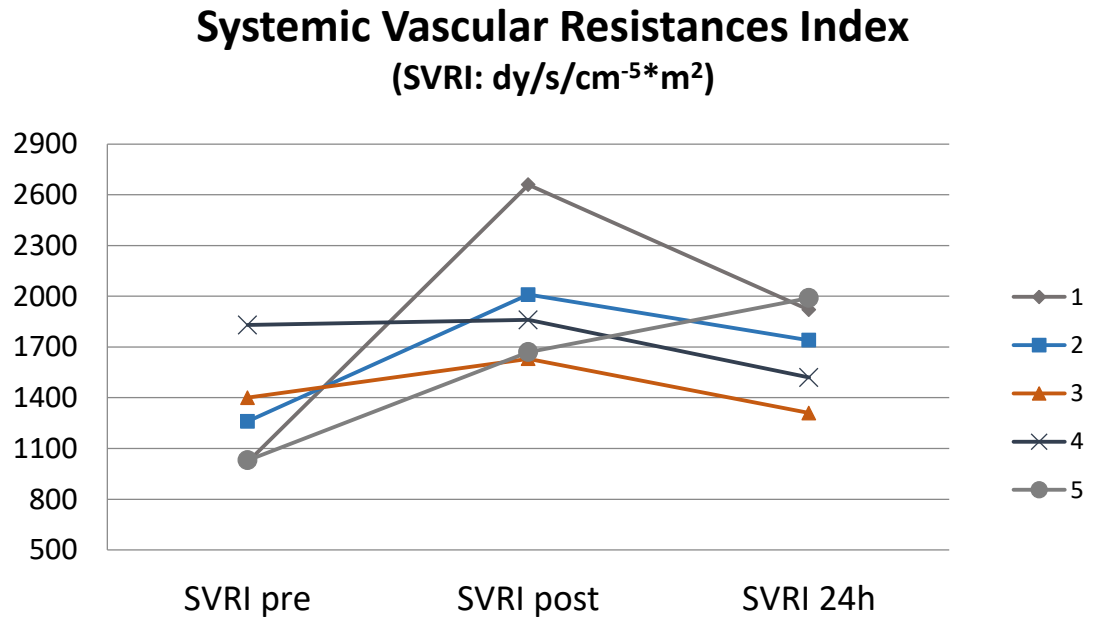


Early Stage Low Cardiac Output Detection

Therapeutic Strategy

D-TGA


Cardiac Index
(CI: ml/kg/min)
VASODILATORS
220
200
180
160
140
120
100
80
CI pre
CI post
CI 24h
1
2
3
4
5


Systemic Vascular Resistances Index
(SVRI: dy/s/cm-5*m2)
2900
2600
2300
2000
1700
1400
1100
800
500
SVRI pre
SVRI post
SVRI 24h
1
2
3
4
5

Case 2

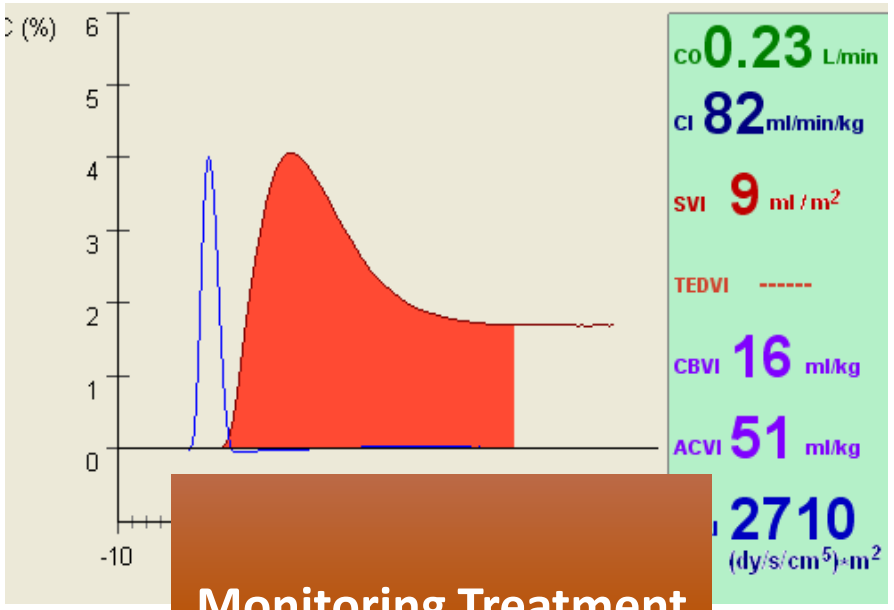
- Term neonate. Weight: 2800 gr
- **Hypoplastic Left Heart Syndrome**

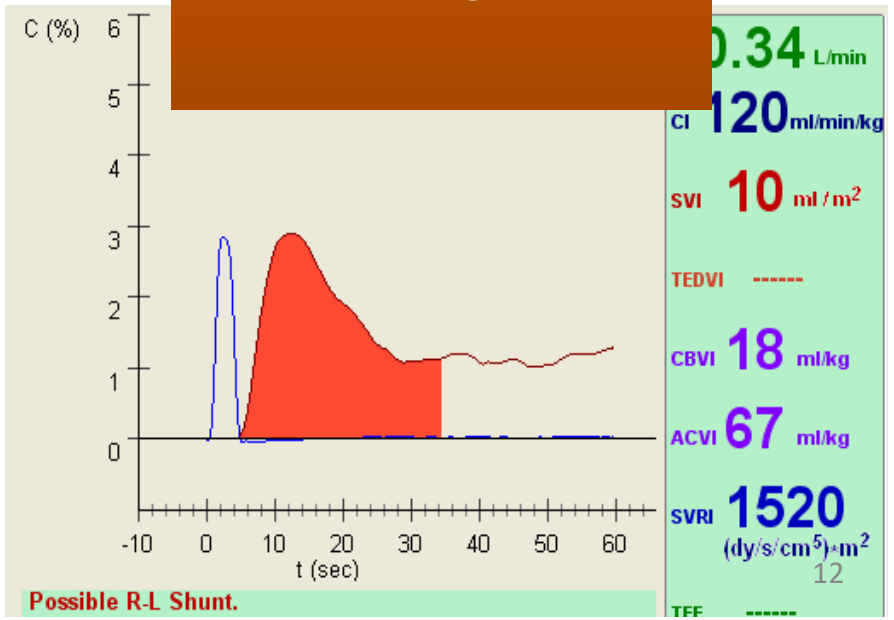
- Furosemide 0.5 mg/kg/12 h
- Respiratory support: nCPAP (FiO_2 0.21)

PRESURGICAL SITUATION	
BP	63/37 mmHg
HR	128 lpm
CVP	5 mmHg
$SatO_2$	90%
Lactate	1,5 mmol/L
OER	12
rSO_{2c}	61

MILRINONE

Monitoring Treatment Changes



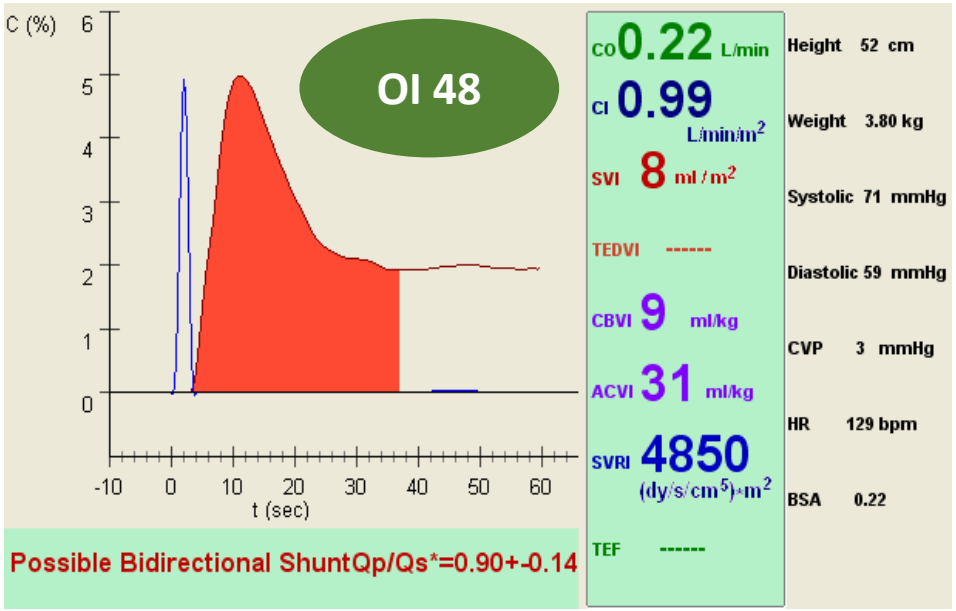


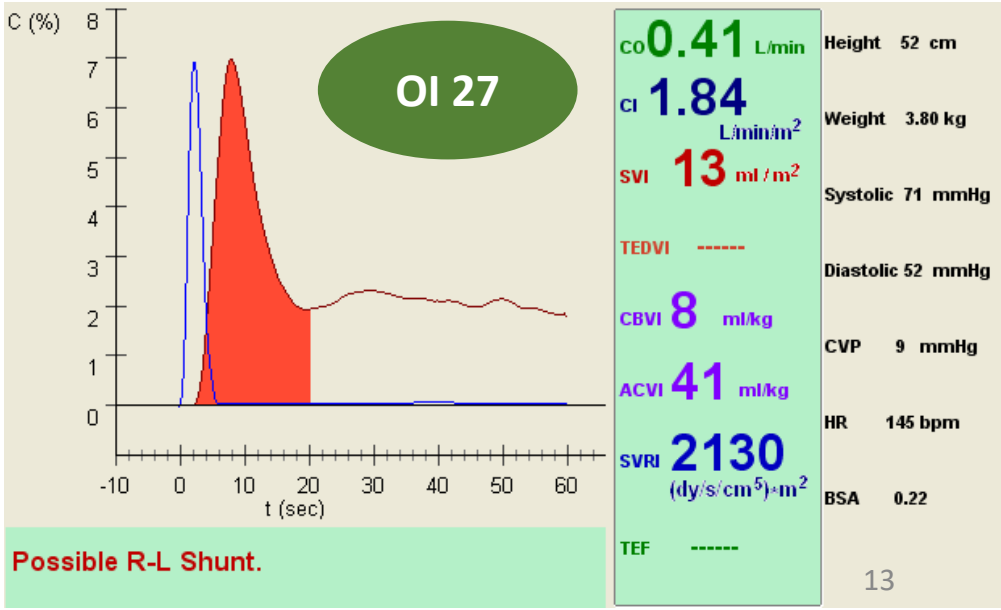
Case 3

- Term neonate. Weight: 3800 gr
- **<u>Meconium Aspiration Syndrome</u>**

- Dopamine 10 µg/kg/min
- Noradrenaline 1 µg/kg/min
- HFOV: MAP 20 cmH_2O; FiO_2 100%

iNO 20 ppm
Dobutamine 10 µg/kg/min
Volume 10 ml/kg





Ultrasound Dilution Technology

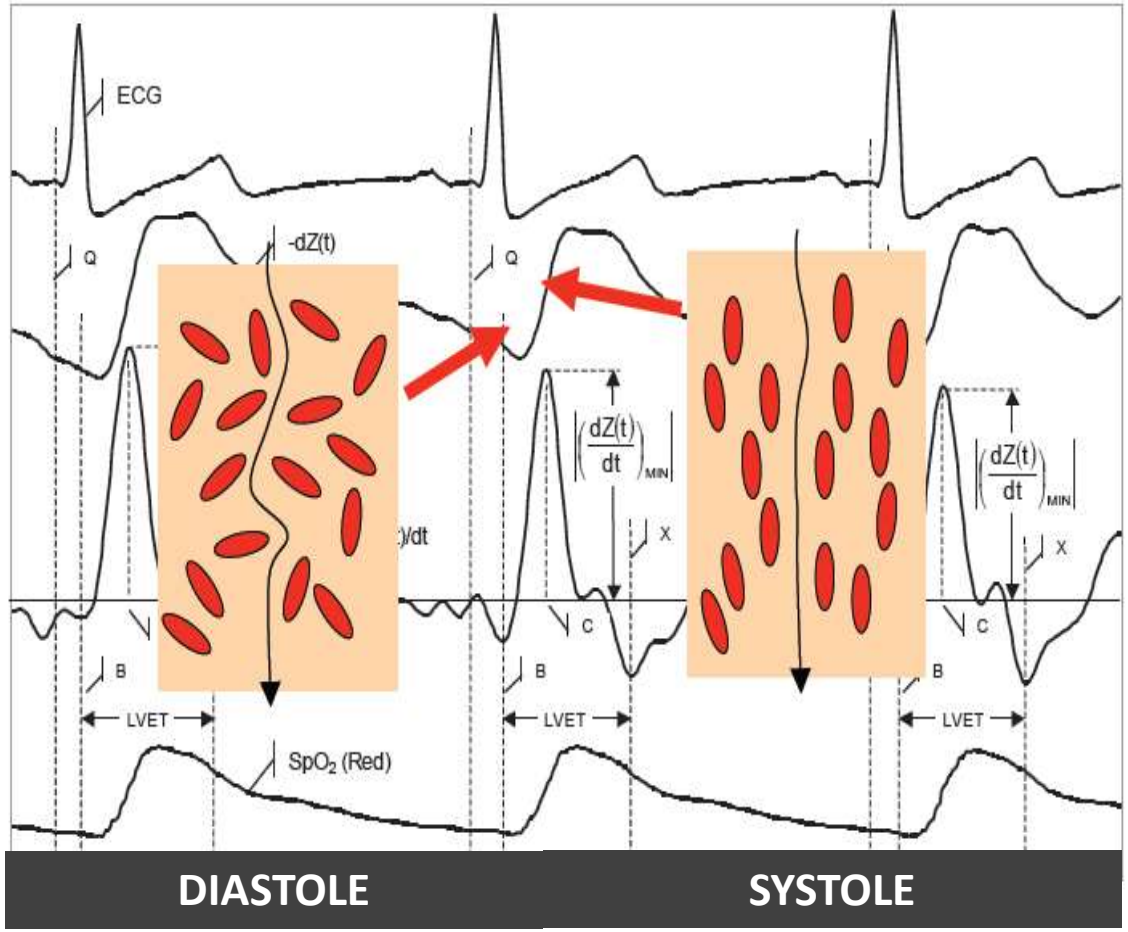
ADVANTAGES	Minimally invasive method Highly accurate	**WEAKNESSES**	No invasive blood pressure monitoring during the measurement period
	Uses existing catheters Innocuous isotonic saline indicator		Risk overload volume in repeated measurements
	No blood loss Independent of patient size		Abnormal shapes in the dilution curves in presence of shunts

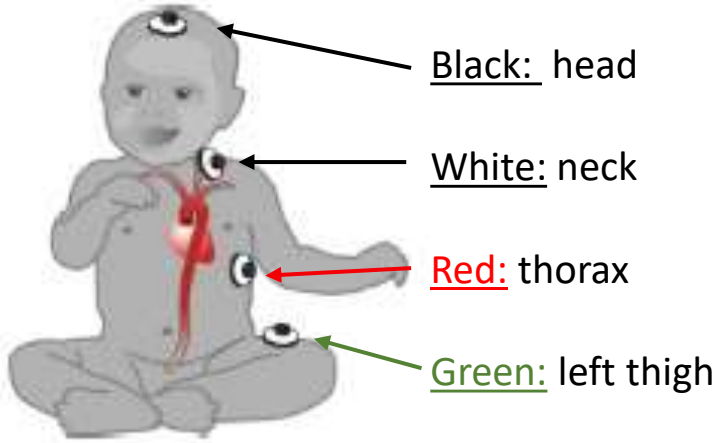
Preterms Cardiac Output Evaluation

- Singular preterm characteristics
- Transition conditions

- The immature myocardium is very sensitive to minimal changes in load conditions.
- Hemodynamic instability: PDA, NEC, septic shock…

Electrical Velocimetry



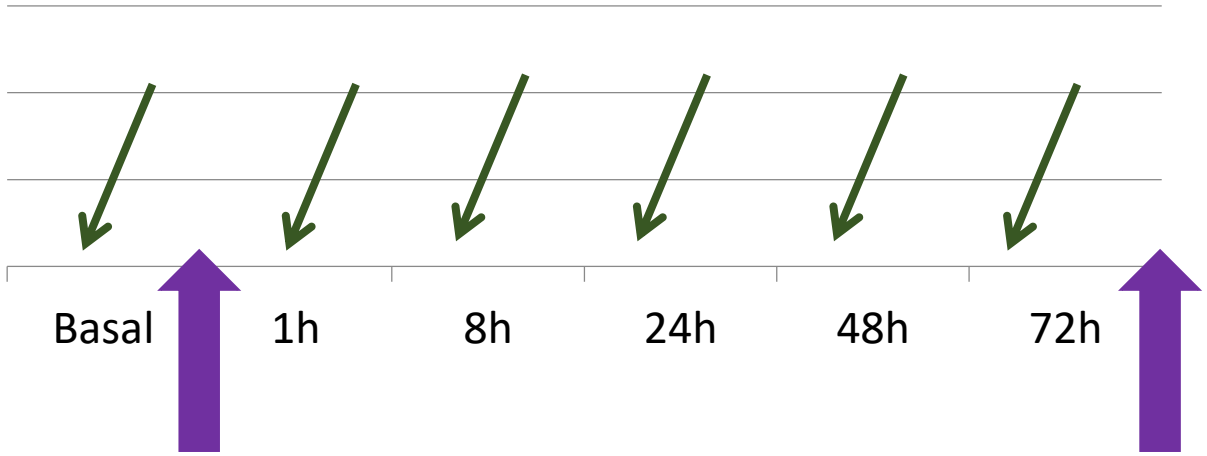


CARDIAC INDEX (CI)	
Systolic Volume	SVI (systolic volume index)
Preload	SVV (systolic volume variation)
Contractility	ICON
Afterload	SVRI (systemic vascular resistances)

PDA treatment monitoring

< 28 weeks

Hemodynamic significant PDA

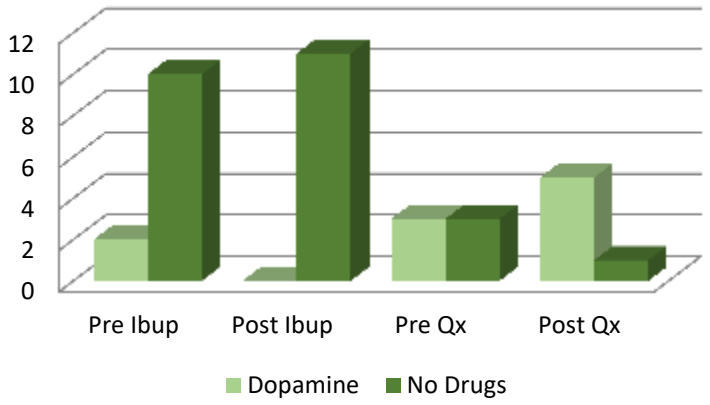


Group 1: Pharmacological treatment
Group 2: Surgical closure

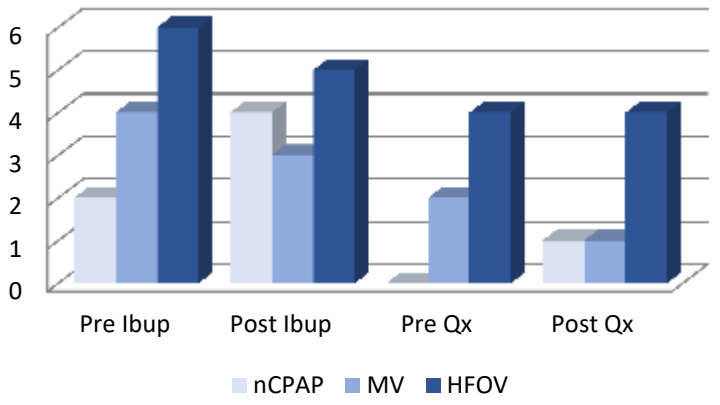
Check ductus status by echocardiography

PHARMACOLOGICAL		SURGICAL
12	*N*	6
$26+^{5}$ (25^{+5}-27^{+3}) weeks	*Gestational age*	25^{+2} (24-26^{+3}) weeks
875 (670-1010 g)	*Weight*	745 (660-820) g
♂8 ♀4	*Sex*	♂4 ♀2
4 (2-6.5) days	*Days of life at treatment*	20 (15.5-24) days
58%	*Confirmed closure*	100%

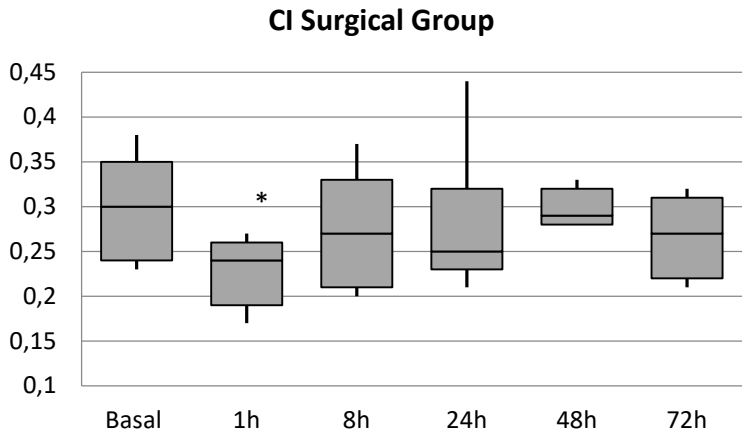
Inotropic Drug- support

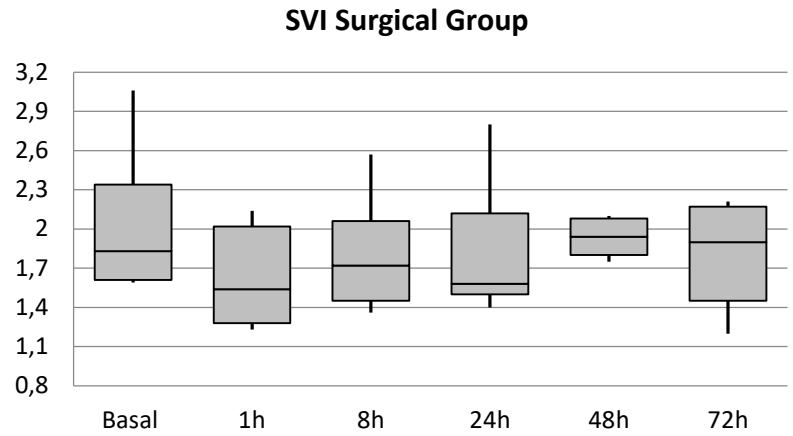


Respiratory Support

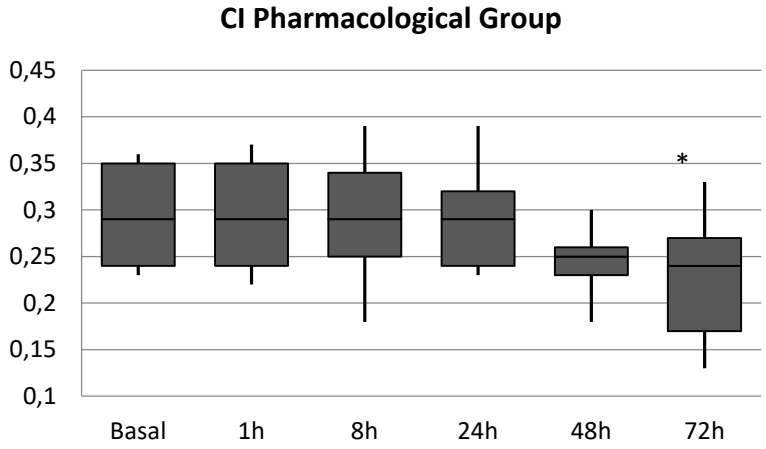


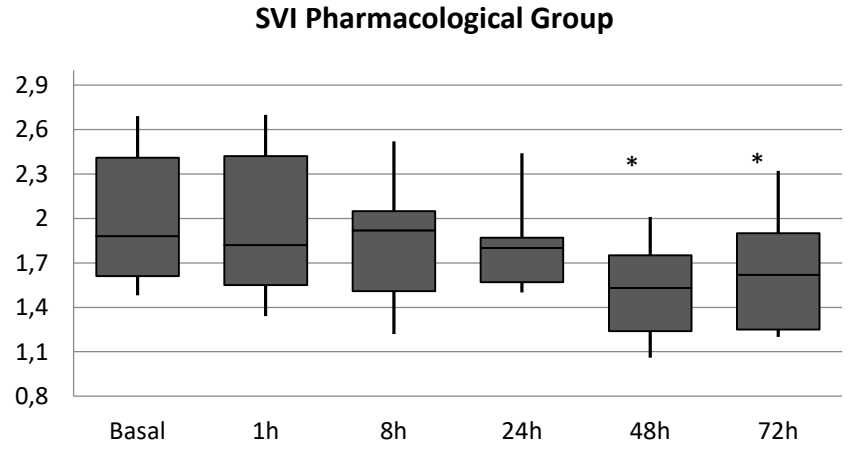
No significant changes in heart rate were documented





⇓ ICON





⇓ ICON

Cardiac output measurements. Boxplot showing interquartile range, median, and outliers. *CI: cardiac index (l/kg/min); SVI: systolic volume index (ml/kg)*

Cardiac Output changes related to ductus closure

SURGICAL CLOSURE

- Ductus ligation generates an acute decrease in the systolic volume
- Acute decrease in LV preload with a significant increase in afterload.
- Deterioration in contractility is mostly determined by the load status.

PHARMACOLOGICAL CLOSURE

- Same hemodynamic changes detected
- Appearing after the second dose of drug administration.
- The gradual drug induced closure might have caused better clinical tolerance to changes in cardiac output.

Electrical Velocimetry

ADVANTAGES	Non invasive method Continue monitoring
	No interference with other monitoring systems
	Good correlation with echocardiography Any size patient

WEAKNESSES	Electrodes' inappropiate contact can lower the signal quality
	Interference by HFOV No studies in unstable patients
	Overestimation if presence of PDA Trends more than absolute values

Conclusions

- Need for a more comprehensive approach to the hemodynamic monitoring of sick neonates

- *Ultrasound Dilution*:
  - Detects changes in an early stage
  - Identifies blood shunts

- *Electrical Velocimetry*:
  - Preterms continuous hemodynamic evaluation

- Holistic approach in therapeutic decisions, in accordance with clinical and echocardiographic information

THANK YOU FOR YOUR ATTENTION