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Pitfalls in hemodynamic assessment in the cath lab

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Measured Variables

- Determination of vascular physiology by
  - Assessment of systemic flow Qs and systemic resistance Rs
  - Assessment of pulmonic flow Qp and pulmonary vascular resistance Rp
  - Qp/Qs; Rp:Rs
- Testing for vascular reactivity (NO, O_2, ? prostacyclin)

Aims

Assessment of hemodynamics

- Grading of PAH
- Decision making for cath. intervention/operation
- PAH selective vasodilators ?
- Effect of therapy

Decision making

In borderline cases there are no clear recommendations which ASD's or VSD's are still amenable for closure

- ASD II: Rp > 12 units x m^2 inoperable, 8-12 units x m^2 = greyzone

  < 8 units x m^2 operable (Steele PM, Fuster V et al. Circulation 1987)
- PVR < 10 – 14 unit x m^2 , Rp:Rs < 0,66 OP possible (Galie.Circ.1989)
- ASDII: AHA guidelines 2008, JACC Class III: irreversible elevation of Rp without LR shunt should not undergo closure (level B)
- VSD: AHA guidelines 2008, JACC Class IIa: closure of a VSD is reasonable when net LR shunt is present at a Qp/Qs ratio > 1.5:1 with PAP < 2/3 SAP (level B)

Nadas and Fyler, Pediatric Cardiology 2nd ed. 2006 p541

Pat. with Rp < 8 U x m^2 can be corrected if

- there is LR shunt
- the patient is < 2 years
- if Rp reacts to O_2 /NO positively (> 30% Rp reduction)

Decision making in a borderline patient with a shunt lesion is based on numbers!

How valid are these numbers?

Calculation of CO

Indicator is O_2, concentration of the indicator is O_2 content (C)
VO_2 is oxygen uptake

$$C.I.(Q) = \frac{VO_2}{C_{art.}O_2 - C_{ven.}O_2} \quad (l/min/m^2)$$

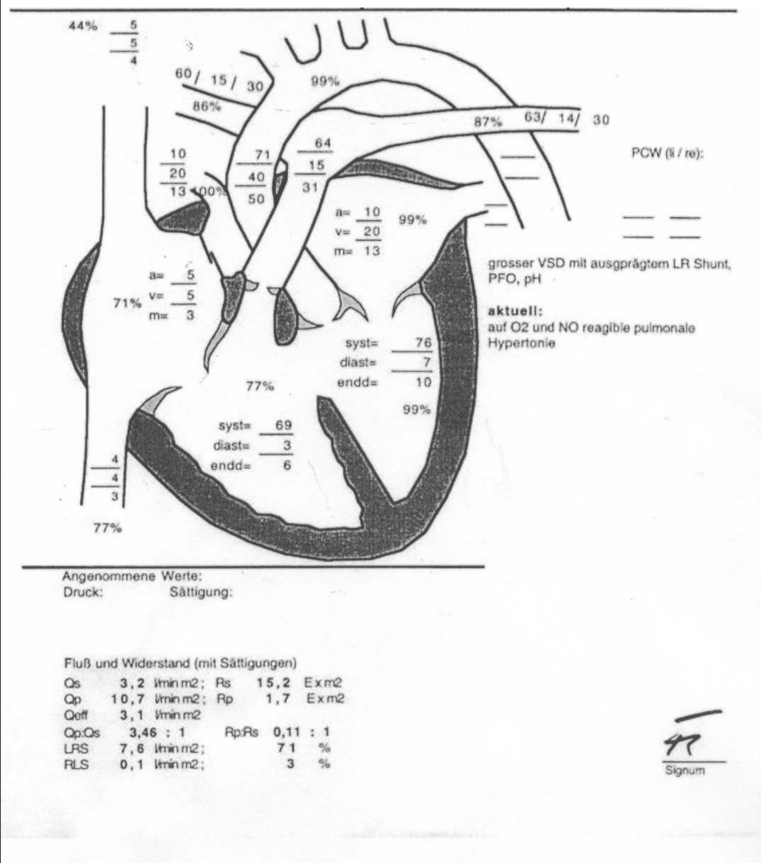
Qp/Qs

Qp/Qs is very helpful and determined easily without VO_2

$$Qp:Qs = \frac{Sat_{Ao} - Sat_{mv}}{Sat_{Pv} - Sat_{Pa}}$$

Qp: pulmonary blood flow
Qs: systemic blood flow
Sat Ao: O_2 sat arterial blood
Sat mv: O_2 sat mixed venous
Sat Pv: O_2 sat LA/Pv
Sat Pa: O_2 sat Pa

Example 1

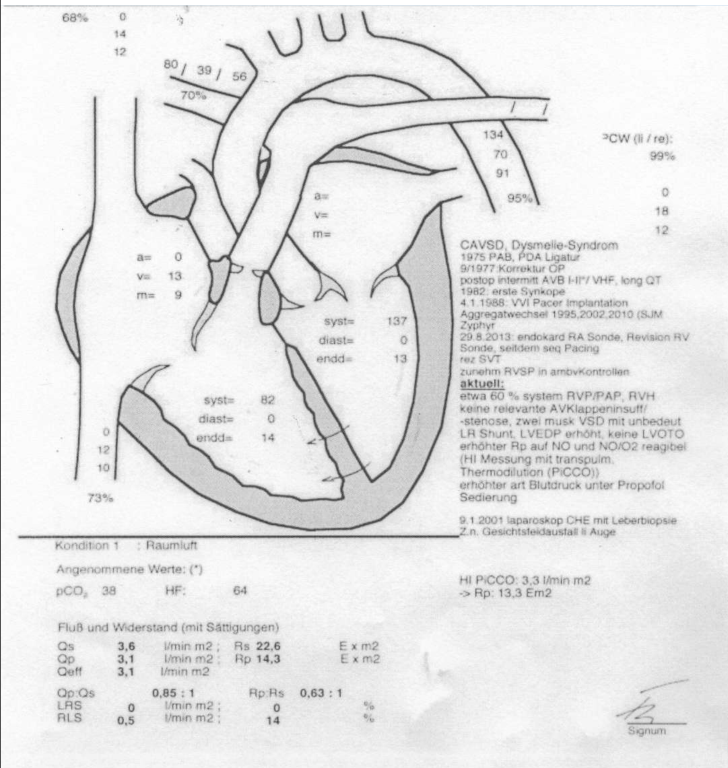


	Basel.	100%O_2	O_2+20ppmNO
SVC %	44	51	51
IVC %	77	89	90
PA %	87	97	96
LA %	99	99	100
Ao %	99	100	100
Qp L/min/m²	10.7	46.5	34.9
Qs L/min/m²	3.2	3.9	3.9
Qp/Qs	3.5:1	12:1	9:1
Rp U x m²	1.7	0.4	0.4
Rs U x m²	15.2	13.1	11.6
Rp/Rs	0.1:1	0.03.1	0.04:1

18 months old girl (75cm, 9.3kg, BSA 0.42 m²)

VO_2 measured 195 ml/min/m²

Example 2



	Basel.	O_2+NO
SVC %	68	88
IVC %	73	80
PA %	70	85
LA %	99	100
Ao %	95	100
Qp L/min/m²	3.1	6.0
Qs L/min/m²	3.6	6.0
Qp/Qs	0.85:1	1:1
Rp U x m²	14.3	4.4
Rs U x m²	22.6	13.3
Rp/Rs	0.63:1	0.33:1
Picco:HZV l/min	3.3	3.1
Calc. Rp Em²	13.3	8.3

40 y. old woman (157bcm, 48 kg, BSA 1.46 m²) VO_2 153 ml/min/m², CAVSD after PAB 1975, Correction 1977, now 60% systemic pressure in PA,
Now PAH and small residual muscular VSD‘s

VO_2 – to measure or not to measure

- Volume of oxygen per minute (VO_2) taken from the literature (LaFarge CG, Miettinnen OS. 1970 Cardiovasc Res;4:23-30) may result in a mistake since the values were taken from healthy individuals. Base line oxygen consumption in patients is different
- Measurement of oxygen consumption may be cumbersome, but if properly done results in the best possible values
- Measurements only make sense in stable circumstances

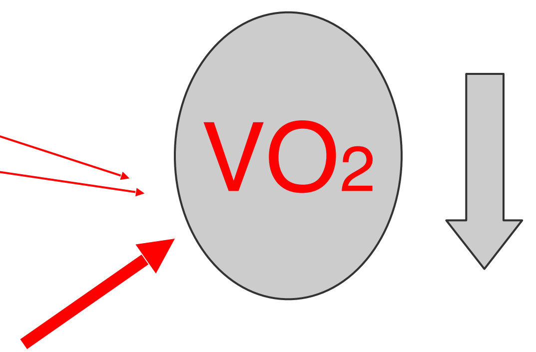
testing of vascuar reactivity

General Anesthesia:

* relaxing agents

* intubation/ventilation

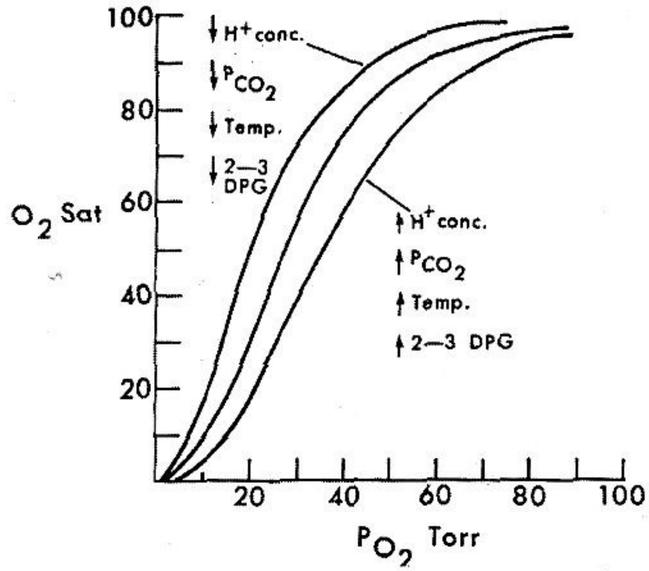
less muscle work

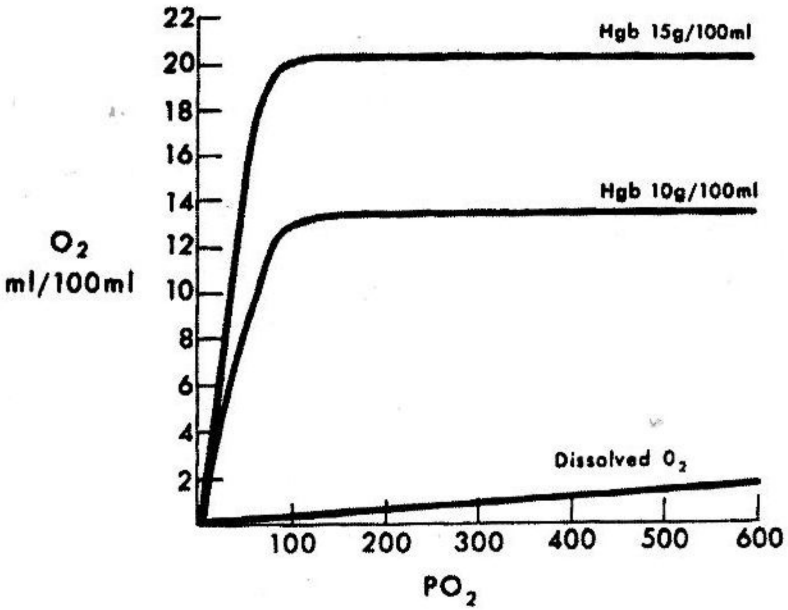


Mixed venous saturation (3xSVC + 1xIVC/4)
Miller HC et al. Br Heart J 1974;36:446-51

- SVC and IVC saturations vary significantly
- SVC saturations more reproducible than IVC sats
  - If no PAPVC is present
  - Or shunting from ASD to SVC occurs
- IVC vary from level of aquisition

Oxygen as indicator





Effect of H+ Ionconc., pCO_2 Temp., und 2,3-DPG auf on the O_2 dissociationcurve

Oxygen content is dependent on Hb value. If FiO2 > 30%, dissolved oxygen has to be taken into account (0,003 × PO_2 [mmHg]).

Oxygen capacity

- Every g Hb can transport 1,36 mL O_2
- oxygen capacity = Hb in g/100mL x 1,36
- If FiO_2 is > 30% dissolved oxygen has to be included if not measured (0,003 × PO_2 [mmHg])

pitfalls

- Measured oxygen saturations and pressures should be interpreted
- For precise values measured oxygen consumption (VO_2) is most precise
- Measurements only make sense in stable circumstances
- The measurements must fit the patient
- If FiO2 > 30% dissolved oxygen has be taken into account
- Numbers are numbers

Thank you !

Beispiel 1: VSD mit L-R Shunt

- *Sat Ao und Sat pv: 96%, Sat pa: 86%, Sat mv: 76%; VO_2 88,4 ml/kg/min*

$$Qp = \frac{88,4}{(0,96 - 0,86)\ 176,8} = 5\ l/min$$

$$Qs = \frac{88,4}{(0,96 – 0,76)\ 176,8} = 2,5\ l/min$$

$$Qpeff = \frac{88,4}{(0,96 – 0,76)\ 176,8} = 2,5\ l/min$$

LR Shunt = 5 – 2,5 = 2,5 l/min

Qp:Qs = 2:1

Beispiel 1: VSD mit L-R Shunt

Heart. 2001 Jan;85(1):113-20.**Haemodynamic calculations in the catheter laboratory.Wilkinson JL.Author informationPMID: 11119478 [PubMed - indexed for MEDLINE] PMCID: PMC1729580**

Beispiel 2: VSD mit R-L Shunt

- Derselbe Patient nach PAB, VO_2, HB und Sauerstoffkapazität bleiben gleich: Sat.Ao 85%, Sat pv: 95%, Sat pa: 70%, Sat mv: 70%; VO_2 88,4 ml/kg/min

$$Qp = \frac{88{,}4}{(0{,}95 - 0{,}70)\ 176{,}8} = 2\ l/min$$

$$Qs = \frac{88{,}4}{(0{,}85 - 0{,}70)\ 176{,}8} = 3{,}3\ l/min$$

$$Qpeff = \frac{88{,}4}{(0{,}95 - 0{,}70)\ 176{,}8} = 2\ l/min$$

$$RL\ Shunt = 3{,}3 - 2 = 1{,}3\ l/min$$

$$Qp:Qs = 0{,}6:1$$

Beispiel 3: VSD mit bidirektionalem Shunt

- Derselbe Patient nach PAB (nicht eng), VO_2, HB und Sauerstoffkapazität bleiben gleich: Sat Ao 90%, Sat pv: 97%, Sat pa: 86%, Sat mv: 66%; VO_2 88,4 ml/kg/min

$$Qp = \frac{88{,}4}{(0{,}97 - 0{,}86)\ 176{,}8} = 4{,}5\ l/min$$

$$Qs = \frac{88{,}4}{(0{,}90 - 0{,}66)\ 176{,}8} = 2{,}1\ l/min$$

$$Qpeff = \frac{88{,}4}{(0{,}97 - 0{,}66)\ 176{,}8} = 1{,}6\ l/min$$

R-L Shunt = 2,1 – 1,6 = 0,5 l/min

L-R shunt = 4,5 – 1,6 = 2,9 l/min

Qp:Qs = 2,14:1

Relevanz des VO_2 Wertes

- *Sat Ao und Sat pv: 96%, Sat pa: 86%, Sat mv: 76%; VO_2 88,4 ml/kg/min*
- *Pap mean 50mmHg; Pla mean 10mmHg; Pao mean 60mmHg*

$$(Qp = \frac{88{,}4}{(0{,}96 - 0{,}86)\ 176{,}8} = 5\ l/min)$$

$$Rp = \frac{Pap - Pla}{Qp} = \frac{40}{5} = 8\ U \times m2$$

Bei VO_2 176,8 ml/kg/min: (Qp = 10 l/m)

$$Rp = \frac{40}{10} = 4\ U \times m2$$

Patienten Daten

- 35 year old native Vietnamese woman (44,6kg, 149 cm) in NYHA III
- Grade III continous murmur 2nd left IC space, fixed splitting P2 with accentuated P2
- ECG: right axis deviation and incomplete right bundle branch block
- X-ray: right and left heart enlargement, increased pulmonary vascular markings

Diagnostic catheterization

Pressures room air: PAP 85/57/66, AoP 83/58/66, RAPm 9, LAPm 10 mmHg

Kondition	Qs l/min/m²	Qp	Qp:Qs Units x	Rp m²	Rs	Rp :Rs %	LRS	RLS
Room air	1.5	3.2	2.2:117	36.7	0.46:1	53	0	
Oxygen	1.7	7.2	4.3:17.5	35	0.21:1	76	0	
NO	1.4	8.4	6.0:15.4	37.9	0.14:1	83	0	
Prostacyclin	2.5	10.1	4.0:13.8	18	0.21:1	75	0	

Follow-up catheterization

Pressures room air: PAP 85/57/66, AoP 83/58/66, RAPm 9, LAPm 10 mmHg

Kondition	Qs	Qp	Qp:Qs	Rp	Rs	Rp :Rs	LRS	RLS
	l/min/m^2		Units x	m^2		%		
Room air	1.5	3.2	2.2:1	17	36.7	0.46:1	53	0
Oxygen	1.7	7.2	4.3:1	7.5	35	0.21:1	76	0
NO	1.4	8.4	6.0:1	5.4	37.9	0.14:1	83	0
Prostacyclin	2.5	10.1	4.0:1	3.8	18	0.21:1	75	0

Four months post PDO

Pressures room air: PAP 75/37/50, AoP 131/80/97, RAPm 10, LAPm 11 mmHg

Kondition	Qs	Qp	Qp:Qs	Rp	Rs	Rp :Rs	LRS	RLS
	l/min/m2			Units x	m2		%	
Room air	3.2	3.2	1:1	11.6	27.2	0.43:1	0	0
Oxygen	3.6	3.6	1:1	9.2	22.5	0.41:1	0	0
NO	3.8	3.8	1:1	8.2	23.2	0.35:1	0	0
Prostacyclin	3.4	3.4	1:1	6.2	27.6	0.22:1	0	0

Fick'sches Prinzip

Adolf Fick 1829 - 1901

1870 wies Fick den klassischen Weg zur Bestimmung des Herzminutenvolumens aus der arteriovenösen Sauerstoffdifferenz. Eine bekannte Menge eines Indikators I wird dem Volumen V einer Flüssigkeit zugeführt. Wenn die Konzentration des Indikators vor CI_1 und nach Zugabe CI_2 bekannt ist kann das Volumen der Flüssigkeit berechnet werden.

$$V = \frac{I}{CI2 - CI1}$$