

## Der Pulmonalkatheter – im Prä-HTX Management unverzichtbar

*Pitfalls & Vorgehensweise*

Gottfried Heinz  
Kardiologische Intensivstation 13H3  
Abteilung für Kardiologie  
Universitätsklinik für Innere Medizin II  
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### Was ich voraussetze

- Grundlagenkenntnisse zum Pulmonalkatheter
- Kenntnis der verschiedenen Modelle

### Was ich behandeln möchte

- Konzentration auf den Lungengefäßwiderstand
- How to "PVR"

### Was ich nicht behandle

- keine in-depth Diskussion der dahinterliegenden Daten
- Die Vielzahl der übrigen erhebbaren Pulmi-Parameter

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### Pulmonalkatheter

- CO/CI CCO
- PAPs, PAPd, PAPm
- PCPW, ZVD
- SV(I)
- LVSWI
- **PVR**
- SVR
- DO<sub>2</sub>
- VO<sub>2</sub>
- SvO<sub>2</sub>
- a-vDO<sub>2</sub>
- AaDO<sub>2</sub>
- O<sub>2</sub> Extraktion
- Qs/Qt
- Oxymetrie step up (Gassprung)



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**Pulmonalkatheter**

- CO/CI CCO
- PAPs, PAPd, PAPm
- PCPW, ZVD
- SV(I)
- LVSWI
- PVR
- SVR
- DO<sub>2</sub>
- VO<sub>2</sub>

- SvO<sub>2</sub>
- a-vDO<sub>2</sub>
- AaDO<sub>2</sub>
- O<sub>2</sub> Extraktion
- Qs/Qt
- Oxymetrie step up (Gassprung)




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**Prä HTX HD- was sind die Ziele?**

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**Erfolgreiche Listung 😊  
Erfolgreiche HTX 😊**

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## ISHLT Guidelines HTX Candidates

### 1.3. Role of Diagnostic Right Heart Catheterization

Recommendation for diagnostic right heart catheterization as follows:

#### Class I:

1. Right heart catheterization (RHC) should be performed on all candidates in preparation for listing for cardiac transplantation and annually until transplantation (*Level of Evidence: C*).

2. RHC should be performed at 3- to 6-month intervals in listed patients, especially in the presence of reversible pulmonary hypertension or worsening of heart failure symptoms (*Level of Evidence: C*).

*J Heart Lung Transplant 2006;25:1024-1042*

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### Listing Criteria for Heart Transplantation: International Society for Heart and Lung Transplantation Guidelines for the Care of Cardiac Transplant Candidates—2006

Mandeep R. Mehra, MD, Jon Kobayashi, MD, Randall Starling, MD, Stuart Russell, MD, Patricia A. Uber, PhD, Jayan Parameshwar, FRCP, Paul Mohassel, MD, Sharon Angelino, NP, Keith Aaronson, MD, and Mark Barr, MD

#### Kontraindikationen

Table 2. Important Hemodynamic Parameters to Assess Potential Cardiac Transplant Candidates

- Pulmonary artery hypertension and elevated PVR should be considered as a relative contraindication to cardiac transplantation when the PVR  $>5$  Wood units or the PVRI is  $>6$  or the TPG exceeds 16 to 20 mm Hg
- If the PVR exceeds 25 mm Hg in conjunction with any 1 of the preceding variables, the risk of right heart failure and early death is increased
- If the PVR can be reduced to  $<2.5$  with a vasodilator but the systolic blood pressure falls  $<85$  mm Hg, the patient remains at high risk of right heart failure and mortality after cardiac transplantation

*J Heart Lung Transplant 2006;25:1024-42.*

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Mit der prä-HTX HD-Evaluierung treffen Sie eine weitreichende Entscheidung für die Transplantierbarkeit, den postoperativen Verlauf & die Prognose des Patienten !!!!!

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**Transplantatversagen  
(Rechtsherz)**

**Nichttransplantierbarkeit  
LVAD**




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February 2018  
Volume 7, Issue 10

**ISHLT Links**

**Making the Call: Pulmonary Hypertension in Cardiac Transplant Candidates**

**Key Message:** For patients with left heart failure (the most common indication for OHT), PH develops for three broad pathophysiologic reasons that are believed to develop in temporal succession. First, elevations in left atrial and pulmonary venous pressure can cause passive congestion of the pulmonary vasculature and elevated pulmonary arterial pressures. Furthermore, as pulmonary venous pressure rises, the pulmonary vasculature becomes less compliant ("more stiff") leading to an increase in pulse-wave load for any given resistance and causing further elevations in systolic and mean pulmonary arterial pressures. Pulmonary edema itself may also elevate PVR. This passive, or post-capillary, PH is often remedied by diuretics, or the administration of natriuretic or vasodilators which unload the left heart and subsequently the pulmonary vasculature. However, the pulmonary vasculature undergoes remodeling when the left heart and subsequently the pulmonary vasculature. Remodeling of the pulmonary vasculature confers a degree of elevation in RV load.

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**Grundlagen**

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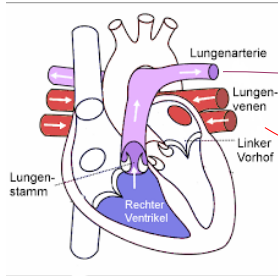
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**Die Lungenstrombahn:**  
*zwischen A.pulmonalis ↔ LA!*



**PVR = PAPm - LA  
 HZV**

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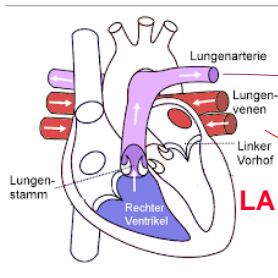
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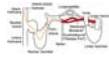
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**Die Lungenstrombahn:**  
*zwischen A.pulmonalis ↔ LA!*



**PVR = PAPm - PCPW  
 HZV**

**LA ~ PCPW**




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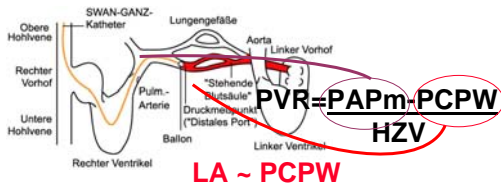
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**Die Lungenstrombahn:**  
*zwischen A.pulmonalis ↔ LA!*



**PVR = PAPm - PCPW  
 HZV**

**LA ~ PCPW**

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$$\text{PVR} = \frac{\text{PAPm} - \text{PCPW}}{\text{HZV}}$$
  
"Wood Units" x 80 = dyn\*sec\*cm<sup>-5</sup>  
SI Einheit

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Messung der Drucke

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....bevor Sie starten...

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### ...Nullabgleich



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### ... Druckdome auf Herzvorhofhöhe..



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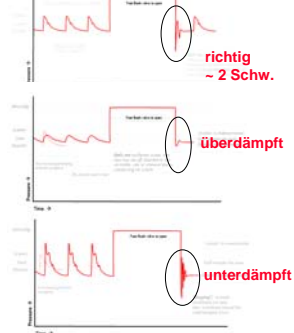
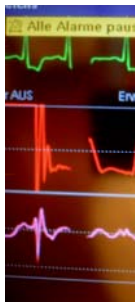
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### ...richtige Dämpfung...



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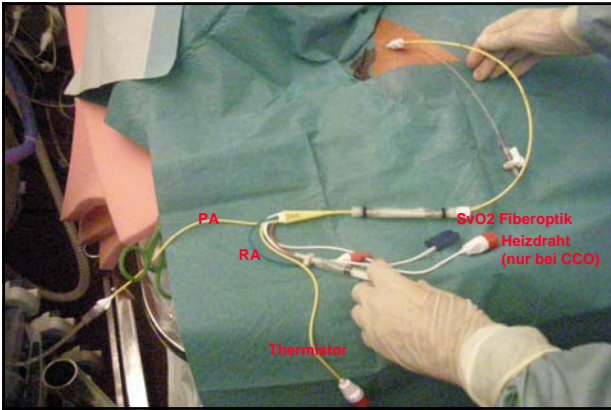
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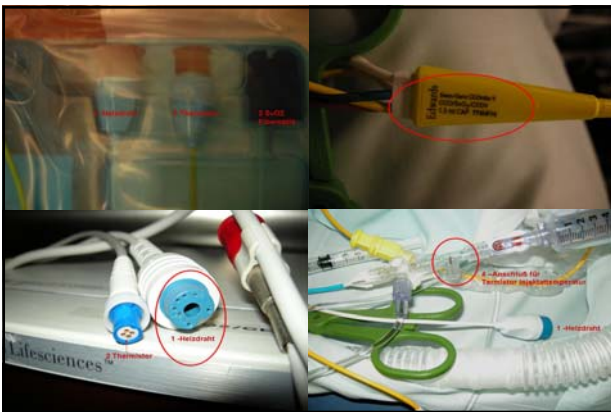
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Orientieren Sie sich an der Druckkurve !

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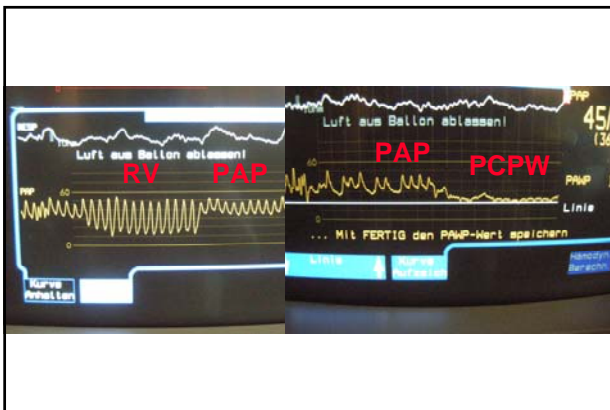
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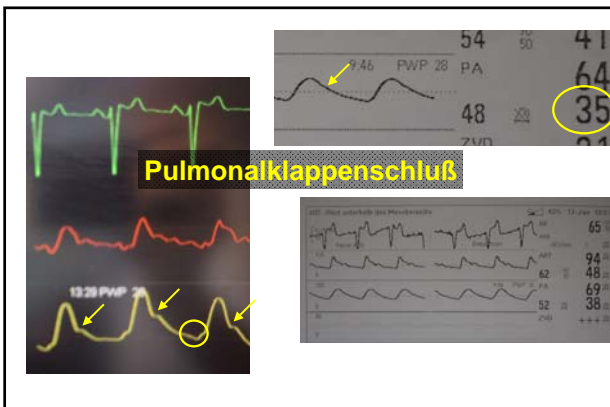
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Messen des PCPW

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...immer endexpiratorisch!!!

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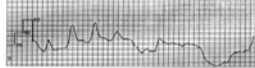
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### Der PAOP wird richtig gemessen

- (A) "oben"
- (B) "unten"
- (C) **endexpiratorisch**

III / PAOP Anterior  
(Clear catheters apply to the base which was taken from a spontaneously breathing patient).



a. The PAOP of this patient is approximately 10 mm Hg

1	2	3	4	5	6	7	8	9
Diastole								Apne
Strongly								Strongly

b. The PAOP of this patient is approximately 20 mm Hg

1	2	3	4	5	6	7	8	9
Diastole								Apne
Strongly								Strongly

c. The PAOP of this patient is approximately 30 mm Hg

1	2	3	4	5	6	7	8	9
Diastole								Apne
Strongly								Strongly

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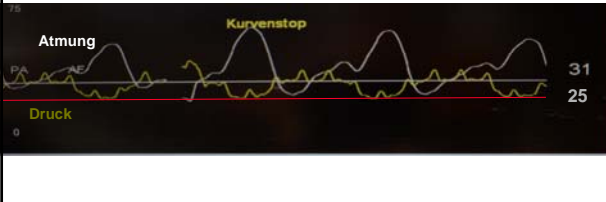
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## PCPW Messung unter Spontanatmung




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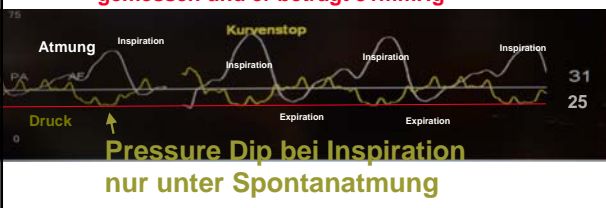
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## Fall MF

Der PCPW wird richtig abgelesen

- (1) bei der roten Linie
- (2) bei der weißen Linie endexpiratorisch gemessen und er beträgt 31 mmHg



Pressure Dip bei Inspiration  
nur unter Spontanatmung

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Sie übernehmen den Nachdienst und machen bei einem **beatmeten**, schockierten Patienten die Hämodynamikrunde. Dabei registrieren Sie folgende PCPW ("Wedge") Kurve. Sie lesen den Druck ab bei



- (A) der roten Hilfslinie
- (B) der weißen Linie

Druckanstieg bei Inspiration durch Überdruckbeatmung

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Sie übernehmen den Nachdienst und machen bei einem **beatmeten**, schockierten Patienten die Hämodynamikrunde. Dabei registrieren Sie folgende PCPW ("Wedge") Kurve. Sie lesen den Druck ab bei



- (A) der roten Hilfslinie
- (B) der weißen Linie

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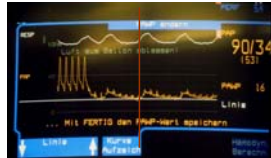
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### PAOP - Methodik

endexpiratorisch

Spontanatmung

Überdruckbeatmung




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### Atemmittellage




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**Messung des HZV**

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**HZV = eigentlich pulmonaler Blutfluß**

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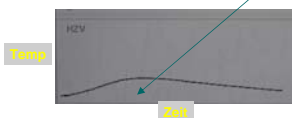
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**Stewart Hamilton Approach  
...gilt für jede Indikator Dilution !**

$$CO = \frac{\text{Quantity of Indicator}}{\int \text{Concentration of Indicator} * dt}$$



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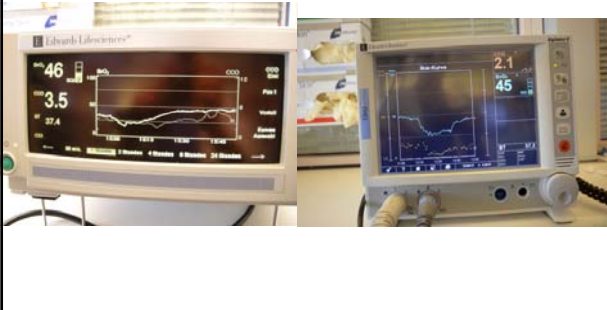
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...kontinuierlich



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...Bolus



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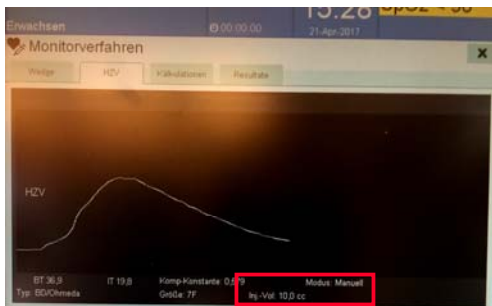
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Beachten Sie die Injektatmengeneinstellung!



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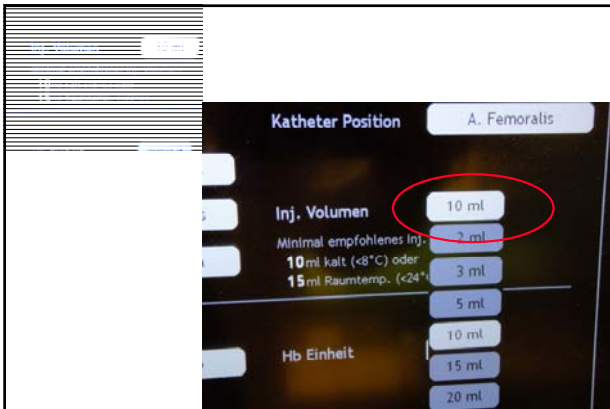
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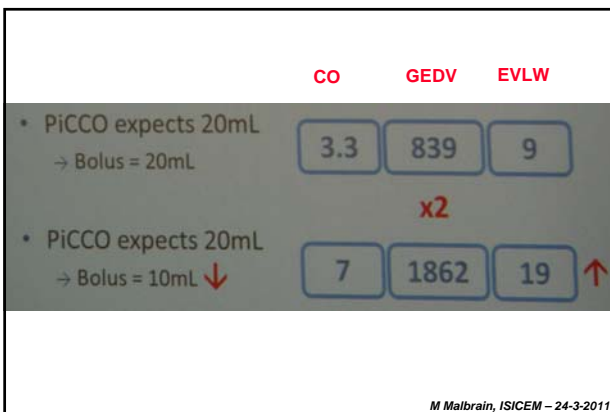
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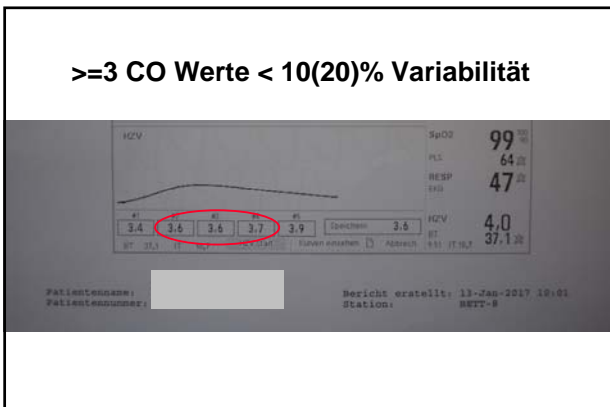
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....Kurven? Hohe Variabilität?...

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....Kurven? Hohe Variabilität?

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## Cardiac Output Thermodilution



- Strenggenommen pulmonaler Blutfluß, nicht linksventrikulärer Output
- Respiratorische Schwankungen - Inspiration unter Überdruckbeatmung vermindert pulmonalen Blutfluß
- Variabilität bis 20%
- Trends vs absoluter Wert
- Absolutwerte vor allem bei kritisch niedrigem Output ( $<2\text{L}/\text{min}/\text{m}^2$ ) fragwürdig

» *J Appl Physiol* 1981;51:584-90  
 » *Crit Care Med* 1986;12:71-9  
 » *Int Care Med* 1986;12:71-9

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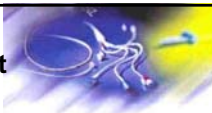
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## Cardiac Output Thermodilution



### respiratorischen Schwankungen, Möglichkeiten:

#### • Injektion des Kältebolus

- gleichmäßige Verteilung über den Atemzyklus, 4 gleichmäßig verteilte Messungen optimal  
 » *Intensive Care Med* 1986;12:71-9
- 6-7 Injektionen des Kältebolus über verschiedene (!) Zeitpunkte des Atemzyklus verteilt  
 » *Crit Care Med* 1982;10:677-80
- streng end-inspiratorische Injektion, "Outlier Rejection" (alles  $>20\%$  Differenz eliminieren)  
 » *Crit Care Med* 1982;10:677-80

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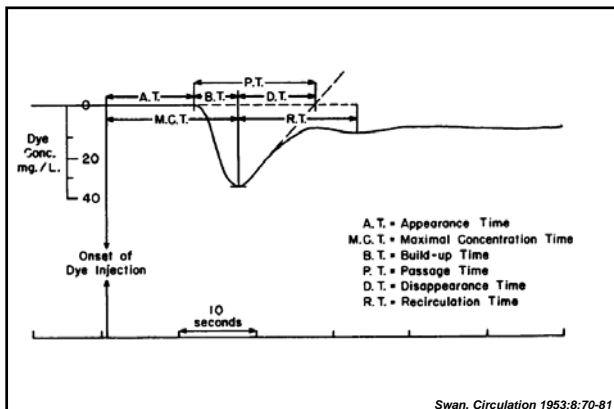
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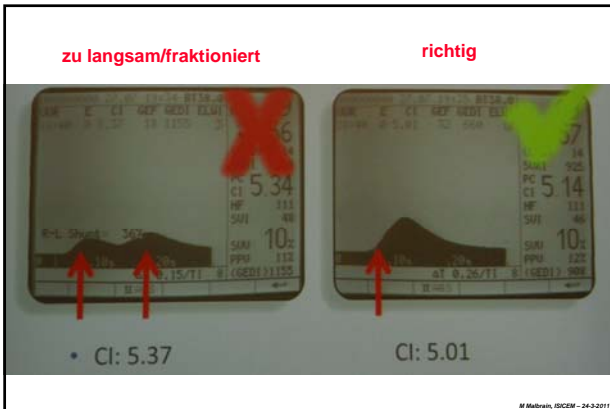
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**HZV – weitere Confounder?**

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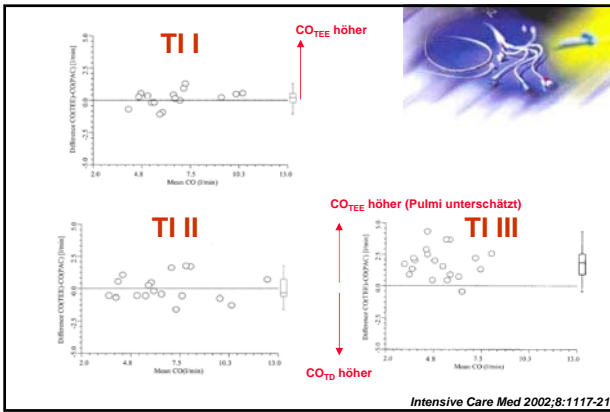
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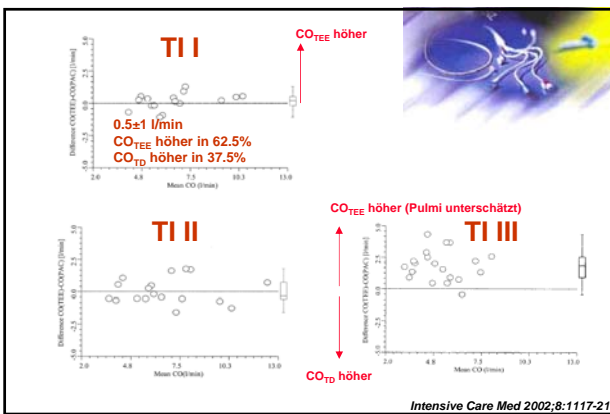
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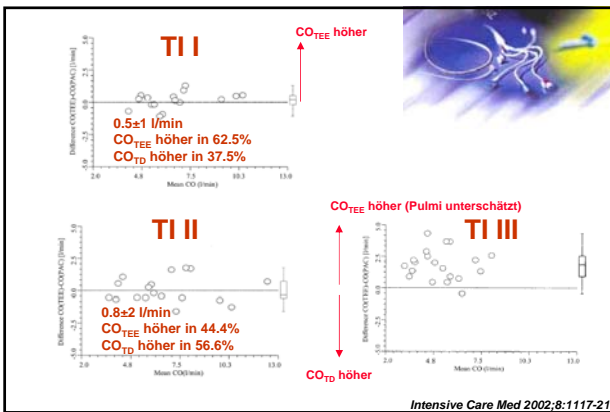
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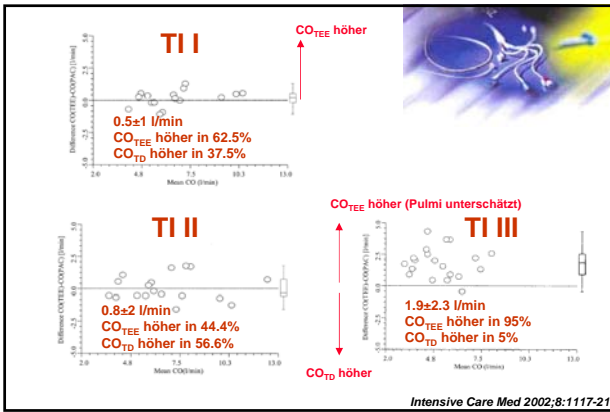
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*Am J Med.* 1999 Apr;86(4):417-20

**Underestimation of cardiac output by thermodilution in patients with tricuspid regurgitation.**

Giordano RO<sup>1</sup>, Lanoce RA, Williams RH, Redolfo JB, Hills LD.

@ Author information

**Abstract**

**INTRODUCTION:** This study was done to assess the accuracy and reliability of the thermodilution technique in measuring cardiac output in patients with tricuspid regurgitation.

**PATIENTS AND METHODS:** In 30 subjects (17 men, 13 women, aged 50 ± 14 [mean ± SD] years), cardiac output was measured in close temporal proximity by thermodilution as well as Fick or indocyanine green dye, after which the presence and severity of tricuspid regurgitation were assessed by contrast right ventriculography or pulsed Doppler echocardiography.

**RESULTS:** In the 13 patients without tricuspid regurgitation, there was excellent agreement between the results of thermodilution and Fick or indocyanine green dye cardiac output determinations (4.95 ± 1.19 liters/minute by thermodilution, 4.90 ± 1.11 liters/minute by Fick or indocyanine green dye; NS). In contrast, in the 17 patients with tricuspid regurgitation, the results of the thermodilution were consistently lower than those of Fick or indocyanine green dye (4.22 ± 1.45 liters/minute by thermodilution, 4.66 ± 1.67 liters/minute by Fick or indocyanine green dye; p less than 0.001).

**CONCLUSION:** Thus, the thermodilution technique of measuring cardiac output is inaccurate in patients with tricuspid regurgitation, yielding results that are consistently lower than the actual outputs.

PMID: 2043022

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**Messen! Nicht "übertragen"**

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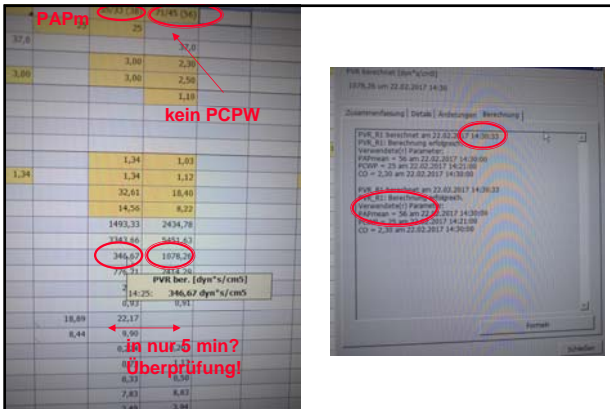
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NAME: \_\_\_\_\_ DATUM: 13.7.2017

Prä-HTX Hämodynamik und vasodynamische Austestung

	Baseline	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Ultraschall	0018	1000														
PAPm mmHg	30	30														
HR 1/min	60	59														
MAP (Graf) mmHg	87	87														
MAP mmHg	75	75														
ZPZ mmHg	24	24														
CO l/min	4	4														
CI l/min/m2	2,14	1,93														
Stroke Vol. ml	48	52														
PVR ber. mmHg	30	400														
PVR ber. mmHg	30	400														
Vasal. mmHg	15	15														
Vasal. mmHg	15	15														
SVI %	2,20	2,30														
SVI	60	60														
PAPm	30	30														
PAPm	30	30														
PAPm	30	30														
CO	4	4														
CI	2,14	1,93														
Stroke Vol.	48	52														

Druckdichte Hilfe Vorlauf ?  
 PCPW nach ?  
 PCPW Drücke gerüstet?  
 CO Methode:  Axius  Koronarsonde  
 Koronarsonde  
 PCPW Methode:  Akromontalage  PCPW Ausblick  
 Pulswellen

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- Ihr Patient hat....**
- TPG >15-20mmHg?
  - PVR um oder > 4 WOOD (320dyn\*sec/cm<sup>5</sup>)?
  - ⇌ vasodynamische Austestung
    - Alprostadin (Minprog) = Prostaglandin E<sub>1</sub>, 1mg/50ml, 2.5 – 5 – 7.5 – 10 – 12.5 – 15 ng/kg/min ..... bis maximal tolerierte Dosis (etwa bis 20ng/kg/min)
    - Hämodynamik nach jedem Steigerungsschritt
    - Reversibilität zeigen
    - Dauertherapie über Hickman Katheter und Reevaluation in 3 Monaten
    - NW: Flush, akrale Schmerzen...

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**Wrap it up**

- Messen, nicht blind übernehmen
- Sind die Druckdome in der richtigen Höhe?
- Sind die Druckdome „genullt“?
- Ist der Patient ruhig, stabil, nicht gehustet, genestelt...
- Liegt der Pulmi richtig? Kurven nicht gedämpft?
- Reproduzierbarkeit? Max 10-20% Variabilität im händischen HZV? Injektattemperatur? Eiswasser verwendet?
- Über ganzen Atemzyklen gleichmäßig injiziert?

IceLand 1993, G.Heinz©

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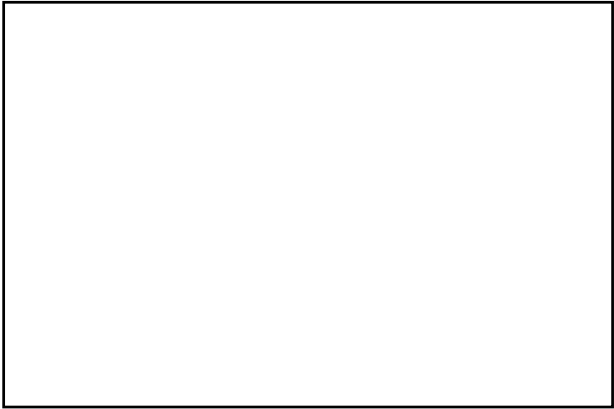
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