Swan Ganz catheter: Does it still have a role?

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How can cardiac output be measured?

- Thermodilution
- Arterial waveform analysis
- Echocardiography
- Esophageal Doppler
- Bioimpedance / Bioreactance
- ....
HEMODYNAMIC ASSESSMENT

CARDIAC OUTPUT:
how to interpret?

Physiologically, cardiac output is an adaptative variable. Accordingly, it should always be analyzed in conjunction with its covariates.
Is cardiac output adequate?

O2 DEMAND

Cardiac output
Hb
SaO2

O2 DELIVERY

SvO2
Do changes in SvcO2 track changes in SvO2?

Reinhart et al
ICM 30:1572;2004

$\Delta \text{ScvO}_2 = 0.89 \times \Delta \text{SvO}_2 - 0.02$

$n = 121$
$r = 0.761$
Do changes in SvcO2 track changes in SvO2?

50% over- or under-estimation of SvO2 changes

Reinhart et al
ICM 30:1572;2004
The choice of the hemodynamic device should be based on its reliability / cost / invasiveness / need for additional measurements.
Pulmonary artery catheter

Hemodynamic measurements:
- Cardiac output
- Pressures
- SvO2 (O2ER)

⇒ Cardiac output + its adequacy (SvO2)
⇒ Preload
⇒ Pulmonary artery pressure
Thermodilution
(right sided or transpulmonary)

Potential issues:
- Catheter specific
- Loss of indicator
- Signal/noise ratio
- Intermittent

Strengths:
- Reliable
- Achievable in most pts
- Few limitations

$\text{CO} \sim \text{area}^{-1}$
Usefulness of pulmonary artery catheter

- Diagnostic approach
- Evaluation response to therapy
- Continuous monitoring
Usefulness of pulmonary artery catheter ???

A particular role in RV dysfunction

RV dysfunction
  • PAP
  • RAP/PAOP
  • CO / SvO2

⇒ Diagnosis
⇒ Effects of therapies
⇒ Impact on forward flow
⇒ On line
Admittedly, echocardiography had supplanted PAC in this indication.

However, monitoring with PAC allows to detect changes in hemodynamic state that would have been missed otherwise.
HEMODYNAMIC ASSESSMENT

When PAC is indicated:

• To indicate administration of fluids
• To monitor the effects of fluids
• To evaluate whether fluids are tolerated
When PAC is indicated:

• To indicate administration of fluids
Central venous pressure

Osman et al
ICM 35:64;2007

96 pts
150 fluid challenges
Pulmonary artery occluded pressure

Osman et al
ICM 35:64;2007

96 pts
150 fluid challenges
Left ventricular end diastolic area

- Tavernier
- Toussignant
- Feissel

Resp  Non resp

cm²/m²

Tavernier: * p<0.05
Toussignant: *
Feissel: * p<0.05

Michard et al
Chest 121:2000;2002
All indices of preload poorly predict fluid responsiveness!
Pulse pressure respiratory variations

\[ \text{DeltaPP} = \frac{(\text{PPmax}-\text{PPmin})}{\left(\frac{\text{PPmax}+\text{PPmin}}{2}\right)} \]
The grey zone concept

N = 413 (surgery)

PPV at baseline (%)
Prediction of fluid responsiveness in patients with respiratory movements

Heenen et al
Crit Care 2006
HEMODYNAMIC ASSESSMENT

Fluid responsiveness

When PAC is indicated:

• To indicate administration of fluids
• To monitor the effects of fluids
FLUID CHALLENGE

- 500 mL of colloid or 1000 mL of crystalloid solution over 30 min in 100 or 250 mL aliquots

- Hemodynamic measurements before and during FC

- Safety rules for stopping FC (increase in PAOP, CVP…)

- Evaluation of effectiveness
  - Positive test: increase in CO of at least 10-15%
  - Negative test: absence of change in CO despite increase in PAOP/CVP
  - Non definite: no change in CO and in PAOP/CVP
Pressure measurements can better evaluate the response to fluid challenge than volume measurements!
Pressure measurements can better evaluate the response to fluid challenge than volume measurements!
When PAC is indicated:
  • To indicate administration of fluids
  • To monitor the effects of fluids
  • To evaluate whether fluids are tolerated
=> Measurement of intracascular pressures is useful to evaluate tolerance to fluid loading.
Whatever is measured, volumes and pressures are linked!

Preload: pressures or volumes?
It is in conditions where PAOP is less predictive of fluid responsiveness (altered LV compliance) that it is the most useful to assess fluid tolerance.
Role of PAOP in the evaluation of tolerance to fluids (Impact of diastolic dysfunction)

LVEDP

Decreased compliance

LVEDV

Normal

LVEDP

LVEDV

Stroke volume

Stroke volume
Implications:

- An increase in pressure or volume indicates an increase in preload.
- An absence of increase in LV volume may mask an increase in preload.
- Patients with diastolic dysfunction have a narrow therapeutic window for fluid administration.
Pressure or volumes: Role of cardiac function

Trof et al
Crit Care 2011
Impact on outcome ?
Kaplan-Meier Survival Curves to One Year

Sandham, J. D. et al.
N Engl J Med 2003;348:5-14

1994 patients ASA III and IV cardiovascular surgery
Huge selection bias of patients included in this study

• Sandham et al (NEJM 2003):
  1994 patients ASA III and IV cardiovascular surgery enrolled in 19 centres in 9 years!

~10 pts/centre/year
FACTT

11,511 Patients screened

10,511 Excluded
  20.8% Had PAC
  15.9% Had physician decline
  12.8% Had chronic lung disease
  10.6% Had high risk of death within 6 mo
  9.3% Required dialysis
  8.4% Exceeded time window
  7.5% Had chronic liver disease
  6.4% Had acute MI
  5.8% Were unable to obtain consent
  4.3% Declined to give consent
  3.6% Were not committed to receiving full support
  2.9% Had neuromuscular disease

2186 pts with PAC

1001 pts with ARDS randomized
HEMODYNAMIC ASSESSMENT

Why did these studies failed?

- Absence of benefit for hemodynamic evaluation
- Lack of specific hemodynamic goals
- Errors in measurements
- Errors in interpretation
- Wrong interventions
- Interventions useless
- Wrong population.

=> The same limitations may apply to other hemodynamic monitoring devices
The incompetence in interpretation of hemodynamic data is not restricted to PAC data
Variability in interventions with PAC data: Impact of the addition of other data

- 126 questionnaires answered by board certified intensivists in Illinois
- Hemodynamic data given to avoid errors in measurements
- Half of the respondents also received information on echographic data
A 72 yo male presents to the ICU with a severe community-acquired lobar pneumonia and was intubated. On AC 60% 600/ 18/PEEP 5, PEAK30, PLATEAU 20 ABG: 7.37/42/67/94%

The patient improves over the next 3 days. On hospital day #4, he becomes acutely hypotensive 85/70, with a precipitous fall in his oxygen saturation. He did not respond to fluid resuscitation.

PAC data: BP- 80/67 RAP-20, RV- 45/18, PA-45/30, PAOP-12, CO- 2.7 and SVR-1570 and PVR-681

Chest X-ray: LLL Infiltrate, unchanged.

I) Was the Pulmonary Artery Catheter Indicated? 1) Yes 2) No

II) Based on the PAC findings what is your next intervention?

1) IV Fluids 2) Dobutamine 3) Dopamine
4) Nitroprusside 5) Lasix 6) None of the above

(ECHO: R VENT DILATATION with a poorly contractile RV, small LV cavity with normal contractility. Septal Bowing into LV)

=> RV failure
## RV failure

Knowledge of echographic data did not improve the adequacy of the responses!

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<th>All (%)</th>
<th>Echo (%)</th>
<th>No echo (%)</th>
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<tbody>
<tr>
<td>Normal saline</td>
<td>17</td>
<td>30</td>
<td>8</td>
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<tr>
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<td>34</td>
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<td>Dopamine</td>
<td>13</td>
<td>6</td>
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<td>3</td>
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<td>Lasix</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>None of the above</td>
<td>30</td>
<td>28</td>
<td>32</td>
</tr>
</tbody>
</table>

Jain et al
ICM 29:2059;2003
PAC vs TPTD

Mortality day 28: PAC 38% vs TPTD 42%

Trof R et al
CCM 40:1177;2012
PAC vs TPTD

Trof R et al
CCM 40:1177;2012
• In many instances, hemodynamic monitoring with pulmonary artery catheter provides important information on patient condition that cannot be gathered with other hemodynamic devices.

• PAC helps to guide therapeutic interventions.