

## **Tfy-99.269 Current methods and issues in monitoring physiological systems**

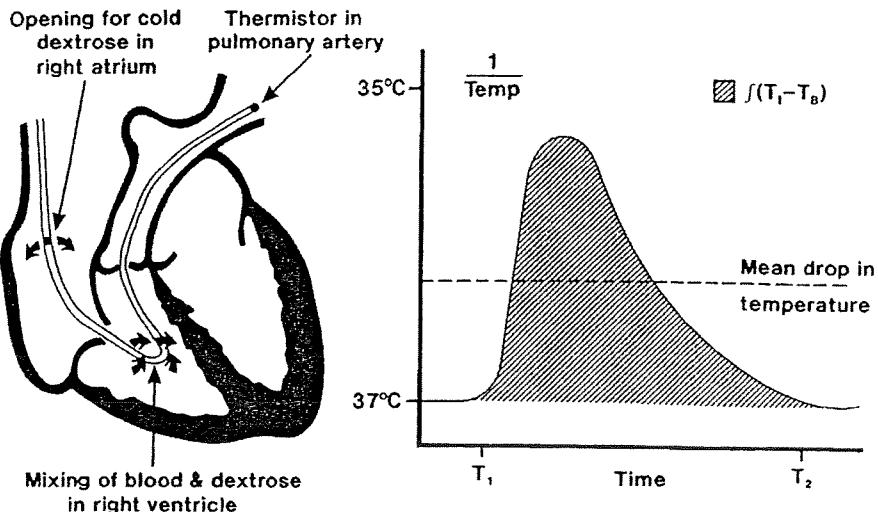
### **Problems for examination on December 8, 2003**

1. Based on the Stewart-Hamilton equation elaborate and discuss the inherent methodological and practical sources of inaccuracy in measuring cardiac output by cold bolus injection method.
2. Describe and analyse a body temperature measurement system based on a sensor utilising a temperature dependent resistor as the primary transducer.
3. Evaluate which option is causing more reduction in blood oxygenation of an average size person breathing room air: a) physiological dead space of 20%, or b) shunt (venous admixture) of 20% ?
4. Draw a pressure-volume loop for a typical flow pattern generated by a constant pressure ventilator with a short pause between inhalation and exhalation. What can be said about the information contents of this loop regarding monitoring of relevant lung mechanics parameters?
5. Compare the attached Bland-Altman plots of two different CO<sub>2</sub> rebreathing methods against thermodilution in measuring cardiac output. What are your conclusions?

**-The attached selected lecture material is at your disposal**

**-You may answer either in English or Finnish**

### Cardiac output refresher: bolus thermodilution

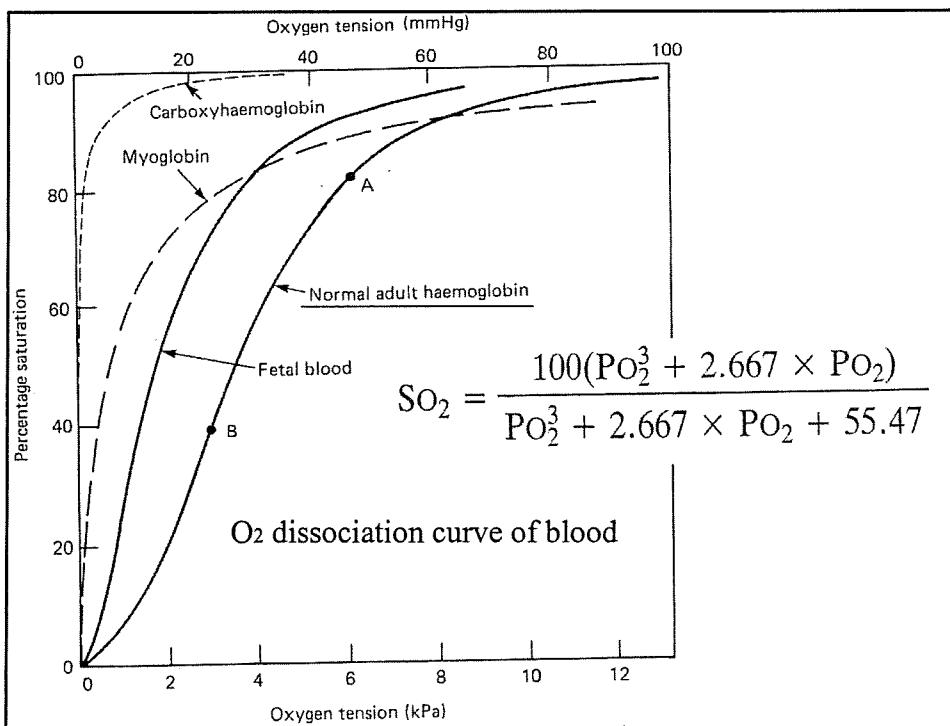
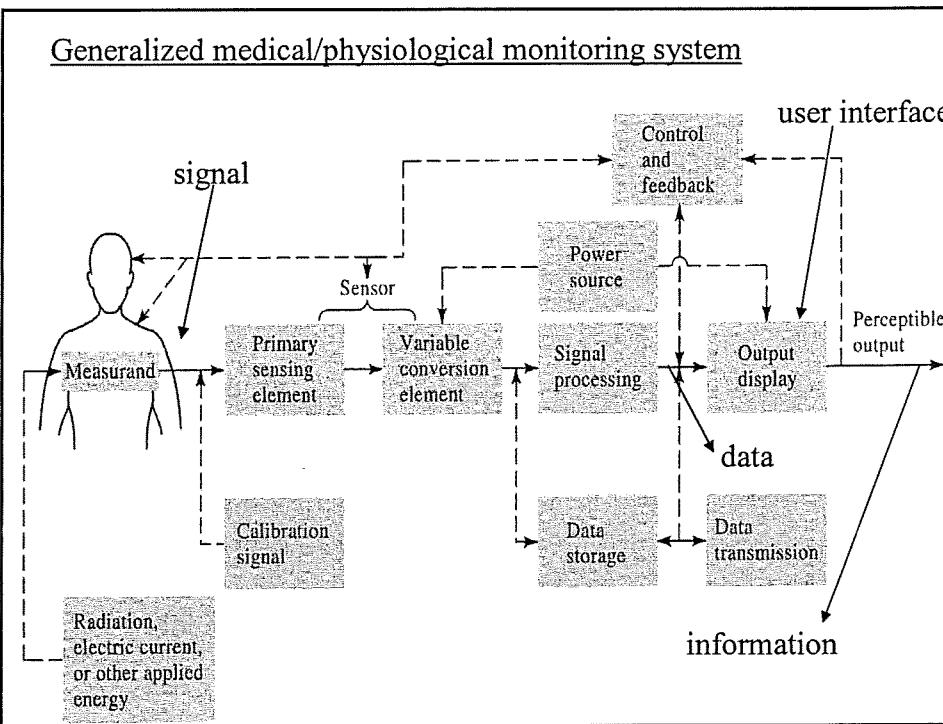


**Fig. 1**—Injection of cold dextrose and temperature/time graph.

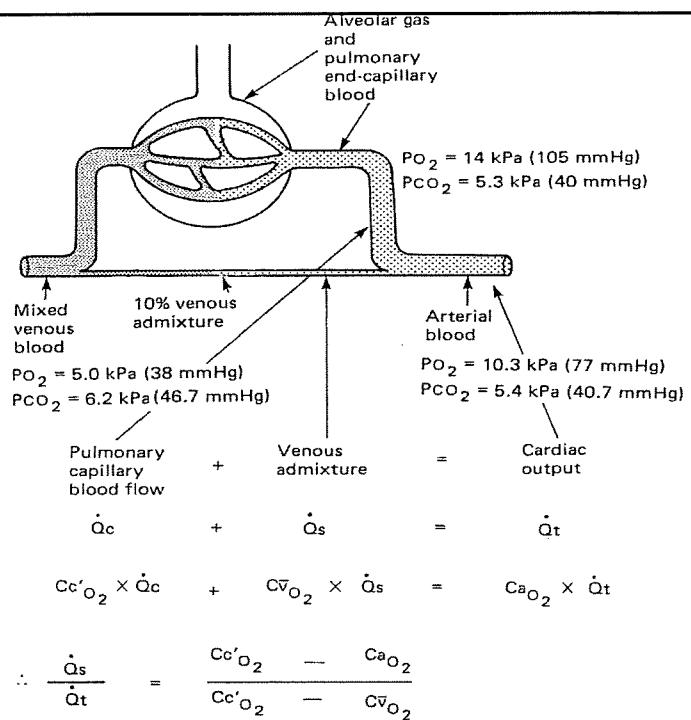
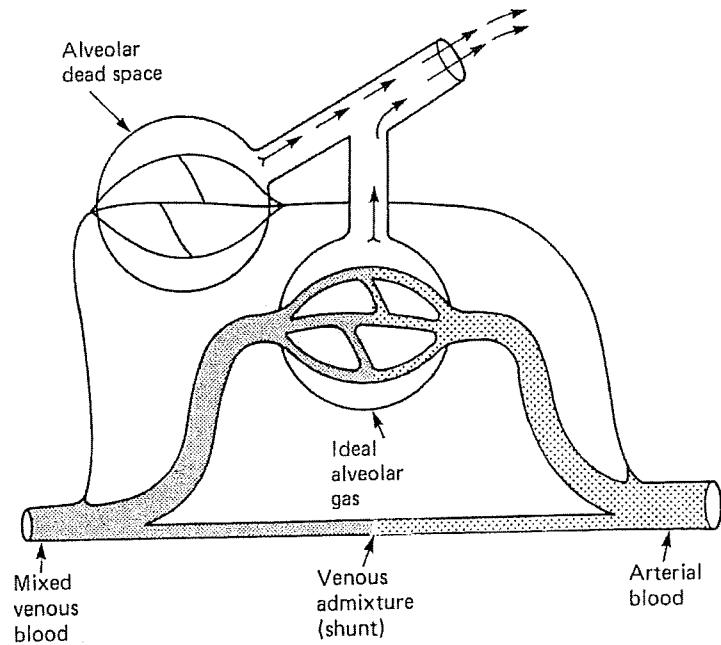
Thermodilution techniques applied to flow-directed pulmonary artery catheters with thermistors (Ganz *et al.*, 1971) allowed the use of cold water as the indicator and revolutionized the clinical application of cardiac output measurement. Only by an adequate understanding of the theory and assumptions behind the measurements can potential problems be recognized and averted. The Stewart-Hamilton equation is used to calculate cardiac output by the thermodilution technique:

$$\text{cardiac output} = V_i \times \frac{(T_b - T_i)}{\int_0^{\infty} \Delta T_b(t) dt} \times \frac{(S_i \times C_i)}{(S_b \times C_b)} \times 60 \times k$$

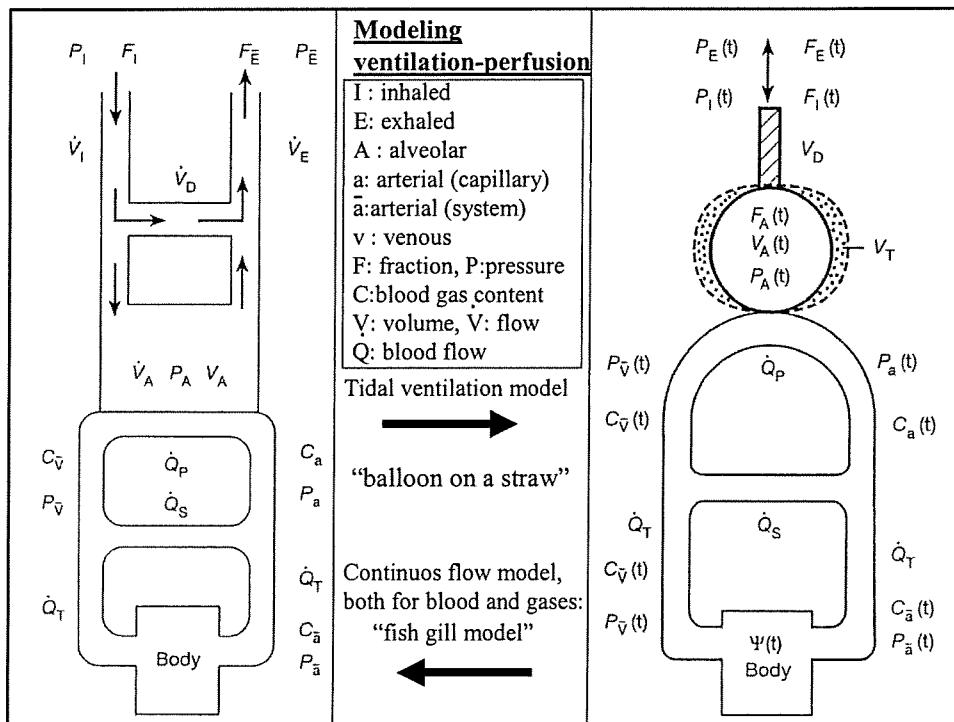
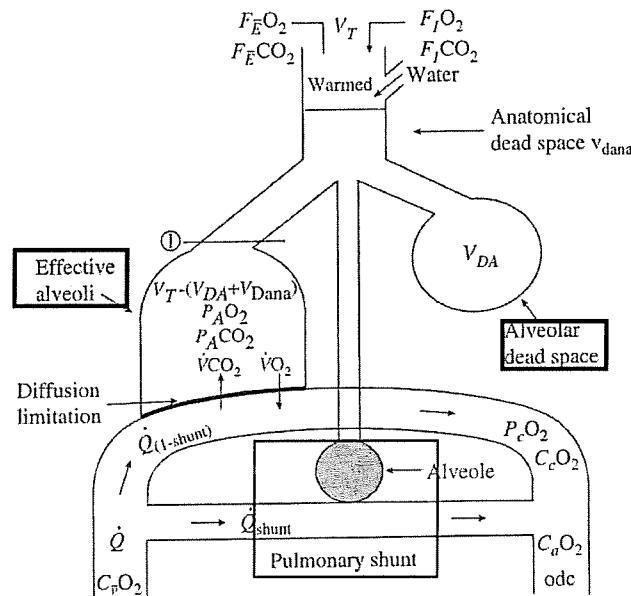
where  $V_i$  = volume injected;  $T_b$  = temperature of blood;  $T_i$  = temperature of injectate;  $S_i$  = specific gravity of injectate;  $S_b$  = specific gravity of blood;  $C_i$  = specific heat of injectate;  $C_b$  = specific heat of blood; and  $k$  = correction factor for loss of indicator during transit. The error associated with the manufacturers' calibration is < 5%.



Three-compartment model



### Simplified ventilation-perfusion model: 3 compartments



## CONTINUOUS-VENTILATION MODEL

The general mass balance equation for the alveolar gas:

$$V_A \frac{dF_A}{dt} = \dot{V}_A(F_I - F_A) - \dot{Q}_P(C_a - C_{\bar{V}})$$

Dead space:

$$\frac{\dot{V}_D}{\dot{V}_T} = \frac{F_{\bar{E}} - F_A}{F_I - F_A}$$

Shunt fraction:

$$\frac{\dot{Q}_S}{\dot{Q}_T} = \frac{C_a - C_{\bar{a}}}{C_a - C_{\bar{V}}}$$

Assume steady state:

$$\frac{dF_A}{dt} = 0$$

Heavily low-passed filtered!

Effects of lung volume variation missed!

For insoluble inert gases (e.g. wash-in/wash-out FRC):

$$V_A \frac{dF_A}{dt} = \dot{V}_A(F_I - F_A)$$

### PROBLEM/L5: $P_{AO_2}$

APPLY CONTINUOUS FLOW MODEL IN STEADY STATE

$$V_A \frac{dF_A}{dt} = \dot{V}_A(F_I - F_A) - \dot{Q}(C_a - C_{\bar{V}}) = 0$$

$\Rightarrow$  FOR  $O_2$ :  $\dot{V}_A(F_{IO_2} - F_{AO_2}) = \dot{V}_{O_2}$  (at alveolar-capillary boundary)

FOR  $CO_2$ :  $\dot{V}_A(F_{ACO_2} - F_{AO_2}) = -\dot{V}_{CO_2}$  — “ —

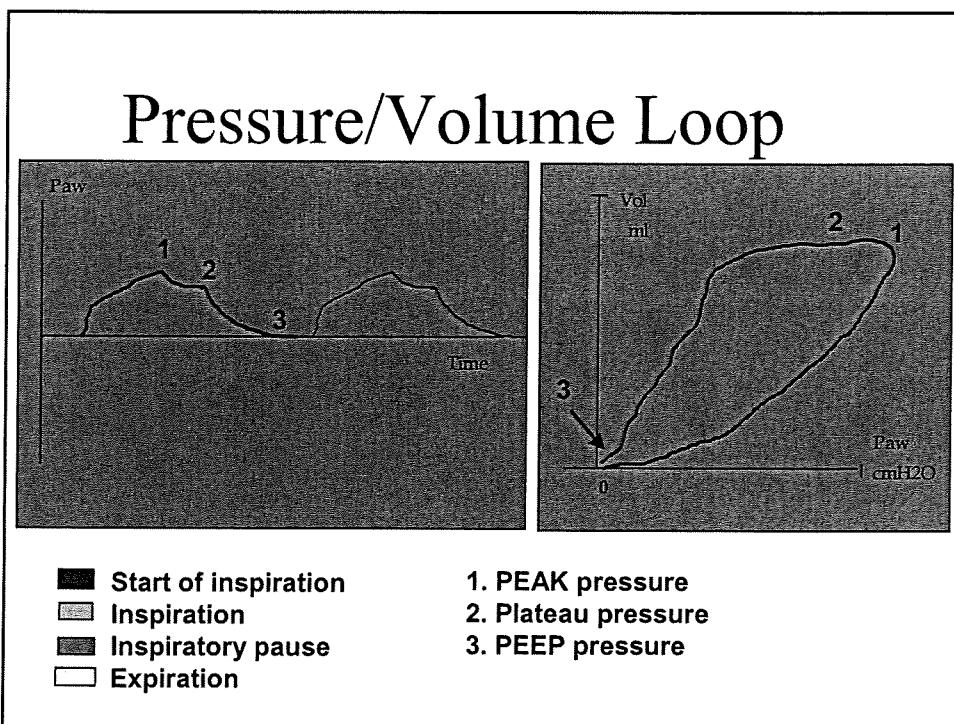
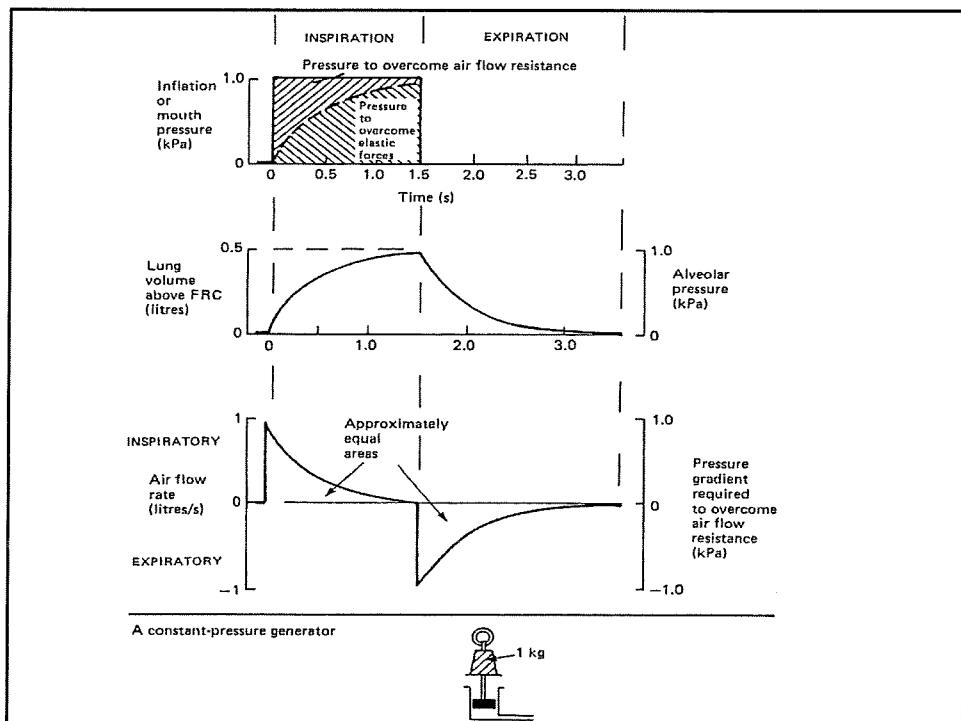
$$F_{ACO_2} \approx 0 \Rightarrow \dot{V}_A \cdot F_{ACO_2} = \dot{V}_{CO_2} \therefore \dot{V}_A = \frac{\dot{V}_{CO_2}}{F_{ACO_2}}$$

$$\Rightarrow \frac{\dot{V}_{CO_2}}{F_{ACO_2}} (F_{IO_2} - F_{AO_2}) = \dot{V}_{O_2}$$

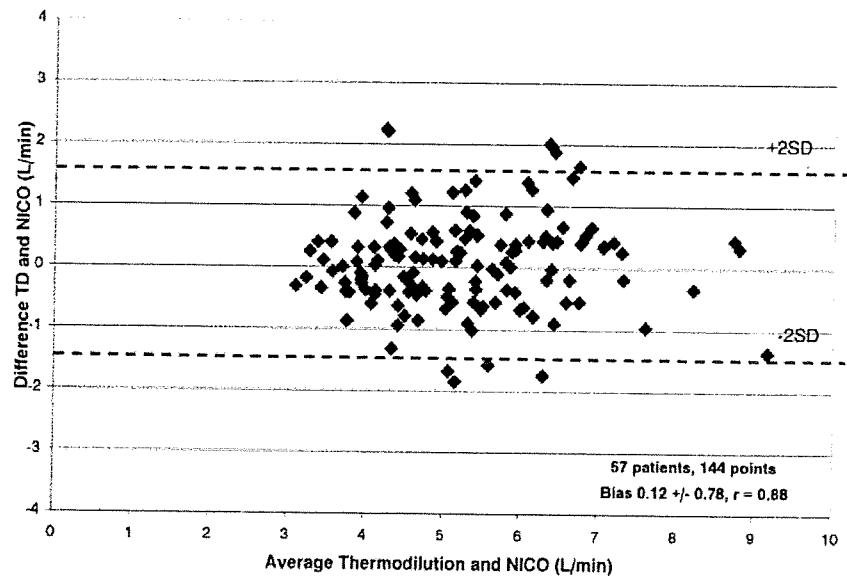
$$F_{IO_2} - F_{AO_2} = \frac{F_{ACO_2}}{\dot{V}_{CO_2}/\dot{V}_{O_2}} = \frac{F_{ACO_2}}{R}$$

$$\Rightarrow F_{AO_2} = F_{IO_2} - \frac{F_{ACO_2}}{R} = F_{IO_2} - \frac{F_{ACO_2}}{R}$$

$$\boxed{\boxed{P_{AO_2} = P_{IO_2} - \frac{F_{ACO_2}(P_{atm} - 47 \text{ mmHg})}{0.8}}}$$



NICO vs. thermodilution, Bland-Altman plot



Note e.g., how much can the worst case difference be at 4 L/min!

Gedeon vs. thermodilution

