Index of Microvascular Resistance (IMR) and Absolute Coronary Blood Flow (ACF)

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1. Concept(s) of dilution methods

2. Bolus injection: IMR

3. Continuous Infusion: ACF
Concept(s) of dilution methods

Indicators
- Dye
- Contrast Intensity
- Viscosity
- Hemoglobin
- pH
- Crypton
- Temperature
...

Concentration vs. Time, s
Concept(s) of dilution methods

1. Mixing of the indicator is complete
2. Heat exchange with adjacent tissue is negligible
3. Flow is constant during the measurement
4. No recirculation of the indicator during the measurement
5. The injection of the indicator does not cause any change to the flow
Concept(s) of dilution methods

\[ F = M / \int_{0}^{\infty} c(t) \, dt \]

- Amount ‘M’ of indicator should be known
- Vascular volume should not be known
Concept(s) of dilution methods

Rest: CO = 4.8 L/min
Dobutamine: CO = 8.7 L/min
Concept(s) of dilution methods

\[ F = \frac{M}{\int_0^\infty c(t) \, dt} \]

- Amount ‘M’ of indicator should be known
- Vascular volume should **not** be known

\[ F = \frac{V}{T_{mn}} \]

- Amount of ‘indicator’ should **not** be known
- Vascular volume ‘V’ should be known

**IMR and ACF**

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Concept(s) of dilution methods
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Temperature of the shaft of the wire

Temperature of the sensor
Concept(s) of dilution methods
Mean Transit Time, $T_{mn}$

= Mean time needed for the indicator to travel from the guiding to the sensor

Pijls NHJ et al Circulation 2002 105:2482
General Principle of Coronary Thermodilution

\[ F = \frac{V}{T_{mn}} \]

\[ T_{mn} (s) = \frac{V (mL)}{F (mL/s)} \]

\( T_{mn} (s) \) = an index of flow
$T_{mn}(s) = \text{an index of flow}$
IMR: Definition

Myocardial Resistance ($R_{myo}$) = \( \frac{P_d - P_v}{F} \) (mm Hg.mL\(^{-1}\).min\(^{-1}\))

Since: 
(1) \( F \approx \frac{1}{T_{mn}} \)
(2) \( P_v \approx 0 \) mm Hg

Then, \( IMR = \frac{P_d}{1 / T_{mn}} \)

Fearon WF et al Circulation 2003;107:3129
IMR = 79 \times 0.17 = 13.3
Bolus Coronary Thermodilution

Pitfalls and Limitations

- Location of the sensor too close to guiding
- Injection time ($T_{inj}$) too long
- ‘Wedging’ of the guiding in the ostium
- $T_{mn}$ too short (< 0.1 s)
- Side branches (especially when far from the guiding)
IMR: Definition

IMR = \( P_d \cdot T_{mn} \)

To take into account the effect of collaterals

Driving Pressure Across the Myocardium
Myocardial Flow

IMR = \( P_a \cdot T_{mn} \cdot \frac{P_d - P_w}{P_a - P_w} \)
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Continuous Infusion: ACF

Constant Flow of injectate (mL)

Concentration (temperature) over time (g/mL/min)

To be known:
- Flow of the pump (20 mL/min)
- Proximal Temperature
- Distal Temperature

\[ Q = Q_i \times \frac{T_i}{T} \times 1.08 \]

Aarnoudse W et al J Am Coll Cardiol 2007;50:2294
Continuous Infusion: ACF

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Catheter for continuous saline infusion

- 4 side holes allowing optimal mixing of saline
- Minimal or no saline dripping through the distal port
Catheter for continuous saline infusion

- 4 side holes allowing optimal mixing of saline
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Continuous Infusion: ACF

\[ Q = Q_i \times \frac{T_b - T_i}{T_b - T} \times 1.08 \]

Start infusion (20 mL/min)

Aarnoudse W et al J Am Coll Cardiol 2007;50:2294
Continuous Infusion: ACF

Tip guiding catheter

Infusion catheter

sensor
\[ Q = Q_i \times \frac{T_b - T_i}{T_b - T} \times 1.08 \]
Continuous Infusion: ACF

\[ Q = 25 \times \left( \frac{7.1}{0.97} \right) \times 1.08 = 173 \text{ mL/min} \]
IMR and ACF

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Pa mean: 85
Pd mean: 77
FFR: 0.91

-1.95 dT
CURSOR: 119.73

AUTOSCALE
Absolute hyperemic coronary flow: 126 mL/min
Minimal myocardial resistance: 0.436 mm Hg/mL/min
ACF: Validation Studies

IMR and ACF

DOGS

MAN

Aarnoudse W et al J Am Coll Cardiol 2007;50:2294
Conclusion

Coronary thermodilution using a **bolus injection** allows the measurements of the mean transit time ($T_{mn}$, an index of coronary flow) and of IMR.

Coronary thermodilution by **continuous infusion** allows the measurement of absolute coronary blood flow.