**2017-2-10**  
*Compare and contrast two methods of measuring cardiac output.*

**Cardiac output:**
Amount of blood pumped by the heart in one minute
  \[ \text{Heart Rate} \times \text{Stroke volume} \]

**Cardiac output measurement can be performed:**
- **Invasively**
  - Pulmonary Artery Catheter
    - Thermodilution
    - Fick Principle
  - Indicator Dilution Technique
  - TOE
  - Arterial waveform analysis
    - PICCO
    - Vigileo
- **Non-invasively**
  - TTE
  - MRI
  - Thoracic impedance

<table>
<thead>
<tr>
<th>Thermodilution</th>
<th>Stewart-Hamilton Indicator Dilution Technique</th>
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<tbody>
<tr>
<td>Intro</td>
<td>Thermodilution remains the gold standard of cardiac output measurement. Invasive</td>
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| Equipment      | This technique:
  - Requires a pulmonary artery catheter
    - Various different designs exist. For CO measurement, they require:
      - A proximal port at the RA/SVC
      - A temperature probe at the tip
        - Typically a silicon oxide thermistor.
      - A balloon at the tip
        - To float it into position.
      - A distal (PA) port is required for measuring PAP and the PCWP, but is not required for CO calculation
  - dyes: indocyanine green, isobestic or radioactive isotope. |
| Method/ theoretical basis | Method:
  - A known volume of (typically dextrose) at a known temperature (classically cooled, but this is not required) is injected into the proximal port
  - The temperature of blood is measured at the tip
    This produces a temperature-time curve. The area under the curve can be used to calculate cardiac output, as per the modified Stewart-Hamilton Equation:
  - rapidly inject 10mL of dye into venous circulation in RA.
  - indicator mixes quickly with cardiac contents.
  - during next few beats, blood-indicator mixture is measured by continual sampling from proximal artery in arm for one complete circulation (30 seconds). |
| Adv / Disadv / errors | • Natural variability  
Cardiac output varies up to 10% with changes in intrathoracic pressure during respiration. Therefore:  
  o A mean of 3-5 measurements should be taken  
  o Measurements should be taken at end-expiration  
• Incorrect volume of injectate  
  o Too much underestimates CO  
  o Too little overestimates CO  
• Warm fluid  
The closer the temperature of injectate is to blood, the greater degree of error introduced to the measurement.  
  o Colder injectate is more accurate, but carries the risk of inducing bradyarrhythmias  
• Poorly positioned PAC  
The PAC must be positioned in West's Zone 3 for blood flow to occur past the tip, and for the measured temperature to be accurate.  
• Tricuspid regurgitation  
Results in retrograde ejection of injectate back past the valve.  
• Arrhythmia | • mean concentration of mixture for one circulation determined.  
\[ Q = \frac{\text{amount of indicator injected}}{\text{indicator concentration over time}}. \]  
**Assumptions:**  
• retention of indicator  
• complete mixing  
• constant flow rate  
| Advantages: | • rapid Q determination  
Disadvantages: | • need to continuously withdraw arterial blood to plot the concentration curve.  
• dye can build up.  
• intracardiac shunt will effect recirculation. |

**Examiner Comments:**

35% of candidates passed this question.  
Good answers began with a definition of cardiac output. For each method, it was expected that candidates discuss the theoretical basis, equipment, advantages and disadvantages / sources of error and limitations. Additional marks were awarded when an attempt was made to compare and contrast the two methods (often helped by the use of a table).