# Additional information on pulse contour analysis

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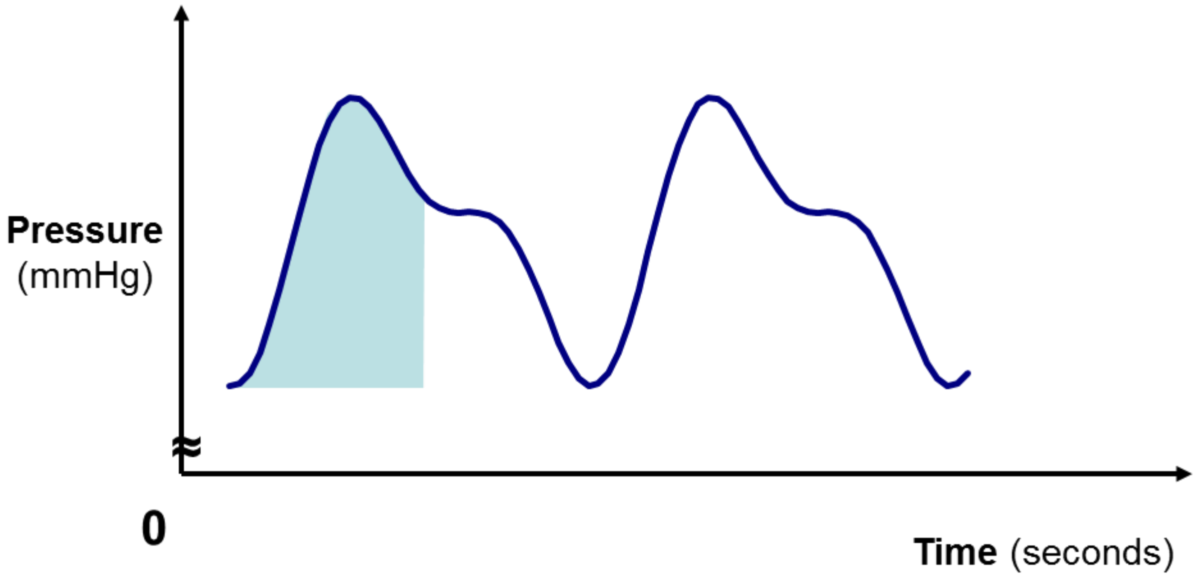
- Pulse contour analysis can be used to determine stroke volume and, thus, cardiac output
- There are two main systems in clinical use:
  - PiCCO
  - LidCO/PulseCO

# PiCCO

- Determine stroke volume using pulse contour analysis:
  - Integrate the arterial pressure waveform to find the area under the systolic part of the curve
  - Divide this value by the systemic vascular resistance (determined by thermodilution)
  - Although the above value can be used to estimate stroke volume, recent versions of PiCCO account for 2 other factors which improve its accuracy:
    - Afterload (represented by aortic compliance)
    - Contractility (represented by dP/dt)
- Determine stroke volume using transpulmonary thermodilution
- Compare the two determined stroke volume values to develop a calibration factor
- Combine these values in a formula to calculate cardiac output

# PiCCO




$$\text{Cardiac output} = cal \bullet HR \bullet \int_{Systole} \left( \frac{P(t)}{SVR} + C(p) \bullet \frac{dP}{dt} \right) dt$$

**Patient- specific calibration factor**
(determined by thermodilution)

**Heart rate**

**Shaded area under the pressure curve**

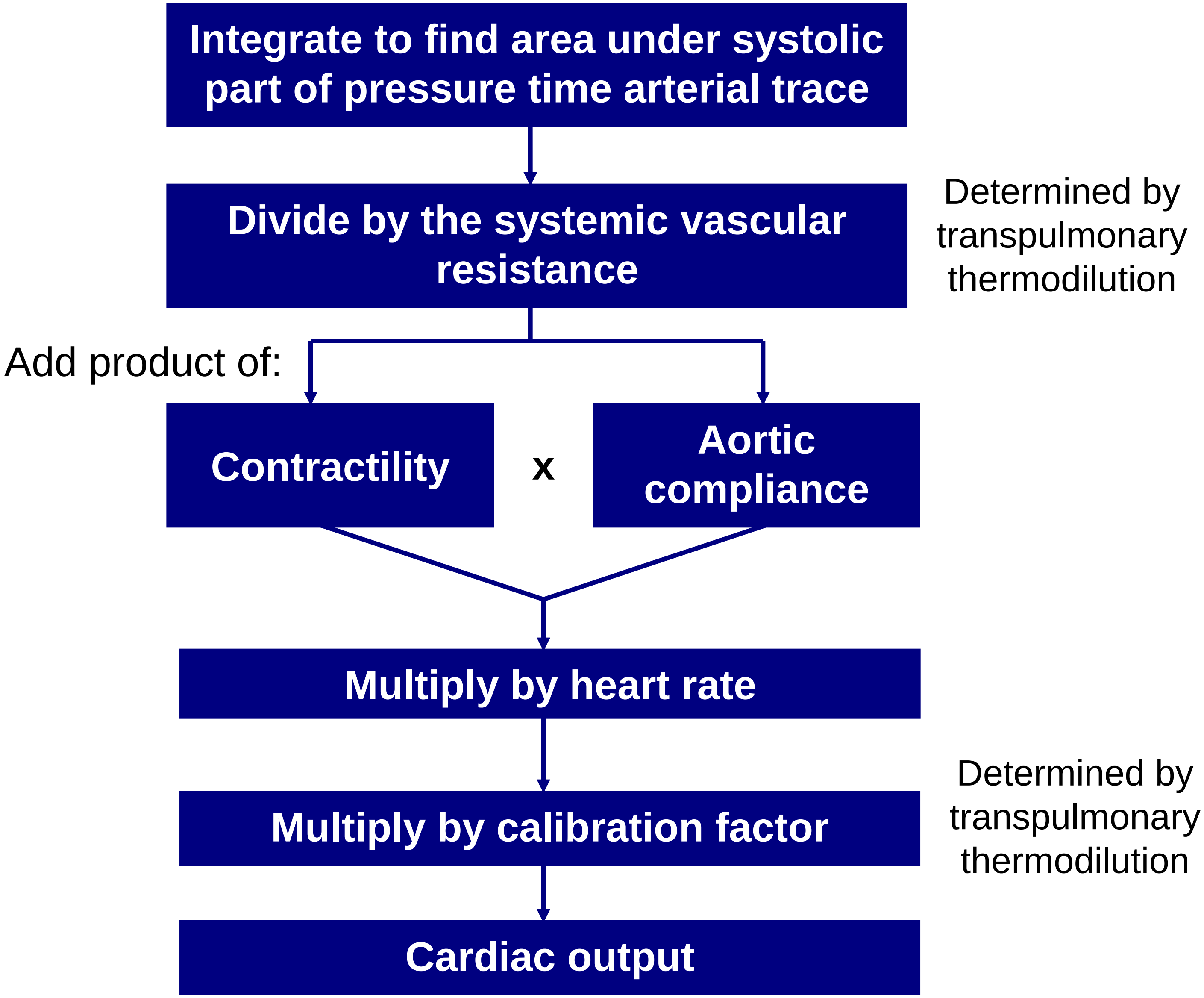
**Aortic compliance**

**Shape of the pressure curve**

**Stroke volume**

Redrawn from Pulsion, Haemodynamic monitoring – Theory & Practice[3]

# PiCCO: Summary

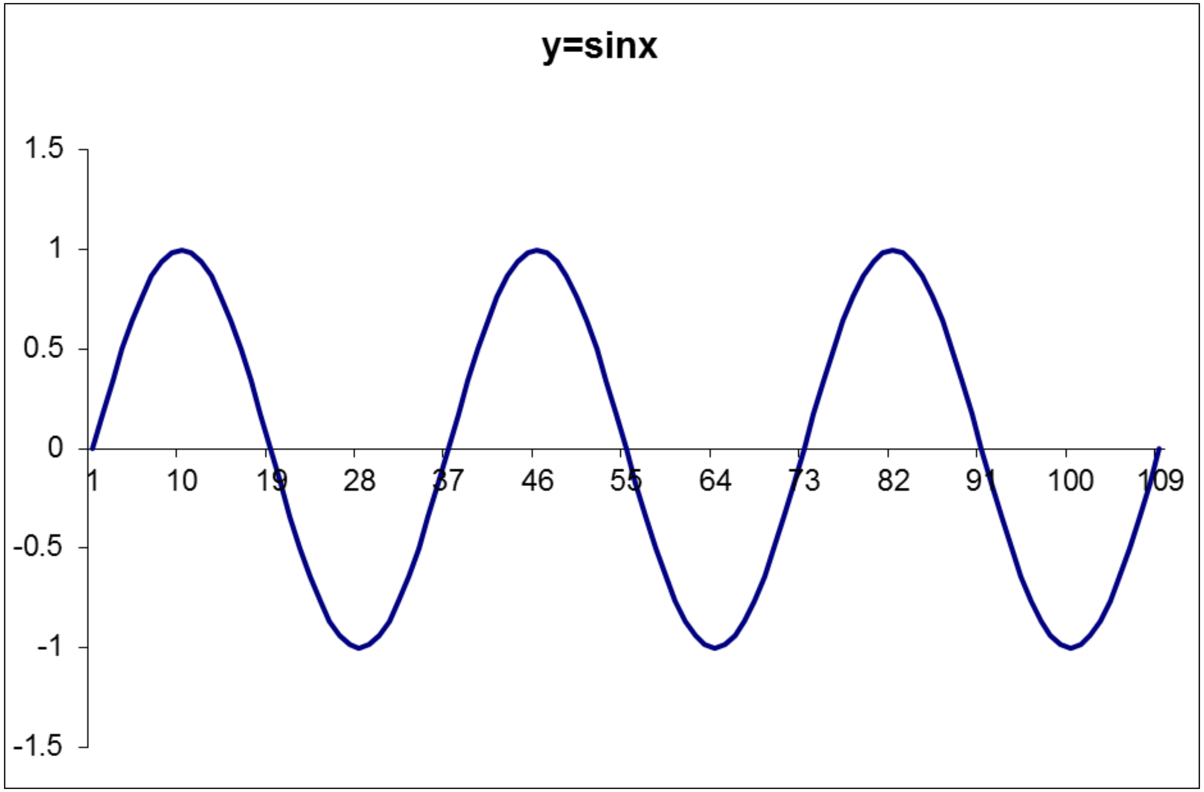


# LiDCO

- The pressure-time arterial trace is converted to a volume-time trace using a look-up table derived from experimental data
- The volume-time trace is then used to derive:
  - Nominal stroke volume using a root-mean-square value to estimate average blood displacement
  - Heart beat duration using a mathematical technique called auto-correlation
- These two parameters are combined to produce a value called nominal cardiac output
- Nominal cardiac output is converted to actual cardiac output using a calibration factor determined by lithium dilution

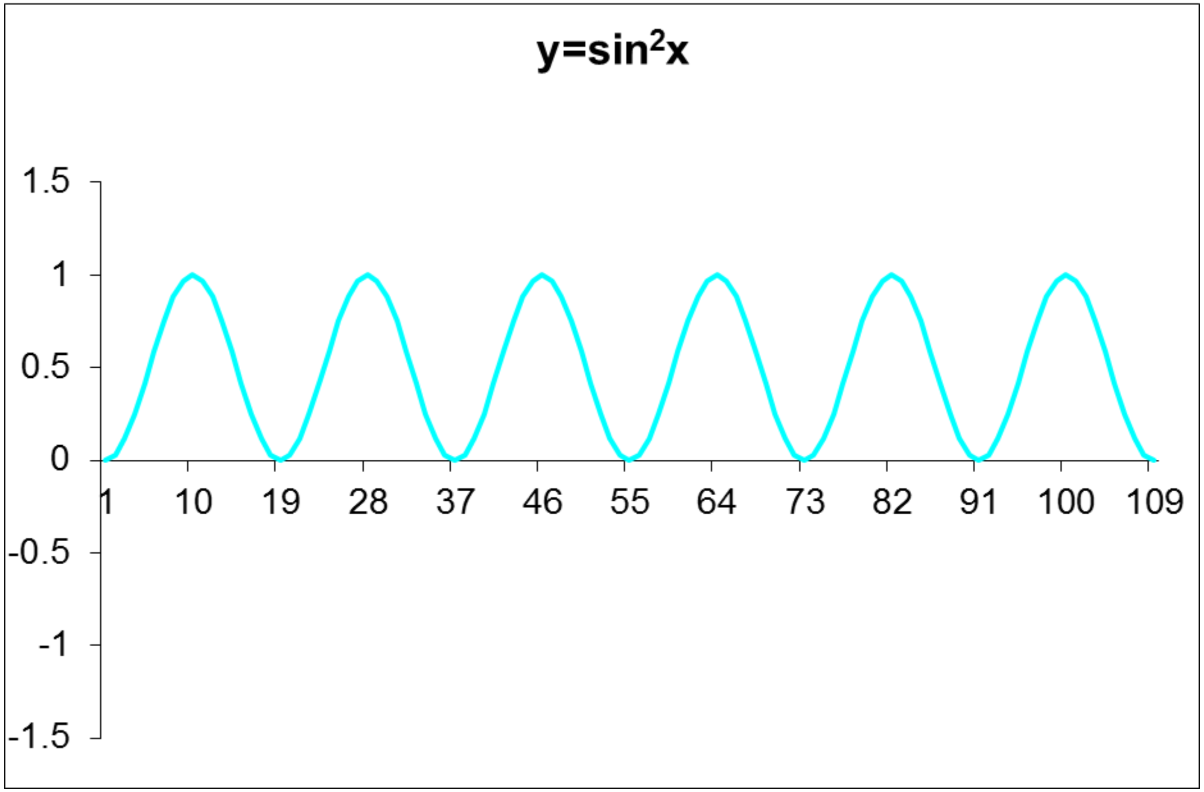
# LidCO: RMS

- Nominal stroke volume is derived by estimating the mean deviation of the arterial blood about a fixed point
- If the mean was calculated as usual, positive and negative aspects of the displacement would cancel each other out
- Deviation is therefore estimated by the root-mean-square (RMS) value
- Calculation of RMS is illustrated using y=sinx



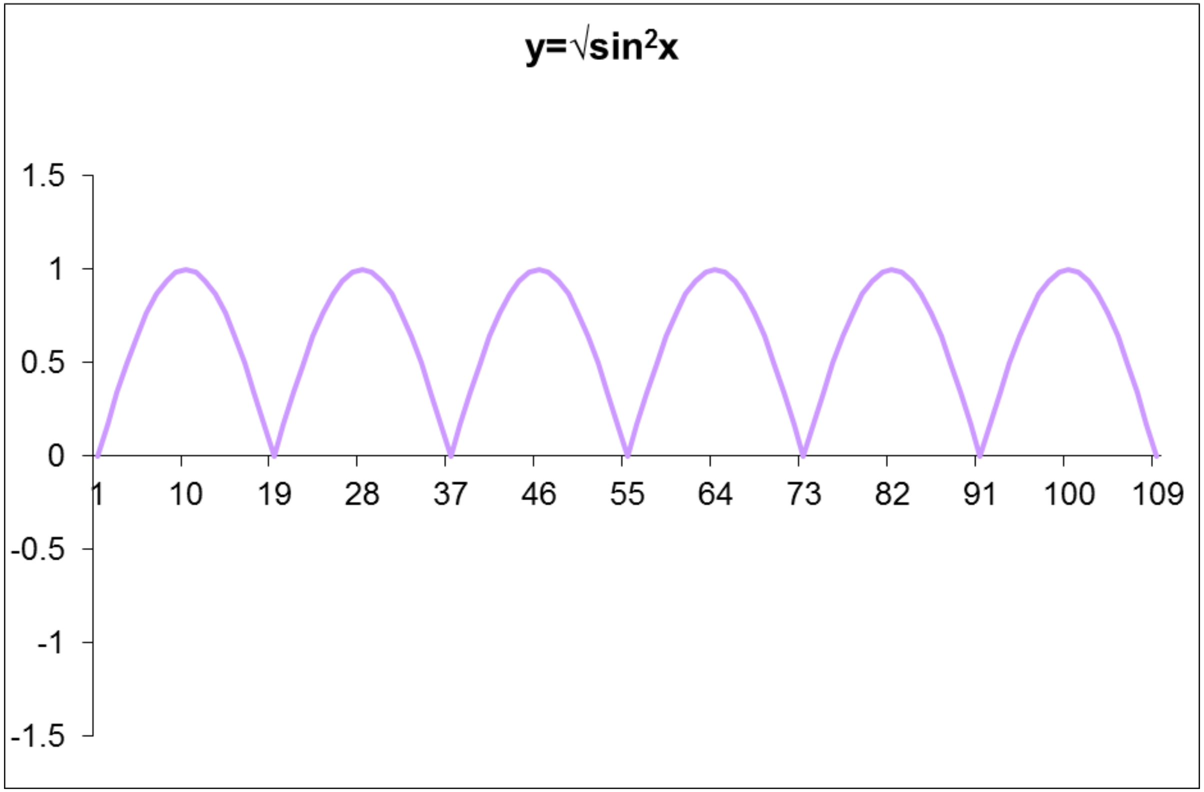
# LidCO: RMS

- First, the values are squared
- After multiplying all the values by themselves, they all become positive



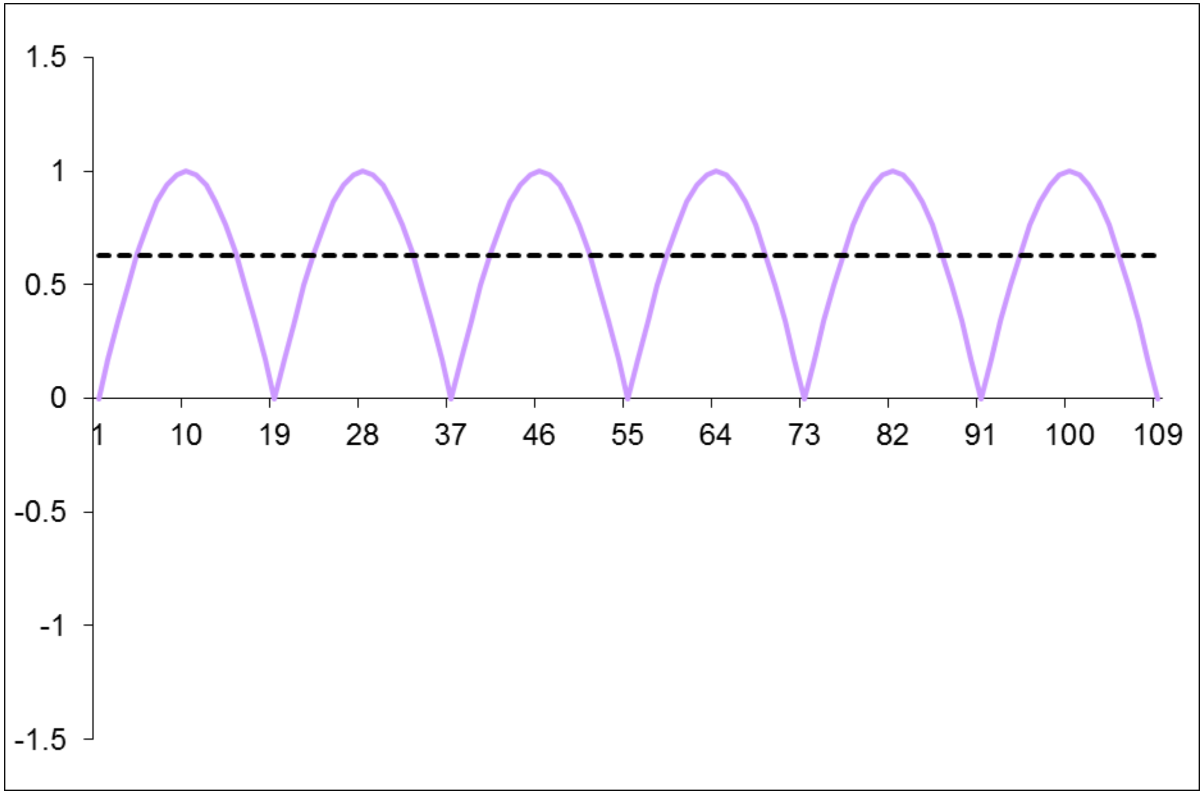
# LidCO: RMS

- A square root is now taken of the values



# LidCO: RMS

- Finally, a mean is taken of the values
- This will equal the root mean square (RMS) value
- It is usually around 70% of the maximum amplitude



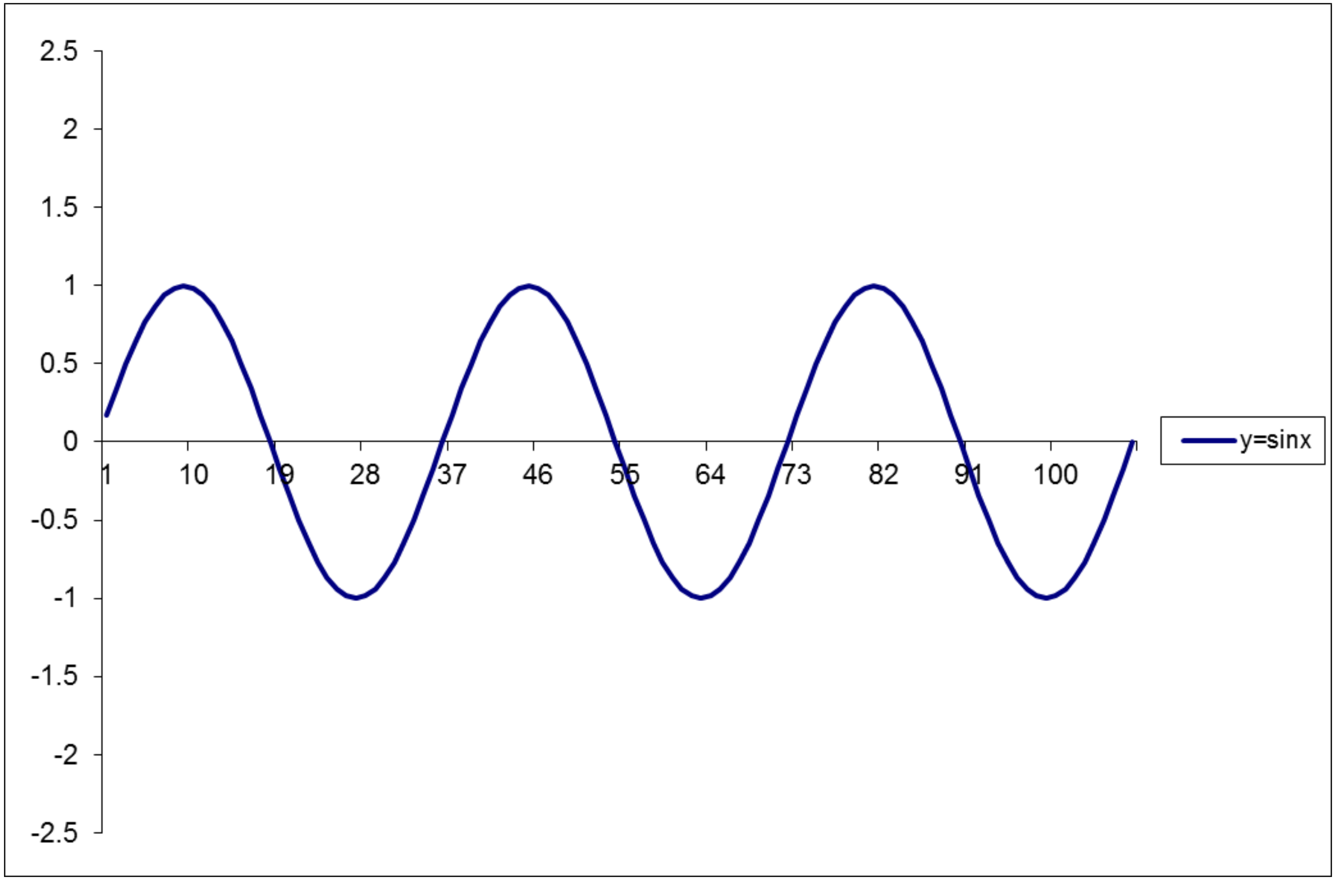

**Root mean square value**

# LiDCO: Autocorrelation

- Autocorrelation is a mathematical technique which is used to determine the time between arterial pressure peaks and thus the duration of a heart beat
- A small phase shift is performed on the wave and added to the original waveform
- This process is repeated with further phase shifts until the combined waveform has its maximum amplitude
- At this point, the waves must once again be in phase and the time between peaks can be calculated from the value of the phase shift

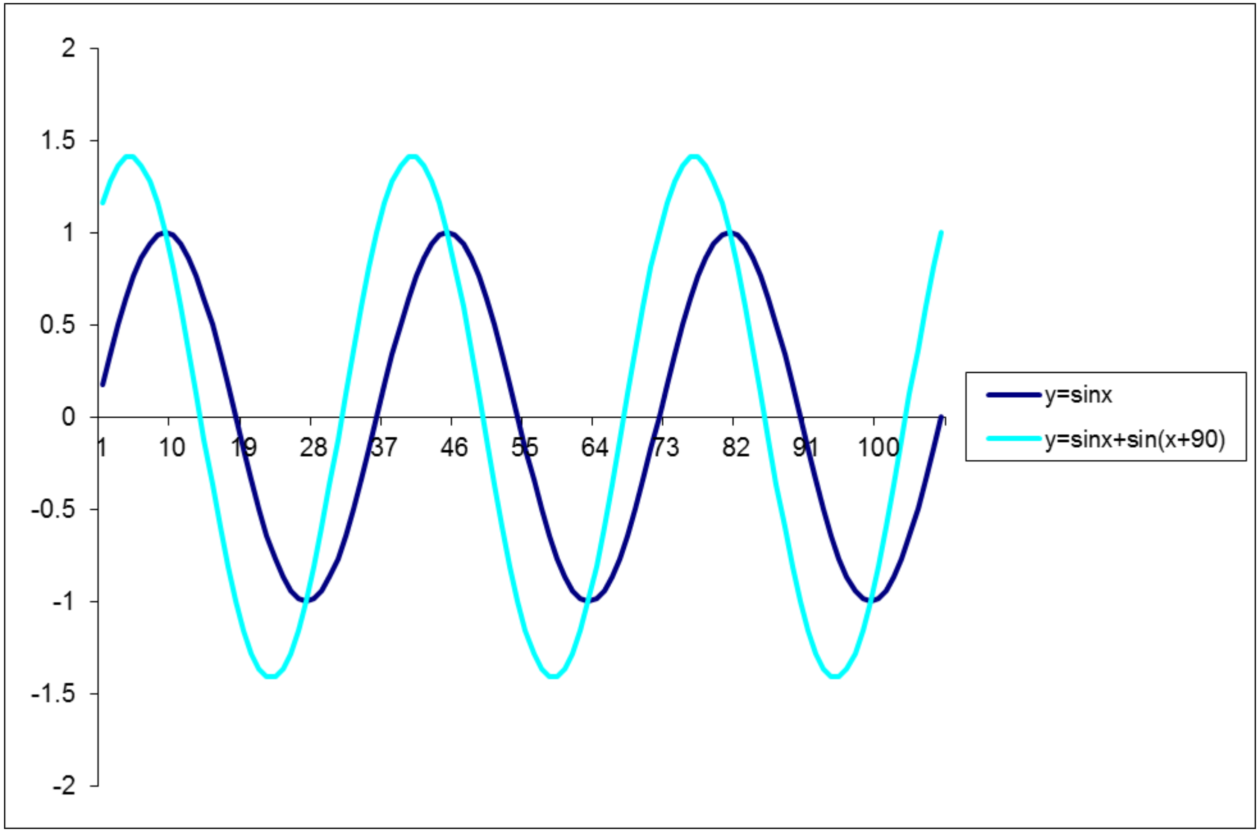
# LiDCO: Autocorrelation

- This can again be demonstrated using y=sinx



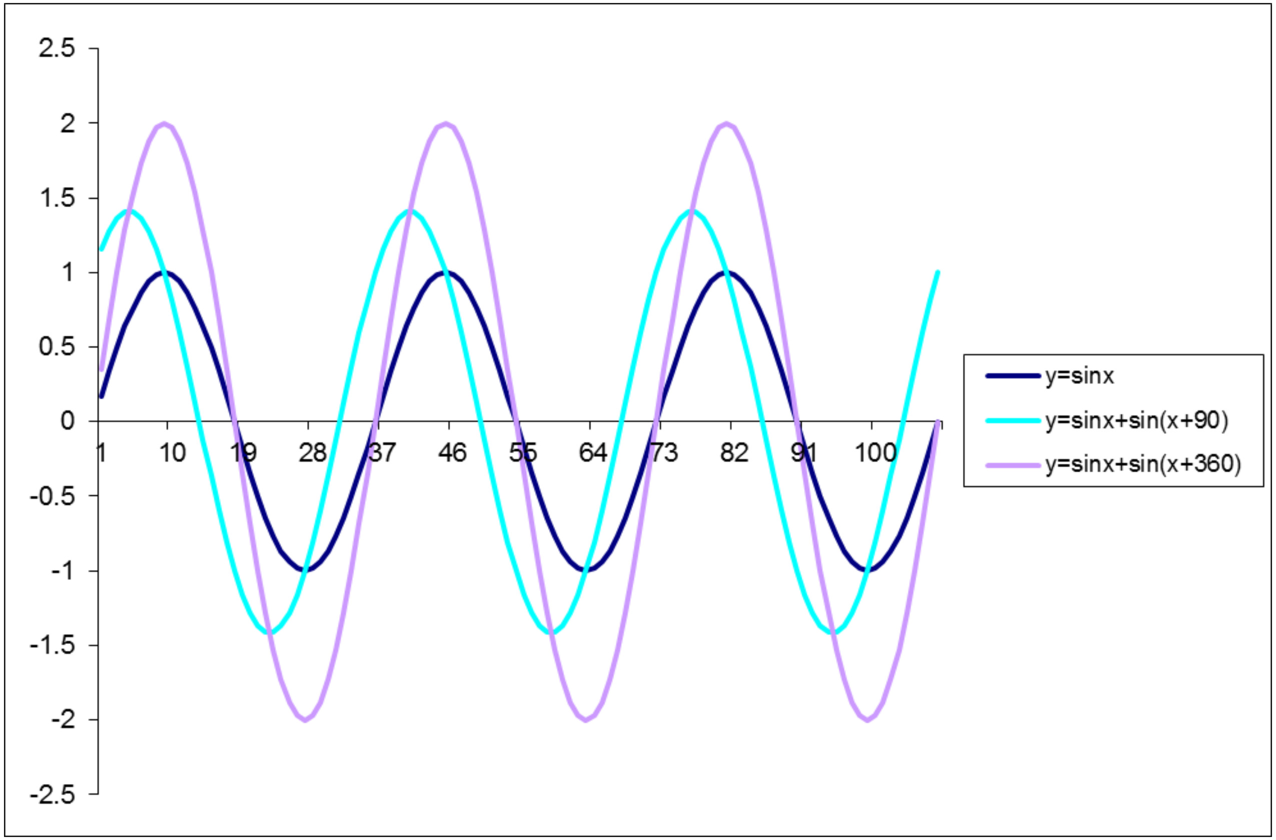
# LiDCO: Autocorrelation

- The sine wave is phase shifted by 90° and added to the original
- The amplitude of the combined sine wave increases



# LiDCO: Autocorrelation

- This process is repeated until the combined wave reaches its maximum amplitude (which is at 360° in this example)
- The degree of phase shift at which this occurs, allows the calculation of the time period of the wave
- This, in turn, is used to calculate the heart beat duration



# LiDCO: Summary