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Clinical Applications of Attractor Reconstruction Analysis

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1. Analysing pulse waveforms using Attractor Reconstruction (AR)

Pulse waveforms contain a wealth of information

Blood pressure and pulse oximetry signals are routinely acquired during physiological assessments. These pulse waveforms contain much physiological information (see right). Currently only simple measures such as heart rate and blood pressure values are routinely extracted from them.

Physiological information in a pulse waveform
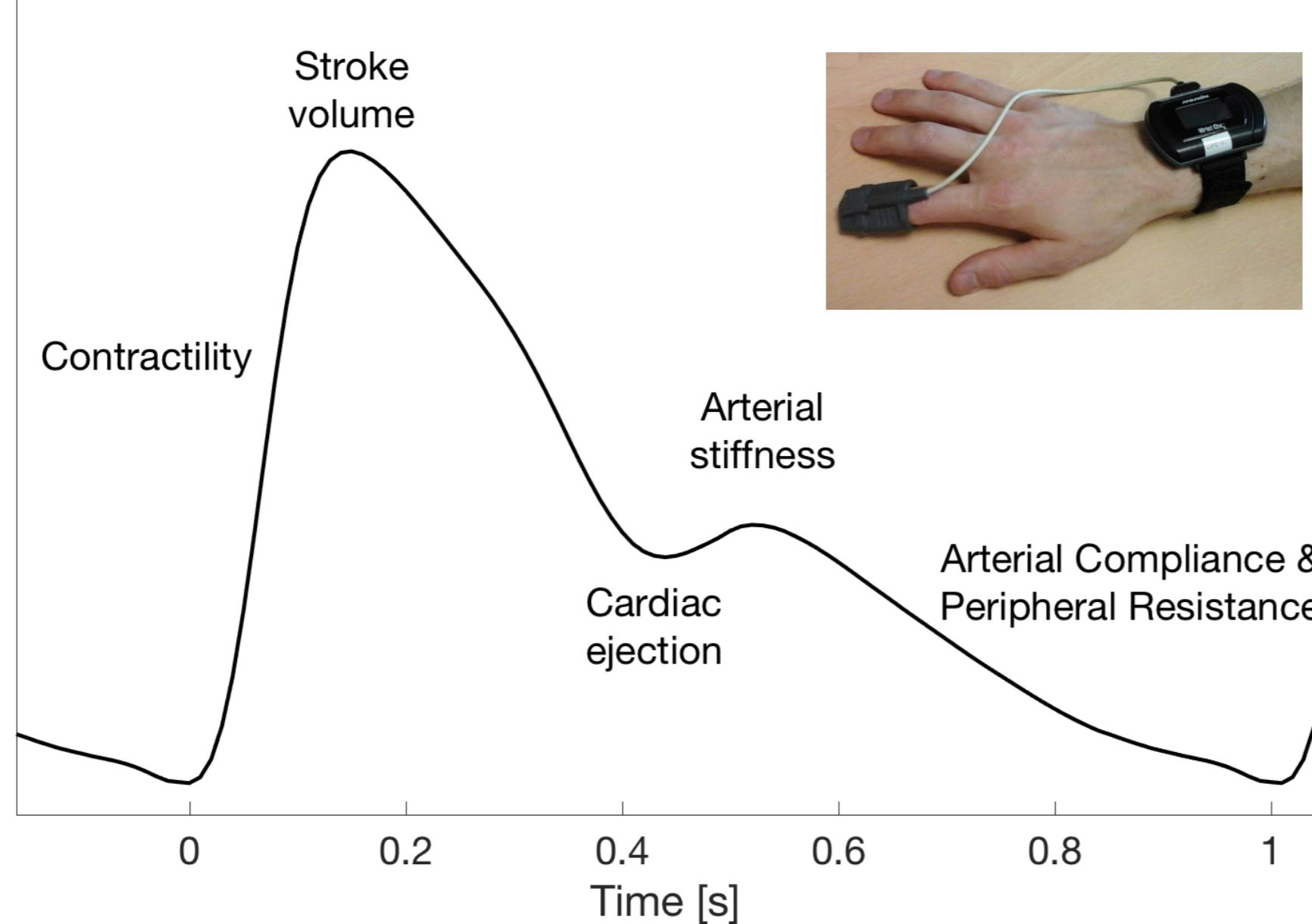
Attractor Reconstruction (AR)

AR is a novel mathematical technique for analysing periodic signals. It transforms a **signal** into an **attractor** (see right). The resulting attractor can be used to extract information on the variability and shape of the signal.

Changes in the shape or variability of an attractor may indicate changes in cardiovascular health, or disease progression.
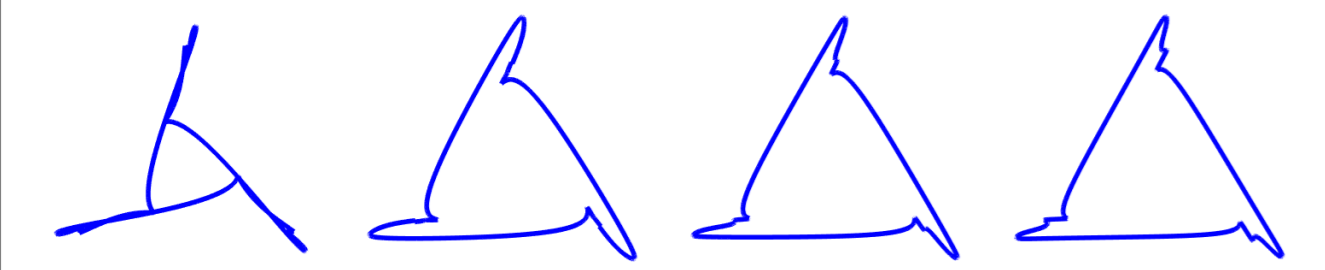

Arterial Blood Pressure Signals (mean). Corresponding Attractors. Low variability. High variability.
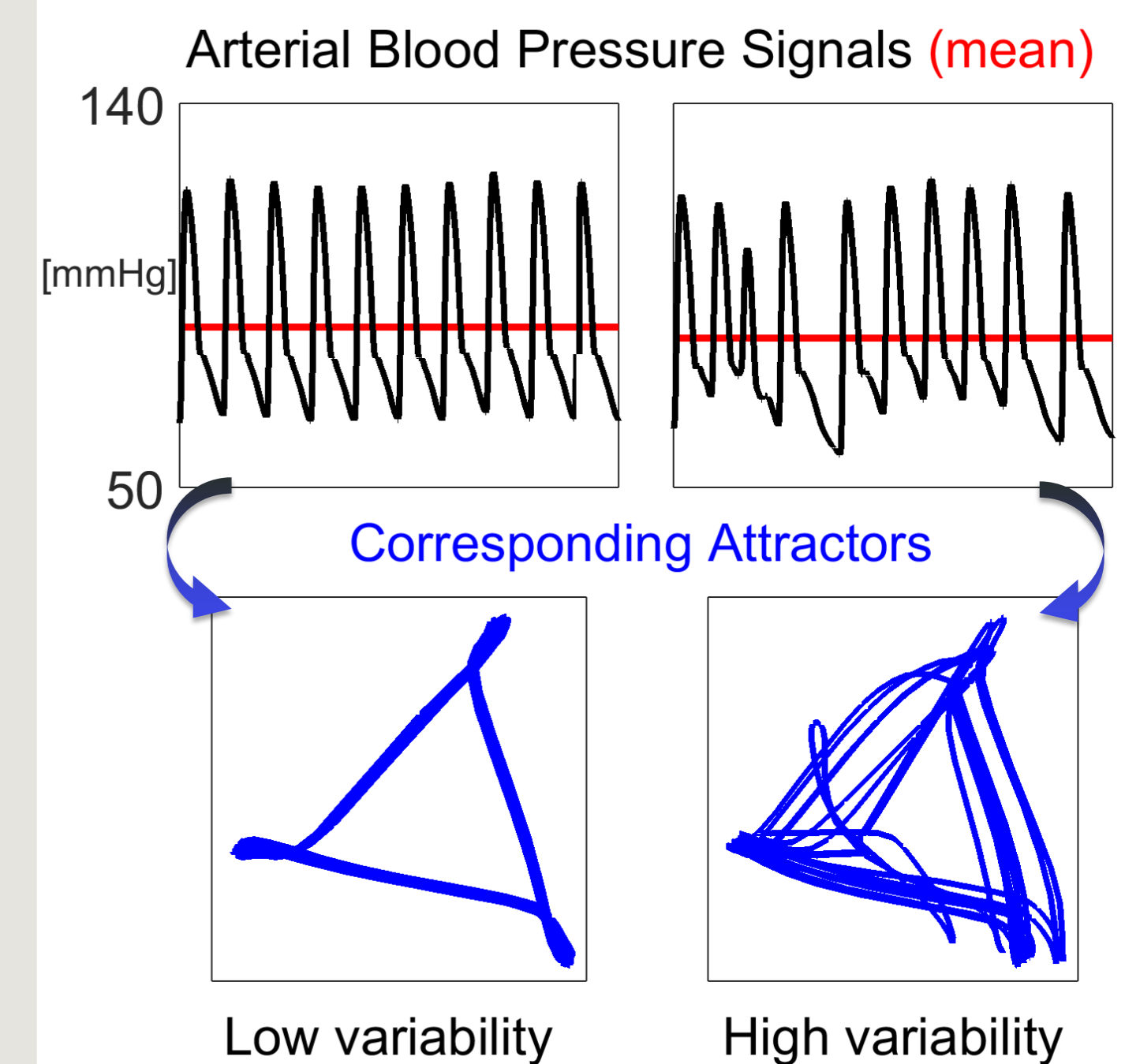
2. Physiological Insights

Vascular Properties

The properties of the smaller arteries affect the morphology of attractors obtained from a pulse oximetry waveform. This is demonstrated for vascular stiffness and diameter below.
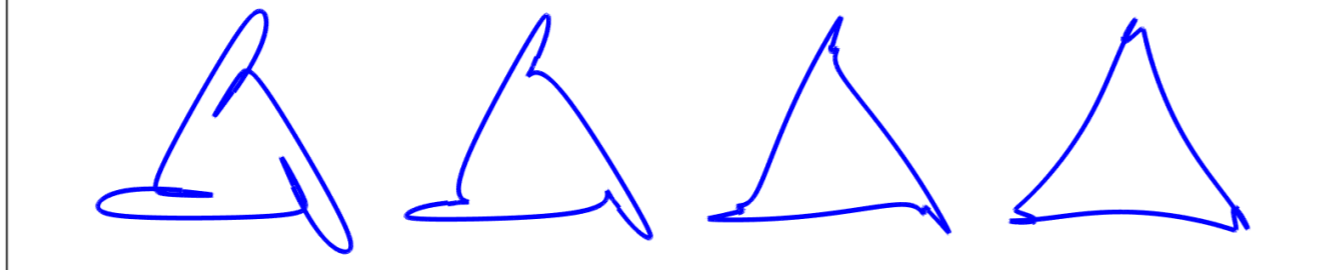

Increasing vascular stiffness
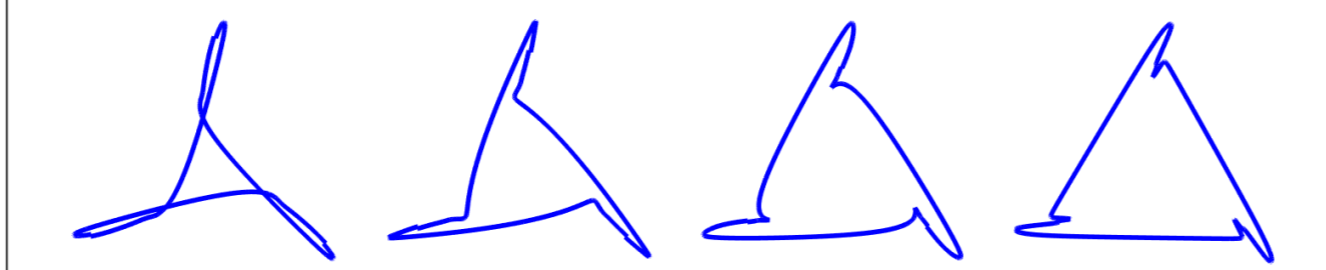Increasing vascular diameter

Cardiac Properties

The properties of the heart affect attractors, even when measured distally using a pulse oximeter waveform. Two examples are shown below: ejection time and heart rate.
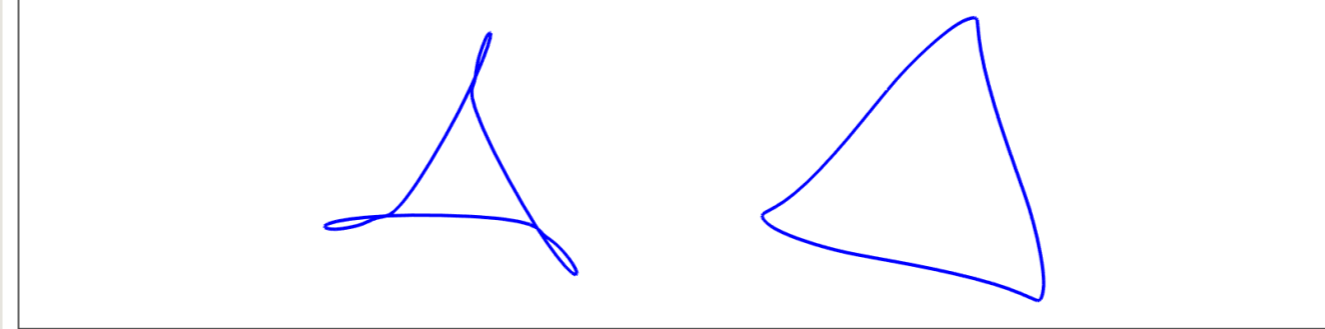

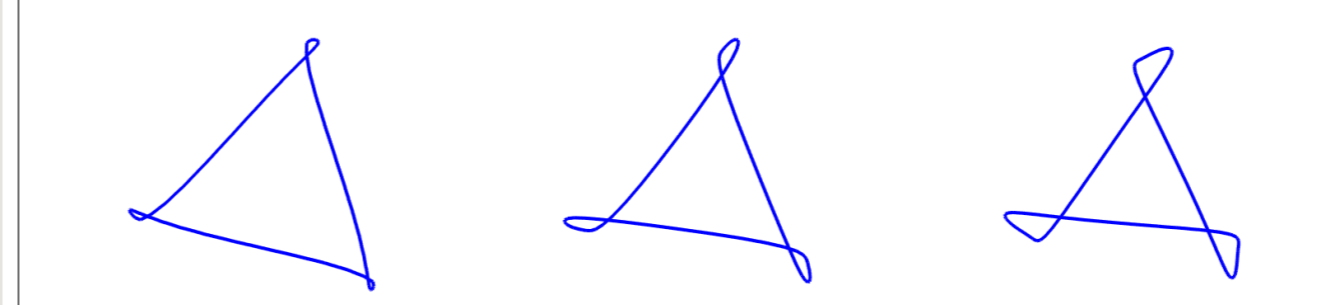Increasing ejection time
Increasing heart rate

Physiological State

The changes shown to the left were obtained from simulations of blood flow. Changes in attractors are also observed during physiological changes, as shown below.
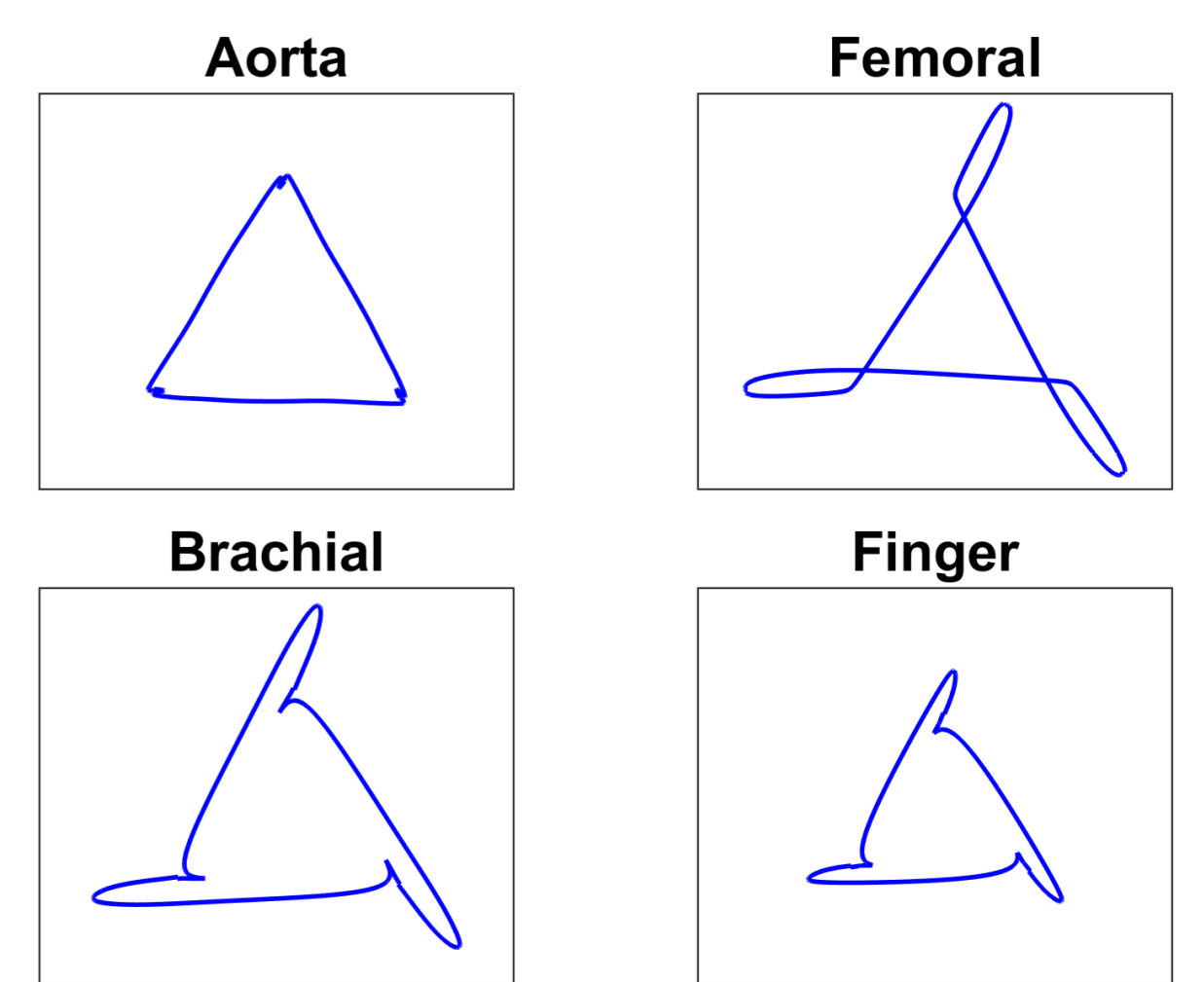

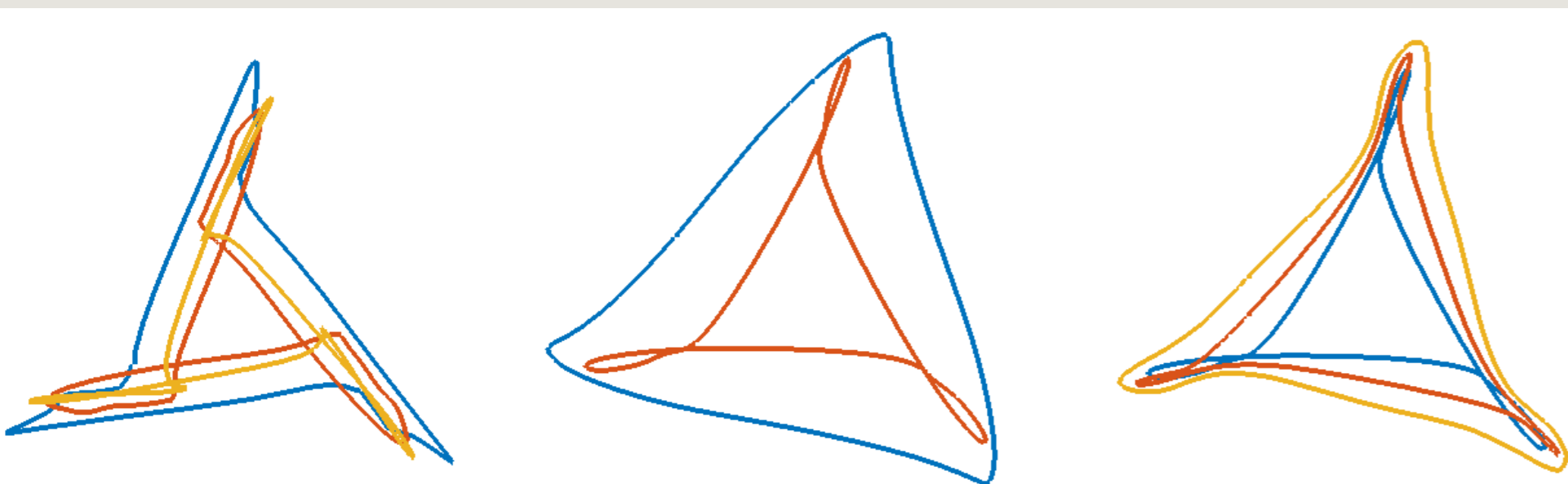Increasing age
Recovery from exercise

Measurement Site

The morphology of attractors varies according to the site at which they are measured, as shown by the four blood pressure attractors below.

Aorta   Femoral   Brachial   Finger

3. Detection of Sepsis

Changes in attractor shape which may be associated with the progression of sepsis

AR may provide early detection of sepsis

Sepsis is a heightened response to infection, which increases morbidity and mortality. Early detection is essential to prevent its progression. AR may allow markers of sepsis to be derived from physiological signals. This is due to the impact of sepsis on the cardiac, vascular and autonomic nervous systems, all of which influence the pulse waveform.

4. Respiratory Monitoring

Inhalation / Exhalation. Pulse Wave. Time [s]
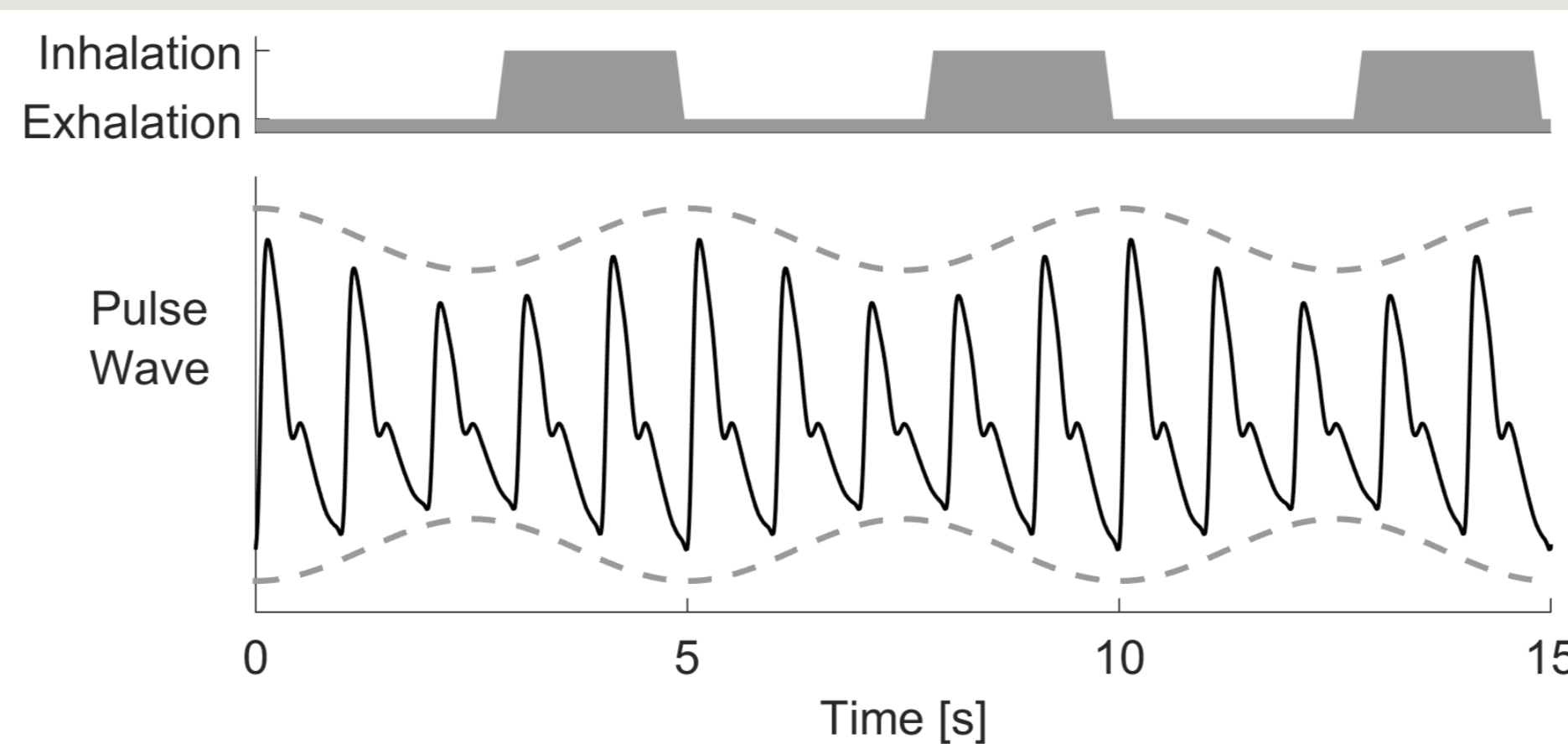
AR can improve respiratory rate (RR) estimation from the pulse oximeter

RR is usually measured by manually counting breaths. Techniques have been developed to estimate RR electronically from the pulse oximetry signal, although these are susceptible to inaccuracies. We have used AR to improve the accuracy of RRs derived from a pulse oximeter.

5. Measurement Accuracy

High quality. Low quality. Pulse oximetry signal. Attractor
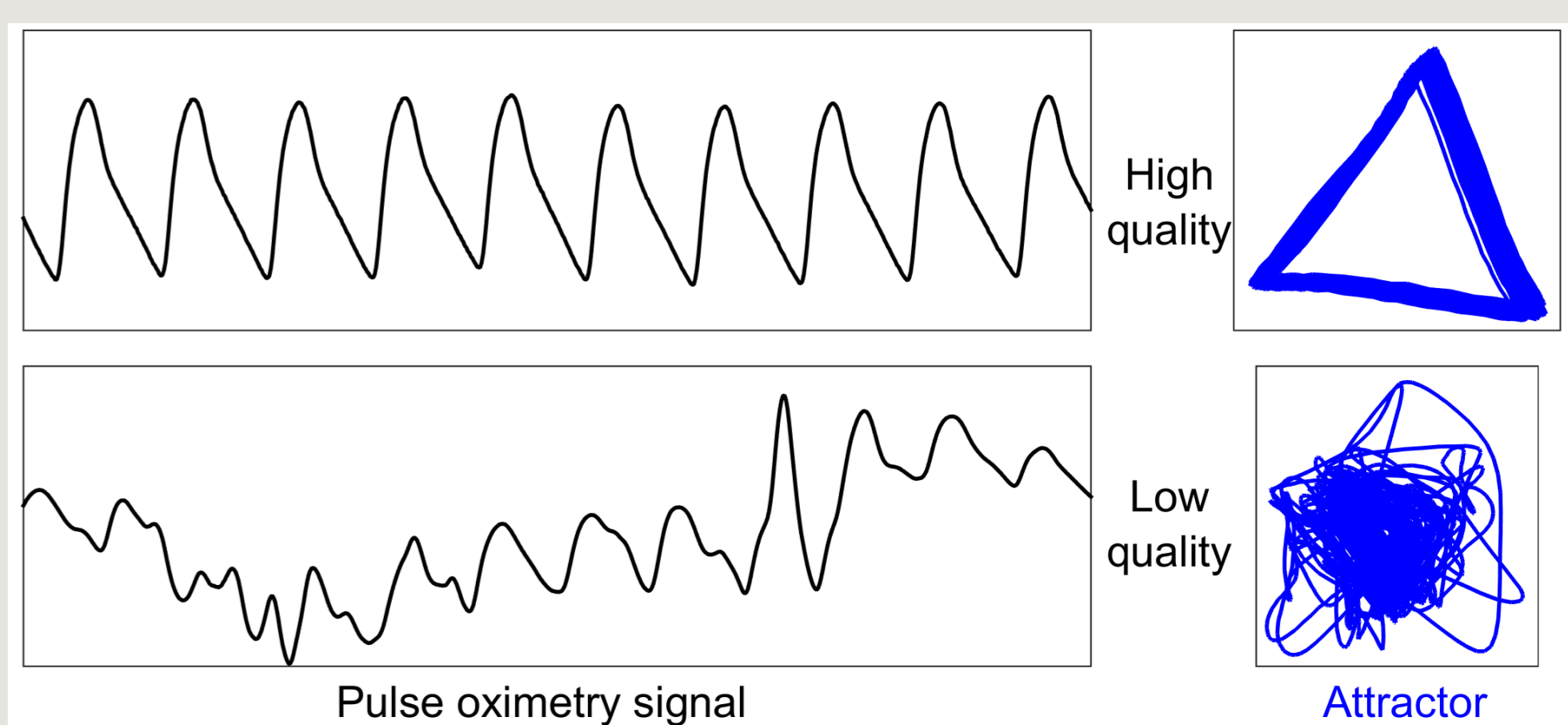
AR can be used to identify and eliminate inaccurate clinical measurements

Several clinical measurements are derived from physiological signals. The signals must be of high quality to ensure accurate measurements. Attractors change dramatically during periods of low signal quality. Therefore, AR could be used to automatically discard inaccurate measurements.

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