Tracking Variations in Cardiac Output from Pressure and Pulse Wave Velocity Measurements: A Proof-of-Concept Study

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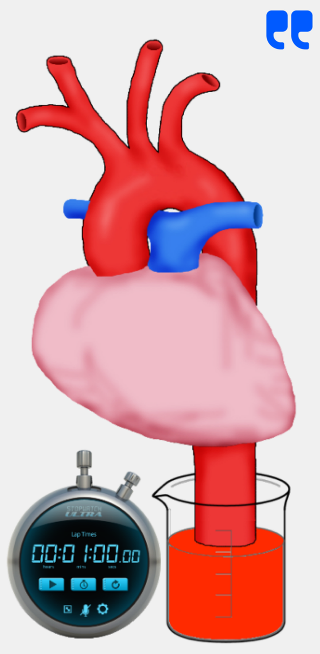
1 The importance of cardiac output

The blood pumped by the heart supplies vital organs with oxygen and nutrients. In intensive care units (ICU), it is of paramount importance to monitor the **volume of blood ejected by the heart in one minute**, called **cardiac output (CO)**, since a fall in CO is the usual cause for death in these units.

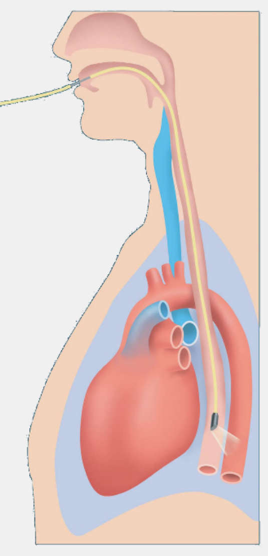


"Fluid management monitoring technologies can reduce mortality rates for elective procedures, improve the quality of care for **more than 800,000 patients a year**, and **save the NHS at least £400m annually**."

Sir David Nicholson,
Chief Executive of the NHS in England

2 Current problems

Accurate measurements of CO require **invasive access** or **specialist equipment**.
Non-invasive alternatives are based on **empirical observations** and could transform critical care outside of ICU, if they were sufficiently accurate, but they **perform poorly when tracking within-patient changes in CO.**

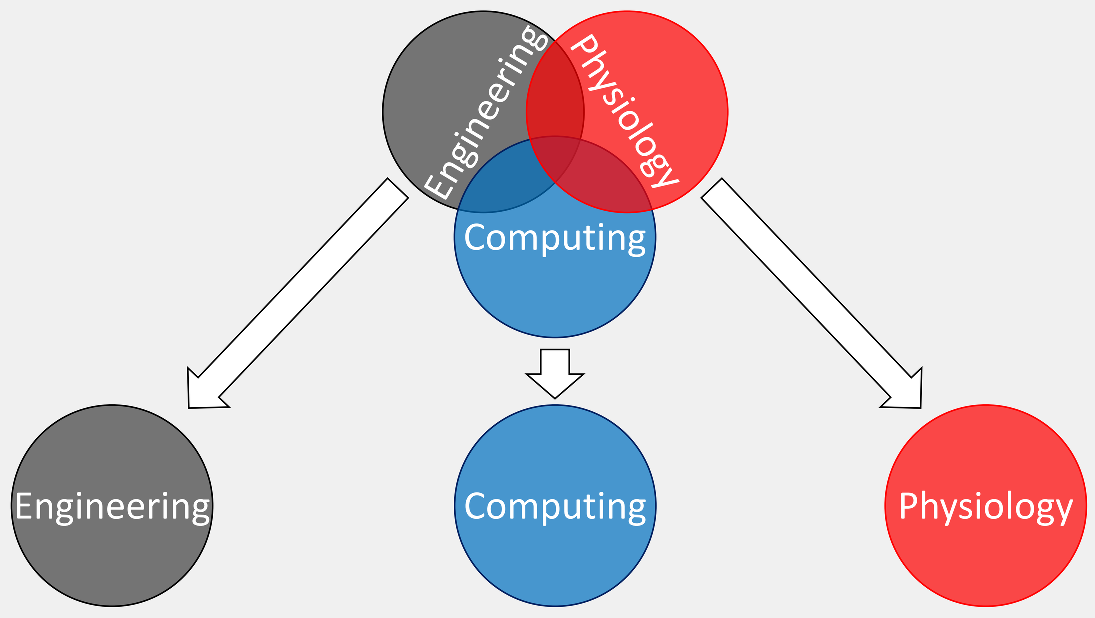


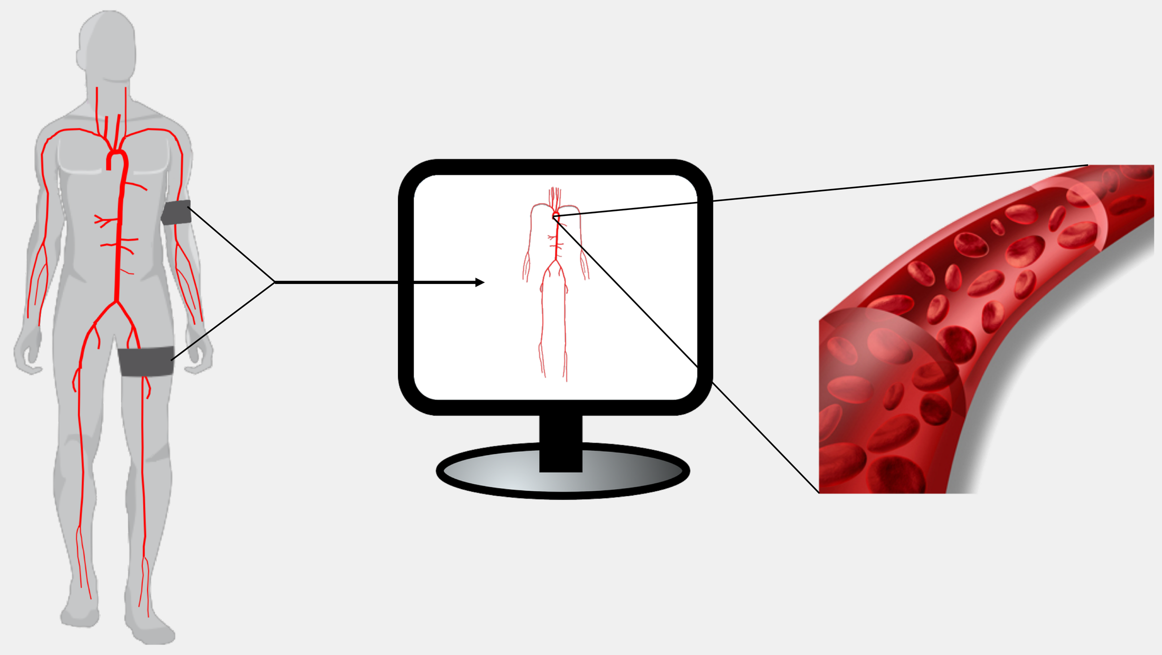
3 Our goal

Develop a protocol for tracking non-invasively variations in CO in patients from readily available blood pressure and pulse wave velocity (PWV) measurements

4 Engineering a protocol

We used a interdisciplinary approach to design the protocol





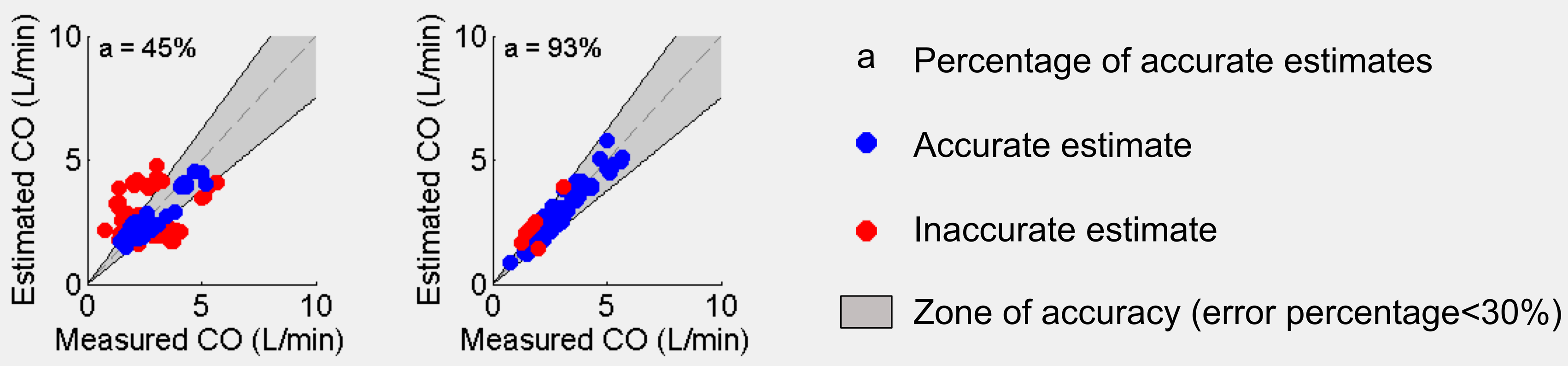
Pressure and PWV are routinely measured by **blood pressure cuffs** in clinics. We used a **validated computer model** of blood flow propagation along the arterial tree to engineer a protocol assessing CO from these measurements. Our protocol is consequently based on the **laws of physics**, unlike existing non-invasive alternatives that are based on empirical observations.

The protocol is composed of an algorithm that was:

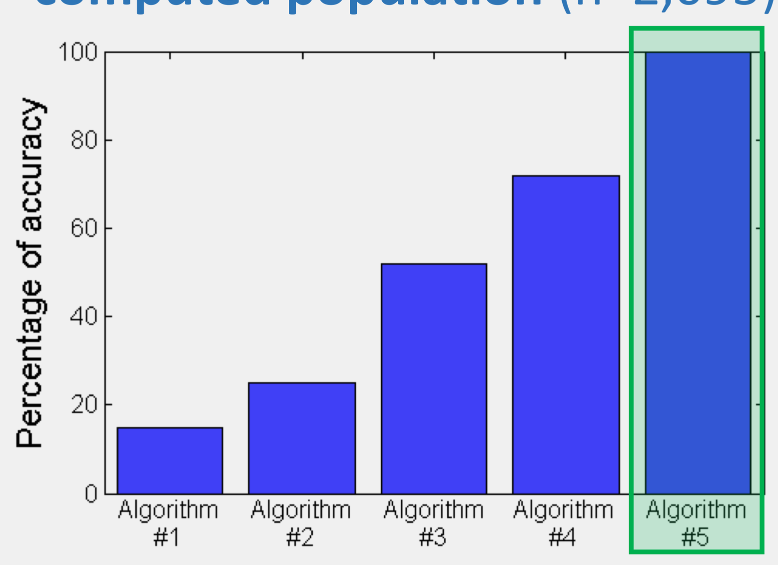
- engineered and refined using a virtual population of 2,095 patients generated by computer.
- tested as a proof-of-concept in 29 patients undergoing general anaesthesia at the Hôpital Lariboisière (Paris, France) to validate it and compare its performance with those of published algorithms used by existing devices (FloTrac-Vigileo, CardioQ-ODM, LiDCO, PiCCO monitors) for estimating 1) single CO values and 2) within-patient variations Δ in CO.

5 A promising proof-of-concept

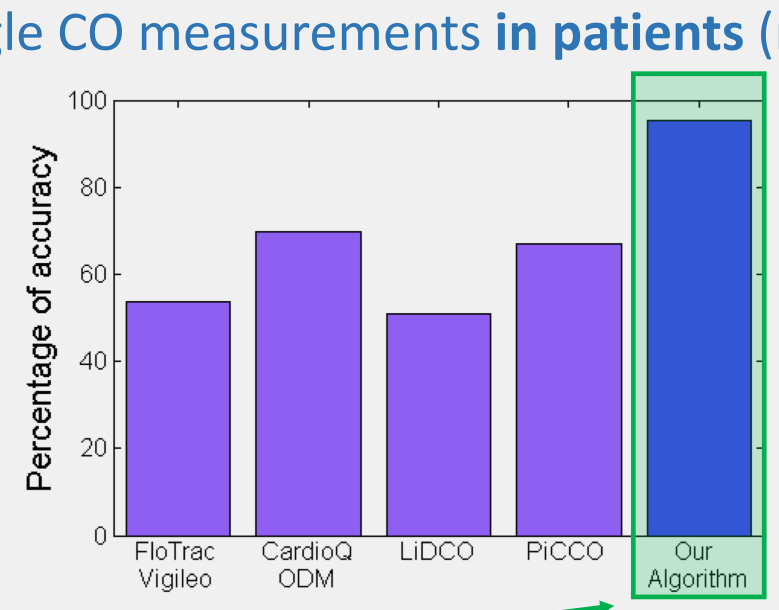
An estimate is deemed accurate if its error percentage **<30%**



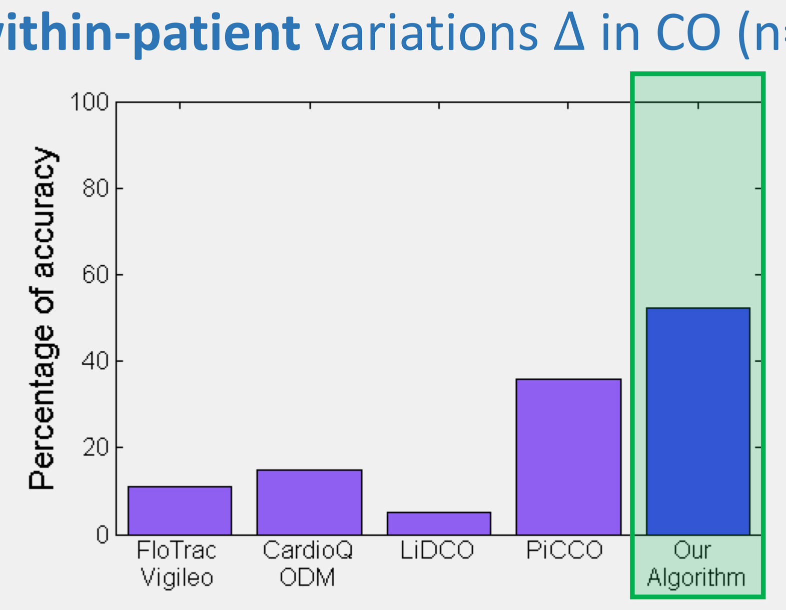
Engineering the algorithm in a **computed population** (n=2,095)



Testing the engineered algorithm by estimating single CO measurements **in patients** (n=106)



Testing the engineered algorithm by tracking **within-patient** variations Δ in CO (n=29)



6 Outperforming existing methods

Our protocol was the **best at estimating single CO measurements** (accuracy of 93%) when compared with algorithms used in existing devices. Importantly, our protocol was the **most accurate for tracking within-patient variations in CO** (accuracy of 52%) despite variations over a relatively small range (mean +6.4% variations across patients).

7 Potential impact

Because our technology only uses routinely measured information as inputs (pressure and PWV), it has the **potential to transform patient care** allowing measurements previously possible only in ICU or operating theatre to be deployed in lower dependency units. **The market for such technology is huge**.

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