

Continuous Non-Invasive Hemodynamic Monitoring to Optimize Atrioventricular Delay in Cardiac Resynchronization Therapy

Zachary I Whinnett, Justin ER Davies, Keith Willson, Anthony W. Chow, Rodney A. Foale, D. Wyn Davies, Alun D. Hughes, Darrel P. Francis, Jamil Mayet.
St Mary's Hospital and Imperial College London

Background

The atrioventricular (AV) delay of cardiac resynchronization devices should be optimized after implantation. Currently this is performed using echocardiography. The most frequently used method of optimisation relies on assessment of left ventricular inflow measured using transmitral Doppler flow.

Disadvantages of the echocardiographic method

- 1) While shortening a long AV delay can be beneficial, it is not clear whether meeting the echocardiographic target necessarily yields the maximal achievable hemodynamic benefit.
- 2) Because echocardiography is difficult at high heart rates, the optimization is typically limited to resting heart rate, which may have limitations in terms of optimizing cardiac performance.
- 3) Echocardiography requires a skilled operator, can be technically difficult and does not lend itself well to making multiple measurements of different combinations of pacing parameters.



Proposed alternative method: Non-invasive blood pressure measurements

In this study we propose the use of continuous non-invasive blood pressure (BP) measurement in order to measure the effect of changes in AV delay.

As Biventricular pacing therapy aims to improve the function of the heart, non-invasive measurement of the consequences of cardiac function on the vasculature (such as the blood pressure) is likely to represent a useful target for optimization.

We apply a finger photoplethysmograph (Finapres) to monitor blood pressure while AV delay is altered in order to identify optimal states.

This device uses an inflatable cuff around a finger in combination with a volume-clamp technique to monitor arterial pressure continuously, yielding beat-by-beat blood pressures.

Methods

The beat-by-beat blood pressure was recorded during adjustment of the AV delay of the subjects' biventricular pacemaker.

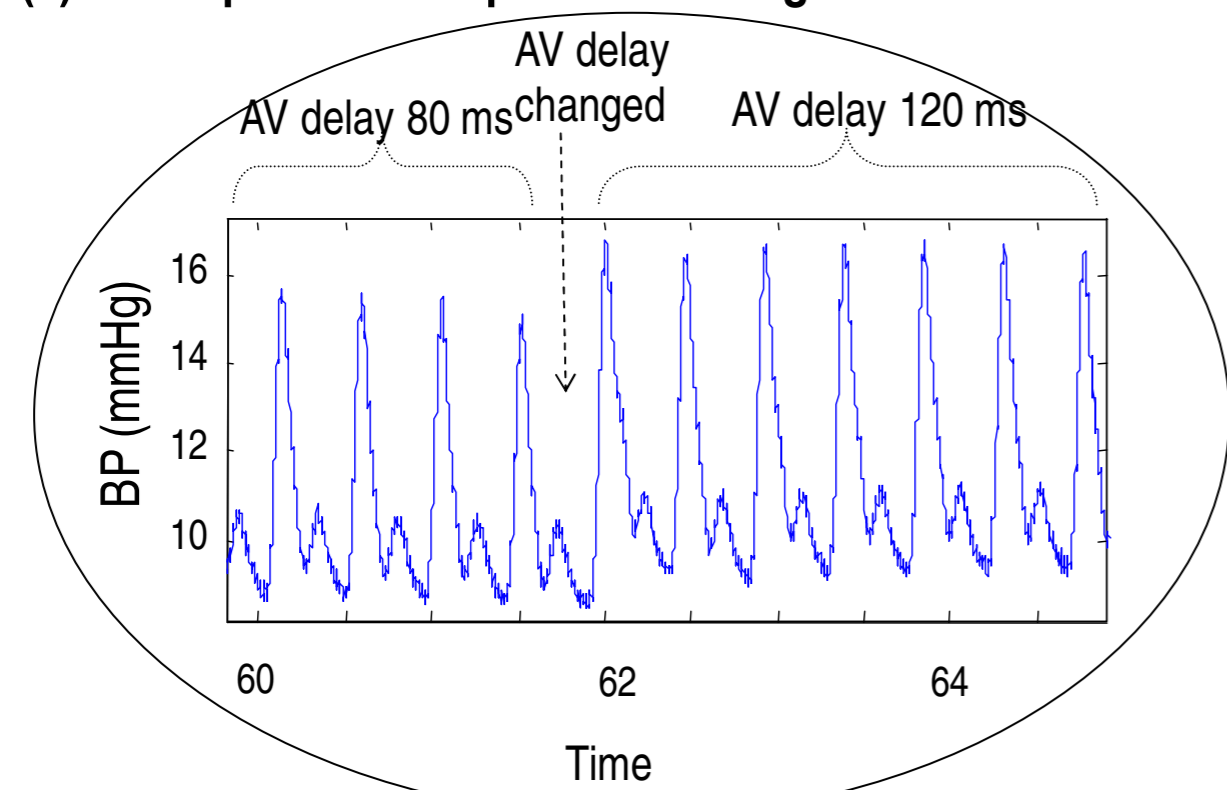
Three effects can mask the acute changes in BP associated with pacemaker reprogramming:

- Spontaneous random trends
- Slow variations in blood pressure
- A tendency to return towards the mean

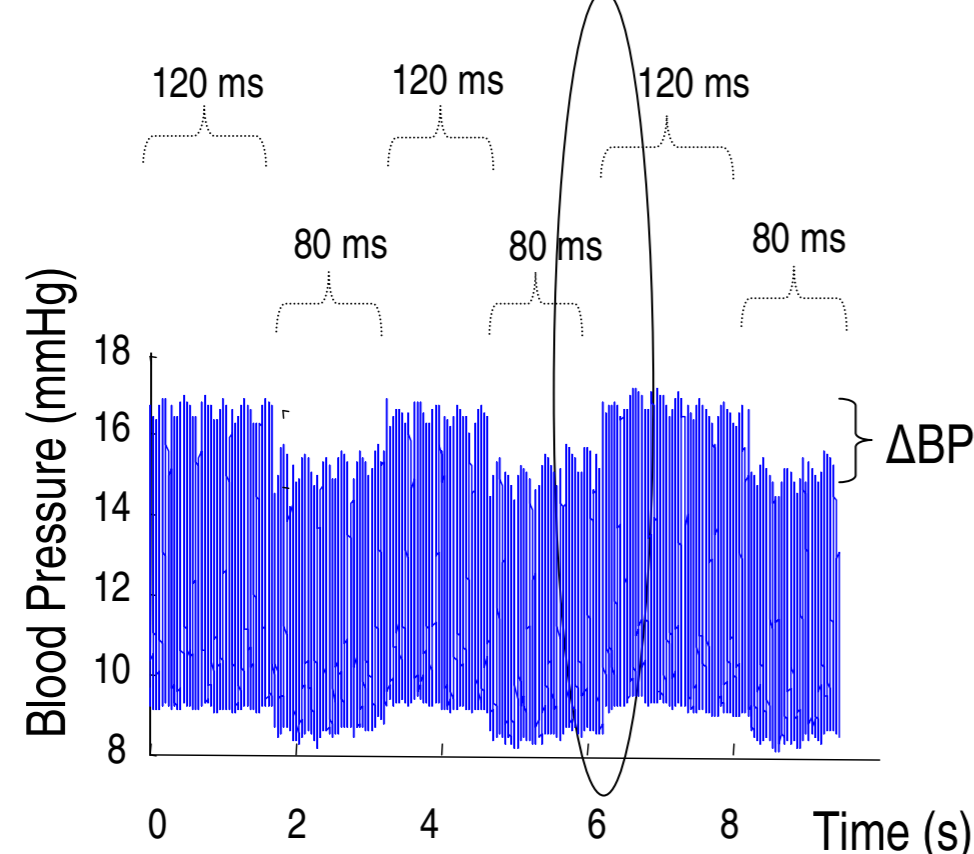
In order to minimise these effects we:

- Compared each tested AV delay with a reference AV delay of 120ms and a VV delay of 0ms
- Calculated the difference in mean systolic BP (Δ BP) between the 10 beats immediately before and the 10 beats immediately after a transition
- Repeated each transition to obtain at least 6 replicate measurements for each delay tested in order to obtain a mean Δ BP

(a) Blood pressure response to change



(b) Multiple alternations



(c) For each AV delay, Δ BP in relation to 120 ms AV delay.

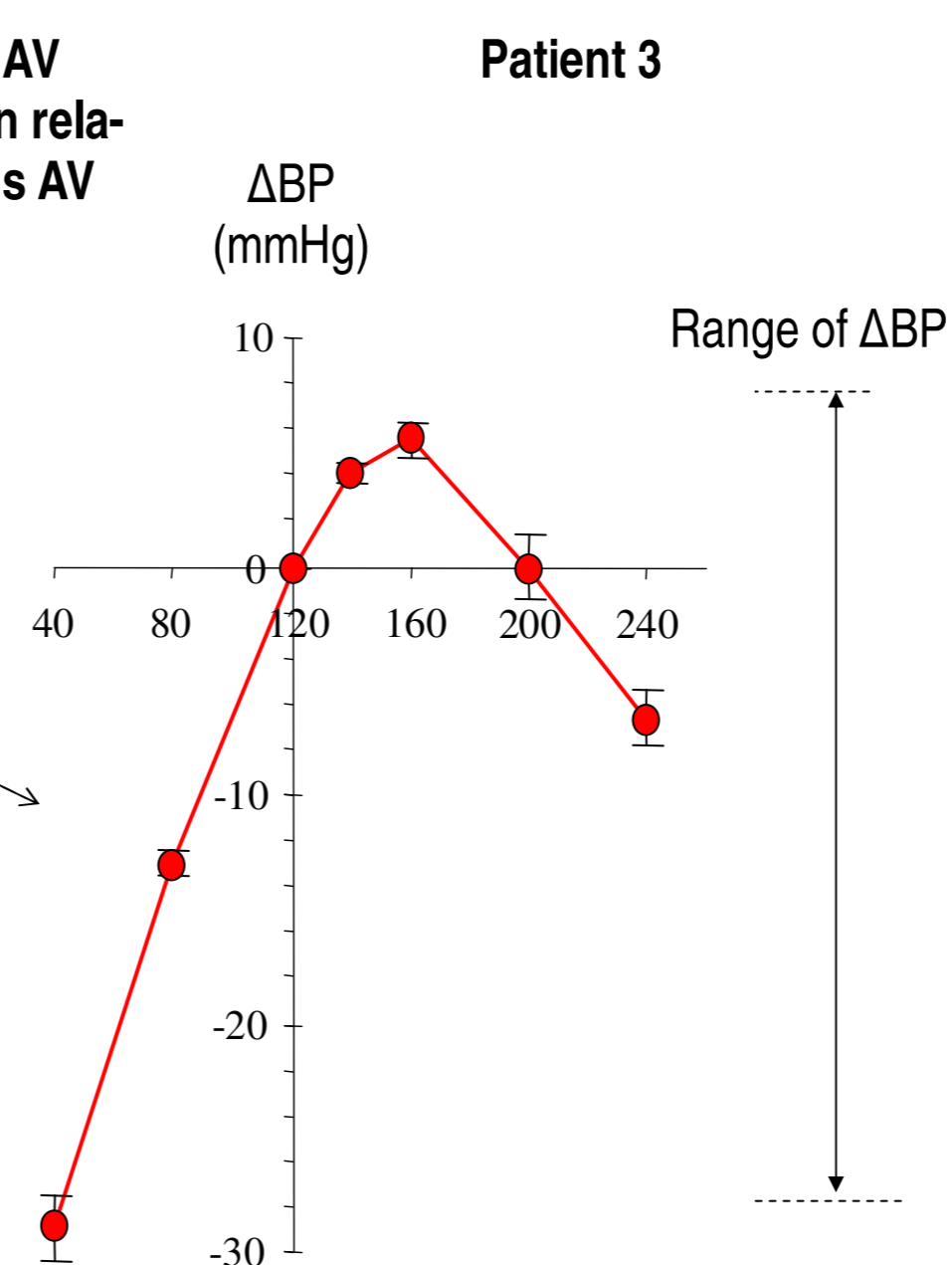


Fig 1 Effect of altering AV delay on blood pressure

Panel (a) shows an example of the prompt change in blood pressure when the AV delay is changed. Panel (b) shows a longer segment of the same recording, which includes several alternations of AV delay (in this example between 80ms and the reference value of 120ms) giving several replicate measures of Δ BP. Panel (c) shows how Δ BP varies as AV delay is varied from 40 to 240ms at a heart rate of 130bpm.

Results

- Using continuous non-invasive blood pressure measurements it was possible to detect changes in systolic blood pressure as AV delay was changed.
- Systolic blood pressure displayed a parabolic pattern of distribution around the optimal AV delay.
- The optimal AV delay varied between individual patients (median 160 range 120 - 200 ms).
- Blood pressure became progressively lower as AV delay was changed away from the individual patient's hemodynamic optimum.
- Even small changes in AV delay cause a statistically significant decline in Blood pressure. 40ms less than the individual's optimum reduced SBP by 4.9 ± 1.1 mmHg ($p < 0.003$); and a delay of 40ms above optimal decreased SBP by 4.4 ± 0.73 mmHg ($p < 0.0005$).

Results & Conclusions

Results (cont'd)

- Changes in AV delay exceeding 40ms caused SBP to fall even further. The average decline across all patients is shown in Figure 2 for the heart rate of 130 bpm.
- The mean absolute difference between the two determinations of optimal AV delay 3 months apart was 3ms (standard deviation 8ms). Same-day reproducibility was also 3ms (standard deviation 8ms).
- The standard deviation of difference between two individual measurements of Δ BP, 3 months apart, was 3mmHg, which is 3% of the mean systolic blood pressure.

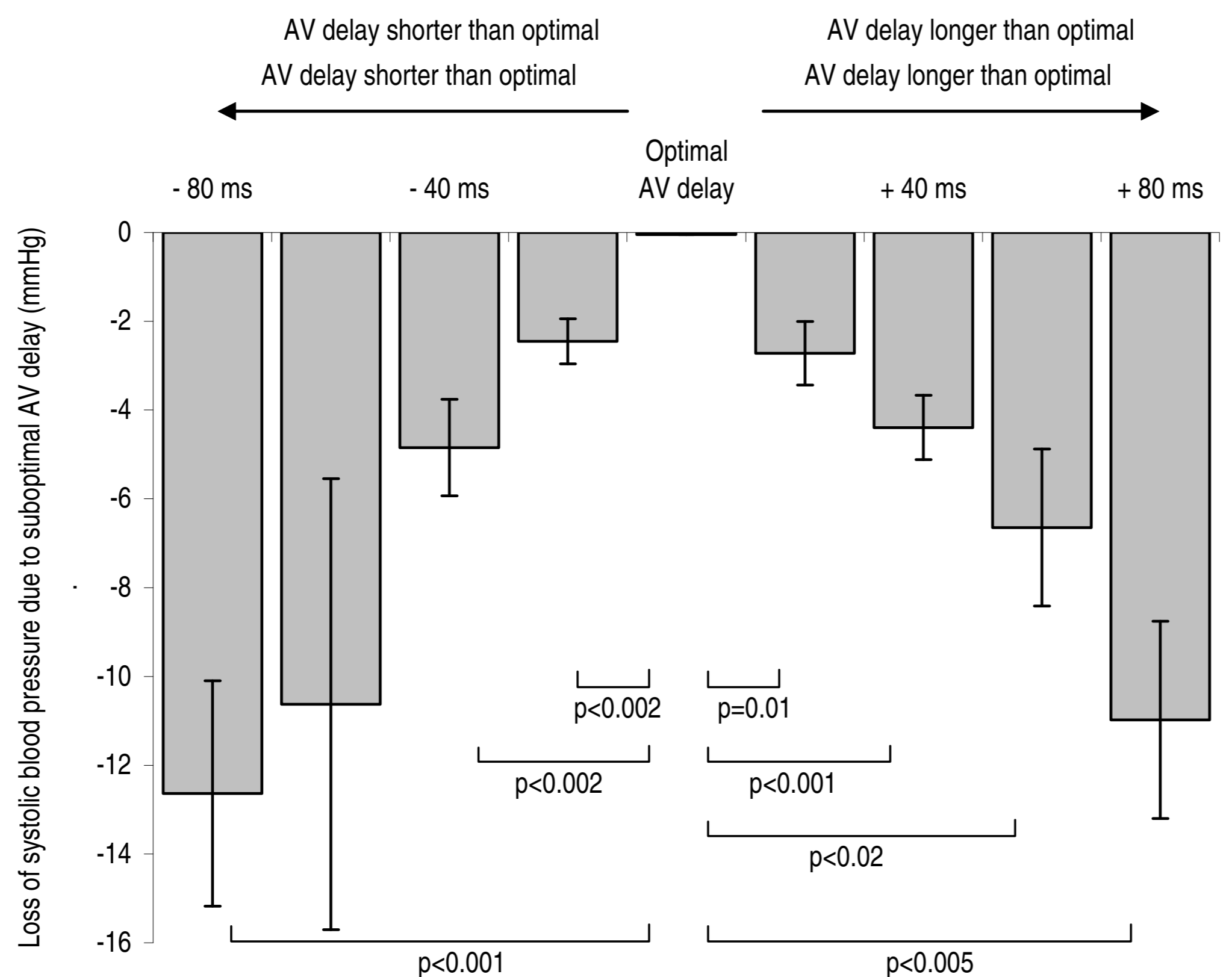


Fig 2 Effect of changing AV delay away from optimal

Change in systolic blood pressure (averaged across all patients) as AV delay is moved away from its patient-individualized optimum. The statistically significant differences from optimal are labeled

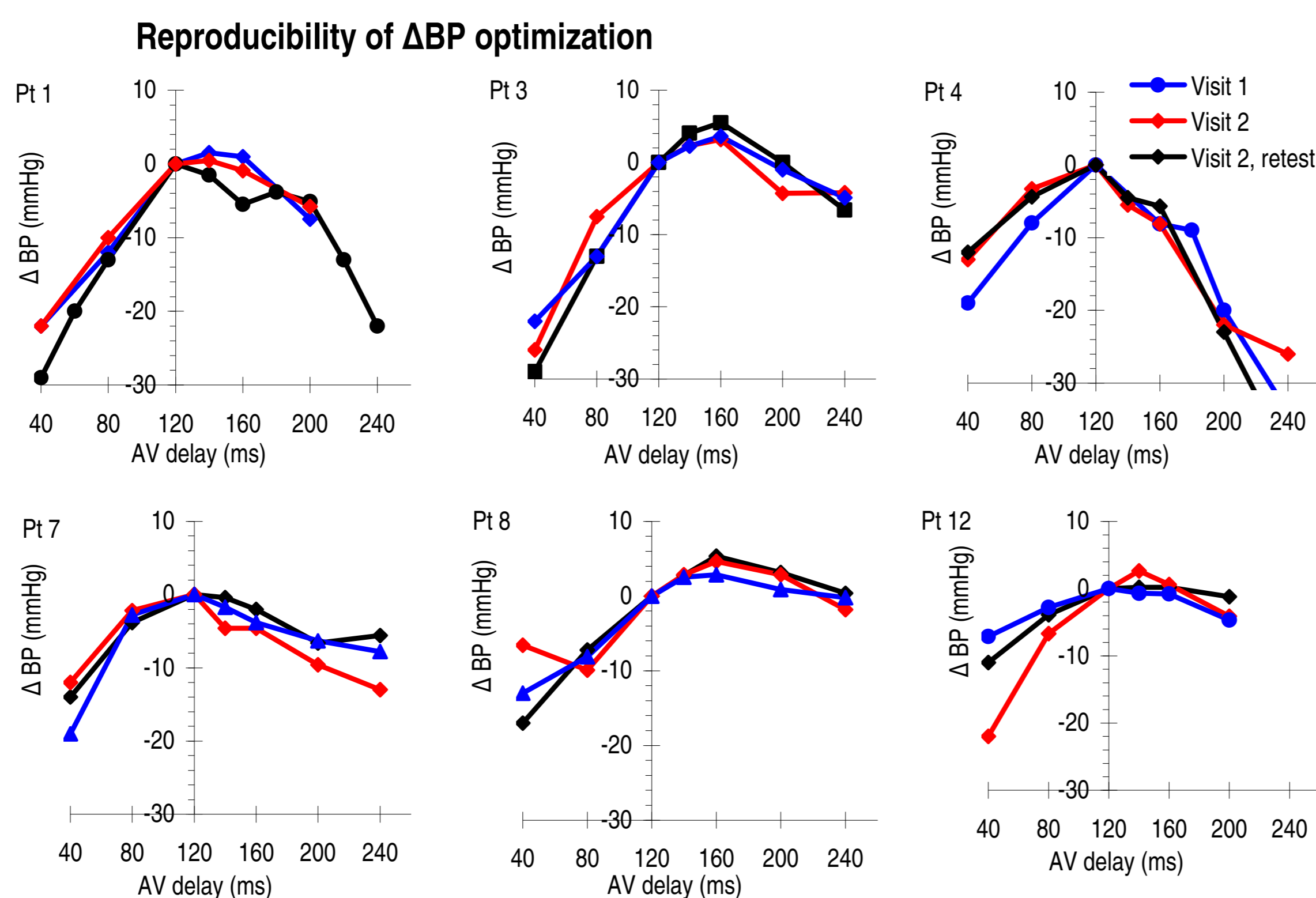


Fig 3 Reproducibility of AV optimisation

Three month and same day reproducibility is shown for individual patients.

Conclusions

- AV optimization using acute hemodynamics can be performed rapidly by non-invasive photoplethysmography, with minimal discomfort to the patient and without prolonged attention from a skilled operator.
- At 130 bpm every patient shows a clear optimal AV delay for acute blood pressure.
- The consequences of non-optimal AV delay are visible as a significant loss of arterial blood pressure.
- AV optimization by non-invasive blood pressure is highly reproducible on the same day and at 3 months.