

# Improved Cardiac Output Monitoring by Innovative Pulse Contour Analysis

## during Common Modes of Hemodynamic Instability

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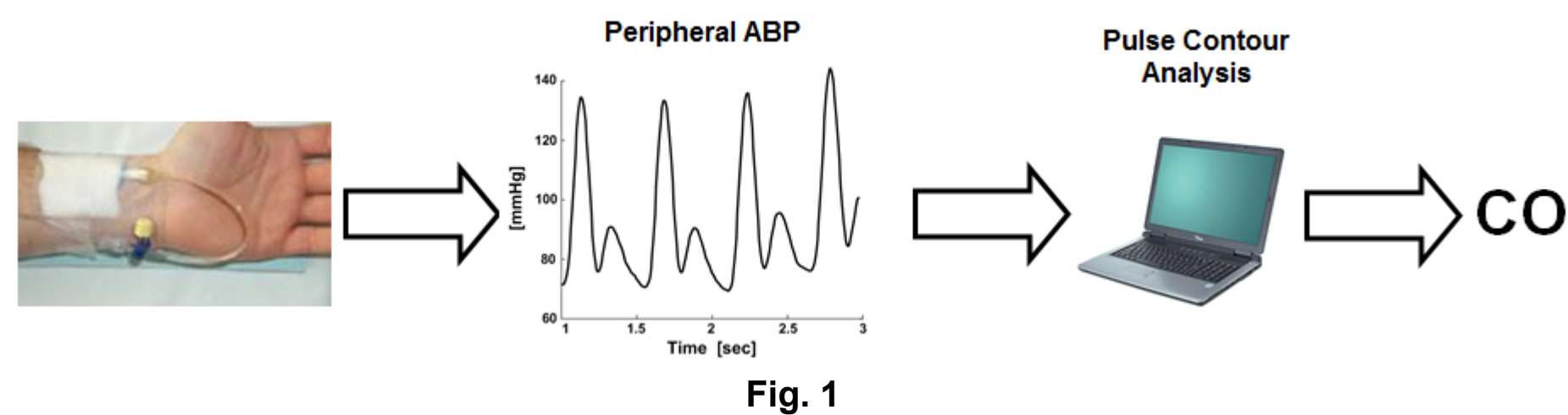
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### ABSTRACT

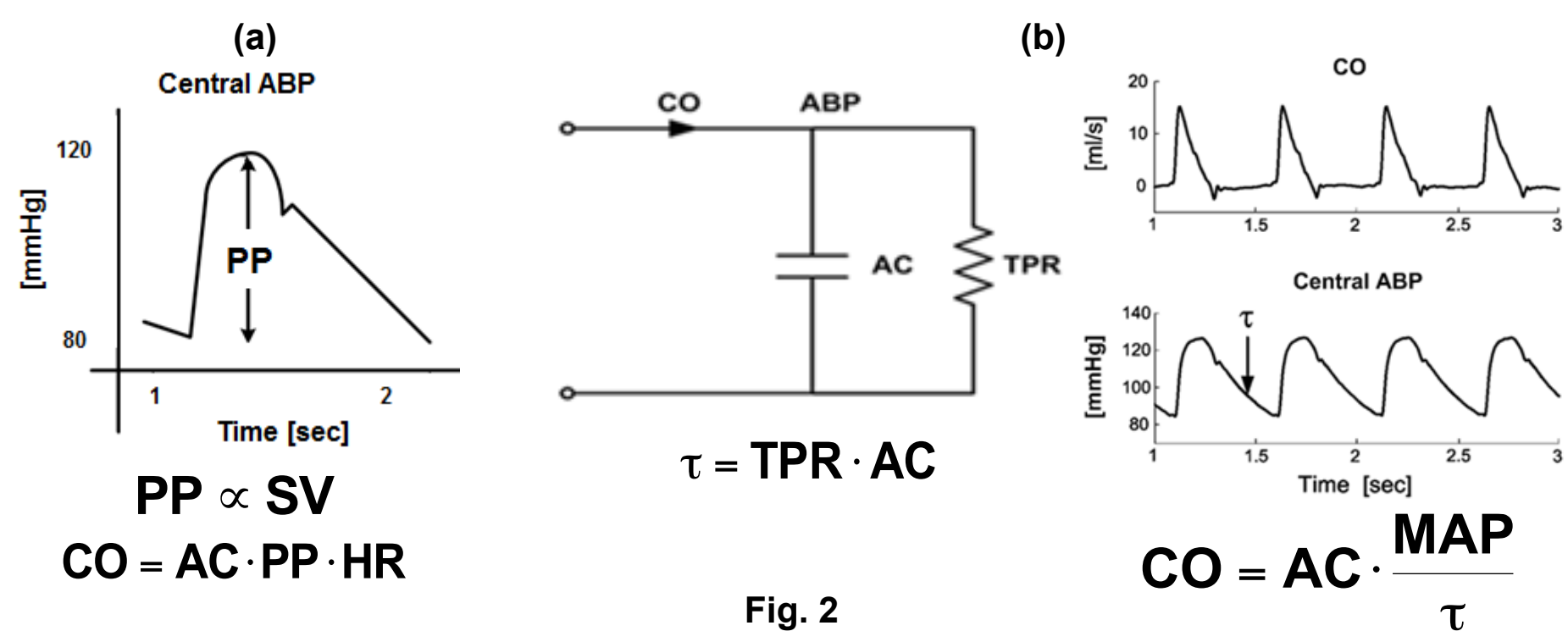
Retia Medical is developing a device for cardiac output (CO) monitoring based on innovative analysis of the radial arterial blood pressure (ABP) waveform. A key idea is to enhance accuracy by analyzing the slow, beat-to-beat variations in the waveform wherein confounding physiologic effects are minimal. To test the pulse contour analysis (PCA) technique, the radial ABP waveform and aortic flow probe CO were measured from 17 swine during hemodynamic drug infusions or hemorrhage. The technique showed significantly improved accuracy and trending ability over the current techniques during both common modes of hemodynamic instability.

### INTRODUCTION

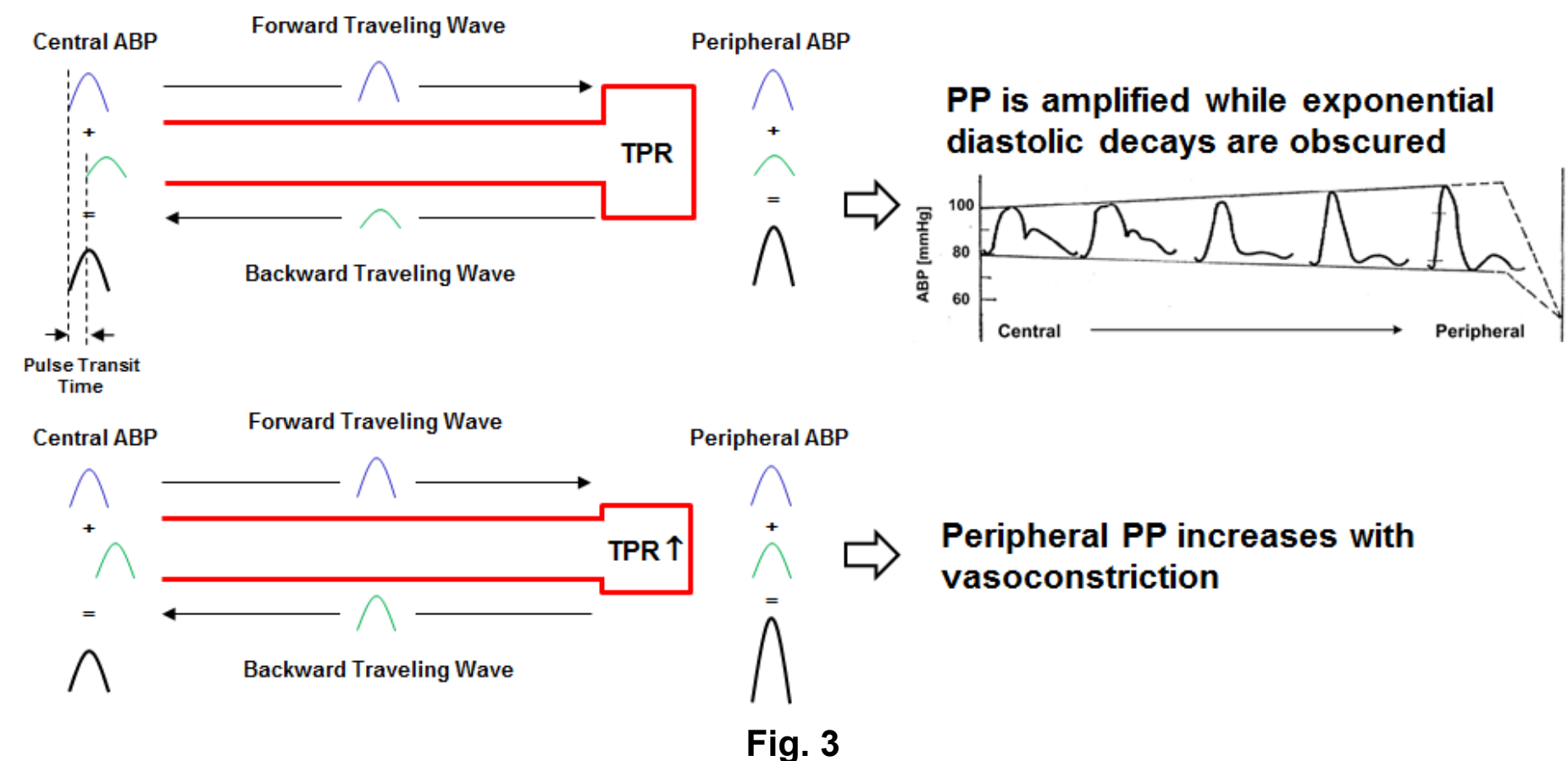
A practical approach for CO monitoring in critically ill patients is to analyze an ABP waveform obtained with an existing radial artery line [Fig. 1].



Several PCA techniques have been developed. The current techniques estimate CO by using pulse pressure (PP) as a surrogate for stroke volume (SV) [Fig. 2a] or determining the ABP diastolic decay rate ( $\tau$ ) to track total peripheral resistance (TPR) [Fig. 2b & 2c].



However, these techniques ignore arterial wave reflection, which has profound impact on the shape of peripheral ABP waveforms [Fig. 3].



For this and other reasons, the available techniques may be inaccurate during the challenging periods of hemodynamic instability [1].

### OBJECTIVE

Retia Medical is developing a new technique that is able to overcome confounding wave reflection. The objective is to test this technique against gold standard reference CO measurements during common modes of major hemodynamic instability.

### METHODS

#### Retia's Technique

The idea is to analyze the slow, beat-to-beat variations in the ABP waveform wherein confounding wave reflection is minimal [Fig. 4] [2].

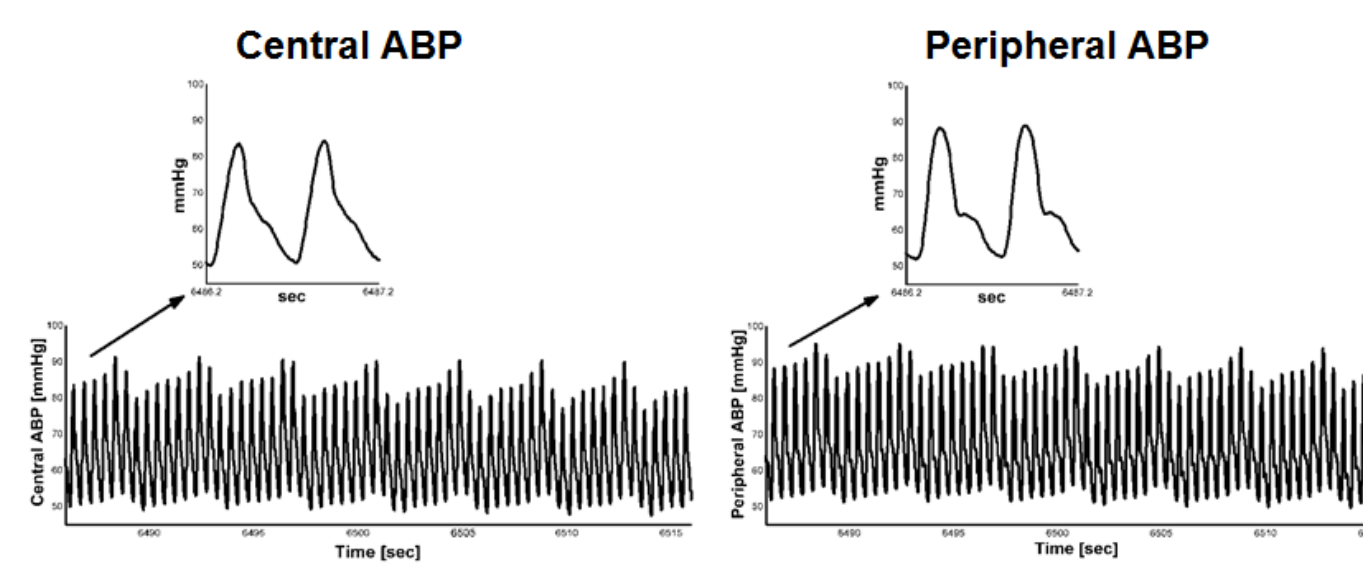


Fig. 4

First, the ABP response to one heart beat ( $h(t)$ ) is estimated by analyzing the waveform over many beats [Fig. 5]. Then,  $\tau$  is determined from the tail end of  $h(t)$  once the faster wave reflection vanishes [Fig. 5]. Finally, CO is determined to within an AC scale factor using  $\tau$  [Fig. 5].

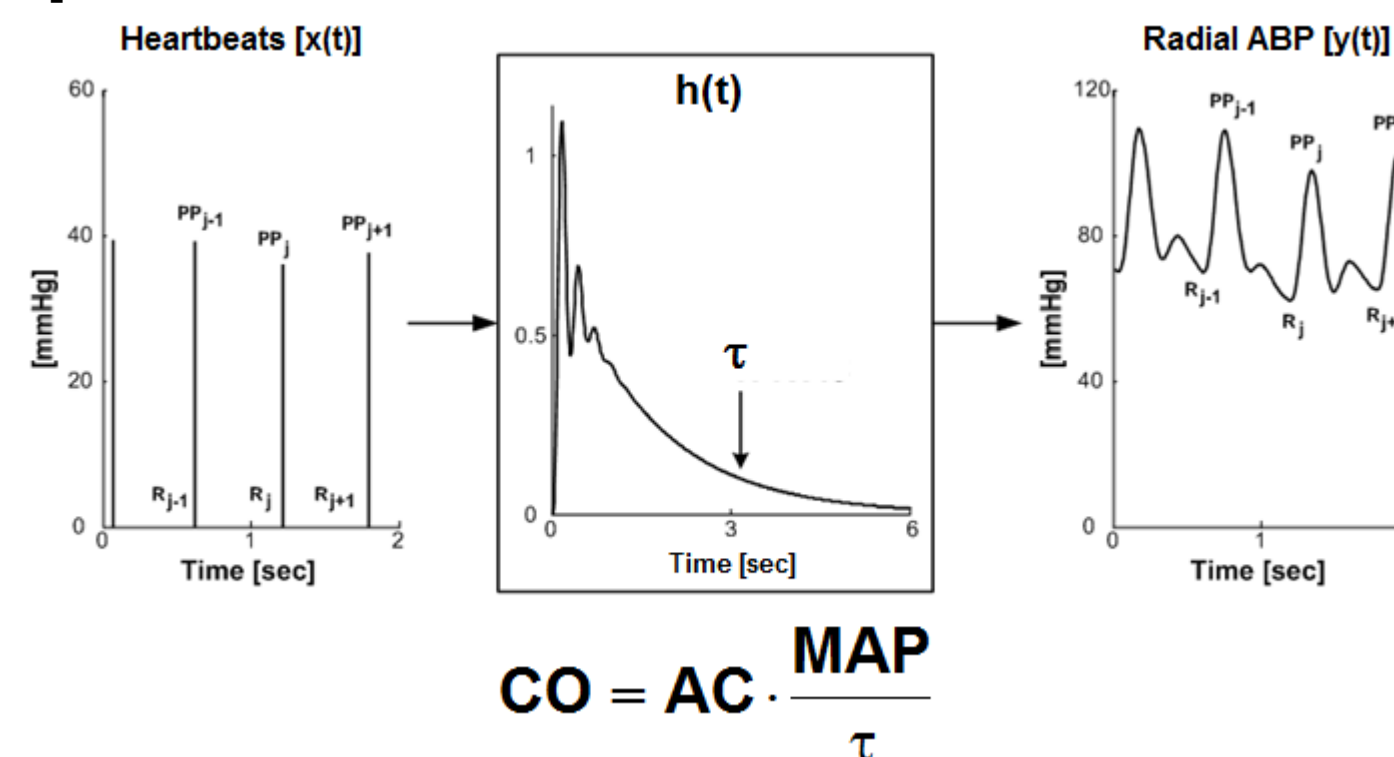


Fig. 5

### Animal Experiments

Seventeen healthy swine (30-40 kg) were instrumented to test the technique [Fig. 6]. Data were recorded during hemodynamic drug infusions or hemorrhage [Fig. 6].

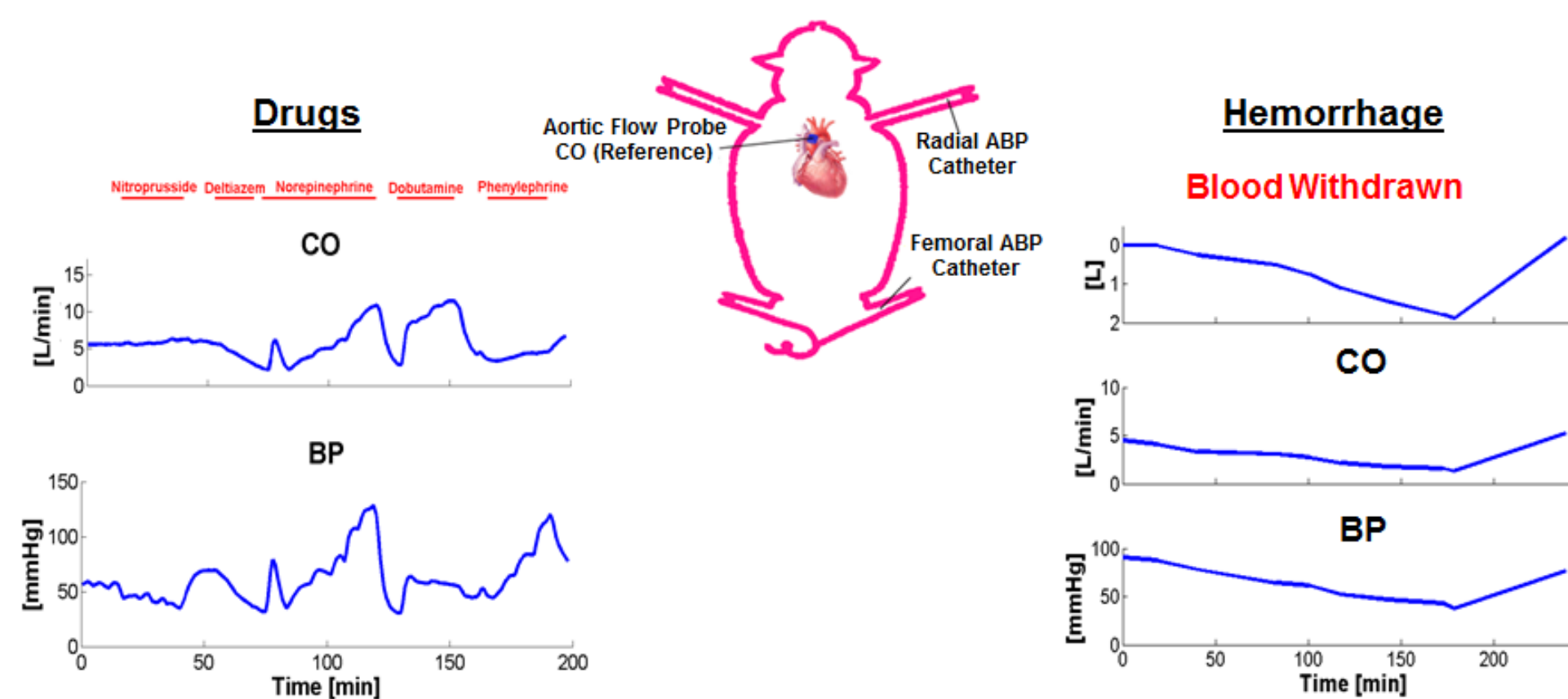


Fig. 6

### RESULTS

The group average calibrated CO errors and sample trends of the calibrated CO estimates for Retia's technique and the current techniques are shown for each drug [Fig. 7] and hemorrhage [Fig. 8].

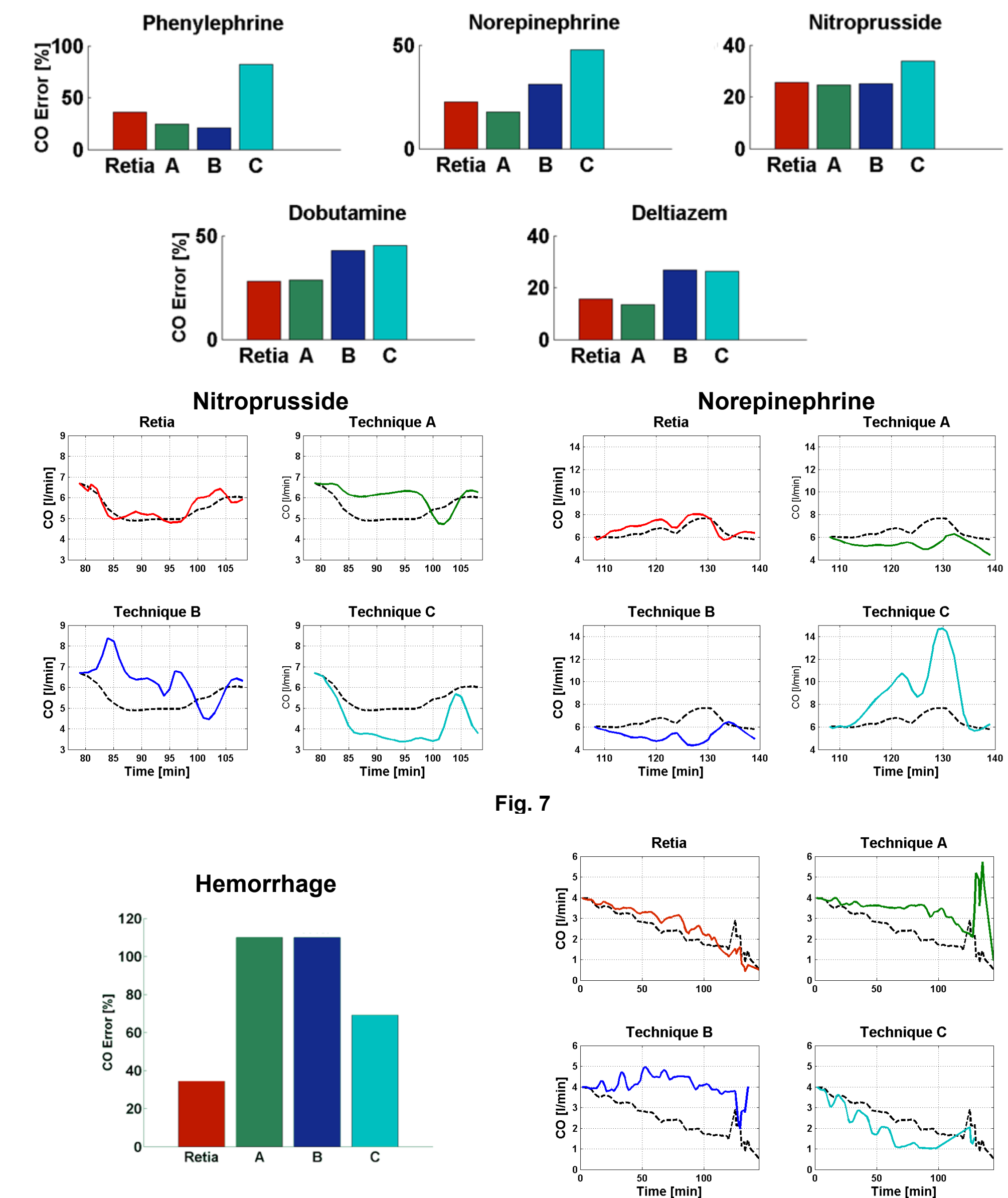


Fig. 7

Fig. 8

### DISCUSSION

None of the current techniques performed well during hemodynamic drug infusions and hemorrhage. Wave reflection played a role in the genesis of their errors but other factors likely contributed as well.

Retia's technique afforded significantly greater accuracy and trending ability over both common modes of instability. This technique may be improved by accounting for additional facets of the physiology.

### REFERENCES

- [1] Cecconi M et al. Pulse pressure analysis: to make a long story short. *Crit Care*, 14:175, 2010.
- [2] Mukkamala R et al. Continuous cardiac output monitoring by peripheral blood pressure waveform analysis. *IEEE Trans Biomed Eng*, 53(3):459-467, 2006.