The peripheral *venous* waveform: a novel physiologic signal for assessment of intravascular fluid status

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Vascular Forum
March 20, 2022

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University of Minnesota Medical School
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Disclosures and Funding

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Non-Invasive Venous Waveform Analysis (NIVA)

The Veins Sing and We Listen

-The **peripheral venous system** is the most **compliant** vascular compartment and long known to serve as the main volume **reservoir**

-This compliance makes it **sensitive** to changes in **intravascular volume**

-Only recently has **amplifying technology** been appropriate to record and **study venous waveforms at the "volume sensitive" low amplitudes**

Venous Waveform Analysis

The Basics
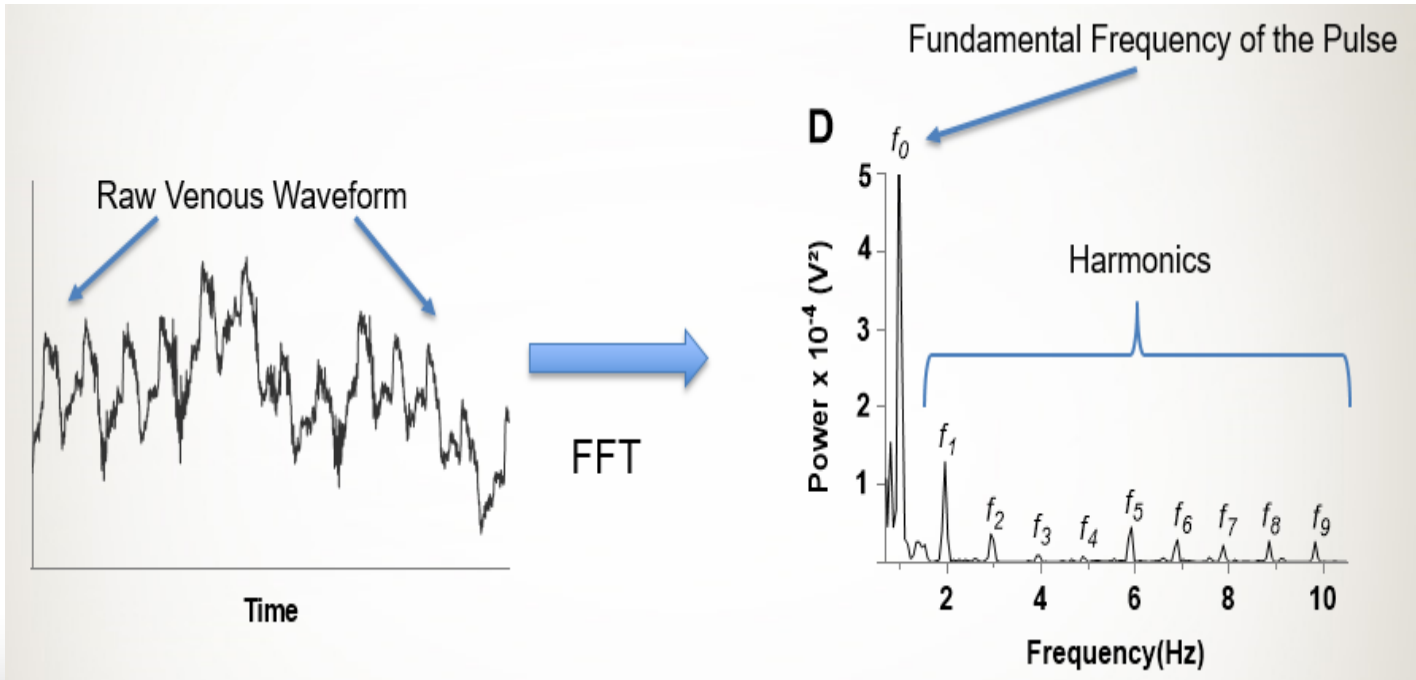
Music of the Veins

-When **raw venous pressure waveforms** are recorded and then **converted** from the time **domain** through fast Fourier transformation (**FFT**) there are **fundamental frequencies** that correspond to the pulse rate and its respective harmonics.

-The **amplitudes** of **these low frequency harmonics** have been found to **change with various volume states**

Venous Waveform Analysis
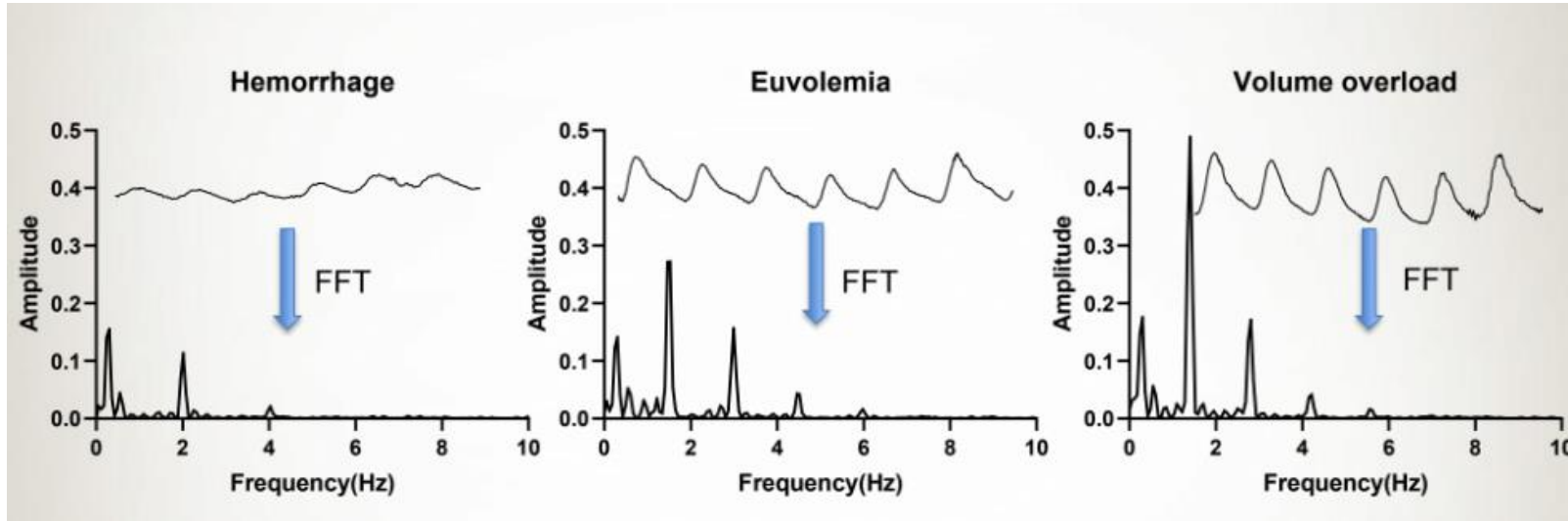
Practical Application: Heart Failure

- **Primary**
  - Assess an optimized NIVA algorithm to estimate PCWP in patients with heart failure ($NIVA_{HF}$).

- **Secondary**
  - Determine the clinical utility of $NIVA_{HF}$ to assess risk of hospital admission

- **Enrollment**
  - Subjects= 18 years or older patients scheduled for right heart catheterization at VUMC
  - 106 patients with adequate PCWP tracings and venous waveforms were used.
  - Statistical Analysis-> Pearson correlation coefficients were calculated for the NIVA score, PAD, and CO compared to PCWP

- **Admission Analysis**
  - 84 of 106 underwent outpatient RHC for 30-day hospital admission
  - Chart review performed to determine if there was a hospital admission secondary to heart failure exacerbation
  - Receiver Operator Characteristic (ROC) curves were used to determine the accuracy of NIVA score to detect admissions.

Practical Application: Heart Failure
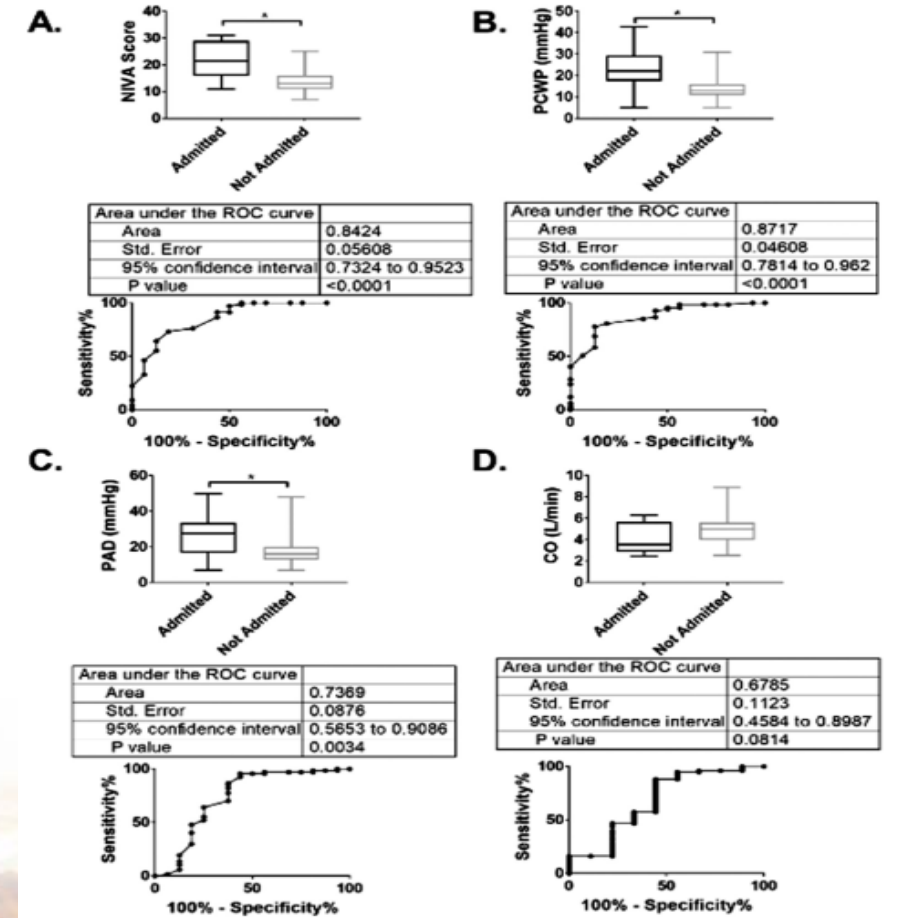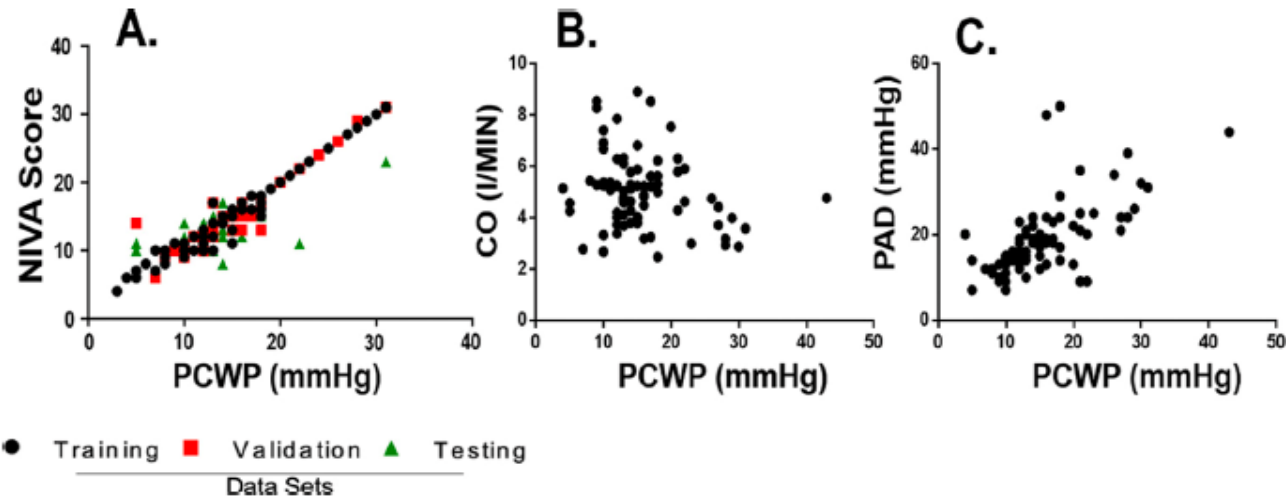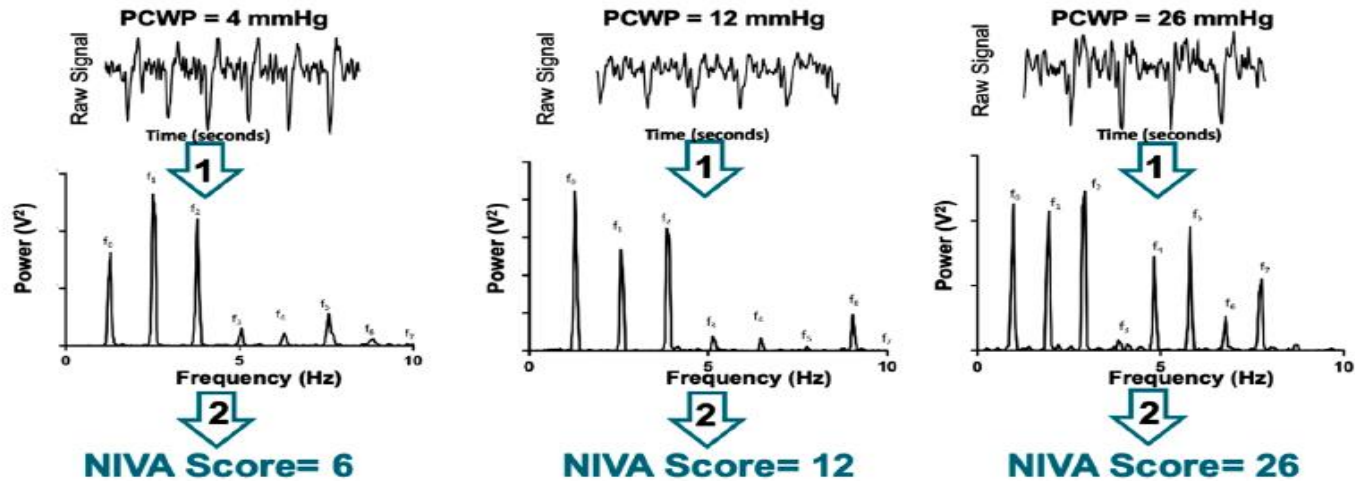
Practical Application: Hemorrhage
## Methods

-Anesthetized, intubated and fully catheterized Yorkshire-Landrace pigs (~40 kg); piezoelectric sensor on hind limb saphenous vein

-Stepwise blood loss (50 mL) increments; full parameters measured every 100 mL

-ANOVA to statistically compare parameters at different degrees of hemorrhage

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Practical Application: Hemorrhage
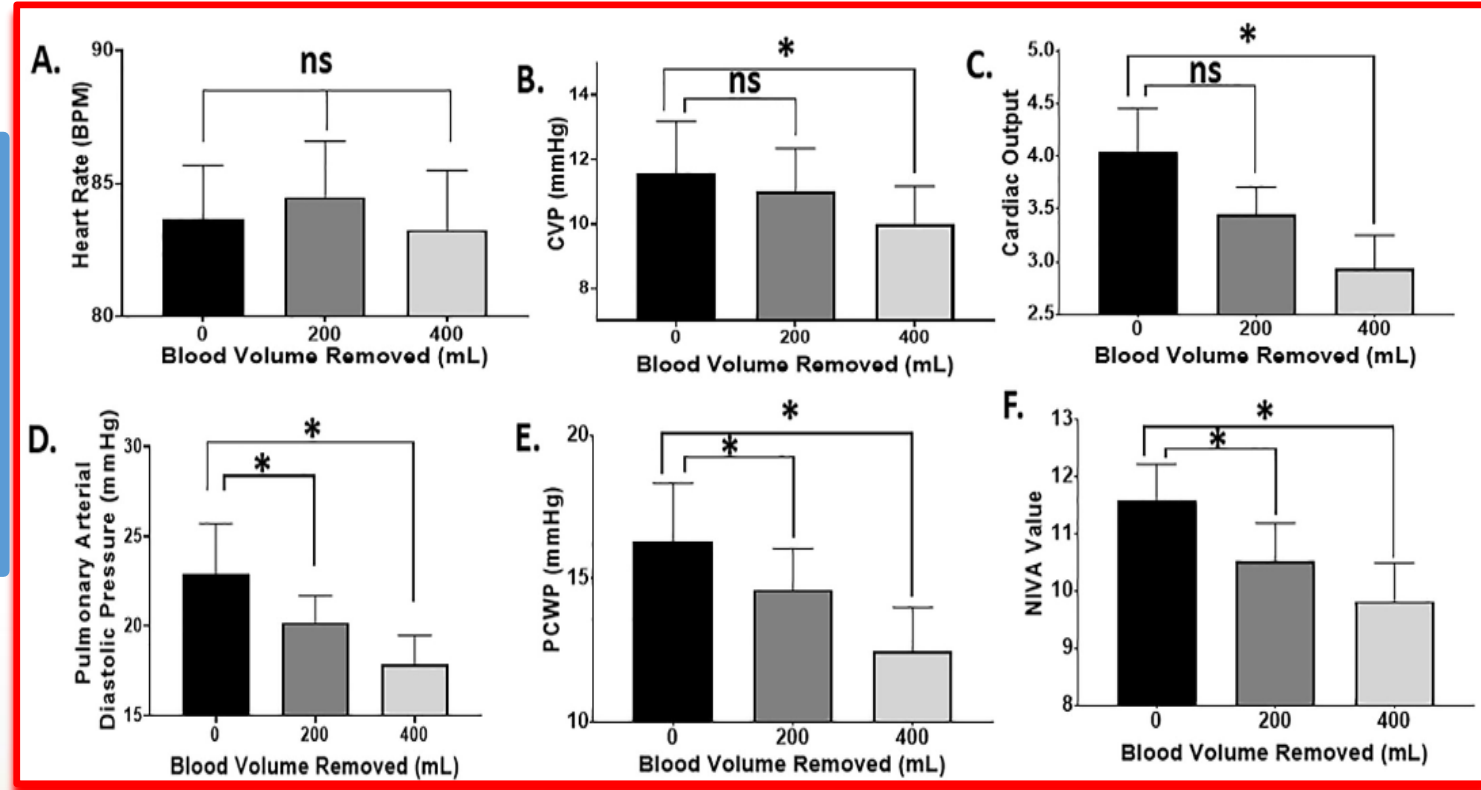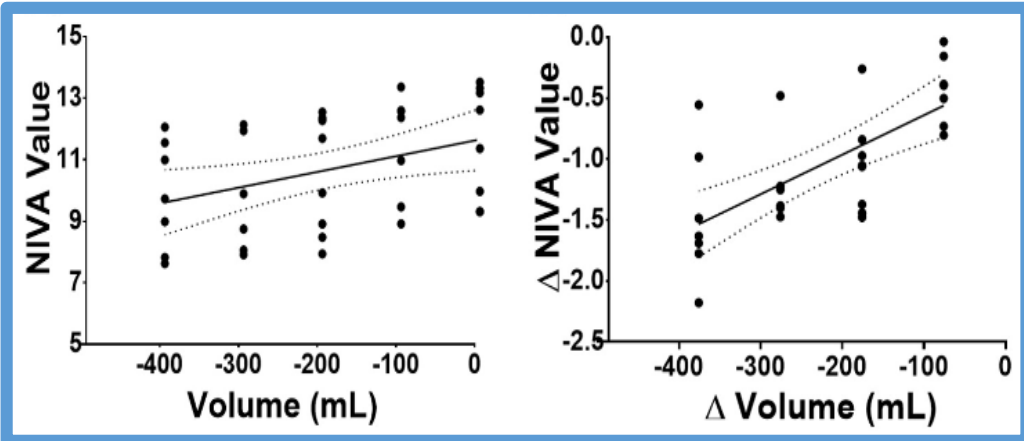
Future Directions

- Prospective validation of detection of heart failure in RHC patients (multi-center)

- Development of novel algorithm for assessment of fluid status and detection of overload during sepsis (Distributive shock) and resuscitation

- Prediction of need for oxygen based on respiratory component of venous waveform

- Pediatric blood loss

Conclusions

- Novel paradigm of volume assessment using easily accessible and under-appreciated venous system

- Demonstrates elaboration of lab-based observation into clinical utility

- Multidisciplinary team approach: Vascular surgeons, bioengineers, critical care anesthesiologists, cardiologists

- Promising, but with multiple limitations

Thank You

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