Clinical Characterization of the Brody Effect Demonstrates an Association Between QRS Morphology and Fluid Status in Patients with Acute Decompensated Heart Failure

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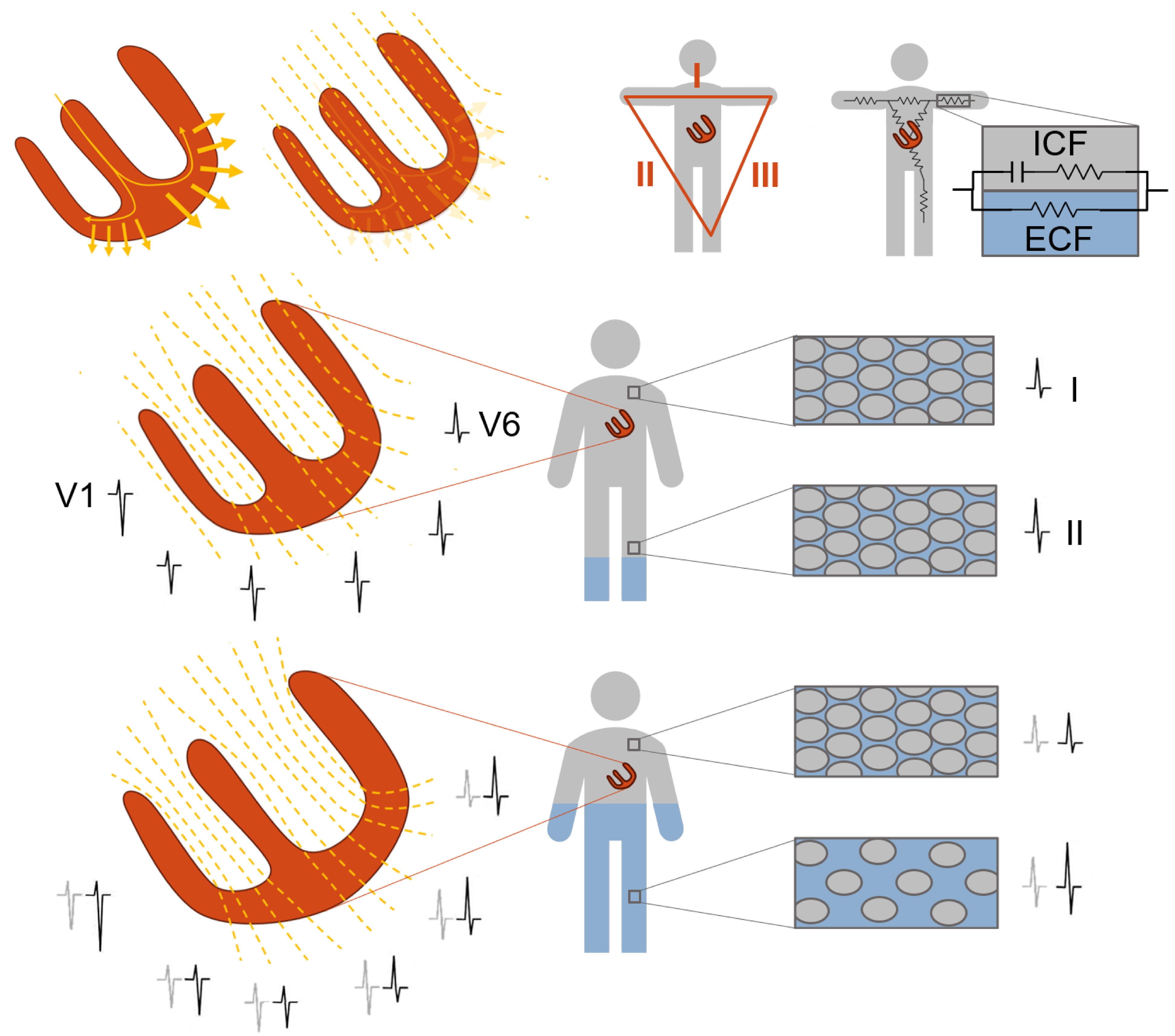
Introduction

Background:

- Clinical volume status drives pharmacologic modulation of hemodynamics, therefore accurate assessment is critical to patient outcomes
- Volume status is poorly described by any single objective clinical instrument (e.g., physical exam, echocardiogram, central venous pressures)[1-3]
- The electrocardiogram (EKG) is known to exhibit signal distortions associated with changes in bioimpedance[4-7]

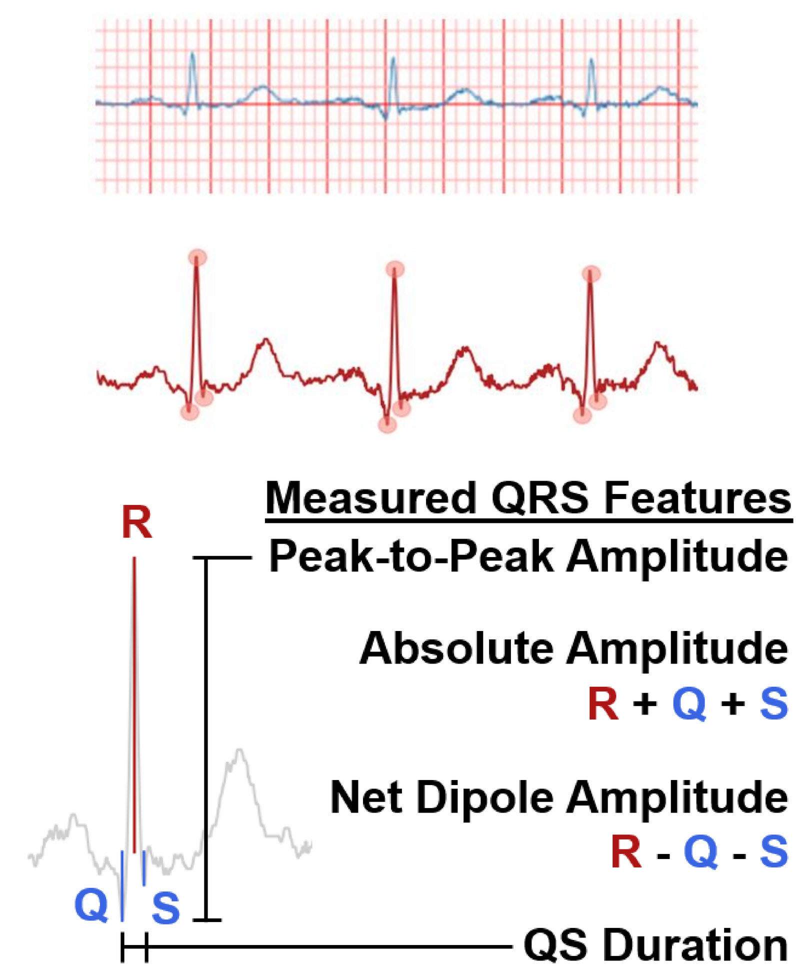
Hypothesis:

QRS morphology is quantifiably related to markers of fluid status including weight loss (i.e., diuresis) and hematocrit (surrogate for plasma volume status[8])



[Left] The classically described "Brody Effect" – current in the electric field generated by cardiac depolarization tends to traverse the relatively lower resistivity of the blood volume, amplifying field vectors radially aligned with the ventricles **[Right]** Peripheral edema decreases the impedance of the extracellular fluid (ECF) relative to the intracellular fluid (ICF) and amplifies low frequency signals

Methodology

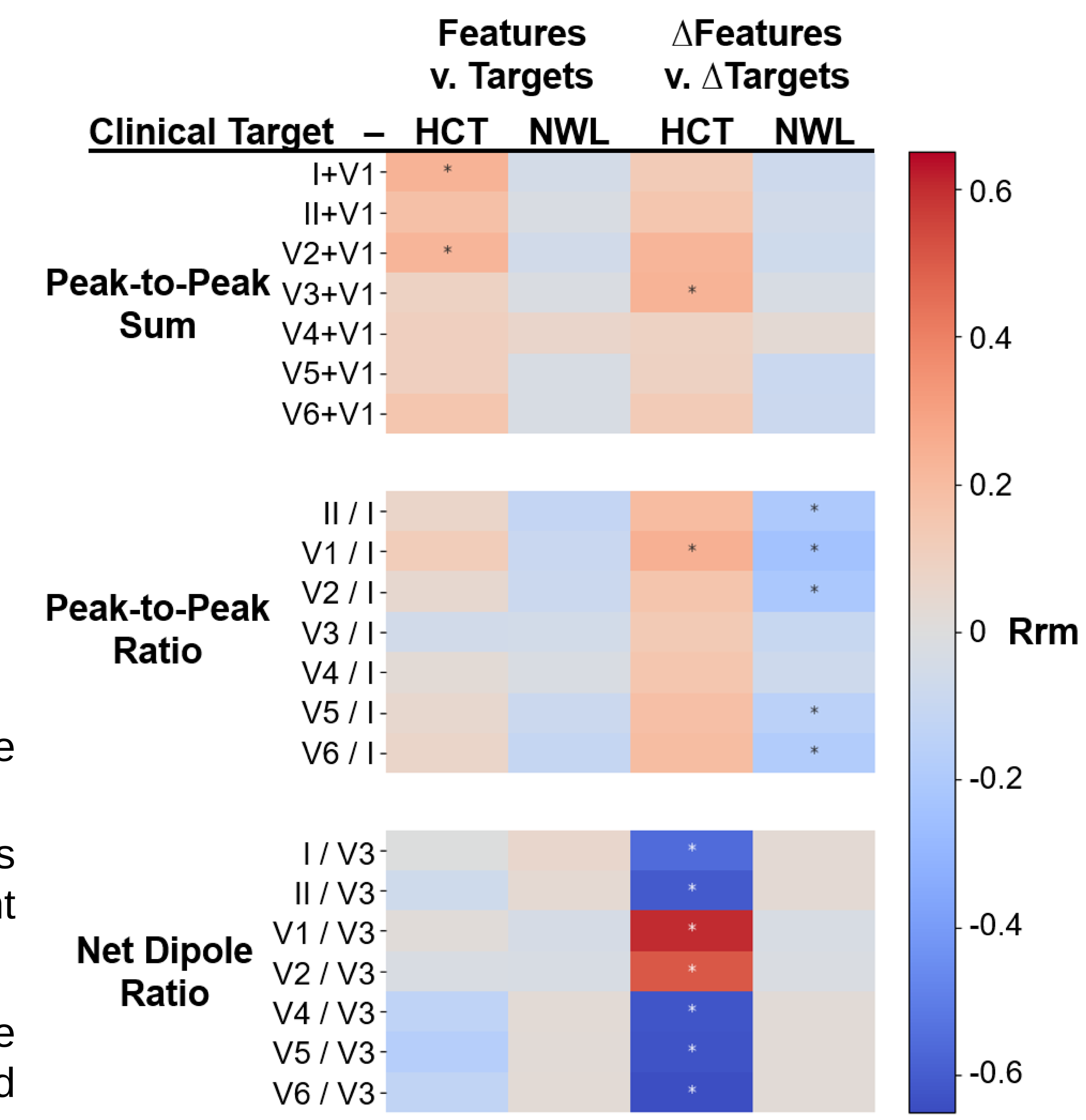


- Exploratory retrospective observational study in the MIMIC-IV hospital admissions database[9-11]
- Inclusion criteria: ICD diagnosis of heart failure, available EKG(s), net weight loss during a <2-week admission
  Exclusion criteria: concurrent diagnoses known to cause dynamic EKG changes (e.g., infarct, effusion, dyskalemias)
- EKGs were digitally processed in Python[12-16] to identify QRS complexes, locate wavelet maxima/minima, extract morphologic features, and perform feature comparisons (via ratio, sum, and difference)
- Repeated measures correlation[17] (Rrm) used to identify statistically significant relationships ($P(Rrm \neq 0) > \alpha = 0.05$) between QRS features and fluid status targets including hematocrit (HCT) and net weight loss (NWL, presumed from diuresis since day of admission)

Findings

Results:

- 160 patients (160 w/ sufficient NWL data, 65 w/ HCT)
- Single ECG QRS Features v. Fluid Status Targets:
  - 272 EKGs for NWL, 162 EKGs for HCT
  - 17 significant correlations to NWL, 27 to HCT
  - Amplitude in V1 emerges as predictive of HCT
- Interstudy ΔFeatures v. ΔTargets:
  - 196 EKG pairs for NWL, 140 EKG pairs for HCT
  - 10 significant correlations to NWL, 36 to HCT
  - Lead I is useful for normalization to emphasize effects on other leads from peripheral edema
  - V3 is a critical inflection point for precordial axis changes potentially related to a left > right amplification from high ventricular preload



Conclusion: These identified relationships constitute promising evidence supporting the physiologic model(s) and a potential role for EKG monitoring in volume assessment

Next Steps: Move towards feature integration + prediction, apply convolutional neural networks to interpret EKGs and predict volume proxies, use principles of transfer learning and interpretable AI to derive a clinically relevant instrument

References / Supplement: