Use of Ventricular Assist Device Acoustical Signatures To Detect Device Thrombosis

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Background

- The most common cause of failure (one out of six patients) for ventricular assist devices (VADs) is due to pump thrombosis, the formation of a blood clot at the interface between blood and the mechanical device (Figure 1).
- Presence of hemolysis (elevated plasma lactate dehydrogenase (LDH) levels) and degradation of device performance (e.g., increased power and decreased pump output) can indicate pump thrombosis.
- Device thrombosis should be mitigated with earlier diagnosis, before triggering any HF exacerbation and additional surgeries.

Hypothesis: *Acoustical signatures of VADs can provide salient information regarding thrombosis state.*

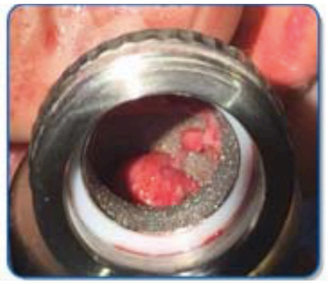

Figure 1. *Pump thrombosis in a left ventricular assist device.*

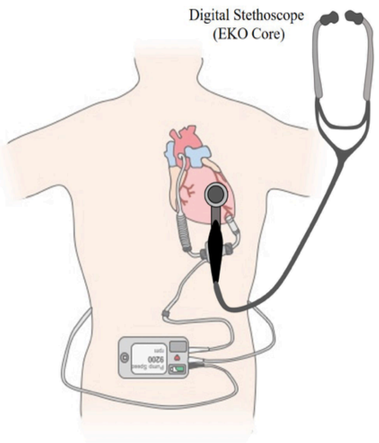

Figure 2. *Experiment setup.*

Methods

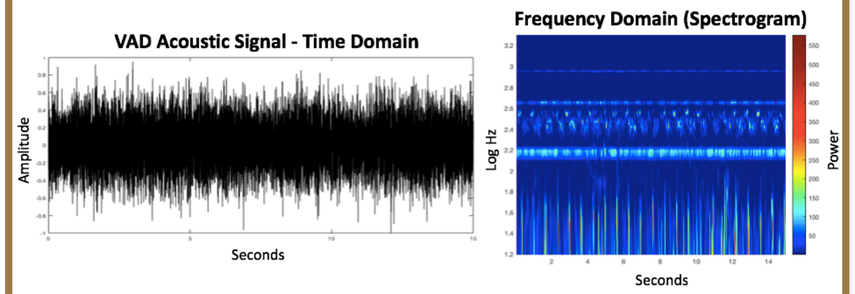

Figure 3. *Examples for the time and frequency domain representations.*

- 10 patients (six axial, four centrifugal VADs) presented with pump power elevations and recurrent abnormal hemolysis markers consistent with thrombosis.
- VAD sounds were recorded multiple times using a digital stethoscope (EKO Core) before developing thrombosis (baseline), during thrombosis and after heparin or tissue plasminogen activator (Figure 2)).
- The acoustical analysis consisted of three steps:
  1. Extracting features (time-frequency domains, acoustic/speech and nonlinearity features) from each recording (Figure 3).
  2. Feature importance ranking using Extreme Gradient Boosting (XGBoost) classifier to evaluate which features were most relevant for distinguishing between different episodes.
  3. Principal Component Analysis (PCA) for dimensionality reduction and 2D visualization (Figure 4).

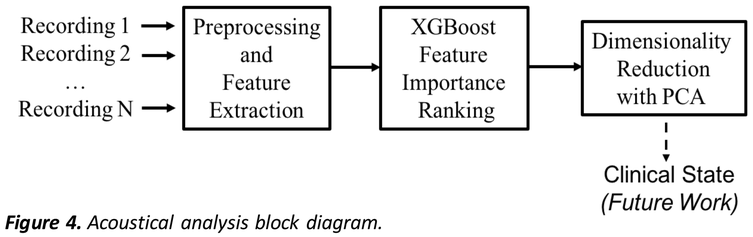

Figure 4. *Acoustical analysis block diagram.*

Results and Conclusion

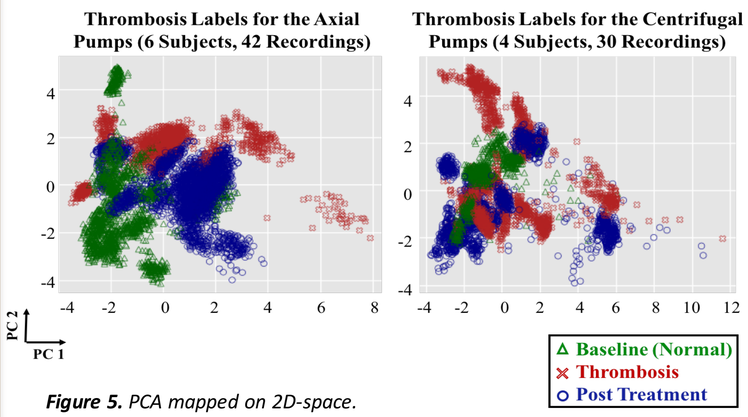

Figure 5. *PCA mapped on 2D-space.*

- In both pumps, sounds recorded from VADs with thrombosis had different signatures than baseline sounds (Figure 5).
- Better separation was observed for axial pumps relative to centrifugal pumps, which may be due to the difference in operating speeds (~9400 vs 2600 rpms, respectively).

We observed a slight overlap between the post treatment and baseline episodes, suggesting the possible presence of residual pump thrombosis that is not identified by hemolysis biomarkers and/or pump powers.

Conclusion: *Applying machine learning algorithms on sound signals can provide substantial information regarding thrombosis states, and even may be more accurate than hemolysis biomarkers and/or pump powers.*

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