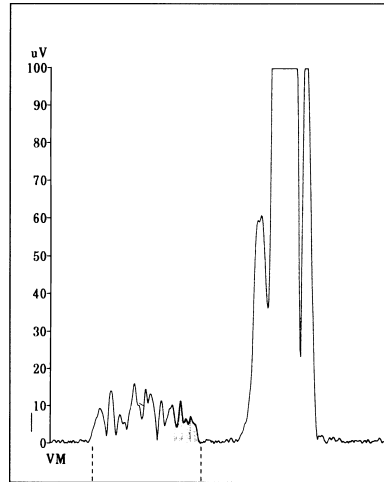




## SIGNAL-AVERAGED HIGH RESOLUTION P-WAVE (PHI-RES) ANALYSIS

High resolution ECG (Hi-Res) analysis has been used for detecting high frequency, low amplitude information in ECGs, such as ventricular (QRS) late-potentials. The signal-averaged high-resolution P wave (PHi-Res) analysis performs signal averaging of P waves using a P wave trigger and provides filtering and delineation of the averaged P-wave. The measurement program in the PHi-Res Analysis provides several parameters including filtered and unfiltered P duration, RMS voltages on the terminal segments (40 ms, 30 ms, 20 ms) of the P-wave, and the integral of P-wave.



### P-Wave Triggered Signal Averaging

Signal averaging aligns and adds a large number of beats to obtain the averaged beat (Figure 1). Noise, which is typically not synchronously related to the ECG signal, is reduced in amplitude, while synchronous signals are reinforced. Beat alignment is a critical part of P wave signal averaging. The PHi-Res Analysis aligns the P waves to within 1 ms accuracy preserving the desired frequency components in the averaged signal.

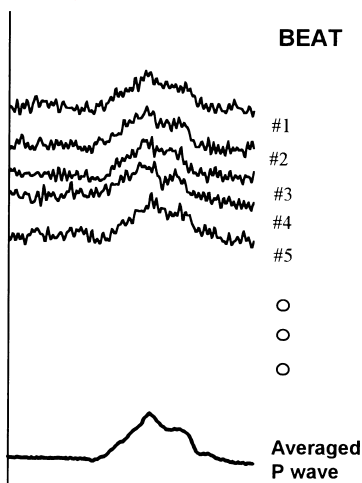


Figure 1: P wave triggered signal-averaging to reduce noise in the P wave.

### PHi-Res Analysis

- True P wave triggered and aligned averaging for PHi-Res analysis
- Linear phase spectral filter to retain signal fidelity
- Analysis on a standard Electrocardiograph (with resting ECG, VCG, and Hi-Res)
- User Friendly Design and Operation: Simple menu-driven selections
- High-Resolution P wave measurements: filtered P duration, RMS voltages, Integral
- Final Report in about Five Minutes
- Storage, Re-analysis, and Database Management option



# SIGNAL-AVERAGED HIGH RESOLUTION P-WAVE (PHI-RES) ANALYSIS

Figure 2 is a schematic representation of the signal-averaging process. QRS detection is performed first. Then, the QRS-T portion is subtracted and a P wave detection function is formed. The algorithm then searches for P waves in a window in front of the QRS.

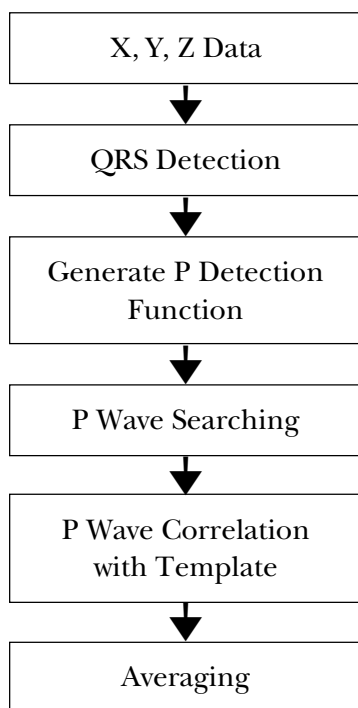


Figure 2: The flowchart of P wave averaging.

Qualified P waves (with acceptable P duration) are cross-correlated with the P wave template. Only those P waves which correlate highly with the P wave template (correlation coefficients greater than 0.95) are averaged (threshold adjustable). The averaging process continues till either the target number of beats, say 250, or a desired noise level, say 0.3  $\mu$ V, is reached.

## Analysis and Measurements

The average beat for each lead is filtered using a Fourier transform filtering technique. All three leads are combined into a vector magnitude (VM) plot, where:

$$VM = \sqrt{(X^2 + Y^2 + Z^2)}$$

PHi-Res parameters are extracted from the VM signal. The filtered and unfiltered P wave durations are measured and presented in the report (Figure 3).

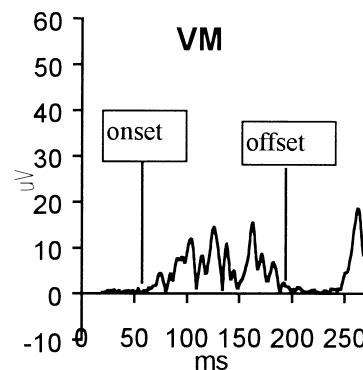


Figure 3: Delineation of P wave on VM signal.

The root-mean-square (RMS) voltage in the terminal 40 ms, 30 ms and 20 ms of the P wave are calculated and presented in the final report. The integral of the voltages in the entire P duration is also calculated.



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