



# Technical aspect of quantification and measurement of TWA

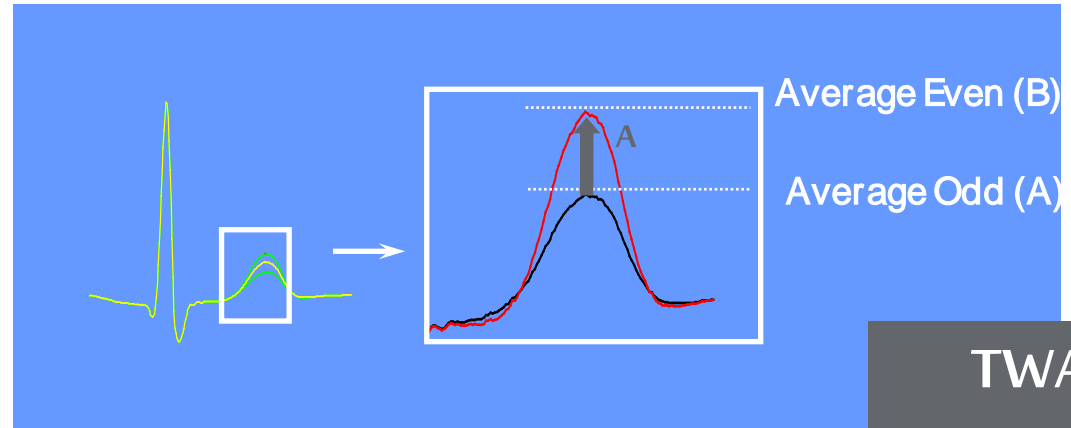
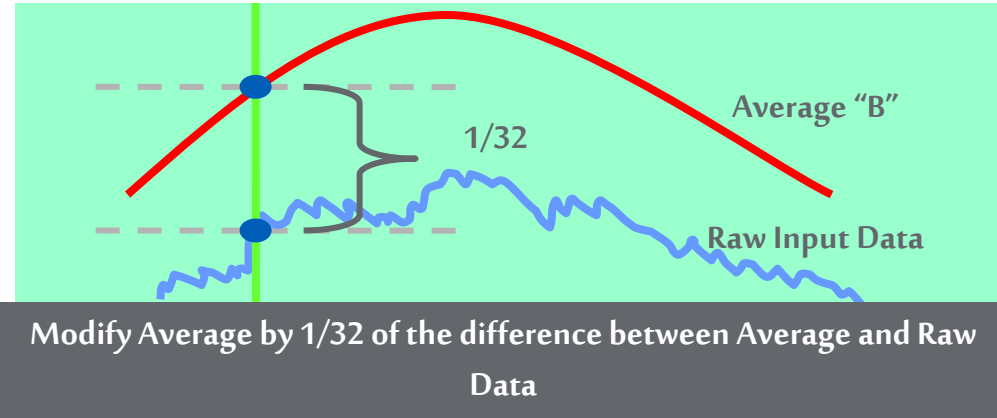
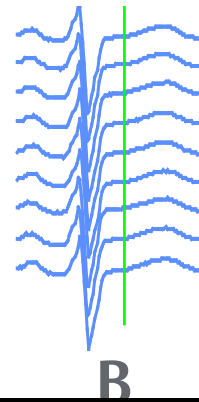
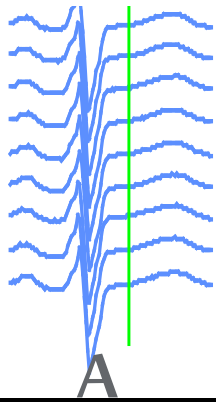
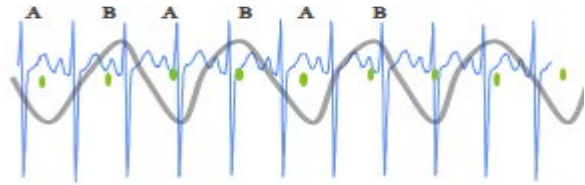
February 11, 2019

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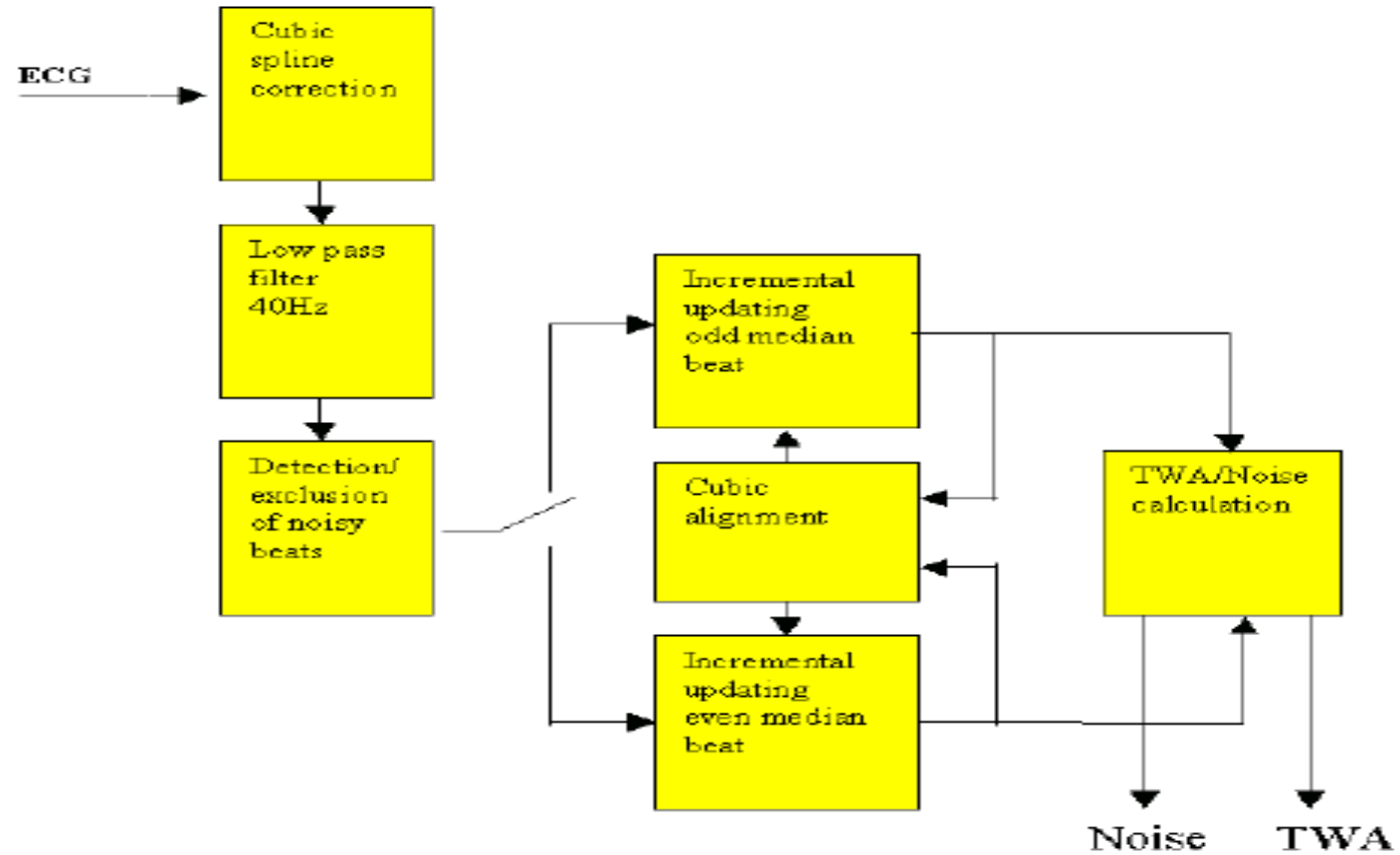
Kina Hu, GE Healthcare

# The Measurement of the Phenomenon

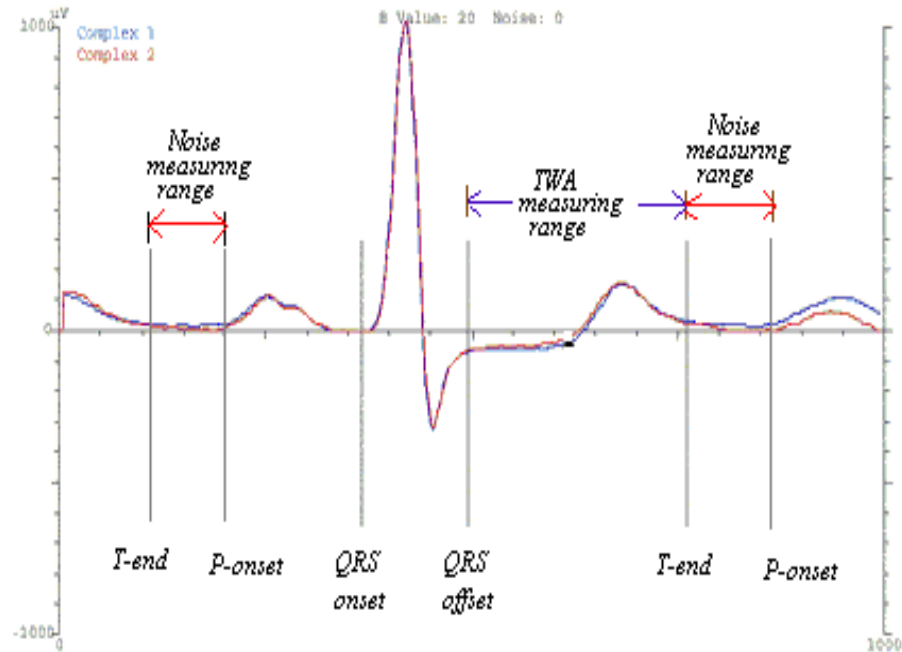
## Modified Moving Average



# Data process



# Noise Measure – GE/ Verrier



Setup

Writer | Screen | Lead Sequence | Protocol Editor | Final Report | Miscellaneous 1 | Miscellaneous 2 | ST/Medians / 12SL | TWA

TWA Heart Rate Limit [bpm]

TWA Noise Limit [%]

TWA at Heart Rate [bpm]

Median Update:

Enable TWA Analysis at Test Begin



# Top level comparison

## Cambridge/Frequency/FFT

## GE/Verrier/Time/MMA

구분	미세전위 T 교대파 검사 (Spectral 방법)
검사 원리	심전도상에서 100만분의 1볼트로 측정된 T파 교호변화를 그래프로 표시하여 심장활동에서 재분극의 변동 정도를 측정하는 검사 중 하나로 Spectral 방법에 의해 분석함.
측정 방법	<ol style="list-style-type: none"> <li>1. 부하심전도 검사를 통해 T 교대파 값을 얻어 측정함.</li> <li>2. 박동을 감지하고 정렬함.</li> <li>3. 짝수/홀수 교대파를 선택함.</li> <li>4. 박동당 0.5주기(cycle)를 선택함.</li> <li>5. 측정을 위한 지점 선택(128박동 전체 선택)</li> <li>6. 평균, 평균 스펙트럼</li> <li>7. 마이크로볼트 단위로 TWA를 측정 (평균 TWA)</li> </ol>
검사 결과	<ul style="list-style-type: none"> <li>▪ FFT(Fast Fourier Transform)를 사용하여 주파수를 나타내는 스펙트럼 형태로 변환시켜 모든 스펙트럼과 평균 스펙트럼을 결합시켜 계산식에 의해 TWA값을 산출</li> <li>▪ 산출된 값에 의해 결과를 음성(negative), 양성(positive), 또는 불확정(indeterminate)으로 보여줌(불확정의 경우, 결과의 판정이 힘들).</li> </ul>



구분	미세전위 T 교대파 검사 (Time Domain 방법)
검사 원리	심전도상에서 T파 교호변화를 미세전위수준(100만분의 1볼트)으로 측정하여 T 교대파를 그래프로 표시하여 심장활동의 재분극 변동 정도를 측정하는 검사 중 하나로 Time Domain 방법에 의해 분석함.
측정 방법	<ol style="list-style-type: none"> <li>1. 부하심전도 검사 또는 홀터 심전도 검사를 통해 T 교대파 값을 얻어 측정함.</li> <li>2. 박동을 감지하고 정렬함.</li> <li>3. 짝수/홀수 교대파를 선택함.</li> <li>4. 짝수/홀수로 박동을 분리함.</li> <li>5. 측정을 위한 지점 선택</li> <li>6. 평균, 점진적 평균 박동</li> <li>7. 마이크로볼트 단위로 TWA를 측정 (peak-to-peak)</li> </ol>
검사 결과	<ul style="list-style-type: none"> <li>▪ A와 B교대파를 구분해서 보여주며 FFT(Fast Fourier Transform)에 의하여 값을 변환시키지 않고 측정값을 마이크로 볼트로 명확하게 표시(정량화된 측정 가능)</li> <li>▪ 짧은 박동(20-30박동) 기간에서도 TWA를 감지하여 보여줄 수 있음.</li> </ul>



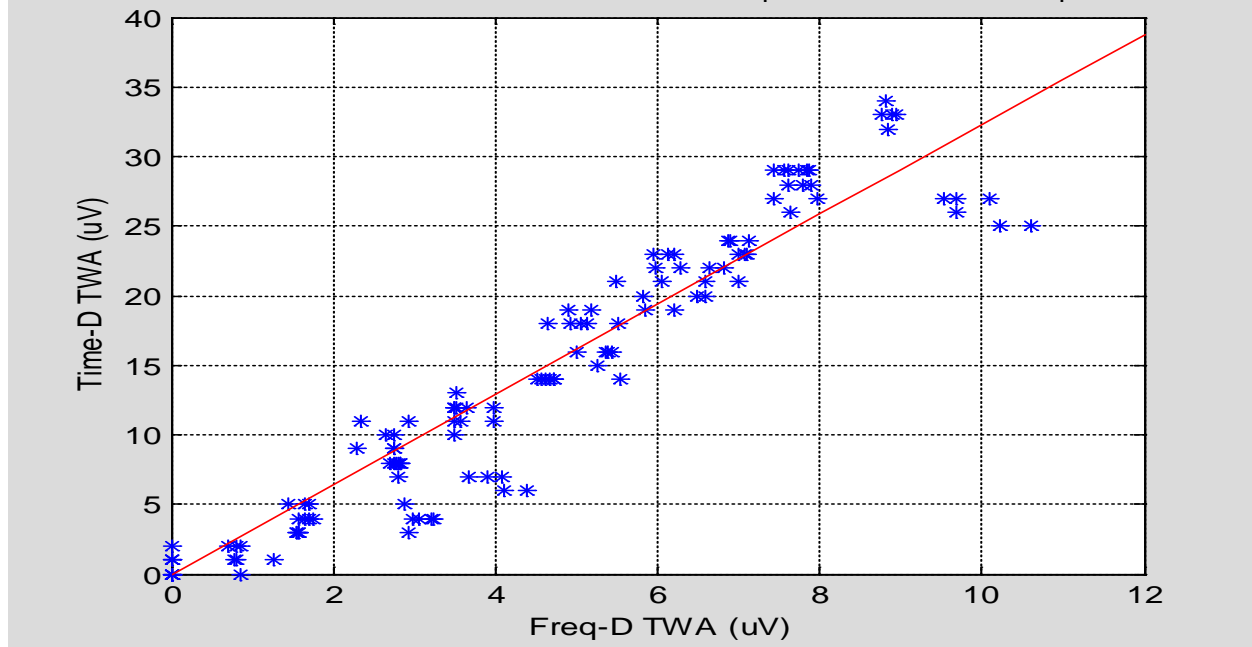
# Measurement Correlation

## Spectral and Modified Moving Average

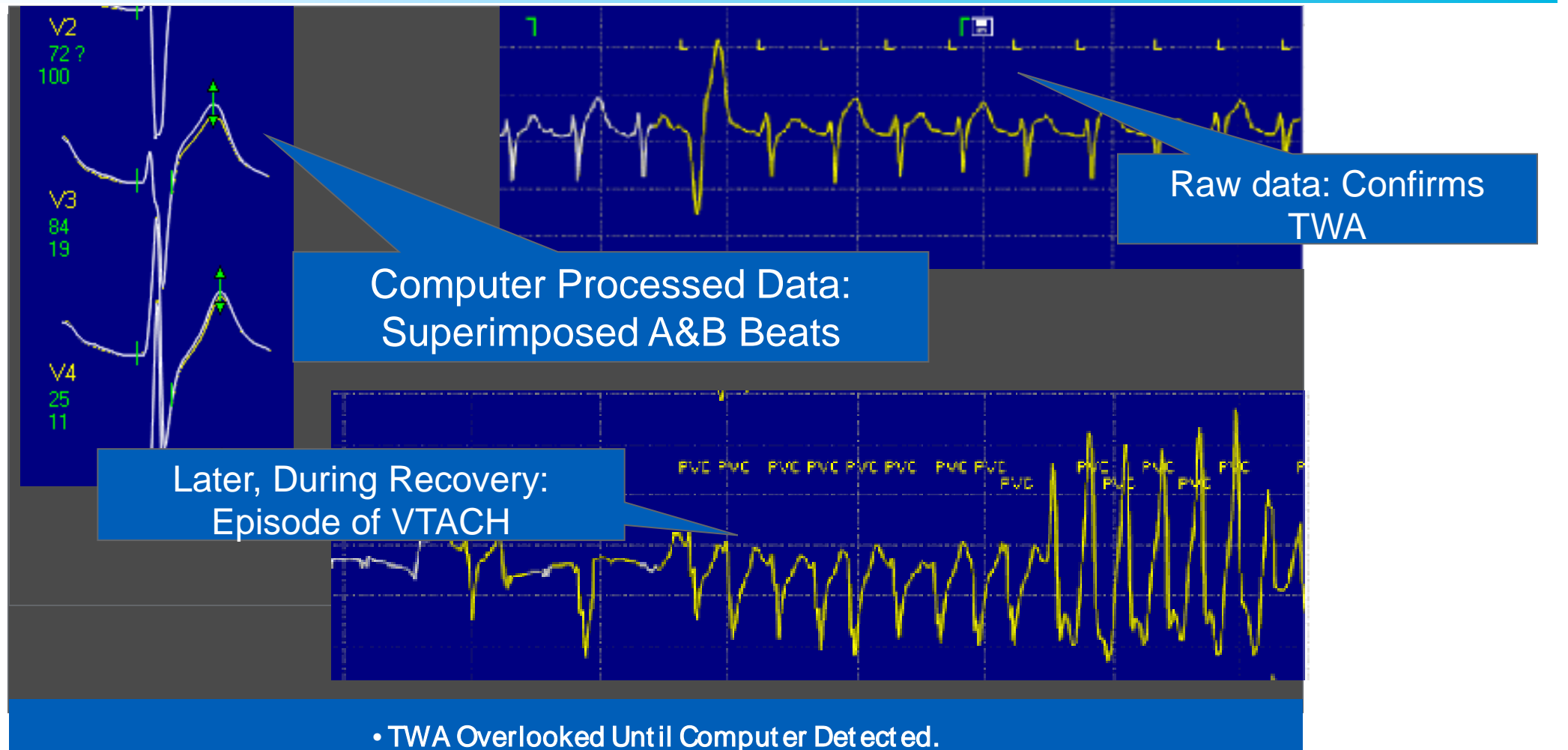
$$\text{TWA\_Time} = 3.23 \times \text{TWA\_Freq}$$

$$R = 0.95$$

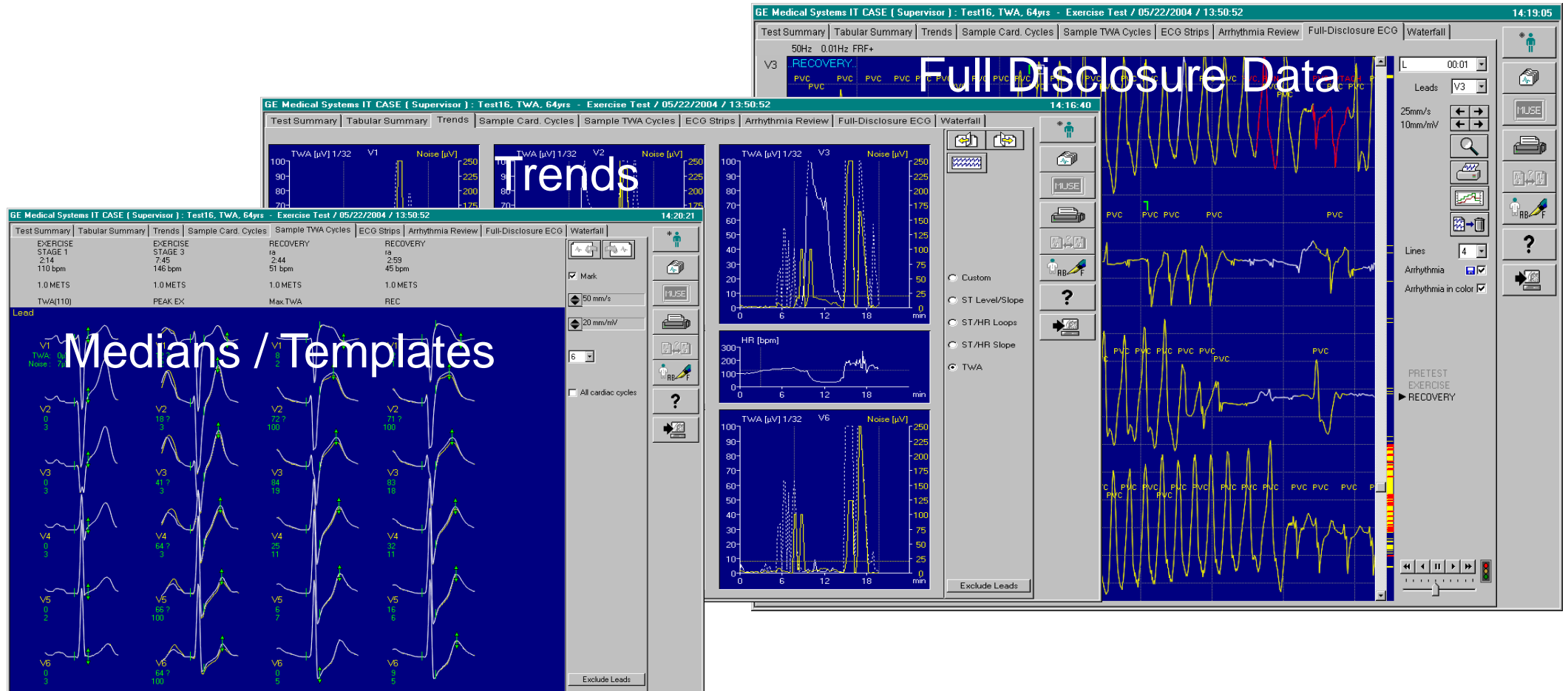
Measured TWA of Time-D(GE) vs Freq.-D(CH) Time<sub>p</sub>WA = 3.2307x Freq<sub>p</sub>WA, r = 0.95397



# Exercise ECG-Based MMA TWA Testing

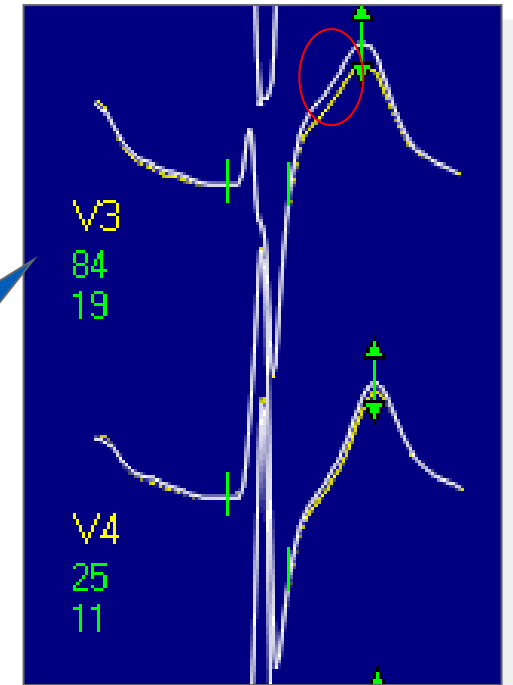
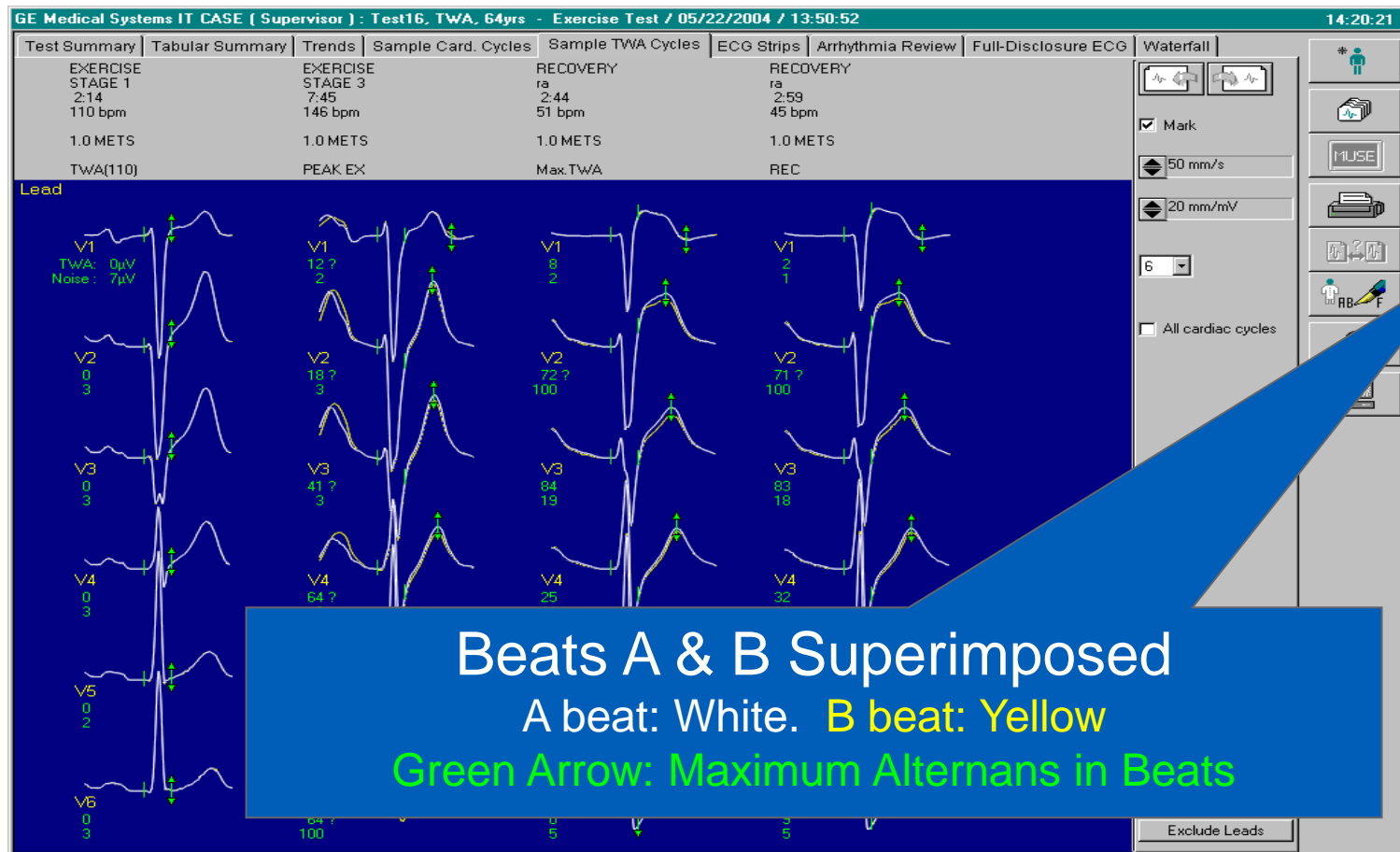


# Report & Data Reviewing Tools

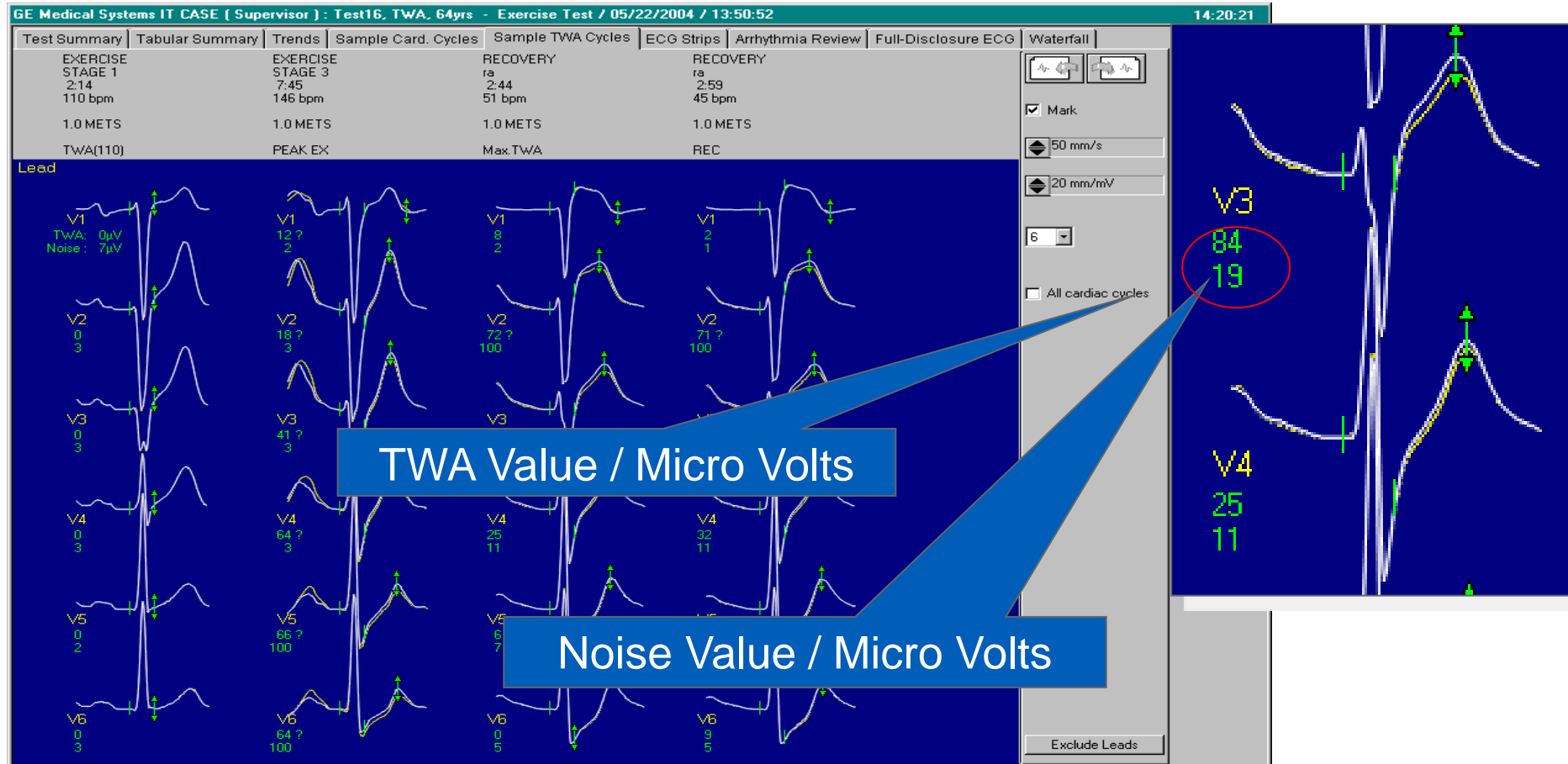




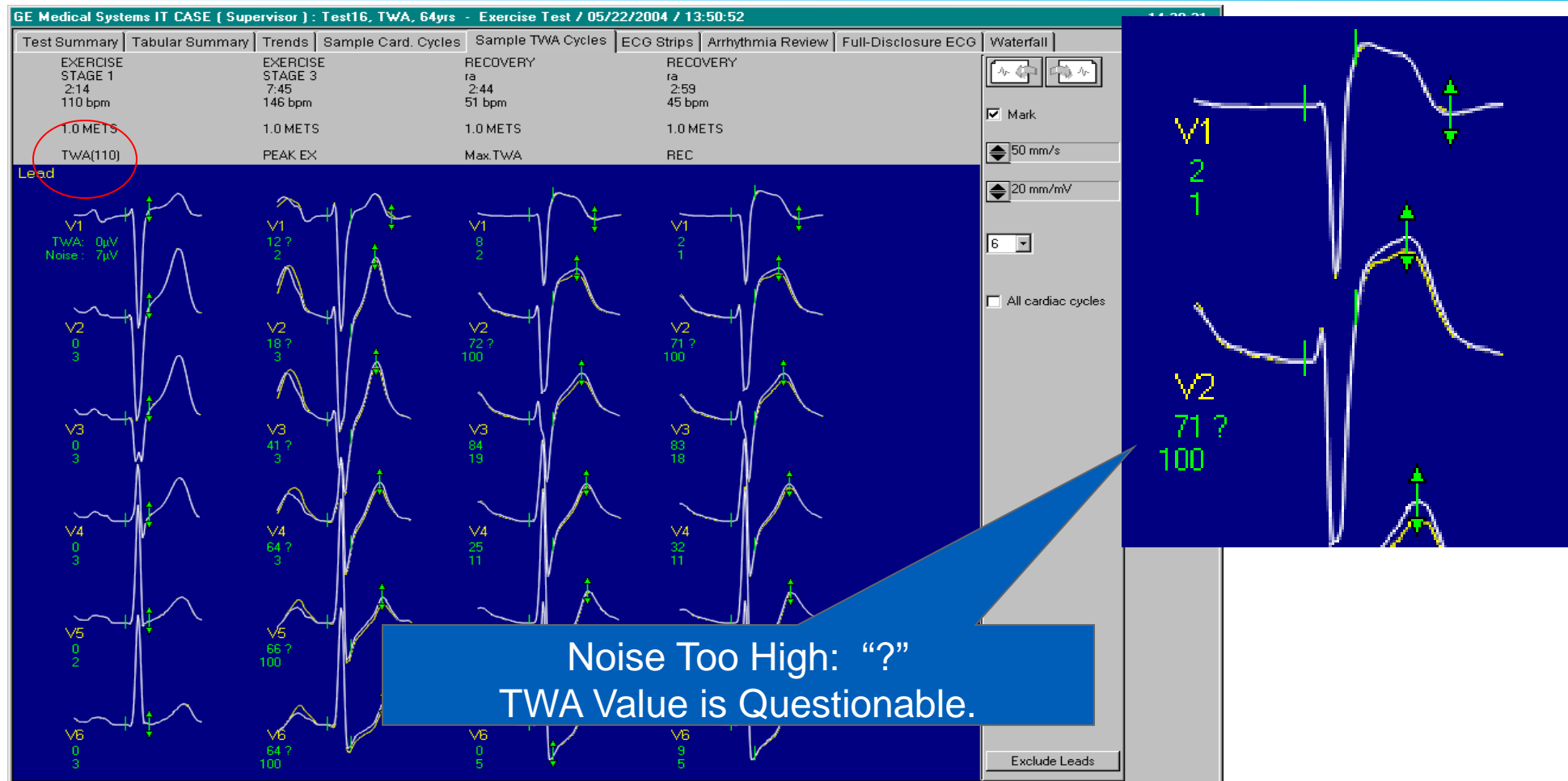
# Medians / Templates: A Closer Look



# Medians / Templates: A Closer Look



# Medians / Templates: A Closer Look



# Trends: A Closer Look

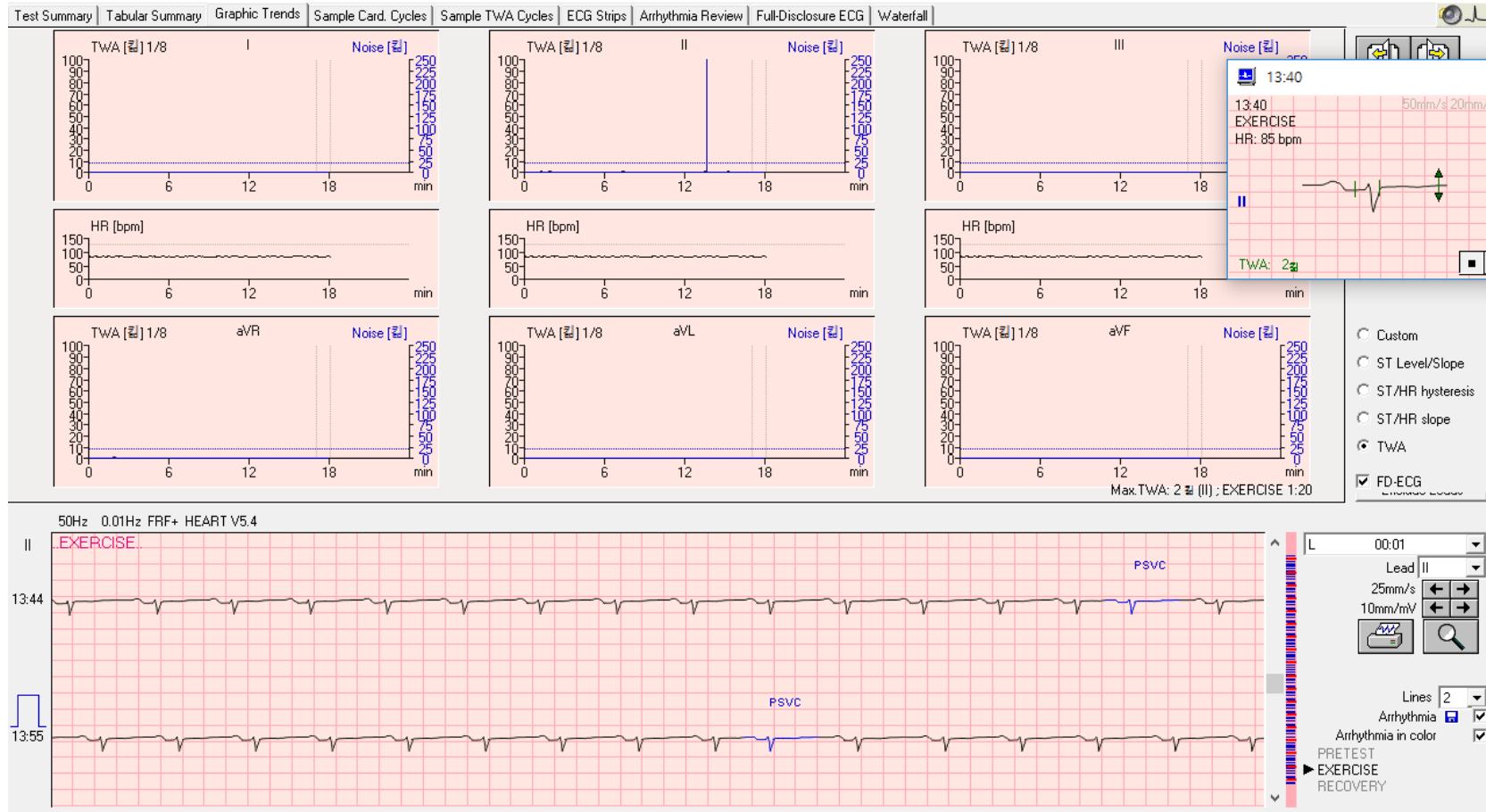


White / Left Axis : TWA values

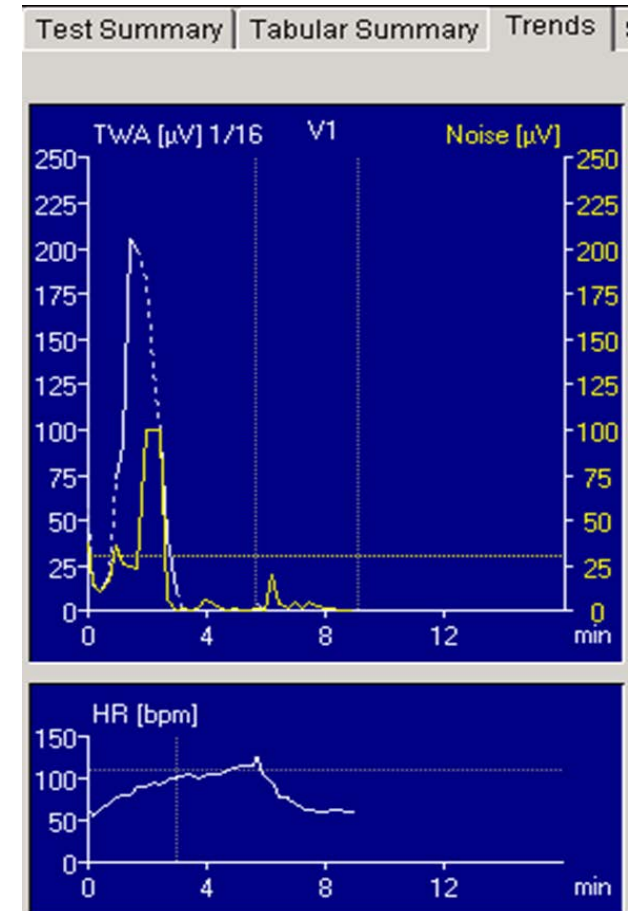
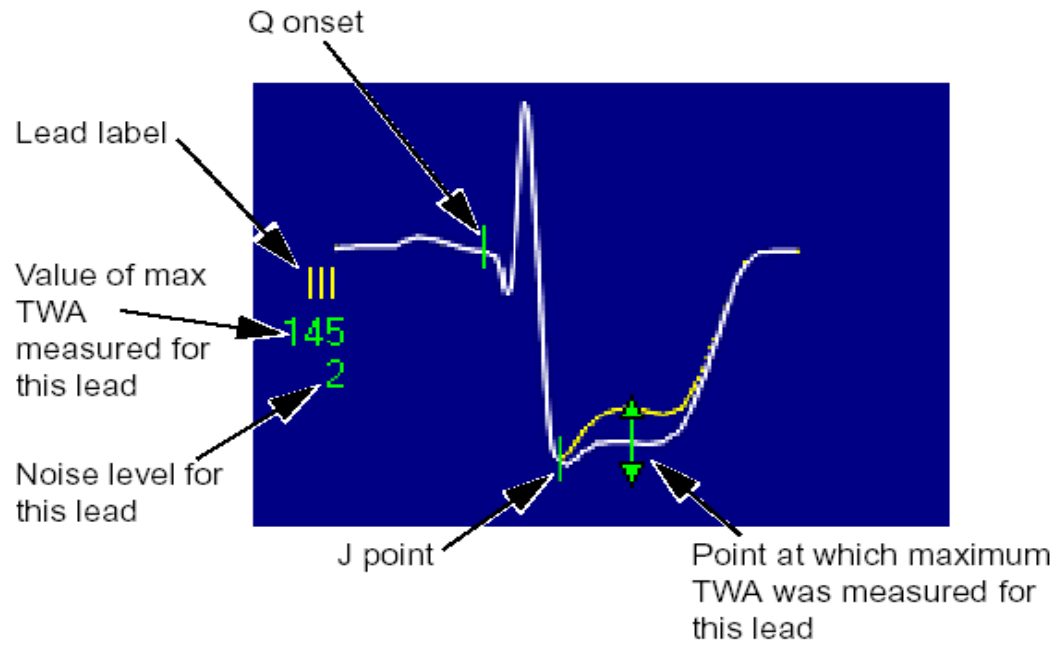
Yellow / Right Axis : Noise values



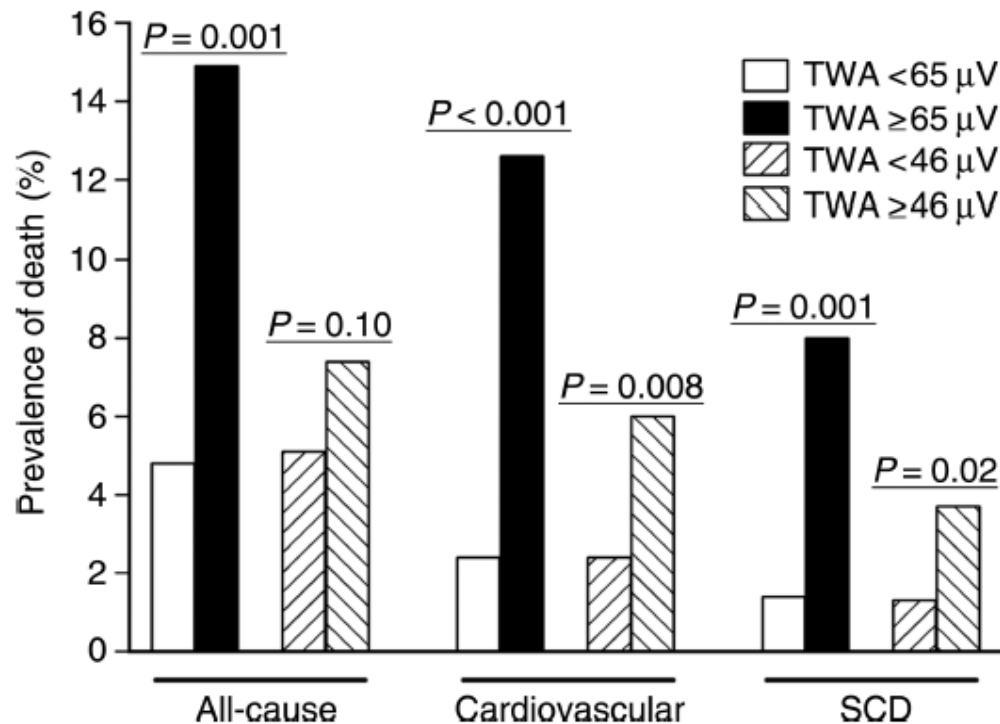
# Trend Review



# CASE TWA Result



# Consecutive Stress Tests on 1,037 TWA Found to Predict SCD



Nieminen, T., et al., T-wave alternans predicts mortality in a population undergoing a clinically indicated exercise test. *Eur Heart J*, 2007



# Ambulatory ECG-Based MMA TWA Testing

## Equipment

- MARS Holter Analysis System - software version 7.0 or above & Cardioday
- Digital recorders—SEER Light, SEER Light Extend, and SEER 12, SEER1000(SEER MC X)

## Lead Selection

- Two precordial lead configurations are recommended (V1, V3, and V5)
- Use of bipolar or Frank X, Y, or Z leads is not recommended for TWA monitoring
- cardiomyopathy or channelopathies such as the long QT syndrome are suspected- 12lead monitoring

## System Configuration

- Update Factor: 1/8
- Heart Rate Limit: 125 beats/min
- Noise Limit: 20 $\mu$ V

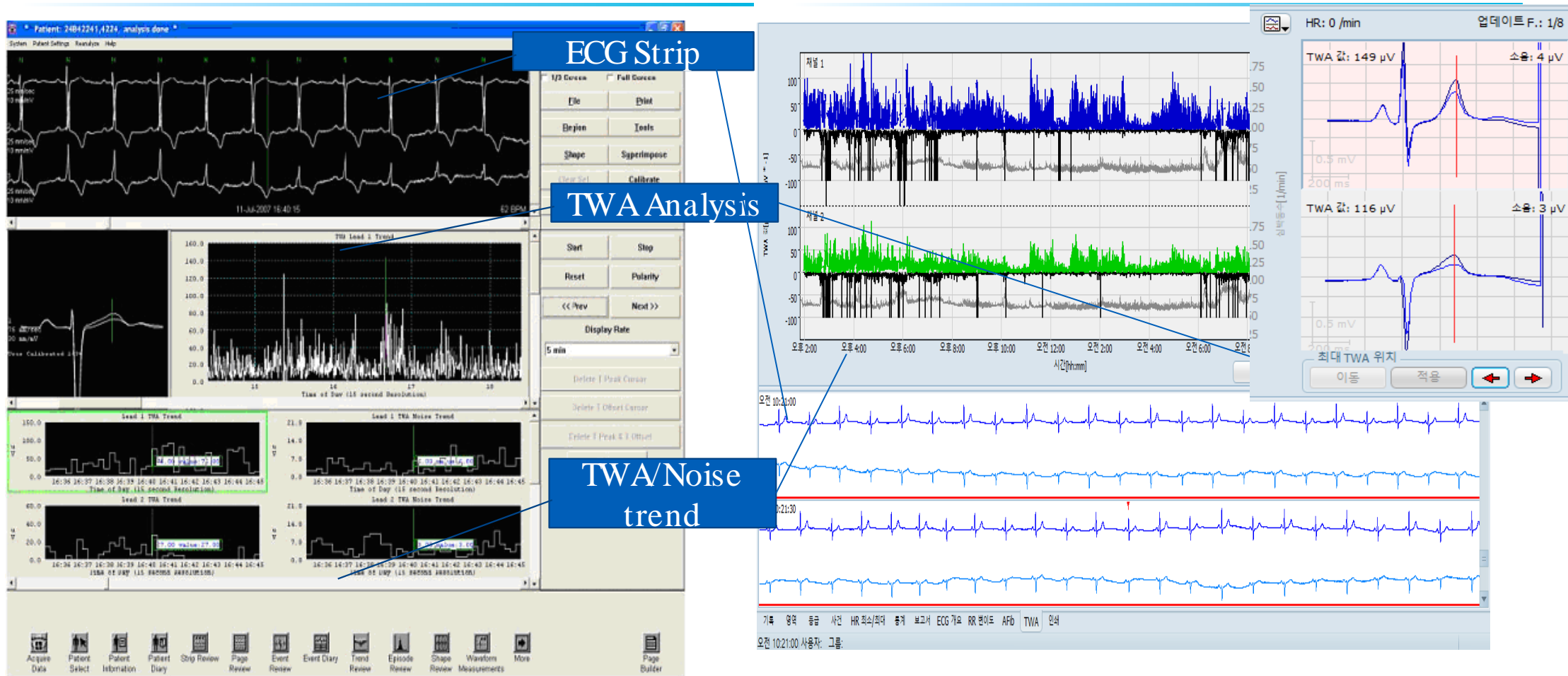




# Recommended screen layout

MARS

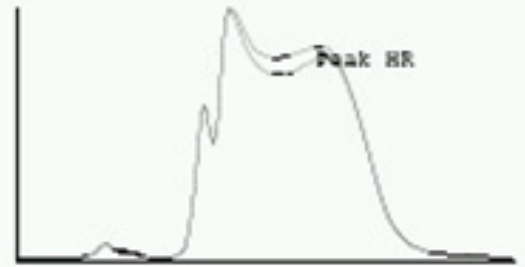
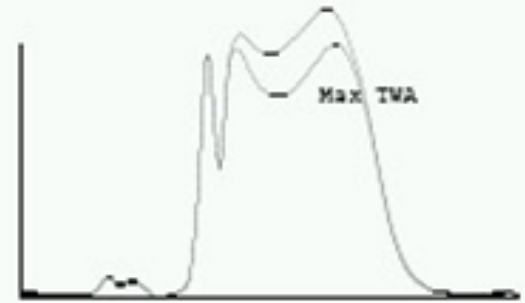
Cardioday



TWA Summary Table Channel 1

32120205000

	Ave RR (1089ms)	Min RR (800ms)	Max RR (1250ms)	RR=1000ms	Overall
TWA (uV)	4+/-11	55+/-**	0+/-**	59+/-28	7+/-**
TWA Noise (uV)	0+/-1	2+/-**	2+/-**	1+/-1	0+/-**
Max TWA:	99 uV	(RR: 857 ms)	16-Jan 08:40		
TWA at peak HR:	55 uV	(HR: 75 bpm)	16-Jan 07:08		
TWA at 8AM:	0 uV	(HR: 57 bpm)			
TWA at peak ST:	7 uV	(ST: **)	16-Jan 07:08		



# Holter TWA, Prospective Study



Sakaki K, Time-domain T-wave alternans measured from Holter electrocardiograms predicts cardiac mortality in patients with left ventricular dysfunction: A prospective study. *Heart Rhythm* 2009

