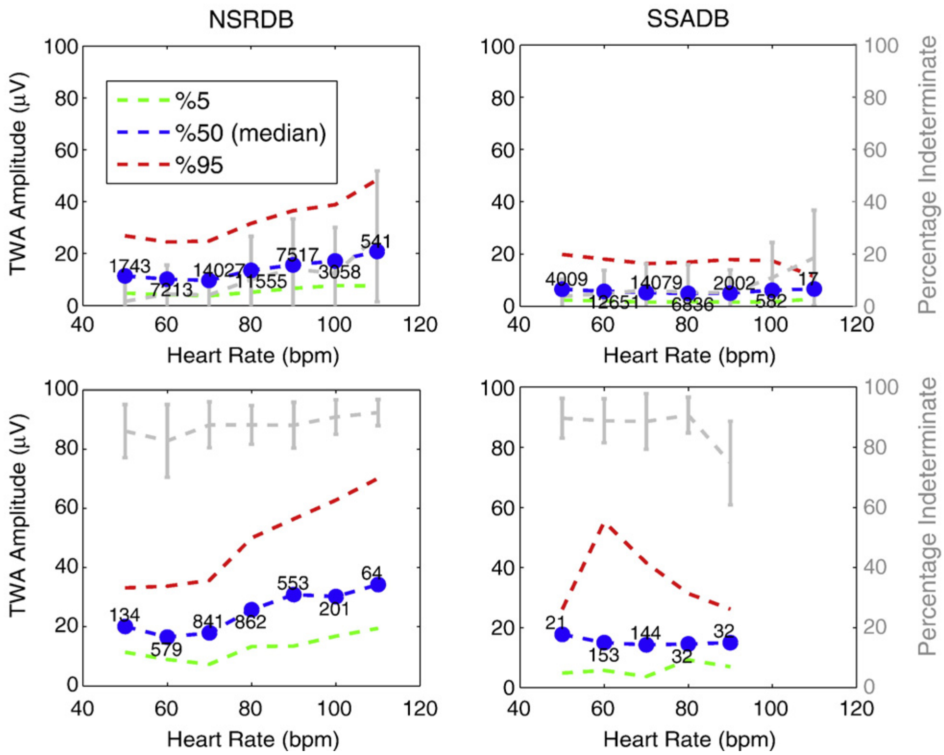

Fig. 1. Comparison of the NSRDB and SADB patient populations (at matched heart rates [HRs]) without significance testing (top) and after significance testing (bottom). The small numbers by the blue circles indicate the number of detected episodes of TWA for the given HR range. The gray error bars signify the percentage of indeterminate cases at each HR range over the entire population. Note that in the top panels, the indeterminate cases are caused by preprocessing failure of associated analysis windows, whereas the indeterminate cases in the bottom panels are an aggregate result of preprocessing failure and application of surrogate significance testing (a = .05). The results indicate that in the healthy population, the TWA activity level tends to increase with heart rate. However, in the sleep apnea patients, there is no apparent increase in TWA activity with an increase in heart rate.

Table 2
Comparison of TWA activity at different HR in the NSRDB, CHFDB, and SCDDB populations using the SAM without significance testing (top) and after significance testing with a = .05 (bottom)

HR band (bpm)	$\Delta_{med(1,2)}$ (μV)	$\Delta_{med(1,3)}$ (μV)
SAM		
40-50	–	−2.28[a]
50-60	0.03[a]	−2.58[a]
60-70	−1.67[a]	−3.14[a]
70-80	−2.82[a]	−6.23[a]
80-90	−1.08[a]	−5.50[a]
90-100	3.05[a]	−5.70[a]
100-110	9.28[a]	−5.60[a]
110-120	25.05[a]	−1.35[a]
After significance testing		
40-50	–	−2.70[a]
50-60	–	18.41[a]
60-70	8.01[a]	6.47[a]
70-80	3.45[a]	0.11[a]
80-90	9.60[a]	6.95[a]
90-100	20.71[a]	0.43[a]
100-110	28.09[a]	9.69[a]
110-120	30.96[a]	41.51[a]

For a given HR range, $\Delta_{med(1,2)}$ is the median TWA amplitude of CHFDB population minus the median TWA amplitude in the NSRDB population. Similarly, $\Delta_{med(1,3)}$ is the median TWA amplitude of SCDDB population minus the median TWA amplitude in the NSRDB population.

[a] Indicates a significant difference between TWA amplitudes at a given HR range using the Kolmogorov-Smirnov test (P < .0001). The empty entries (–) indicate that there were fewer than 10 detected episodes of TWA activity in the corresponding patient populations and thus not amenable to significance testing using the Kolmogorov-Smirnov test.

differences between data in each heart rate decade interval between databases using the Kolmogorov-Smirnov test.

Results: Fig. 1 illustrates the TWA detection statistics after eliminating indeterminate TWA episodes. The lower plots illustrate the statistics after using the surrogate statistical test (P < .01). The results indicate that, in the healthy population, the TWA activity level tends to increase with heart rate. However, in the sleep apnea patients, there is no apparent increase in TWA activity with an increase in heart rate. Moreover, we note that there appears to be a nadir in TWA around 60 to 70 bpm and a small but significant rise in TWA above and below these heart rates. The rise at lower heart rates is not previously reported to our knowledge. We also show that TWA is lower in sleep apnea patients and does not increase with heart rate, although the implications of this finding are unclear (Tables 1 and 2).

doi:10.1016/j.jelectrocard.2010.12.019

O12

Analysis of T-wave alternans in stress tests with periodic component analysis

Violeta Monasterio[a], Juan Pablo Martinez[b]
[a]CIBER de Bioingeniería, Biomateriales y Nanomedicina, Spain
[b]Communications Technology Group, Aragon Institute of Engineering Research, Universidad de Zaragoza, Spain

Background: T-wave alternans (TWA) analysis was performed on stress test electrocardiograms (ECGs), comparing a multilead analysis scheme based on periodic component analysis with a single-lead scheme.

Methods: The data set comprised the 12-lead ECGs of 136 subjects recorded during treadmill exercise test in the University Hospital Lozano

Blesa of Zaragoza (Spain). Records belonged to 2 groups: 66 asymptomatic volunteers who underwent the test with negative results for coronary artery disease and 79 patients with significant stenosis in at least 1 major coronary artery as shown by angiography. Signals were processed with a multilead scheme that combines periodic component analysis (an eigenvalue decomposition technique whose aim is to extract the most periodic sources of the signal) with the Laplacian likelihood ratio method, a single-lead TWA analysis technique. To evaluate the advantages of using a multilead approach, results were compared with those obtained with a single-lead scheme also based on the Laplacian likelihood ratio method.

Results: The multilead scheme provided a higher sensitivity to low-level alternans than the single-lead scheme. With the multilead scheme, TWA was detected in 43.9% of volunteers and 47.1% of ischemic patients, and with the single-lead scheme in 28.7% and 28.5%, respectively. The same sensitivity was set for both schemes by analyzing ECG fragments where no TWA was likely to be found (signals from healthy subjects at heart rates lower than 100 beats per minute [bpm]).

To distinguish between groups according to the risk of sudden cardiac death, results obtained before the heart rate reached a cutoff value were analyzed. With the multilead scheme, the percentage of records with TWA was significantly higher in the ischemic group than in the volunteer group for cutoff points of 100 bpm (7.5% of volunteers, 24.2% of ischemic patients) and 110 bpm (16.6% and 37.1%), whereas this difference was not significant with the single-lead scheme (7.5% and 14.2% for 100 bpm, 13.6% and 21.4% for 110 bpm).

Conclusion: The results suggest that the multilead scheme based on periodic component analysis can improve the prognostic utility of TWA tests. However, a cutoff heart rate to predict cardiovascular events in the study population could not be determined because the follow-up information in terms of arrhythmic events was not available.

doi:10.1016/j.jelectrocard.2010.12.020

O13

Analysis of T-wave alternans using the dominant T wave

Luca Mainardi[a], Roberto Sassi[b]
[a]Department of Bioengineering, Politecnico di Milano, Milan, Italy
[a]Dipartimento di tecnologie dell'informazione, Univerità di Milano, Crema, Italy

Background: The dominant T-wave (DTW) reflects the derivative of the repolarization phase of transmembrane potential of myocytes. T-wave alternans (TWA) is defined as a beat-to-beat alteration of this repolarization morphology that repeats every other heart beat. We investigate if DTW analysis can be useful to enhance information on TWA.

Methods: The CinC Challenge 2008 database consists of 100 multichannel ECG records (2, 3, or 12 leads) sampled at 500 Hz. Thirty-two of these records were generated artificially using 6 electrocardiogram (ECG) models in which TWA was added at different extent (range, 2-60 μV). Also, in 2 synthetic records, no alternans was added. This work processed synthetic records only. The ECG signal was high-pass filtered to remove baseline wander and processed for QRS detection using the freely available software ECGPUWAVE. Two average T-wave patterns were built for even and odd beats. Waves were aligned through cross-correlation. Using a biophysical model of repolarization, it can be shown that the T waves in each thoracic lead are, in first approximation, a scaled version $t = sT$ of a single waveform shape T: the DTW. The scaling factor, s, takes into account the effects of volume conductor and of the differences in repolarization times among myocytes.

Dominant T-wave can be computed through singular value decomposition (SVD) of a matrix H, whose rows contain the T wave measured on each thoracic lead. We have $H = USV'$, where columns of V are the DTW and is derivatives, whereas the singular values, that is, the element of the diagonal of S, are related to the scattering of repolarization times around their mean. We computed DTW for each synthetic recording in the database. Two waves were obtained by performing SVD on the average T-waves template (even and odd beats). In the presence of TWA, we expect that singular values would differ when SVD is performed on even or odd beats' averages.

Results: A significant relationship was observed between synthetic TWA amplitudes and the ratio of the first singular value obtained from even and odd beats' averages ($y = 0.993x - 6.4318$, $P < .00001$ in the log-log space) or their differences ($y = 1.033x+1.697$, $P <$ 0001).

Conclusions: This study shows the potentiality of the DTW concept for quantification of TWA, especially because the parameters we obtained can be linked directly to the physiology of myocytes' repolarization. Further studies are necessary to evaluate the performance of the method on real data and for different noise levels.

doi:10.1016/j.jelectrocard.2010.12.021

O14

Heart rate turbulence denoising benchmarking using a lumped parameter model

Óscar Barquero-Pérez[a], Inmaculada Mora-Jiménez[a], Carlos Figuera-Pozuelo[a], Rebeca Goya-Esteban[a], Juan José Vinagre-Díaz[a], Arcadi García-Alberola[b], José Luis Rojo-Álvarez[a]
[a]Department of Signal Theory and Communications, University Rey Juan Carlos, Fuenlabrada, Spain
[b]Arrhythmia Unit, Hospital Virgen de la Arrixaca, Murcia, Spain

Background: Current heart rate turbulence (HRT) measurements require the average of several HRT tachograms. Filtering isolated tachogram will allow to estimate short-term HRT indices and HRT assessment in a higher number of patients. We aimed to benchmark different denoising techniques for reducing the noise of the HRT, in controlled physiological conditions by using a baroreflex, lumped parameter model.

Methods: We used a lumped parameter model as criterion standard, to benchmark denoising techniques. The sensitivity to the modulation of heart rate by the autonomic system was characterized by a baroreceptor sensitivity parameter (BRS). Two denoising methods were tested: (1) support vector machines (SVM), by our group and (2) cubic splines. A mirror technique was studied for compensating border effects. Tachograms were simulated for 3 BRS values (50, 24, 4), accounting for normal, medium, and low modulation. Tachograms were corrupted with Gaussian noise (SNR = 2, 5, 10, 15 dB). Turbulence slope (TS) was computed for each tachogram realization. Spectral plots of tachograms from the model suggested using the spectral peak (Pmax = max(|FFT|)) to characterize the HRT (Fig. 1). Turbulence slope and Pmax estimations were compared (bias and mean absolute error), with parameters computed in actual, noise-free tachograms.

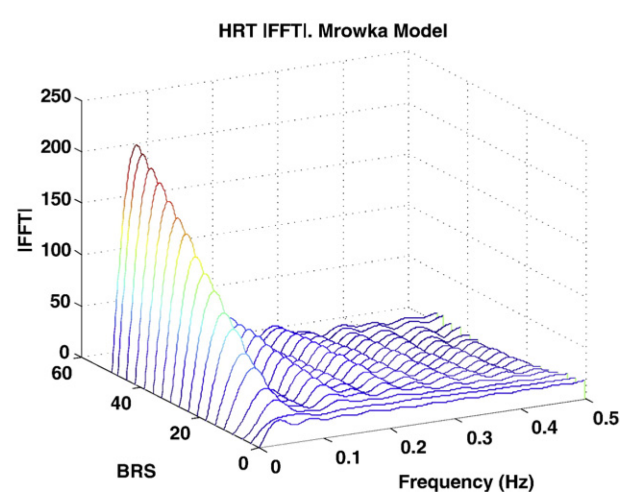

Fig. 1. Heart rate turbulence |FFT|. Mrowka Model.