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.

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O13

Analysis of T-wave alternans using the dominant T wave

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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.

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O14

Heart rate turbulence denoising benchmarking using a lumped parameter model

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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.

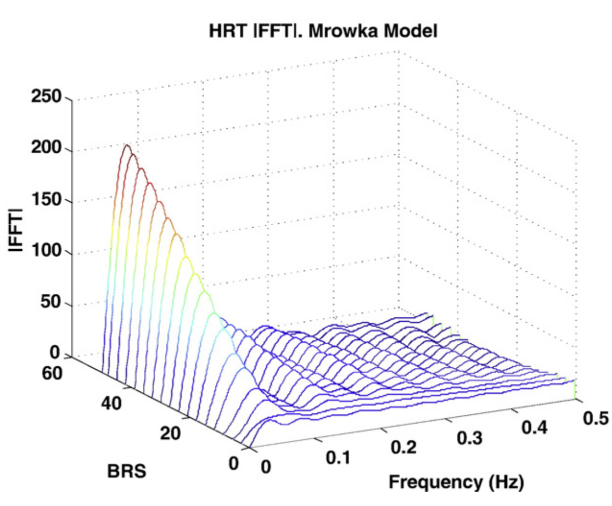

Fig. 1. Heart rate turbulence |FFT|. Mrowka Model.

Results: Parameters in noise-free tachograms were TS (0.61, 3.78, 8.49 ms/RR-Int) and Pmax (27.70, 103.12, 210.02) for low, medium, and normal BRS, respectively. Turbulence slope in denoised tachograms had similar bias when using Spline and SVM for low and medium BRS, whereas the bias was higher using Spline for normal BRS. For normal BRS, TS_Spline(SNR_2) = −2.13 ms/RR-Int, TS_SVM(SNR_2) = −1.40 ms/RR-Int, TS_Spline (SNR_15) = −2.70 ms/RR-Int, and TS_SVM(SNR_15) = −0.52 ms/RR-Int. Mirror technique enhanced TS estimation using SVM, reducing bias and absolute error ([bias,absolute error]) for low-BRS: TS_SVM(SNR_2) = [0.72,0.72] ms/RR-Int; TS_SVM_mirror(SNR_2) = [0.52,0.55] ms/RR-Int; TS_SVM(SNR_15) = [0.29,0.31] ms/RR-Int; TS_SVM_mirror(SNR_15) = [0.12,0.15] ms/RR-Int. Pmax was better estimated with SVM, mainly, in medium and normal BRS. Normal BRS: Pmax_Spline(SNR_2) = 50.38; Pmax_SVM(SNR_2) = 10.54; Pmax_Spline(SNR_15) = 8.41; Pmax_SVM (SNR_15) = −5.52.

Conclusion: Support vector machine denoising provided a more stable and accurate HRT parameters estimation. Mirror techniques allowed to enhance HRT accuracy using SVM. Frequency domain parameters can complement current HRT characterization.

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O15

Heart rate turbulence and phase-rectified signal averaging: methods and clinical application

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Methods analyzing electrocardiograms (ECGs) to assess heart rate variability have to deal with nonstationary and noisy signals. The methods presented, heart rate turbulence and phase-rectified signal averaging, facilitate the processing of such signals to extract clinical relevant information. Heart rate turbulence assess the reaction of the autonomic nervous system when a premature ventricular complex (PVC) occurs by analyzing the sinus rhythm after premature ventricular complexes. Thus, heart rate turbulence looks at specific segments of an ECG. Phase-rectified signal averaging on the other hand analyses the whole ECG and provides a high sensitivity to detect small oscillations in the heartbeat tachogram. Phase-rectified signal averaging also allows to analyze separately oscillations related to heart rate decelerations and heart rate accelerations. Both methods enable a better risk stratification in post–myocardial infarction patients than the standard heart rate variability parameters.
The presentation will explain both methods in more detail and the clinical application of both methods.

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O16

A statistical approach for accurate detection of atrial fibrillation and flutter

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Background: Atrial fibrillation (AF) is the most common clinical arrhythmia afflicting 2 to 3 million Americans. It is a major risk factor for ischemic stroke, and therefore, early detection of AF and mitigation of its deleterious consequences must be a public health priority. Atrial fibrillation is generally considered to be a random sequence of heart beat intervals with markedly increased beat-to-beat variability.

Methods: We have developed an algorithm for real-time detection of AF and atrial flutter, which combines 4 statistical techniques to exploit these characteristics, namely, the root mean square of successive R-R interval differences to quantify variability, the turning points ratio to test for randomness of the time series, Shannon entropy to characterize its complexity, and a high-resolution time-frequency spectral method to find the number of high-frequency spectral peaks in a given 128-beat R-R interval segment.

Results: In an analysis of long-term recordings in the MIT Atrial Fibrillation database, we have achieved a sensitivity of 95% and a specificity of 96.7% in detecting AF. It should be recognized that for clinical applications, the most relevant objective is to detect the presence of AF in a given recording but not necessarily every single AF beat. Using this latter criterion, we achieved episode detection accuracy of 100% for the MIT-BIH AF database. In a more recent analysis of 72 Holter recordings provided by the Scottcare Corporation (www.scottcare.com), we correctly identified the presence of AF episodes in all subjects with a beat-to-beat sensitivity of 95% and specificity of 87%. The algorithm performed well even when tested against AF mixed with several other potentially confounding arrhythmias in the MIT-BIH Arrhythmia Database (sensitivity = 90.2%, specificity = 91.2%). The flutter detection algorithm has undergone preliminary testing on 2 files of the MIT AFIB database which contained around 80 minutes of atrial flutter. High sensitivity (97%) and specificity (95%) have been obtained. Due to the simplicity of our algorithm, the computational speed is higher, thus making it easier to implement and requiring less memory than competing algorithms that store training data information.

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O17

Space-time standardization of magnetocardiography—closer to the goal

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Background: The magnetocardiogram (MCG) is a new noncontact medical tool for detecting and visualizing cardiac electrical activation in the heart. To determine the abnormalities in the heart disease patients using MCG, we have produced a large-scale MCG database and a standard MCG waveform of healthy subjects. In this presentation, we have summarized MCG features regarding to the time length and current distribution.

Methods: We measured 869 MCG data (male: 554; female: 315) using a conventional 64-channel MCG system, which covers the whole heart. Of 869 subjects, 464 people (male: 268, female: 196) were identified and analyzed as a normal group using ECG data. Time intervals (PQ, QRS, QT, and QTc), current distributions (maximum current vector and the total current vector) of MCG data of the 464 normal subjects were analyzed to obtain basic MCG parameters. Furthermore, the measured data were averaged after shortening or lengthening and normalization to produce a standard MCG waveform. Using the standard MCG waveforms, the current distribution feature was clarified in each waveform.

Results: Although the mean values of PQ and QRS intervals of the male subjects were about 10 (PQ) and 6 milliseconds (QRS) longer than those of the female subjects, no intervals were correlated with sex or age. The correlation (R^2 = 0.8) between PQ intervals of ECG and those of MCG was better than the correlation (R^2 = 0.3 or 0.4) between QRS and QT intervals of ECG and those of MCG. Both maximum current vector and total current vector angles were much smaller (30%-50%) than the electrical-axis angle in ECG. Furthermore, the current distribution of the produced standard waveform had a “breakthrough” at 25 milliseconds from the QRS onset.

Conclusion: The large-scale MCG database provides a standardization for space-time MCG analysis.

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