Evaluation of Restitution Properties using a Quasi-stationary Exercise Protocol

Joseph Starobin*, Vivek Varadarajan and Vladmir Polotski

Department of Physics & Astronomy, UNCG, Greensboro, NC, United States

Cardiac restitution portrait can be used as an effective tool for assessment of properties of cardiac electrical restitution and prediction of cardiac arrhythmias. Restitution portraits are usually measured in invasive experiments with prolonged pacing plateaus, since obtaining them from surface ECG recordings is complicated by the presence of physiological variations in QT and diastolic (DI) intervals. To overcome this problem we implement a quasi-stationary exercise protocol which minimizes exercise induced interval variations and modulates them as small fluctuations superimposed on the gradually changing QT and DI interval trends. Using such a protocol we develop an adaptive signal processing method which can be used for non-invasive assessment of restitution portraits. Firstly, we separate slow varying beat-to-beat QT and DI interval trends from high frequency fluctuations by time domain filtering of the corresponding signals. Secondly, we compute a cross correlation signal (CC) between QT and DI interval using an adaptive least-mean-square filtering algorithm. This filter provides point-to-point estimates of QT interval fluctuations that are physiologically related to DI interval fluctuations. Thirdly, we determine either correlated ($CC>0.8$) or anti-correlated ($CC<-0.8$) strips of QT and DI fluctuations longer than five beats. Finally, we compute linear regression of QT intervals on corresponding DI intervals within each correlated and anti-correlated strip. These regression lines determine S1-S2 and basic cycle length (BCL) restitution slopes, respectively. This method has been implemented for evaluation of restitution properties in seventeen normal individuals who volunteered to exercise on a treadmill. It was found that in each individual the magnitudes of S1-S2 and BCL restitution slopes increased with heart rate. It was also shown that the average S1-S2 slopes were higher for volunteers in whom peak heart rates exceeded one hundred beat per minute. These findings can be instrumental in theoretical modeling and quantification of instabilities of cardiac rhythm.