Observational error in time domain HRV analysis

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Desription of the problem

HRV analysis in clinical and physiological studies is popular. Unfortunately a role of accuracy of the determined HRV parameters is usually not discussed. Multiple steps of computations propagate the observational error, which magnitude in final result is usually unknown or at least is difficult to predict. Therefore the results might have doubtful statistical reliability.

Objectives

We propose the estimation of the impact of observational error on basic time domain parameters of HRV: mean RR, SDNN, SDSD, RMSSD, pNN50 [1]. Note, that we focus on observational errors associated to the ECG sampling rate only. We do not remove or replace arrhythmias in our simulations,therefore we use pRR50 instead pNN50, SDRR instead of SDNN.

Methods

(1) $X_i = RR_i + \xi_i$

the random variable X_i instead of the RR_i interval is proposed. We assume that observational errors ξ are normally distributed with zero mean and standard deviation σ.

(2) We assume constant σ with range of milliseconds *1-12ms*

(3) Perform computations on real data from MIT-BIH Arrhythmia Database [2]

(4) Monte Carlo simulations (MC)

(5) Each time domain parameter is characterised by distribution with the standard deviation **β.**

Results

Resultant parameters are presented in percentage scale-as ratio of determined variable to original one. Statistics for time domain parameters burdened by particular observational error σ are shown in box-plots separately.

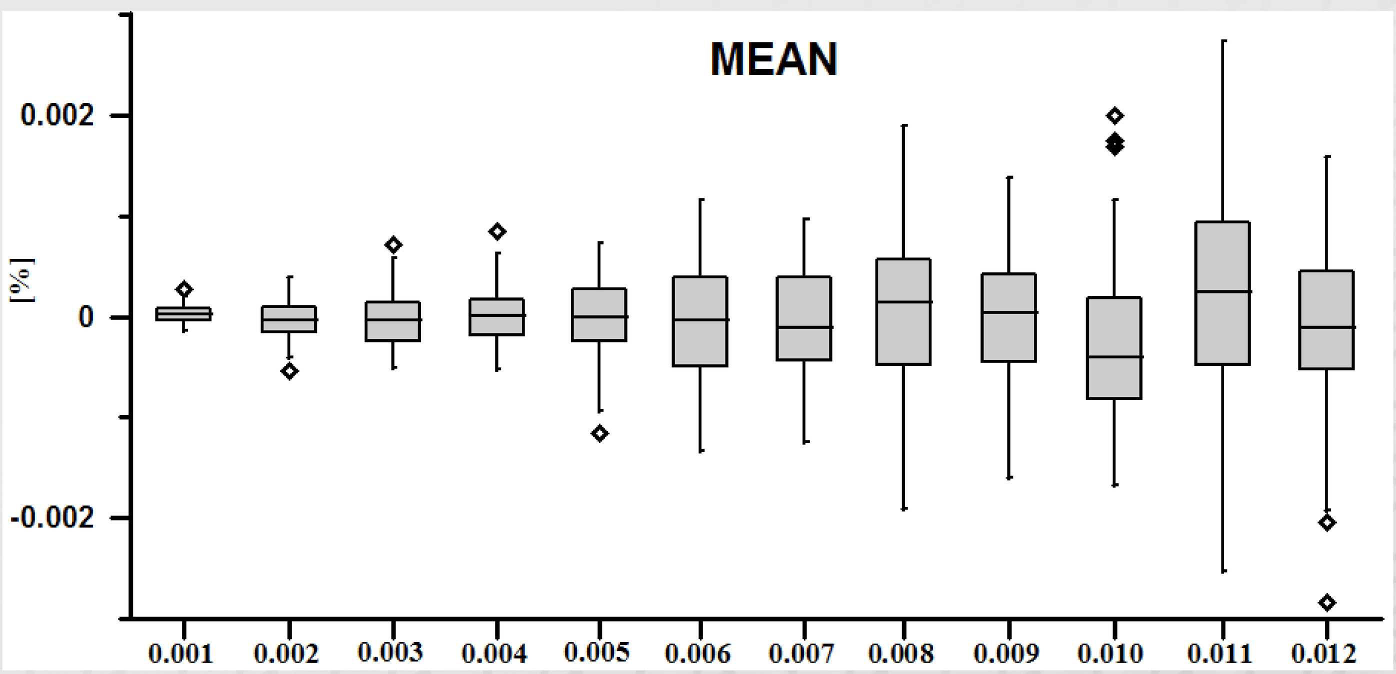
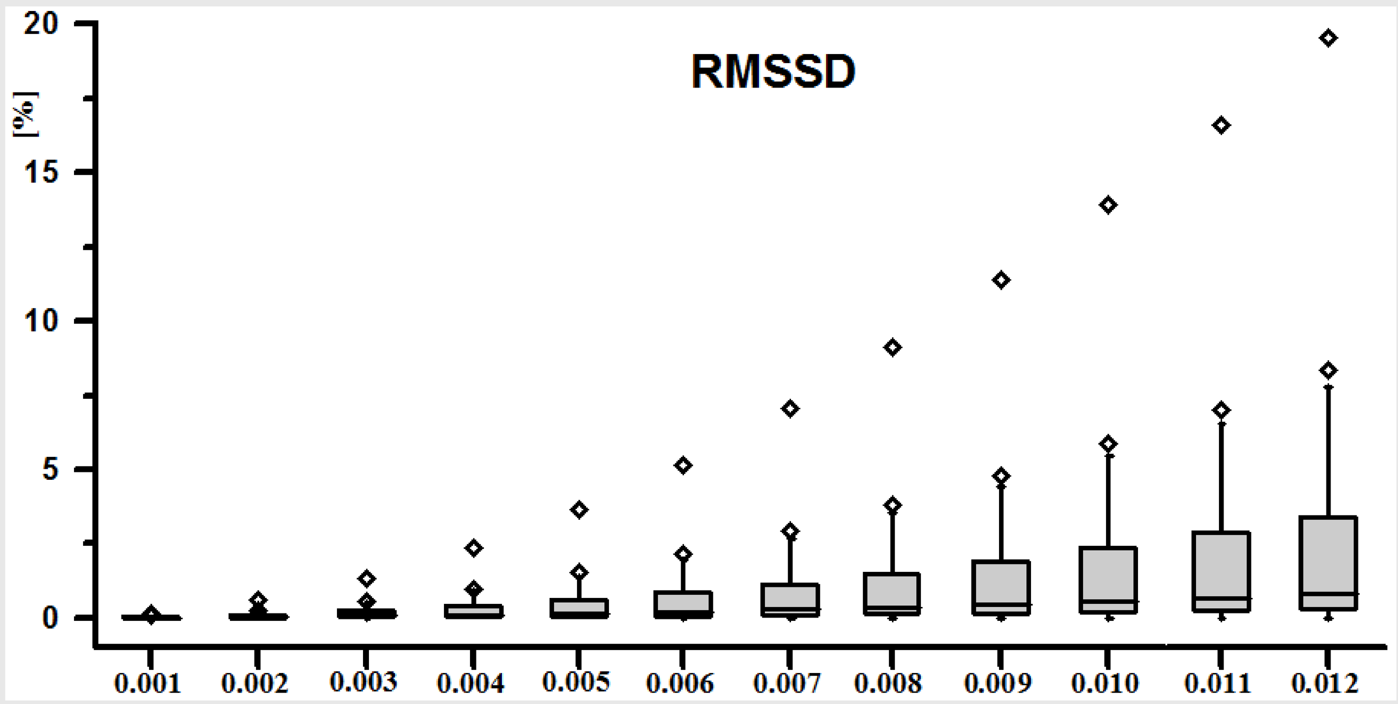
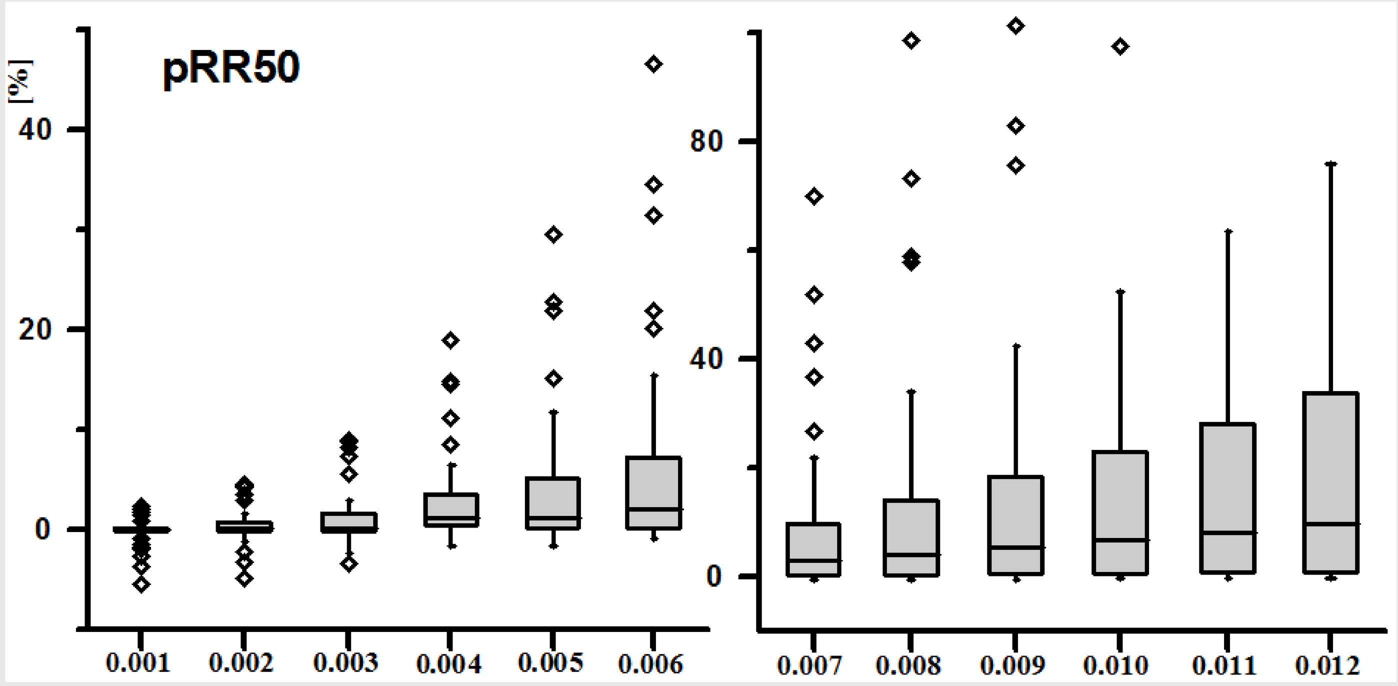


Fig. 1. For mean RR we observe low fluctuations around 0%. Observational error does not impact the parameter.

Mean RR, SDRR, SDSD, RMSSD parameters are charactrerised by low sensitivity to observational error. Percentage magnitudes in precented Fig. 1,2 do not exceeds 10%.



With increasing σ, RMSSD parameter diverges from original value.



The pRR50 parameter is the most sensitive for measurement error. We observe even more than 10% increse of the variable.

For supporting MC simulations, we introduce percentage p_k error of parameter Y_k={mean RR, SDRR, SDSD, RMSSD, pRR50} obtained from observational error σ. p_k provides information about assessment of precision of HRV parameters if we assume, that ECG measurement has limited accuracy due to limited sampling frequency of ECG recorders. p_k is computed from formula:

$\beta / \langle Y_k \rangle * 100\%$

σ [ms]	Mean RR	SDRR	RMSSD	pRR50
4	0.01 [%]	0.09 [%]	0.14 [%]	1.54 [%]
8	0.02 [%]	0.17 [%]	0.28 [%]	2.68 [%]
12	0.03 [%]	0.26 [%]	0.41 [%]	4.01 [%]

Summary

For assessment of accuracy of time domain parameters we introduce the standard deviation β. β is a magnitude of general parameter error, which occurs as result of measurement error σ propagation in computations of time domain methods. Mean RR has low sensitivity for observational error. Other time domain parameters changes significantly with increasing σ. This results show, that comparisons of data sets with different sampling frequency rate should be done carefully.

References

[1] Malik et al Circulation (1996) 93(5):1043-65

[2]Goldberger A et al. Circulation (2000) 101(23) e215-e220