QRS and T Loops Area Changes During Haemodialysis

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Abstract

We studied 58 patients, age 59±13 years, 52% males, with renal disease duration 9.7±6.7 years and haemodialysis (HD) duration 5.2±4.4 years. Digital ECGs were recorded before and after HD. Serum electrolytes (potassium-K, sodium-Na, phosphorus-Ph and calcium-Ca), urea and creatinine levels were evaluated. Percentage change of the above mentioned parameters during HD was estimated.

Orthogonal X, Y and Z leads were derived from the standard 12-leads and VCG parameters changes in response to HD were analysed. QRS loop area increased significantly after HD, while T loop area did not change significantly. Maximal QRS vector increased significantly, maximal T vector decreased significantly, and QRS-T angle remained relatively the same.

The increase of QRS area did not show a significant correlation with any of the demographic factors, clinical characteristics and laboratory parameters. The increase of maximal QRS vector was inversely correlated with HD duration in years (p = 0.002). The decrease of T loop area and maximal T vector correlated negatively with Na shift during HD (p = 0.02 and p = 0.03, respectively). The decrease of maximal T vector correlated positively with the change in K concentration (p = 0.04).

1.   Introduction

Haemodialysis is the most common method used to treat end-stage renal disease. It removes waste products and free water from the blood, restoring a proper balance of electrolytes. This procedure causes substantial changes in the electrical activity of the heart, observed by analysis of electrocardiograms (ECG) and vectorcardiograms (VCG).

The most commonly observed ECG changes are an increase of the QRS amplitude [1] and QRS time-voltage area after haemodialysis [2].

Some authors argue that the VCG is still superior to the scalar ECG in very specific situations, such as in the evaluation of electrically inactive areas, in the identification and location of ventricular pre-excitation, in the evaluation of particular aspects of Brugada Syndrome [3]. Others believe that VCG is more reliable for the diagnosis of atrial enlargement and right ventricular hypertrophy [4]. It is more sensitive than the ECG in the recognition of myocardial infarction, especially if the infarction is inferior or if it occurs in the presence of left bundle branch block or left anterior hemiblock.

The most common VCG parameters used for analysis of haemodialysis ECG changes are: magnitude of maximal spatial QRS and T vector, angle between them, azimuth and elevation angles of maximal vectors, etc.

It has been found that haemodialysis causes changes in dynamic vectorcardiographic ischemia monitoring parameters [5], especially in the QRS vector difference and the ST vector magnitude. These changes are mostly related to blood volume and extracellular water shift.

We did not find a material describing QRS and T loops area change during haemodialysis. QRS loop area has only been analysed to describe myocardial damage in Chagas' disease patients (tropical illness caused by a parasite) [6].

The aim of the study is to analyse VCG parameters changes in response to haemodialysis: magnitude of QRS and T maximal vectors and angle between the two vectors. We are focusing also on QRS and T loop areas – parameters that have not been used so far during haemodialysis.

2.   Materials and methods

2.1.   Haemodialysis matabase

We studied 58 patients, age 59±13 years, 52% males, with renal disease duration 9.7±6.7 years and haemodialysis duration 5.2±4.4 years. Digital ECGs (1-minute duration, 12-standatd leads, 500 Hz sampling rate)
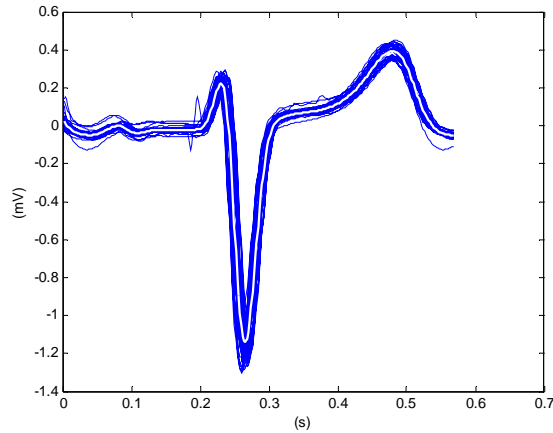
Figure 1. Superimposition of all P-QRS-T intervals (blue traces) and their mean signal (white trace)

Figure 2. Area is calculated by adding the blue and subtracting the red strips.

were recorded before and after haemodialysis session. Serum electrolytes (potassium-K, sodium-Na, phosphorus-Ph and calcium-Ca), urea and creatinine levels were evaluated before and after haemodialysis. Percentage change of the above mentioned parameters during haemodialysis was estimated. We calculated also mean haemodialysis clearance.

All patients signed an informed consent for personal data analysis. The study protocol is in accordance with the Declaration of Helsinki.

2.2. Signal processing

The ECG signals were preprocessed to eliminate or suppress the powerline interference [7], the drift [8] and the electromyographic noise [9].

QRS detection was applied [10] and fiducial points for best matching of successive P-QRS-T intervals were achieved by cross correlation. The fiducial points' location was needed because the used QRS detection algorithm triggers at arbitrary moment inside the QRS.

The average heart rate was obtained and the length of the P-QRS-T interval was calculated in accordance to it.

Mean signal in the P-QRS-T interval was calculated taking into account the fiducial points. Working with a mean signal excludes the random selection of atypical or contaminated by noise signal. Superimposition of all P-QRS-T intervals of a certain lead and the calculated mean signal are shown in Figure 1.

The orthogonal X, Y and Z leads were derived from the standard 12-leads, using the transfer formulas of Levkov [11]:

$X = -0.4R_F + 0.1C4_F + 0.2C5_F + 0.5C6_F$

$Y = -0.3L_F - 0.8R_F - 0.2C5_F + 0.3C6_F$

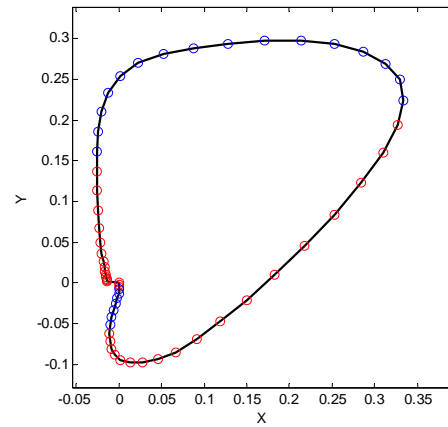$Z = 0.1L_F + 0.2R_F - 0.3C1_F - 0.1C2_F - 0.1C3_F - -0.2C4_F - 0.1C5_F + 0.4C6_F,$

where R_F, L_F, $C1_F$, …, $C6_F$ are the primary 8-channel leads, 2 peripheral and 6 precordial, taken with respect to the left leg electrode (F) [8].

Several VCG parameters were obtained:
- magnitude of the QRS and T maximal vectors,
- angle between the QRS and T maximal vectors,
- QRS and T loops area.

The spatial angle between QRS and T maximal vectors was calculated by:

$$Angle = \cos^{-1} \frac{QRS_{x1}*T_{x2} + QRS_{y1}*T_{y2} + QRS_{z1}*T_{z2}}{\sqrt{QRS_{x1} + QRS_{y1} + QRS_{z1}} * \sqrt{T_{x2} + T_{y2} + T_{z2}}}$$

where x_1,y_1,z_1 are the 3D coordinates of the point of the maximal QRS vector and x_2,y_2,z_2 are the 3D coordinates of the point of the maximal T vector

The area of the loops is calculated for the frontal (X,Y) plane, for any strip with abscissa

$$Dx(i)=x(i+1) -x(i)$$

Starting with initial value of Area=0 any subsequent strip is added, if $Dx(i) \geq 0$ (Fig. 2, blue points) or else subtracted to the Area (Fig. 2, red points).

2.3. Statistics

We tested the distribution of continuous variables using the Kolmogorov-Smirnov test. Normally distributed data were presented as mean ± standard deviation (SD), whereas non-normally distributed data – as median and interquartile range (IQR) (the difference between the 25th and 75th percentile). Categorical variables were presented in percentage terms. We compared baseline and post-haemodialysis laboratory and ECG / VCG parameters using one sample t test for normally distributed data and the Mann-Whitney U test for non-normally distributed data. Significant correlation between percentage changes in different parameters during haemodialysis was sought with Pearson's correlation analysis. We performed a multivariable analysis using Linear Regression Model with the stepwise procedure with a criterion to enter
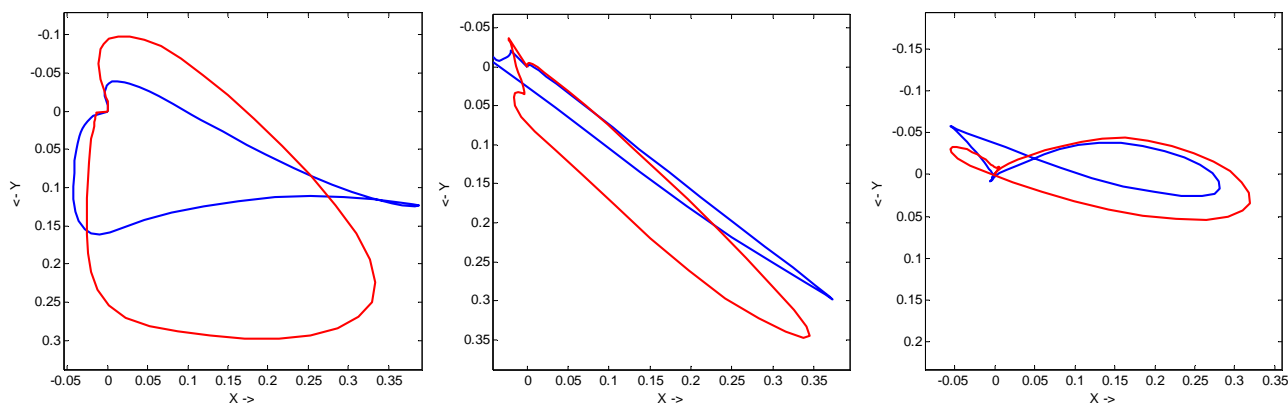
Figure 3. Typical examples of QRS loops before (blue trace) and after (red trace) haemodialysis

≤0.05 and criterion to remove ≥ 0.1. A two-tailed p value < 0.05 was considered statistically significant. Statistical analysis was performed using SPSS statistical software for Windows version 13.0.

3. Results

QRS loop areas increased significantly after haemodialysis (typical examples are shown in Fig.3), while the T loop areas did not change significantly. Maximal QRS vector increased significantly, maximal T vector decreased significantly, and QRS-T angle remained relatively the same – Table 1.

Table 1. VCG parameters change during haemodialysis (HD)

Parameter	Baseline	After HD	Significance
QRS area ($mV^2/1000$)	34.9 ± 34.8	50.4 ± 47.3	$p < 0.001$
T wave area ($mV^2/1000$)	1.9 ± 2.3	1.6 ± 1.7	ns
Max QRS vector (mV)	0.48 ± 0.2	0.54 ± 0.22	$p < 0.001$
Max T wave vector (mV)	0.14 ± 0.05	0.12 ± 0.05	$p < 0.001$
QRS-T angle	55 ± 39.7	55.7 ± 43.5	ns

We performed a correlation analysis and found that % change in QRS area did not show a significant correlation with any of the demographic factors, clinical characteristics and laboratory parameters, nor was it independently predicted by any of the aforementioned factors in multivariable regression analysis.

Percentage change in maximal QRS vector was inversely correlated with haemodialysis duration in years (correlation coefficient -0.41, p = 0.002) and the same parameter turned out to be an independent predictor for maximal QRS vector change during haemodialysis.

Percentage change in T-wave area and maximal T vector during haemodialysis correlated positively with the change in K concentration (only for the vector: 0.27, p = 0.04) and negatively with Na shift during haemodialysis (-0.31, p = 0.02 and -0.29, p = 0.03, respectively). Only the change in Na concentration, however, was independent predictor for % change in T-wave area and maximal T wave vector in regression analysis.

4. Discussion

In the present analysis we evaluated VCG changes during haemodialysis and for the first time employed QRS loop and T wave area measurement in this setting. We found that maximal QRS vector increased after haemodialysis, which has been shown also in previous studies [5, 12-14]. This increase in our study was independently predicted and negatively correlated to haemodialysis duration in years, i.e. the longer a patient has been on this treatment, the lesser is the change in QRS vector during haemodialysis. And since QRS vector amplitude increase during haemodialysis has been previously linked to volume shift during the procedure, our finding could probably mean that percentage change in maximal QRS vector could be regarded as an indirect marker of the efficiency of haemodialysis.

Maximal T wave vector change during haemodialysis has been less well studied. In our group it turned out that this parameter decreased during the procedure and the decrease could be partially explained and inversely correlated to Na-concentration change. Another interesting fact is that T wave area, although negatively correlated with Na shift during haemodialysis, did not change significantly after the procedure. Also the angle between QRS and T loop vectors did not show a significant difference during haemodialysis.

In four patients of the study group a significant reduction of the QRS-T spatial angle with more than 70˚ was observed as a result of the haemodialysis. This

moves those patients from the borderline (105 to 135°) and abnormal (135 to 180°) groups to the normal group (0 to 105°) of QRS-T angle predictor for a risk for cardiac death [15].

We were the first to prove that QRS loop area increased during haemodialysis. One could probably argue that this is an expected finding, given the increase in QRS vector and amplitude following this procedure (which is a well-known fact, confirmed also in this study). But as could be seen from T loop analysis – maximal T loop vector decreases, while in the same time the area remains the same during haemodialysis. So the change in vector is not necessarily linked to a change in area, and the observed increase of QRS loop area after haemodialysis probably has its own clinical significance. A confirmation to the latter is the fact that the magnitude of change in QRS area did not show a significant correlation with any of the demographic factors, clinical characteristics and haemodialysis and laboratory parameters, nor was it independently predicted by any of the aforementioned factors in multivariable regression analysis.

5.   Conclusion

The haemodialysis is associated with an increase in the QRS area and maximal QRS vector, and a decrease in maximal T-wave vector. Percentage change in QRS and T max vectors could be partially explained by clinical variables, while QRS-area-change could not, and possibly has its independent clinical significance.

Acknowledgements

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