CLINICAL STUDY

Relation of ventricular late potentials and intradialytic changes in serum electrolytes, ultrafiltration, left ventricular ejection fraction and left ventricular mass index in haemodialysis patients

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Abstract

Background: **End-stage renal failure patients on haemodialysis (HD) suffer from increased risk of sudden cardiac death. Abnormal late potentials (LP) on signal-averaged electrocardiogram (SAAECG) has proved valuable for identification of increased risk of malignant ventricular tachyarryhythmias in various settings of patients. Abnormalities in LP were reported in HD patients, but their role is still not clear. The aim of the study was to evaluate: 1. the influence of HD on SAECG, 2. the correlation of intradialytic changes of serum electrolytes, weight change and ultrafiltration with intradialytic changes of LP, 3. the correlation of left ventricular ejection fraction (LVEF) and left ventricular mass index (LVMI) with LP before and after HD.**

Methods: **LP (parameters fQRSd, RMS40, LAS40) were obtained in 39 patients in sinus rhythm within one hour before and after chronic maintenance HD. Patients with permanent atrial fibrillation or on antiarrhythmic therapy (other than betablockers) were excluded. Echocardiography was performed within three days before HD.**

Results: **No difference in fQRSd before and after HD was found. Postdialytic RMS40 (47.0±30.1 μV vs 37.1±22.6 μV, $p<0.05$) and LAS40 (25.9±9.7 ms vs 30.8±12.5 ms, $p<0.05$) significantly improved. Weak significant negative correlation between intradialytic Na change and fQRSd change was found ($R=-0.33$, $p<0.05$). Correlations between intradialytic changes of other electrolytes (K, Ca, P. Mg) and individual LP parameters were nonsignificant. There was no correlation found between intradialytic weight change/ultrafiltration and intradialytic differencies of SAECG. LVEF was weakly inversely correlated with predialytic fQRSd ($R=-0.37$, $p<0.05$) and postdialytic fQRSd ($R=-0.35$, $p<0.05$). LVMI was weakly positively correlated with predialytic fQRSd ($R=0.39$, $p<0.05$) and postdialytic fQRSd ($R=0.40$, $p<0.05$). LVEF respectively LVMI did not correlate neither with RMS40 nor with LAS40 before or after HD.**

Conclusions: **SAECG partially improved in end-stage renal failure patients after HD (RMS40 and LAS40 but not fQRSd). Intradialytic differencies of SAECG were not correlated neither with ultrafiltration nor with weight change. Pre-/postdialytic fQRSd inversely correlated with LVEF and positively correlated with LVMI. Further controlled, prospective studies investigating the impact of LP on HD patient care are needed.** ***(Tab. 6, Ref. 19.)***

Key words: echocardiography, haemodialysis, late potentials, signal-averaged electrocardiography, ventricular function.

End-stage renal failure patients on haemodialysis (HD) suffer from increased risk of cardiac arrhythmic mortality. Sudden cardiac death accounts for 15–38 % of the 7–10 % total annual mortality rate among HD patients (1, 2). Therefore, the search for methods capable to detect individual patients at high risk for sudden cardiac death is essential for reducing mortality from ventricular arrhythmias (3). Among the three different mechanisms of ventricular tachyarrhythmias (reentry, abnormal automaticity and triggered activity) reentry is believed to be the most frequent and clinically most important. The presence of abnormal late potentials (LP) on the signal-averaged electrocardiogram (SAECG) is commonly accepted as a noninvasive electrocardiographic marker of the structural substrate required for reentrant ventricular tachycardias. SAECG is a useful diagnostic tool for assessing delayed ventricular depolarization.

The presence of abnormal ventricular LP has proved valuable for identification of patients at increased risk of malignant ventricular tachyarrhythmias in various settings of patients, like post myocardial infarction, chronic ischemic heart disease, dilated and hypertrophic cardiomyopathy and patients with unexplained syncope (3). LP are high-frequency, low amplitude signals at the end of QRS complex, which can be detected by SAECG. Abnormal LP in various heart diseases are thought to be due to myocardial

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fibrosis creating barriers that lenghten the excitation pathway and delay electrical conduction. Fragmentation of ventricular depolarization due to islands of fibrosis and areas of viable myocardium is a prerequisite for reentry circuit, which is one of unavoidable conditions needed for reentrant monomorphic ventricular tachycardia. The mechanism of reentrant ventricular tachycardias is thought to depend on areas of slow conduction and dispersion of refractoriness (1, 3, 4). Functional mechanisms present during HD, like volume, electrolyte, acid-base balance, heart rate and blood pressure changes, can serve as triggers and modulating factors, which can transform a stable substrate into an unstable one (2).

Abnormalities in SAECG were reported in HD (1, 2, 5–8) and continuous ambulatory peritoneal dialysis (CAPD) patients (6), but the role of SAECG in them is still not sufficiently clear. Prognostic value of SAECG in end-stage renal failure patients on HD has not been yet definitively established. Similarly as in general cardiology, abnormal SAECG failed until now to predict sudden cardiac death in these patients (1, 9). Conversely, valuable is a very high negative predictive value of SAECG in prediction of sudden cardiac arrhythmic death (10). Predictive accuracy of SAECG can be increased by combining with echocardiographic measurement of left ventricular (LV) function (3). A simple algorithm that combines prolonged QT dispersion >40 ms with the duration of filtered QRS complex >114 ms in SAECG may prove useful in determining patients at risk for ventricular tachyarrhythmias (11). LP are dynamic and HD-dependent, but it is of interest, that various investigators observed controversial results regarding the changes of LP parameters after HD (2, 5, 8). Some authors reported improvement of certain LP indices (2), while others published opposite results (5, 8). No sufficient data are available on whether pharmacologic or nonpharmacologic interventions in HD patients with abnormal LP significantly influence the arrhythmic mortality.

The aim of this study was to evaluate: 1. the influence of HD on LP parameters, 2. the correlation of intradialytic change of serum electrolytes, weight change, ultrafiltration and heart rate change with intradialytic differencies of LP parameters, 3. the correlation of left ventricular ejection fraction (LVEF) and left ventricular mass index (LVMI) with LP parameters before and after HD.

As to our knowledge the relation between LV global systolic function and pre-/postdialytic LP as well as the relation between ultrafiltration and intradialytic change of LP have not been published yet.

Methods

Patient population

The study group consisted of 39 patients on chronic maintenance HD (18 male, 18 female; mean age 52.0±12.5 years, range 24–78). Patients with antiarrhythmic therapy (other than beta-blockers) or with permanent atrial fibrillation were excluded. The mean time on HD was 19.1±13.8 months, range 1–60 months. 14 patients had ischemic heart disease (4 with history of an old myocardial infarction), 2 patients had PTCA. In 7 patients, documented heart failure was present. Before start of the study, 2 patients were successfully resuscitated from sustained ventricular tachycardia deteriorating in ventricular fibrillation. 6 patients suffered from paroxysmal atrial fibrillation, but all were in sinus rhythm during LP recording. 31 patients had arterial hypertension, 8 patients had diabetes mellitus and in 8 patients, hyperlipoproteinemia was present.

Mean follow-up period after LP analysis was 19.5±12.3 months (median 9.5 months). One patient was transplanted. 5 patients (12.8 %) have died (the causes were sudden cardiac death, acute myocardial infarction, progressive heart failure, uraemic encephalopathy and sepsis).

Signal-averaged electrocardiogram recording

SAECG was recorded and analysed using Schiller AT-60 Late Potentials system from the data of the standard bipolar leads X, Y and Z calculated on the basis of the 12 simultaneous standard leads of the resting ECG. 300 QRS complexes were averaged and filtered using high-pass bidirectional 40—250 Hz filter. Acceptable noise level was less than 0.7 μV (3). In each patient LP were examined within one hour before and after HD. The following LP indices were computer-calculated from the SAECG: 1. fQRSd – the duration of filtered QRS complex, 2. RMS40 – the root mean square voltage of the high frequency signals of the last 40 ms of the QRS complex, 3. LAS40 – the duration of the high frequency, low amplitude portion of QRS complex, starting at the point where the signal drops below 40 μV. Normal LP parameters were defined: a) in patients with the duration of nonfiltered QRS complex (QRSd) ≤120 ms: fQRSd ≤114 ms, RMS40 ≥20 μV, LAS40 ≤38 ms, b) in patients with QRSd >120 ms: fQRSd ≤155 ms, RMS40 ≥17 μV, LAS40 ≤55 ms. Abnormal LP were considered as present if fQRSd plus either RMS40 or LAS40 were abnormal.

Haemodialysis and serum electrolytes analysis

Blood samples were drawn for serum electrolytes (Na, K, Cl, Ca, Mg, P) immediately before and after HD. Patients underwent HD three times a week. The blood flow rate was maintained at 220–300 ml/min. The dialysate contained Na 140 mmol/l, K 2.0–4.0 mmol/l, Ca 1.25–1.75 mmol/l, Cl 113.5–115.5 mmol/l, Mg 0.5 mmol/l, HCO_3 32 mmol/l. The mean duration of bicarbonate HD was 4.3±0.5 hours, the mean ultrafiltration 3050±1412 ml and the mean weight decrease after HD was 2.41±1.31 kg.

Echocardiography

Echocardiography was performed within three days before HD with Advanced Technique Laboratories HDI 3000 or Ultramark 9 systems, using 2.25 and 2.5 MHz transducers, respectively. The enddiastolic thickness of interventricular septum (IVSd), left ventricular internal enddiastolic diameter (LVIDd) and the thickness of the left ventricular posterior wall (LVPWd) were determined in centimeters by M-mode according to the guidelines of the American Society of Echocardiography (12). LVEF was calculated according to Simpson's biplane method. Left ventricular mass (LVM, in grams) was calculated according to the modified formula of Devereux and Reichek: $LVM=0.8x1.04[(IVSd+LVIDd+LVPWd)^3-LVIDd^3]+0.6$ (13).

Tab. 1. Serum electrolytes before and after haemodialysis.

	Pre-HD (mmol/l)	Post-HD (mmol/l)	p
Na	136.9±4.0	136.1±2.4	NS
K	5.07±0.68	3.59±0.50	<0.001
Cl	103.6±5.4	102.0±4.7	<0.05
Ca	2.39±0.25	2.69±0.26	<0.001
P	2.01±0.55	0.96±0.24	<0.001
Mg	1.00±0.13	0.84±0.07	<0.001

Data are mean±standard deviation, HD — haemodialysis, NS — nonsignificant

Tab. 2. Late potentials parameters, heart rate and noise before and after haemodialysis.

	Pre-HD	Post-HD	p
QRSd (ms)	93.4±12.4	93.3±11.6	NS
fQRSd (ms)	85.4±14.0	85.3±14.3	NS
RMS40 (μV)	37.1±22.6	47.0±30.1	<0.05
LAS40 (ms)	30.8±12.5	25.9±9.7	<0.05
Heart rate (bpm)	73.2±11.9	77.2±13.2	<0.05
Noise (μV)	0.53±0.41	0.57±0.36	NS

Data are mean±standard deviation, HD — haemodialysis, QRSd — duration of nonfiltered QRS complex, fQRSd — duration of filtered QRS complex, RMS40 — root-mean square voltage of terminal 40 ms of the QRS complex, LAS40 — duration of low-amplitude signal <40 μV at the terminal segment of the QRS vector, NS — nonsignificant

Tab. 3. Correlation of intradialytic changes of serum electrolytes and intradialytic changes of late potentials parameters.

	Δ QRSd	Δ fQRSd	Δ RMS40	Δ LAS40
Δ NA	-0.534***	-0.331*	0.089	-0.190
Δ K	-0.100	-0.013	-0.044	0.191
Δ Cl	-0.358*	-0.278	0.004	-0.063
Δ Ca	0.151	0.142	0.101	-0.108
Δ P	0.006	0.178	-0.311	0.117
Δ Mg	0.146	0.186	-0.124	0.224

Data are correlation coefficients. Δ — intradialytic change (predialytic value — postdialytic value), QRSd, fQRSd, RMS40, as in the Table 2. Significance of correlation coefficients, * p<0.05, *** p<0.001.

Tab. 4. Correlation of ultrafiltration, intradialytic weight change, electrolytes and intradialytic changes of late potentials parameters.

	Δ QRSd	Δ fQRSd	Δ RMS40	Δ LAS40
Ultrafiltration	-0.124	-0.126	-0.053	0.095
Δ weight	-0.105	-0.127	-0.053	0.117
Δ heart rate	-0.318	-0.070	0.151	0.029

Data are correlation coefficients. Legend as in Table 3. All correlations are nonsignificant.

LVMI was defined as LVM/BSA (body surface area). Left ventricular hypertrophy was judged considered to be if LVMI>125 g/m^2 in men and if LVMI>100 g/m^2 in women (14).

Statistical analysis

The significance of differencies between measurements obtained before and after HD was assessed using the paired Student's *t*-test. Quantitative data were correlated using linear regression. P values <0.05 were considered to be statistically significant. The analysis was carried out using Statistical Package Program for Social Sciences (SPSS 10.0, 1998).

Results

Abnormal ventricular LP were observed in 3 patients (7.7 %) before HD and in 2 patients (5.1 %) after HD.

Mean LVEF was 63.4±11.5 %. 33 patients (84.6 %) had preserved left ventricular systolic function, with LVEF >50 %. 2 patients (5.1 %) had mild LV global systolic dysfunction (LVEF=40–50 %). In 4 patients (10.3 %) moderate dysfunction was present (LVEF=30–40 %). No patient had severe LV global systolic dysfunction with LVEF <30 %. On echocardiography, LV hypertrophy was present in 30 patients (76.9 %). Mean LVMI was 162.9±56.1 g/m^2.

Mean pre-HD and post-HD values of serum electrolytes are listed in Table 1. Besides similar sodium concentrations, the differencies of all other mean serum electrolytes concentrations reached statistical significance.

No difference in fQRSd before and after HD was found (Tab. 2). Significant improvement of two other LP parameters after HD was observed – increase of RMS40 (37.1±22.6 μV vs 47.0±30.1 μV, p<0.05) and decrease of LAS40 (30.8±12.5 ms vs 25.9±9.7 ms, p<0.05). Post-HD heart rate was significantly higher. The difference of the noise levels did not reach significance.

On linear regression analysis (intradialytic changes of serum electrolytes as independent variables and intradialytic changes of LP parameters as dependent variables) low statistical significance was retained only for correlation between sodium change and fQRSd change (R=-0.331, p<0.05) (Tab. 3). Any other correlations were not significant.

There was no correlation found between intradialytic weight change, ultrafiltration, intradialytic heart rate change and intradialytic differencies of LP parameters (Tab. 4).

LVEF was weakly inversely correlated with post-HD QRSd (R=-0.375, p<0.05). Correlation between LVEF and pre-HD/post-HD fQRSd reached a low significance. LVEF did not correlate neither with RMS40 nor with LAS40 before and after HD (Tab. 5). Similar results on linear regression analysis were observed for correlations between LVMI and LP indices. LVMI positively correlated with pre-HD and post-HD fQRSd. However, there was no correlation between LVMI and RMS40/LAS40 before and after HD (Tab. 6).

Discussion

In our study, abnormal LP were found in 7.7 %/5.1 % of patients before/after HD. This rare positivity could be at least partially associated with well preserved LV systolic function and low prevalence of myocardial infarction in the study group and it can

Tab. 5. Correlation of left ventricular ejection fraction and late potentials parameters before and after haemodialysis.

	Pre-HD QRSd	Pre-HD fQRSd	Pre-HD RMS40	Pre-HD LAS40
LVEF	-0.324#	-0.368*	0.112	-0.018
	Post-HD QRSd	Post-HD fQRSd	Post-HD RMS40	Post-HD LAS40
LVEF	-0.375*	-0.348*	0.052	-0.110

Data are correlation coefficients. LVEF — left ventricular ejection fraction, QRSd, fQRSd, RMS40, as in the Table 2, HD — haemodialysis. Significance of correlation coefficients, * $p<0.05$, # $p=0.05$.

Tab. 6. Correlations of left ventricular mass index and late potentials parameters before and after haemodialysis.

	Pre-HD QRSd	Pre-HD fQRSd	Pre-HD RMS40	Pre-HD LAS40
LVMI	0.329#	0.385*	0.021	-0.018
	Post-HD QRSd	Post-HD fQRSd	Post-HD RMS40	Post-HD LAS40
LVMI	0.377*	0.395*	-0.065	-0.065

Data are correlation coefficients. LVMI — left ventricular mass index, QRSd, fQRSd, RMS40, as in the Table 2, HD — haemodialysis. Significance of correlation coefficients, * $p<0.05$, # $p=0.05$

reflect low incidence of sudden cardiac death during the follow-up period (2.6 %). Relatively surprising is the finding of Roithinger et al, that patients with and without abnormal LP did not differ significantly with respect to the presence of hypertrophy, compromised ventricular function, or coronary artery disease (1). Recent studies reported various prevalence of abnormal LP before HD: 0 % (5)–11 % (6)–14 % (1,2)–25 % (8). Gonsorcik et al recorded 8 % postdialytic prevalence of abnormal SAECG in a group of patients on HD or CAPD (9). Only one study dealed with the prevalence of abnormal SAECG in CAPD patients – 7 % in the study of Yildiz et al (6). Relatively broad range of results is mainly due to not conforming criteria of LP positivity. Various authors used different „cut-off" values of individual LP parameters. Other possible explanation for relatively broad range of LP positivity are patient selection criteria, with different ratio of patients with structural heart disease. It is evident, that higher prevalence of abnormal SAECG can be expected in the population with higher proportion of previous myocardial infarction. The prevalence of abnormal LP in normal subjects has been quite low, ranging from 0 % to 7 % (15, 16). Girgis et al found a significant increase of RMS40 from 63.0 μV to 79.0 μV and significant decrease of LAS40 from 28.3 ms to 24.9 ms after HD, without significant change of fQRSd (2). Our results were very similar. It is worth noting that Morales et al found opposite results – a significant increase in fQRSd without significant changes in RMS40 and LAS40 after HD (8). Similarly, in the study of Ichikawa et al postdialytic fQRSd was significantly increased compared with predialytic value and LAS40 tended to increase (5).

The mechanisms of postdialytic improvement of LP parameters are still not established with certainty. One potential explanation could be favourable changes in electrolyte levels. However, neither in the study of Girgiz et al (2), nor in our study, no significant correlations between these changes and intradialytic changes in LP parameters were found (with exception of weak correlation between changes in Na and fQRSd in our study). Other favourable mechanism of SAECG improvement after HD could be fluid removal with body weight decrease (2). Girgiz et al concluded that improvement of LP parameters (RMS40 and LAS40) after HD may be a consequence of decrease in fluid load achieved through ultrafiltration (2). They found significant negative correlation between the change in body weight and RMS40 change. RMS40 improved only in patients with but not without fluid removal (2). Conversely, we did not find correlation between change in LP parameters and neither weight change nor ultrafiltration. Therefore we assume, that favourable postdialytic change of SAECG is probably more complex and it does not depend only on ultrafiltration. An agreement between the study of Girgiz et al (2) and our study was reached regarding no correlation between the change in Ca, K or Mg and the change in RMS40. Our results are in contradiction with inverse correlation between fQRSd change and dialysis-induced serum potassium reduction reported by Morales et al (8). Likewise these authors, the changes in RMS40 and LAS40 had no relationship to the changes in the electrolytes levels. Exceptionally, Ichikawa et al reported a correlation between intradialytic changes in LAS40 and changes in potassium level (5).

Inverse correlation between LVEF and fQRSd is not surprising. In patients with dilated cardiomyopathy and poor LVEF is QRS complex duration >120 ms an established indication criterion for biventricular resynchronization pacing therapy of congestive heart failure (17). As to our knowledge, our study presents the relation between LV systolic function and SAECG in patients on HD for the first time in the literature. In hypertensive patients without coronary artery disease no linear correlations between SAECG parameters and LVEF or diastolic function indices were observed (18).

We confirmed the finding of Yildiz et al, that fQRSd positively correlates with LVMI (6). There was a lack of correlation between RMS40/LAS40 and LVMI revealed. Positive correlation between fQRSd and LVMI could explain the fact, that prolonged fQRSd is attributed to longer depolarization due to hypertrophied LV myocardium. Very high prevalence of LV hypertrophy in patients under maintenance HD is known (6). It must be mentioned, that some authors suggest this explanation is unlikely, because they did not detect a significant difference in LVM between the groups with and without abnormal LP before HD (8). fQRSd du-

ration is significantly prolonged in HD patients in comparison with healthy controls. Probably it reflects the higher prevalence of LV hypertrophy and increased LVMI. Patients on HD or CAPD with LV hypertrophy have longer fQRSd duration compared to patients without hypertrophy (6). The prolonged fQRSd in patients with abnormal SAECG may reflect abnormal inhomogenous activation, but longer fQRSd may be also the expression of a greater LV mass (19). Raineri et al found a significant positive linear correlation between fQRSd and LVM in healthy subjects, and only a low positive correlation between LAS40 and LVM and a low negative correlation between RMS40 and LVM (19). In their conclusion a prolonged fQRSd does not depend only on a delayed, fragmented electric activity, but is also the electrographic expression of a greater mass of myocardium. Similarly, Wojszwillo et al found in hypertensive patients low positive correlation between LAS40 and LVM (18).

Up to date it is unclear, whether electrophysiologically potentially advantageous post-HD changes of SAECG lead to clinical benefit. Roithinger et al reported that SAECG has not been proven to be useful in identifying HD patients at risk for sudden cardiac death (1). The lack of positive predictive value of SAECG can be due to different mechanisms of arrhythmic development in uraemic patients (1). In chronic HD patients ventricular arrhythmias of Lown class 4A or 4B were not associated with arrhythmogenic substrate revealed by abnormal LP or autonomic dysfunction assessed by heart rate variability (7). It should be answered, whether combination with other electrocardiographic or other noninvasive methods will improve positive predictive value of LP in HD patients. Goldner et al reported in non-HD patients, that QT interval dispersion is more sensitive than LP in predicting malignant ventricular arrhythmias. fQRSd combined with QT dispersion was more sensitive than either test alone in detecting patients susceptible to ventricular tachycardias (11).

Published studies were not large enough to determine, whether abnormal LP are able to identify HD patients at risk for sudden arrhythmic death (2). Further controlled, prospective studies investigating the impact of LP on HD patient care are needed. They should answer three principal questions: 1. do abnormal LP predict the risk for sudden cardiac death in HD patients?, 2. does HD significantly improve the LP parameters?, 3. does such improvement of LP parameters after HD improve patient's prognosis in terms of reduced risk of sudden cardiac death? The first question is very attractive in the era of implanted cardiac defibrillators, which can effectively minimize the risk of sudden cardiac death. If abnormal LP would be capable to identify increased risk of arrhythmic death, those patients who persistently show an abnormal SAECG despite adequate HD can be considered for electrophysiological testing and automatic cardioverter-defibrillator implantation (2).

References

1. Roithinger FX, Punzengruber C, Rossoll M, Pachinger O, Kramar R, Prischl FC. Ventricular late potentials in haemodialysis patients and the risk of sudden death. Nephrol Dial Transplant 1992; 7: 1013—1018.

2. Girgis I, Contreras G, Chakko S et al. Effect of hemodialysis on the signal-averaged electrocardiogram. Am J Kidney Dis 1999; 34: 1105—1113.

3. Breithardt G, Cain ME, El-Sherif A et al. Standards for analysis of ventricular late potentials using high-resolution or signal-averaged electrocardiography: a statement by a Task Force Committtee of the European Society of Cardiology, the American Heart Association, and the American College of Cardiology. J Am Coll Cardiol 1991; 17: 999—1006.

4. Dubrava M. Methods of recording late ventricular potentials as a basis for their rational clinical use. Vnitr Lek 1994; 40: 184—189.

5. Ichikawa H, Nagake Y, Makino H. Signal averaged electrocardiography (SAECG) in patients on hemodialysis. J Med 1997; 28: 229—243.

6. Yildiz A, Akkaya V, Sahin S et al. QT dispersion and signal-averaged electrocardiogram in hemodialysis and CAPD patients. Perit Dial Int 2001; 21: 186—92.

7. Tamura K, Tsuji H, Nishiue T et al. Determinants of ventricular arrhythmias in hemodialysis patients. Evaluation of the efffect of arrhythmogenic substrate and autonomic imbalance. Am J Nephrol 1998; 18: 280—284.

8. Morales MA, Gremigni C, Dattolo P et al. Signal-averaged ECG abnormalities in haemodialysis patients. Role of dialysis. Nephrol Dial Transplant 1998; 13: 668—673.

9. Gonsorcik J, Franko J, Szakacs M, Mydlik M. Prevalence and prognostic significance of abnormal signal-averaged electrocardiogram in dialysed patients. In: Timio M, Wizemann V, Venanzi S (Eds). Cardionephrology 4. Editoriale Bios, Cosenza, 1997, 201—202.

10. Hall PA, Atwood JE, Myers J, Froelicher VF. The signal averaged surface electrocardiogram and the identification of late potentials. Prog Cardiovasc Dis 1989; 31: 295—317.

11. Goldner B, Brandspiegel HZ, Horwitz L, Jadonath R, Cohen TJ. Utility of QT dispersion combined with the signal-averaged electrocardiogram in detecting patients susceptible to ventricular tachyarrhythmia. Am J Cardiol 1995; 76: 1192—1194.

12. Sahn DJ, Demaria A, Kisslo J, Weyman A. Recommendations regarding quantitation in M-mode echocardiography: results of a survey of echocardiographic measurements. Circulation 1978; 58: 1072—1077.

13. Devereux RB, Reichek N. Echocardiographic determination of left ventricular mass in man. Anatomic validation of the method. Circulation 1977; 55: 613—618.

14. Oparil S, Weber MA. Hypertension: a companion to Brenner and Rector's The Kidney. W.B. Saunders Company, Philadelphia, 2000; 757.

15. Coto H, Maldonado C, Palakurthy P, Flowers NC. Late potentials in normal subjects and in patients with ventricular tachycardia unrelated to myocardial infarction. Am J Cardiol 1985; 55: 384—390.

16. Flowers NC, Wylds AC. Ventricular late potentials in normal subjects. Herz 1988; 13: 160—168.

17. Molhoek SG, Bax JJ, van Erven L, van der Wall EE, Schalij MJ. 14—20 % of patients with implantable cardioverter-defibrillator indication may benefit from resynchronization therapy. Eur Heart J 2002; 4 (Suppl): 667.

18. Wojszwillo A, Jaroch J, Loboz-Grudzien K. Signal-averaged ECG in patients with different patterns of left ventricular geometry in hypertension. Eur Heart J 2001; 22 (Suppl): 23.

19. Raineri AA, Traina M, Lombardo RMR, Rotolo A. Relation between late potentials and echocardiographically determined left ventricular mass in healthy subjects. Am J Cardiol 1991; 67: 425—427.

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