CATHETER ABLATION FOR ATRIAL FIBRILLATION AND SPECTRAL ANALYSIS OF HEART RATE VARIABILITY

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Submitted in June, 2003

The results of a short term recording of spectral analysis (SA) of heart rate variability (HRV) in 22 patients with paroxysmal atrial fibrillation (aged 53.69 ± 11.95; 20 male and 2 female) in whom circumferential catheter ablation (CA) was done are presented in this article. Measurement was done in the morning before CA and one day after CA. A standard orthoclinostatic test in three positions (supine–standing–supine) was used. The influence of catheter ablation on SA HRV was identified by standard and complex parameters (Stejskal, Šlachta, Elfmark, Salinger, & Gaul-Aláčová, 2002).

After CA, heart rate increased and almost all individual and complex indexes decreased. This finding gives evidence of reduction of activity in both branches of the autonomous nervous system. Vagal activity reduction was larger, so the sympathovagal balance shifts towards sympathicus.

Keywords: Spectral analysis of heart rate variability, autonomous nervous system, vagal activity, sympatho-vagal balance, atrial fibrillation, catheter ablation.

INTRODUCTION

Spectral analysis (SA) of heart rate variability (HRV) is a non-invasive method enabling us to quantify the activity of the autonomous nervous system (ANS) (Stejskal & Salinger, 1996).

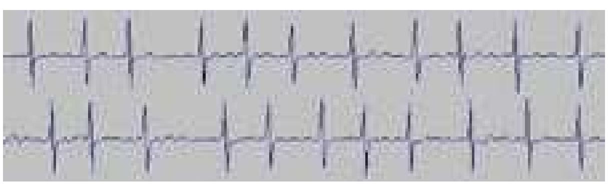
There are three main spectral components in the spectrum of short term HRV recording: VLF (very low frequency, in our modification – 0.02 to 0.05 Hz) – its output is related to the thermoregulatory sympathetic activity of blood vessels, to the level of circulating catecholamines or to oscillations in the rennin-angiotensin system; LF (low frequency – 0.05 to 0.15 Hz) – reflects baroreflex activity in which sympathetic and parasympathetic activity participate; HF (high frequency – 0.15 to 0.50 Hz) – is influenced by efferent vagal activity only (Opavský, 2002; Stejskal & Salinger, 1996; Task Force, 1996).

Atrial fibrillation (AF) is the most common supraventricular tachyarrhythmia characterised by uncoordinated atrial activation with consequent deterioration of atrial mechanical function (Haïssaguerre et al., 1998; Prystowsky et al., 1996). Its prevalence is increasing along with the aging of the population (Fuster et al., 2001; Kannel, Abbott, Savage, & McNamara, 1982; Krahn, Manfreda, Tate, Mathewson, & Cuddy, 1995). On the electrocardiogram (ECG), AF is described by the replacement of consistent P waves by rapid oscillations or fibrillatory waves that vary in size, shape, and timing, associated with an irregular, frequently rapid ventricular response when atrioventricular conduction is intact (Fig. 1) (Gregor & Widimský, 1994; Lukl, 2004; Štejfa et al., 1998).

Symptoms associated with AF vary and depend on several factors including ventricular rate, cardiac function, concomitant medical problems and individual patient perceptions. Most patients complain of palpitations, chest pain, dyspnoea, fatigue, lightheadedness, or syncope (Fuster et al., 2001; Prystowsky et al., 1996). The ANS is a commonly accepted factor participating in arrhythmogenesis (Fuster et al., 2001).

One of the possible treatments for AF is catheter ablation (CA). This ablation procedure is used to terminate AF by introducing a catheter into the heart and

Fig. 1
Atrial fibrillation on the ECG



directing radiofrequency energy to specific areas of the heart's tissue found to be a source of irregular rhythm and the tissue is destroyed (Štejfa et al., 1998). AF often originates from the pulmonary veins (PVs) in many patients, thus circumferential radiofrequency lesions are created around the ostia of PVs with the aim to isolate these veins from the left atrium (Pappone et al., 2001; Stejskal, Fiala, & Salinger, 2003). It assumes that a rather large intervention in the left heart atria produces a disruption of the conduction system and heart innervations and ANS activity will be influenced.

The aim of the study was to analyze and to interpret changes in ANS activity after catheter ablation in patients with AF. The influence of catheter ablation on SA HRV was identified by standard and complex parameters (Stejskal et al., 2002).

METHOD

This research was done in 2002–2004 in the Faculty hospital in Olomouc and the Podlesí hospital in Třinec. We tested 22 patients aged 53.69 ± 11.95 years (20 men, 2 women), who had been suffering from atrial fibrillation for 8.45 ± 6.67 years. In these patients, circumferential catheter ablation (CA) was done. Measurement of SA HRV was done in the morning before CA and one day after CA. All patients were informed about the SA HRV examination in advance and they agreed to it.

We measured HRV by means of the original VarCor PF5 hardware and software, which was produced by the Faculty of Physical Culture in Olomouc (Salinger et al., 2003). Information about measurement is displayed in graphical (graphical output of an ECG signal and a column graph of calculated R-R intervals) and numerical forms (duration time of all examinations, duration times of individual procedures and values of current HR) on the Pocket PC display (Fig. 2), which enables direct visual control of the recording while measuring (Salinger, 2004).

Fig. 2
Graphical and numerical output on the Pocket PC display during measuring

The number of the recordings of cardiac cycles was increased from 300 to 330 in each position of the orthoclinostatic test because of the time data stability and the possibility of improving the filtration of heart contractions not related to the regular activity of the sinus node (Stejskal & Salinger, 2003). The more frequent multiple arrhythmias and artefacts are, the less reliable the analysis of the record is (Stejskal & Salinger, 1996). Artifacts can be cleared away automatically or manually at the end of the measurement. Only patients with sinus rhythm on the ECG during measuring were chosen for this research. For the SA HRV calculation the standard number of 256 R-R intervals was used.

The SA HRV measurement was done in a standardized manner – in the morning, on an empty stomach, in a quiet room and before all other examinations. The patients kept their eyes closed during the entire testing process in order to reduce disturbance in perception. The patients were examined by means of an orthoclinostatic test in three positions (supine-standing-supine). In each position subjects stayed until 330 heart contractions had been recorded (approximately six minutes). ECG registration started 45 seconds after changing each position, thus all periods of measurement were carried out in steady state. The ECG record from the first position was not evaluated and this was only used for measurement standardization.

The following individual SA HRV parameters for statistical processing were chosen: total spectral power (P_T), spectral power of individual components (P_{VLF}, P_{LF}, P_{HF}), coefficients of variance of the individual component (CCV VLF, CCV LF, CCV HF), percentage of the individual components (%VLF, %LF, %HF), frequencies of the individual components (fVLF, fLF, fHF) and ratios between individual components (VLF/HF, LF/HF, VLF/LF) in a second supine position from the supine-standing-supine test. From among time domain parameters the MSSD parameter was chosen; this parameter is accepted as a vagal activity index. Further, the heart rate (HR) was monitored and recorded.

In addition to these parameters, also the complex indices of SA HRV were calculated: a complex index of the total score of SA HRV (TS), a complex index of vagal activity (VA), and a complex index of sympatho-vagal balance (SVB) (Stejskal et al., 2002). The values of complex indexes are expressed in points within a range of 10 points (from –5.0 to +5.0 points). Normal values of TS range from –1.5 to +1.5 points, normal values of VA and SVB range from –2.0 to +2.0 points (Stejskal, Jakubec, Přikryl, & Salinger, 2004).

Of basic statistical characteristics, mean (M) and standard deviation (SD) were calculated. The overwhelming majority of the data was not up to normal data distribution standards (according to the Kolmogorov-Smirnov and Anderson-Darling statistical tests), that is why the nonparametric paired Wilcoxon test was used. The data were statistically processed by means of software programs SPSS and Microsoft Excel. The α level was established at the 0.05, 0.01 and 0.001 levels.

RESULTS

HR significantly increased after CA (on an average of 12 beats/min), complex TS and VA parameters significantly decreased while the complex SVB index decreased insignificantly. P_T, P_{VLF}, P_{LF}, P_{HF}, its coefficients of variance (CCV VLF, CCV LF and CCV HF) and the time domain index MSSD after CA, significantly decreased. The average values of %HF decreased and %VLF increased; both shifts were insignificant, while %LF significantly decreased. The increase in VLF/HF ratio and LF/HF ratio after CA was not significant; VLF/LF increased significantly. The frequency of the LF component significantly decreased while fVLF increased insignificantly; the frequencies of both components moved closer to each other significantly ($p < 0.01$); fHF significantly increased after CA (TABLE 1).

DISCUSSION

HRV is influenced by many external and internal factors, therefore standardization of measurement is necessary (measuring at the same times of day, minimizing sensual stimulations – quiet room, closed eyes during

TABLE 1
Comparison of SA HRV parameters in the morning before and one day after catheter ablation (n = 22; 20 men, 2 women, age 53.69 ± 11.95 years)

Index		Before CA	After CA		Index		Before CA	After CA	
TS [points]	*M*	−2.24	−4.62	**	% VLF [%]	*M*	32.11	44.39	ns
	SD	2.41	0.96			*SD*	22.68	23.61	
VA [points]	*M*	−2.01	−4.04	**	% LF [%]	*M*	30.73	22.72	*
	SD	2.11	0.97			*SD*	17.17	13.67	
SVB [points]	*M*	−0.56	−1.49	ns	% HF [%]	*M*	37.16	32.89	ns
	SD	2.28	2.69			*SD*	24.41	29.79	
P_T [points]	*M*	−1.43	−4.54	***	VLF/HF	*M*	2.83	3.93	ns
	SD	3.37	1.20			*SD*	5.36	4.65	
P_T [ms²]	*M*	1522.81	149.34	***	LF/HF	*M*	1.57	1.64	ns
	SD	2272.15	244.76			*SD*	1.46	1.51	
P_{VLF} [ms²]	*M*	456.63	72.66	**	VLF/LF	*M*	2.03	3.81	*
	SD	1050.31	142.62			*SD*	3.05	5.27	
P_{LF} [ms²]	*M*	385.89	39.03	***	fVLF [mHz]	*M*	27.71	29.11	ns
	SD	497.25	67.75			*SD*	6.22	8.08	
P_{HF} [ms²]	*M*	680.29	37.65	**	fLF [mHz]	*M*	85.63	66.92	*
	SD	1506.32	58.38			*SD*	32.15	14.84	
CCV VLF [%]	*M*	1.63	0.72	**	fHF [mHz]	*M*	245.54	299.63	**
	SD	1.57	0.50			*SD*	82.08	64.30	
CCV LF [%]	*M*	1.68	0.51	***	fLF-fVLF [mHz]	*M*	57.91	37.80	**
	SD	1.29	0.36			*SD*	33.73	19.49	
CCV HF [%]	*M*	1.82	0.50	***	MSSD [ms²]	*M*	1908.96	144.53	***
	SD	2.04	0.30			*SD*	4033.08	197.36	
					HR [beat/min]	*M*	62.59	70.87	**
						SD	12.75	16.00	

M – average value; *SD* – standard deviation; CA – catheter ablation; TS – total score of SA HRV; VA – complex index of vagal activity; SVB – complex index of sympatho-vagal balance; P_T [points] – total spectral power (point value). Indexes from the second supine position from the supine-standing-supine test: P_T – total spectral power; P_{VLF}, P_{LF}, P_{HF} – spectral power of VLF, LF, HF components; CCV – coefficient of variance; % – relative part of individual component in total power; VLF/HF, LF/HF, VLF/LF – ratio of spectral power of individual components; fVLF, fLF, fHF – frequency of individual components; fVLF–fLF – distance between fVLF a fLF; MSSD – root mean square of consecutive R-R intervals; HR – heart rate; *** p < .001; ** p < .01; * p < .05; ns – no significant difference.

the examination, etc.) (Opavský, 2002; Stejskal & Salinger, 1996). In spite of the effort of the nursing staff it was not possible to maintain all conditions; especially the length of time of the examination oscillated within the range of more than two hours.

Patients used antiarrhythmics (most often propaphenone, sotalol and amiodaron), which may have influenced the HRV measurements. However, Vikman et al. (1999) did not find significant differences in AF patients who were on medication as opposed to in those who were not on medication, which suggests that cardiac medication itself had no major effect on HRV observations. In any case, the important fact is that within our measurement (before and after CA) each patient was on the same medication, because potential changes of medication occur after one month following CA.

Before CA the average values of age adjusted P_T were, in comparison to the healthy population (Stejskal et al., 2002), slightly reduced (–1.43 points). This finding confirmed that in patients with AF is changed ANS activity (Stejskal, Fiala, & Salinger, 2003) and a significantly lower P_T in comparison with the healthy population (Galuszka, Stejskal, Lukl, & Zapletalová, 2002) can often be found. The main reason for ANS activity reduction (the low average value of TS) is, in the first instance, vagal activity reduction: the complex index of vagal activity (VA) is decreased and individual parameters of vagal activity (P_{HF} a CCV HF) are low as well. Galuszka et al. (2004) came to a similar conclusion that, in patients with AF, in comparison to healthy population, P_{HF} is reduced.

However, in lower ANS activity, relatively low sympathetic activity participates as well – the average value of the complex index of sympatho-vagal balance (SVB) is normal and %VLF and VLF/LF and VLF/HF ratios do not point to a noticeable predominance of sympathicus. This finding proved also an average value of HR, which corresponds to normal values of HR in the healthy population.

From individual patient data it is evident that it is not possible to generalize that all patients with AF have lower ANS activity. A criterion for an ANS state can be TS values – TS < –1.5 points (low ANS activity), –1.5 points > TS < 1.5 points (normal values of ANS activity), TS > 1.5 points (high ANS activity). According to this criterion our group of patients can be divided into three subgroups: 16 patients had lower ANS activity, 3 patients had normal ANS activity and 3 patients had higher ANS activity. This finding means that approximately in 27% of the patients ANS activity reduction was not found. According to Huang, Wen, Lee, Chang and Chen (1998), minimally two types of AF can be distinguished – the vagal and sympathetic type. The so called sympathetic type of AF can be found mostly in patients with organic based disease; in these patients there is usually a low value of P_{HF} and an increased LF/HF ratio. In our patients we found this type of AF in approximately 32% of cases. Patients with the so called vagal type of AF usually have an idiopathic form of AF. The beginning of paroxysm is connected with P_{HF} increase and LF/HF ratio decrease. We found this type of AF in almost 14% of our patients. In the rest, 54% of the patients, 40% of them had ANS activity rather lower, but a dominance of some branch of ANS was not unambiguously expressed; in about 14% of the patients ANS activity corresponds to the normal healthy population.

All complex parameters (TS, VA and SVB) decreased after CA (Fig. 3). The decrease of all spectral power components (P_T, P_{VLF}, P_{LF}, P_{HF}) and their coefficients of variance (CCV VLF, CCV LF a CCV HF) and time domain index MSSD was significant as well. This finding gives evidence of reduction activity in both branches of ANS after CA; vagal activity reduction was larger.

This finding was more evident in patients with normal or higher ANS activity and dominance of vagal activity before CA. On the contrary, in patients with reduced vagal activity before CA, the changes after CA were lower. This fact influenced statistical evaluation of SA HRV results only in indexes of sympatho-vagal balance (SVB, %VLF, VLF/HF and LF/HF), where the shift from parasympathetic towards sympathetic was not statistically confirmed (TABLE 1). Thus we can say that ANS activity in both branches of ANS was reduced; vagal activity reduction was larger so sympatho-vagal balance shifts towards sympathicus.

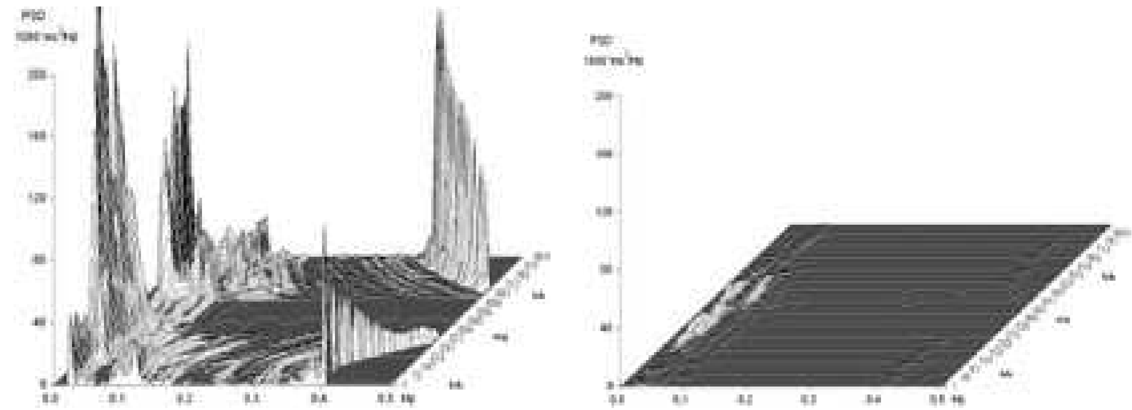
The decrease of HRV parameters and increase of LF/HF ratio after CA was also found by Pappone et al. (2004). This fact is, according to them, evidence of parasympathetic attenuation by pulmonary vein denervation during CA. However their previous study (Pappone et al., 2001) pointed to P_{HF} increase and LF/HF ratio decrease after circumferential CA. The authors described it as a shift of sympatho-vagal balance towards vagus, which is an opposite finding to that in their study of 2004. If we take the results of our patients with different levels of ANS activity separately, we can find in most of our patients with low ANS activity a decrease of LF/HF ratio after CA and, on the contrary, in most of the patients with normal or higher ANS activity, LF/HF ratio increased after CA. The possible explanation of different results of Pappone's et al. studies is then a different level of ANS activity of their patients in each study.

Vagal activity reduction after CA resulted in a significant increase of HR, which corresponds with results of Pappone et al. (2004); according to these authors HR returned to preablation values within six months after CA.

The significant decrease in activity in the sympathetic and mainly in the parasympathetic part of ANS is evidence of the isolation of the area starting up AF and also of the interruption of vagal afferentation from the

Fig. 3
Three-dimensional graph of SA HRV and tabular comparison of complex SA HRV parameters in the morning before and one day after CA in a 46-year patient with AF
CA – catheter ablation; TS – complex index of total score; VA – complex index of vagal activity; SVB – complex index of sympatho-vagal balance; P_T [points] – total spectral power (point value).

Before CA ***After CA***



Index	*Before CA*	*After CA*
TS [points]	1.48	–5.00
VA [points]	0.81	–4.27
SVB [points]	2.75	–2.00
P_T [points]	3.76	–5.00

pulmonary vein region after CA. Restoration of a new balance comes up after one (Hsieh et al., 1999), six (Pappone et al., 2004), or more months; for instance according to Stejskal et al. (2003), ANS activity gradually increased even one month after CA. Detailed investigation of ANS activity after CA over time will be the topic of our next research project.

CONCLUSION

Although the number of examined patients with paroxysmal atrial fibrillation is not large, it does not seem correct to say that all patients have altered ANS activity. CA gets to decrease ANS activity in all patients with AF, first of all because of vagal activity reduction. SA HRV evaluation using complex indexes enables us to make a more complex evaluation of both branches of ANS.

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KATETROVÁ ABLACE PRO FIBRILACI SÍNÍ A SPEKTRÁLNÍ ANALÝZA VARIABILITY SRDEČNÍ FREKVENCE

(Souhrn anglického textu)

Cílem studie bylo zkoumání vlivu katetrové ablace na parametry spektrální analýzy (SA) variability srdeční frekvence (HRV). Krátkodobý záznam SA HRV byl snímán u skupiny 22 pacientů s paroxysmální fibrilací síní (FS) ve věku 53,69 ± 11,95 let (20 mužů a 2 ženy), u kterých byla provedena cirkumferenční katetrová ablace (KA). Měření probíhalo ve třech polohách (leh-stoj-leh), za standardizovaných podmínek, ráno před KA a jeden den po KA. K vyhodnocení výsledků byla použita jak standardní, tak nová metodika hodnocení SA HRV pomocí komplexních ukazatelů.

Po KA pro FS došlo ke zvýšení srdeční frekvence (SF) a zhoršení většiny jednotlivých i komplexních ukazatelů. Tento nález svědčí o redukci aktivity obou větví autonomního nervového systému. Protože snížení aktivity vagu je výraznější, posouvá se sympatovagová rovnováha mírně směrem k sympatiku.

Klíčová slova: spektrální analýza variability srdeční frekvence, autonomní nervový systém, aktivita vagu, sympatovagová rovnováha, fibrilace síní, katetrová ablace.

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Scientific orientation

Study of autonomous nervous system activity in patients with atrial fibrillation with the use of SA HRV method.

First-line publication

Žujová (Vlčková), E., & Vařeka, I. (2003). Hodnocení posturální stability akcelerometrem TriTrac-R3D. *Rehabilitace a fyzikální lékařství, 10(3),* 109–111.

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