SCRIPTA MEDICA (BRNO) – 73 (2): 111–116, *April 2000*

ALTERED CHRONOME OF HEART RATE VARIABILITY DURING SPAN OF HIGH MAGNETIC ACTIVITY

OTSUKA K.[1], YAMANAKA T.[1], CORNÉLISSEN G.[2], BREUS T.[3], CHIBISOV S.M.[3], BAEVSKY R.[4], SIEGELOVÁ J.[5], FIŠER B.[6], HALBERG F.[2]

[1] Tokyo Women's Medical University, Daini Hospital, Tokyo, Japan
[2] Halberg Chronobiology Center, University of Minnesota, Minneapolis, Minnesota, USA
[3] Space Research Institute, Moscow, Russia
[4] Institute for Biomedical Problems, State Research Center, Moscow, Russia
[5] Department of Functional Diagnostics and Rehabilitation, Faculty of Medicine, Masaryk University, Brno
[6] Department of Physiology, Faculty of Medicine, Masaryk University, Brno

Abstract

A decrease in heart rate variability (HRV), gauged by the standard deviation, had been associated earlier with exposure to a magnetic storm in space in a transverse study on cosmonauts. A longitudinal study now confirms this result on a clinically healthy man who monitored his ECG for 7 days. The decrease in HRV is documented both in a time-domain and in a frequency-domain measure of HRV, and is found to affect frequencies lower than one cycle in about 3.6 sec, pointing to an underlying physiological mechanism other than the parasympathetic as being putatively responsible for the physiological response to changes in magnetic activity. In the search for mechanisms, new invasive and non-invasive hardware-software systems offer themselves to assess long-term and short-term hemodynamic changes.

Key words

heart rate variability, high magnetic activity, cardiovascular risk

Abbreviations:

BRS - baroreflex sensitivity, HRV - heart rate variability

INTRODUCTION

Earlier, in a transverse study of cosmonauts in space, exposure to a geomagnetic storm had been found to be associated with an about 30% decrease in heart rate variability (HRV) (*1*). A decrease in HRV was also found to be associated with an increased solar activity (*2*), as seen in a longitudinal record obtained mostly at 30-min intervals, around the clock, for 11 years on a clinically healthy man (*3*) and in another series of self-measurements (5-6 per day during waking) spanning 31 years (*4*).

The ultrastructure of cardiomyocytes of rabbits was also found to be altered during a strong magnetic storm as compared to quiet conditions, as was the circadian variation of several hemodynamic variables (*5*). *Chibisov et al. (5*) postulate that the destruction and degradation of mitochondria in cardiomyocytes, the increase of lipids, and the decrease in oxygen content in blood observed in these „Chinchilla“ rabbits could result in a decrease of heart contractile power.

A decreased HRV, in turn, constitutes a putative mechanism underlying the increased incidence of myocardial infarctions observed on the day following an inversion of the interplanetary magnetic field (*6-8*). A decreased HRV indeed characterizes patients after a myocardial infarction (*9, 10*) as well as patients who are to develop coronary artery disease in the next 6 years (*11*).

SUBJECT AND METHODS

On several occasions, a 48-year-old clinically healthy man recorded his ECG for 7 days using a Holter monitor (Fukuda Denshi, Tokyo, Japan). The data were retrieved and processed over consecutive 14.4-min intervals to obtain estimates of time- and frequency-domain as well as chaotic endpoints of HRV (*12-16*). One of the 7-day profiles coincided with a 3-day span of high magnetic activity, which allowed a longitudinal assessment of any effects on HRV. The different endpoints, summarized for each day separately, were compared by Student t-test between the 3 days of high magnetic activity and the 4 days of quiet conditions.

RESULTS

As in the earlier transverse investigation, HRV (expressed as a percentage of the average R-R interval) was reduced on days of high magnetic activity (7.46% ± 0.16%) by comparison with quiet days (9.74% ± 0.46%) (t=4.061; P=0.010),

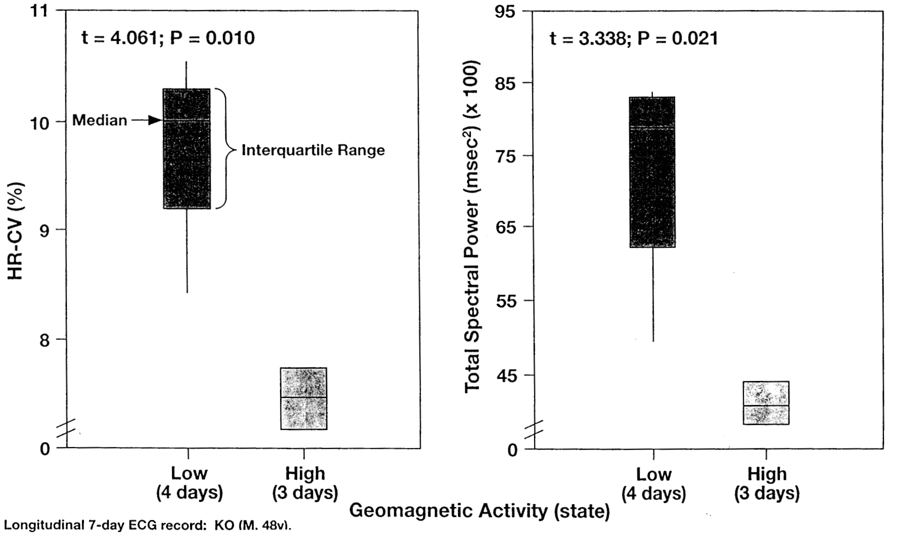

Fig. 1.
Reduced heart rate variability during days of high magnetic activity revealed by two related endpoints

Fig.1 (left). The total spectral power was also reduced from 7232 ± 789 (msec^2) to 4082 ± 169 (msec^2) (t=3.338; P=0.021), *Fig. 1* (right).

The decrease in spectral power could be further investigated in three spectral ranges, below one cycle in 25 sec („VLF“), around one cycle in 10.5 sec (0.04-0.15 Hz) (circadecisecundan, DSs, or „LF“), and around one cycle in 3.6 sec (0.15-0.4 Hz) (circaquadrisecundan, QSs, or „HF“). HRV was found to be reduced primarily in the „VLF“ (<0.04 Hz or >25 sec) region of the spectrum, from 2844 ± 294 msec^2 to 1821 ± 55 msec^2 (t=2.917; P=0.033), *Fig. 2* (left). The reduction in HRV in the DS („LF“) region of the spectrum (around one cycle in 10.5 sec) was only of borderline statistical significance (t=1.942; P=0.110), *Fig. 2* (middle), and it was not statistically significant in the QS („HF“) region of the spectrum (around one cycle in 3.6 sec) (t=0.906; P=0.416), *Fig. 2* (right). This result suggests that the physiological mechanism underlying a response in HRV to magnetic disturbances may involve the sympathetic rather than parasympathetic central nervous system.

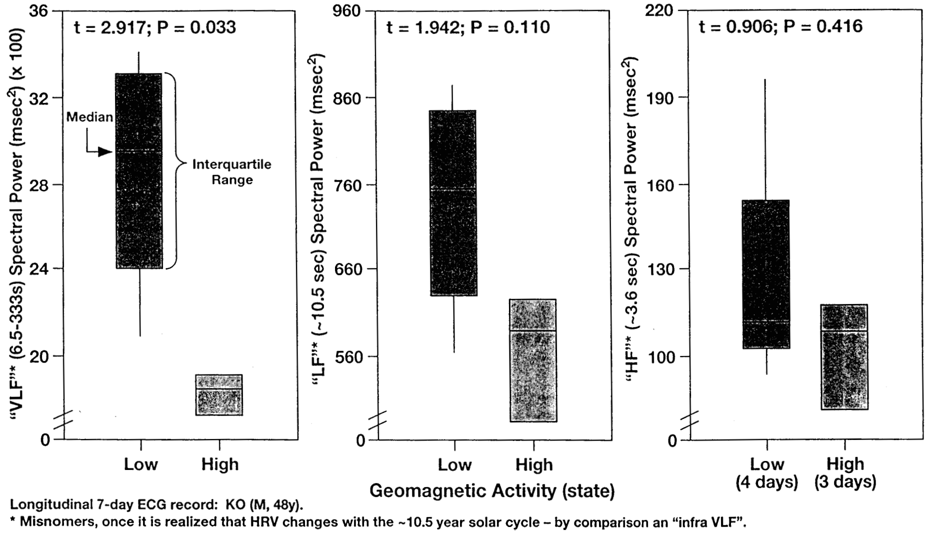

Fig. 2.
During days of high magnetic activity, heart rate variability (HRV) is reduced (left) to a different extent or not at all (right), in different spectral regions

A chronobiologic analysis of the 7-day ECG record as a whole revealed a particularly prominent about-weekly component, as well as a spectral peak in the circadian range away from precisely 24 hours for HRV endpoints such as the slope of the 1/*f* spectral behavior and for the relative spectral power around 10.5 sec (DSs or „LF“), both variables peaking at a period of about 21 hours. A spectral peak around 28 hours characterized the relative spectral power below one cycle in 25 sec („VLF"). Such an alteration of the circadian component of the chronome occurred only for some but not all HRV endpoints, all variables investigated showing a clear secondary peak at 12 hours, whether or not the circadian period coincided with or differed from exactly 24 hours. These results are reminiscent of those reported by *Chibisov et al. (5),* namely a functional desynchronization of the circadian system of „Chinchilla" rabbits' heart function, which was accompanied by morphological changes in the ultrastructure of cardiomyocytes in association with the occurrence of magnetic storms.

DISCUSSION AND CONCLUSION

The ongoing Asian Chronome Ecologic HRV (ACEHRV) investigation, now extended internationally (ICEHRV), a part of a broader project on the Biosphere and the Cosmos (BIOCOS) (*17*), is eminently suited to prospectively study effects of geomagnetic storms on the chronome of HRV in health as reference standards for detecting alterations in disease.

Another relatively new tool for exploring underlying mechanisms is the non-invasive assessment of baroreflex sensitivity (BRS) by means of spectral analysis, without the need for intravenous administration of pharmacological agents such as phenylephrine. The availability of relatively cost-effective instrumentation for the beat-to-beat non-invasive monitoring of blood pressure and R-R intervals enables the large-scale clinical assessment of short-term changes in BRS in response to different stimuli (such as a change in blood pressure brought about by the administration of phenylephrine), opening the door to new cardiological applications.

Like HRV, BRS, an index of autonomic nervous function, reportedly predicts survival in cardiovascular disease (*18*). Clinical applications are broadened when BRS is assessed by spectral analysis of blood pressure values and R-R intervals (*19*) (BRS-1), allowing continuous observation. BRS-1 was validated by comparison with the traditional infusion of phenylephrine (BRS-2), and used to study BRS dynamics (BRS-3) associated with an increase in blood pressure.

The validation was done with a Holter electrocardiographic record (Fukuda Denshi, SCM280), started at 14:00 on 10 healthy volunteers (19-47 years of age), and a catheter placed while the subject was resting supine. Non-invasively (JENTOW-7000; Colin Medical, Komaki, Japan; 20), the arterial blood pressure waveform was recorded continuously for at least 80 sec after phenylephrine was injected intravenously. Using the JENTOW-7000 software, a target systolic pressure elevation of 40 mmHg served to calculate BRS-2. Blood pressure and R-R variability was analyzed by maximum entropy using MemCalc software (Suwa-Trust, Tokyo) (*21*). BRS-1 was calculated as the square root of the ratio between the ~10.5-sec (0.04-0.15 Hz; DSs or „LF") power of R-R and that of blood pressure (*19).* Dynamic changes in BRS were assessed longitudinally

(BRS-3, in msec/mmHg) over 30-sec spans progressively displaced by 5 sec throughout the time series of systolic blood pressure, diastolic blood pressure and R-R intervals obtained during the about-80-sec pressor response to phenylephrine, yielding 10 sequential records.

Like HRV, BRS is circadian stage-dependent (*22-25*). The non-invasive continuous monitoring of blood pressure and R-R intervals by arterial tonometry thus allows the evaluation of BRS over very short spans, rendering possible the detailed study of changes in response to different stimuli. In particular, this methodology awaits applications to study effects of magnetic disturbances on HRV, the reduction of which may constitute a risk for coronary artery disease, left ventricular hypertrophy and myocardial infarction (*26*).

Acknowledgements

This study was supported by the U.S. Public Health Service (GM-13981) (FH), University of Minnesota Supercomputer Institute, Dr. h.c. Dr. h.c. Earl Bakken Fund and Dr. Betty Sullivan Fund, and Mr. Lynn Peterson, United Business Machines, Fridley, MN (GC, FH).

Otsuka K., Yamanaka T., Cornélissen G., Breus T., Chibisov S.M., Baevsky R., Siegelová J., Fišer B., Halberg F.

ZMĚNĚNÝ CHRONOM VARIABILITY SRDEČNÍ FREKVENCE V PRŮBĚHU VYSOKÉ MAGNETICKÉ AKTIVITY

S o u h r n

Snížení variability srdeční frekvence hodnocené pomocí standardní odchylky bylo dříve spojováno s vystavením magnetické bouři v kosmu v transversální studii provedené na kosmonautech. Longitudinální studie nyní potvrzuje tento výsledek na klinicky zdravém muži s monitorovaným EKG po dobu sedmi dnů. Snížení variability srdeční frekvence je dokumentováno jak v časové, tak i ve frekvenční doméně. Je zjištěno, že ovlivňuje frekvence nižší než jeden cyklus v asi 3,6 s, což ukazuje na to, že fyziologická reakce na změny magnetické aktivity je vyvolávána jiným fyziologickým mechanizmem než prasympatikem. Při hledání výše uvedených mechanizmů jsou k dispozici nové invazivní a neinvazivní počítačové systémy pro hodnocení dlouhodobých a krátkodobých hemodynamických změn.

REFERENCES

1. *Baevsky RM, Petrov VM, Cornélissen G et al.* Meta-analyzed heart rate variability, exposure to geomagnetic storms, and the risk of ischemic heart disease. Scripta medica 1997;70:199-204.
2. *Cornélissen G, Halberg F, Schwartzkopff O et al.* Chronomes, time structures, for chronoengineering for „a full life“. Biomedical Instrumentation & Technology 1999;33:152-187.
3. *Watanabe Y, Cornélissen G, Sothern RB et al.* Numerical counterparts to sunspot cycles in human blood pressure and heart rate variability. In: Proc. 3rd International Symposium of Chronobiology and Chronomedicine, Kunming, China, 1998:145.
4. *Sothern RB, Cornélissen G, Bingham C, Watanabe Y, Grafe A, Halberg F.* Solar cycle stage: an important influence on physiology that must not be ignored. In: Proc. 3rd International Symposium of Chronobiology and Chronomedicine, Kunming, China, 1998:144.
5. *Chibisov SM, Breus TK, Levitin AE, Drogova GM*. Biological effects of a planetary magnetic storm. Biophysics 1995;40:957-966.

6. *Halberg F, Breus TK, Cornélissen G et al.* Chronobiology in space. Medtronic Chronobiology Seminar Series1991;1:21.
7. *Cornélissen G., Wendt H.W., Guillaume F., Bingham C., Halberg F., Breus T.K.,* Rapoport S., Komarov F. Disturbances of the interplanetary magnetic field and human pathology. Chronobiologia 1994;21:151-154.
8. *Breus T, Cornélissen G, Halberg F, Levitin AE*. Temporal associations of life with solar and geophysical activity. Annales Geophysics 1995;13:1211-1222.
9. *Orth-Gomér K, Halberg F, Sothern R, Ĺkerstedt T, Theorell T, Cornélissen G* The circadian rhythm of ventricular arrhythmias. In: Takahashi R, Halberg F, Walker C, eds. Toward Chronopharmacology, Proc. 8th IUPHAR Cong. and Sat. Symposia. Oxford: Pergamon Press, 1982:191-202.
10. *Cornélissen G, Bakken E, Delmore P et al.* From various kinds of heart rate variability to chronocardiology. Am J Cardiol 1990;66:863-868.
11. *Otsuka K, Cornélissen G, Halberg F.* Circadian rhythmic fractal scaling of heart rate variability in health and coronary artery disease. Clinical Cardiology 1997;20: 631-638.
12. *Otsuka K, ed*. Chronome & Janus-medicine: Heart Rate Variability (HRV) and BP Variability (BPV) from a viewpoint of chronobiology and ecology. Tokyo: Medical Review, 1998: 213.
13. *Otsuka K, Cornélissen G, Halberg F*. Heart rate variability measures and the autonomic nervous function. Diagnosis and Treatment 1997;85:1500-1506.
14. *Otsuka K, Nishikawa Y, Kubo Y, Cornélissen G, Halberg F*. Chronomes (rhythms, chaos, and age trends) of human heart rate variability in both genders. Computers in Cardiology 1997; 24:49-52.
15. *Otsuka K, Cornélissen G, Halberg F et al*. Vagal tone and various assessments of complexity of heart rate variability in healthy Japanese subjects. Therapeutic Research 1998;19:265-275.
16. *Otsuka K, Nishimura Y, Kubo Y et al*. Chronos and chaos: heart rate variability in healthy Japanese. The Autonomic Nervous System 1998;35:271-279.
17. *Halberg F, Syutkina EV, Cornélissen G*. Chronomes render predictable the otherwise-neglected human „physiological range“: position paper of BIOCOS project. Human Physiology 1998;24:14-21.
18. *Billman GE, Schwartz PJ, Stone HL*. Baroreceptor reflex control of heart rate: A predictor of sudden cardiac death. Circulation 1982;66:874-880.
19. *Robbe HWJ, Mulder LJM, Ruddel H, Langewitz WA, Veldman JBP, Mulder D*. Assessment of baroreflex sensitivity by means of spectral analysis. Hypertension 1987;10:538-543.
20. *Sato T, Nishinaga M, Kawamoto A, Ozawa T, Takatsuji H*. Accuracy of a continuous blood pressure monitor based on arterial tonometry. Hypertension 1993;21:866-874.
21. *Saito K, Koyama A, Yoneyama K, Sawada Y, Ohtomo N*. A recent advance in time series analysis by maximum entropy method. University Press: Sapporo, Hokkaido 1994:397.
22. *Fišer B, Siegelová J., Dušek J, Cornelissen G, Halberg F*. Determination of heart rate baroreflex sensitivity in man by spectral analysis during 24-hour period. Scripta medica 1993;66: 11-14.
24. *Siegelová J, Fišer B, Dušek J, Al-Kubati M*. Die Baroreflex-sensitivitätsmessung bei Patienten mit essentieller Hypertonie. Einfluss von Enalapril. Nieren und Hochdruckkrankheiten 1995; 24(1):20-22.
26. *Kawano Y, Tochikubo O, Miyajima E, Ishii M*. Circadian variation in baroreflex sensitivity evaluated by beat-to-beat hemodynamic change in patients with essential hypertension. J Cardiol 1995;26: 159-165.
28. *DiRienzo M, Parati G, Mancia G, Pedotti A, Castiglioni P.* Investigating baroreflex control of circulation using signal processing techniques. IEEE Engineering in Medicine and Biology 1997;16: 86-95.
30. *Eicher JC, Dobšak P, Wolf J.E.* L’échocardiographie – Doppler permet elle d’evaluer l’effect des thérapeutiques dans la myocardiopathie hypertrophique? Réalités Cardiologiques 1997;106:15-19.