The Effect of Solar-Geomagnetic Activity During Hospital Admission on the Prognosis of Cardiovascular Outcomes in Patients with Myocardial Infarction

J. Vencloviene[1,3*], R. Babarskiene[2], B. Kaminskaite[2] and D. Vasiliauskas[3]

[1]Department of Environmental Sciences, Vytautas Magnus University, Vileikos St. 8, Kaunas, 44404, Lithuania,
[2]Department of Cardiology, Lithuanian University of Health Sciences, Eivieniu St. 2, Kaunas, Lithuania
[3]Institute of Cardiology, Lithuanian University of Health Sciences, Eivieniu St. 2, Kaunas, Lithuania.

Authors' contributions

This work was carried out in collaboration between all authors. Author JV was responsible for the heliophysical data, statistical analysis, read and approved the final manuscript. Author RB was responsible for the medical data, read and approved final manuscript. Author BK performed the evaluation of the data, wrote the first draft of the paper. Author DV was responsible for the medical data, designed the study. All authors read the final version of the manuscript. All authors read and approved the final manuscript.

ABSTRACT

Aims: Some evidence has been reported on the increase in the rate of myocardial infarction, stroke and change in number cardiovascular parameters during geomagnetic storms. The aim of this study was to evaluate the risk of in-hospital lethal or major adverse cardiovascular events (myocardial infarction, stroke, and death) (MACE) in patients with myocardial infarction, depending on the patients' clinical data and the heliophysical environment during hospital admission and on the first subsequent days.
Place and Duration of Study: The study included 1,579 patients who in 2005-2006 were treated in the Hospital of Lithuanian University of Health Sciences and survived for more

Corresponding author: Email: j.vencloviene@gmf.vdu.lt;

than one day. During hospitalization, 35 (2.2%) cases of death and 60 (3.8%) cases of MACE were registered.

Methodology: The effect of geomagnetic storms, solar flares, and solar proton events was estimated by applying multivariate logistic regression, adjusting for clinical variables.

Results: Geomagnetic storms occurring one day after hospital admission increased the risk of in-hospital death and MACE by over 2.9 times (respectively, OR=3.69, 95% CI 1.29-10.5; and OR=2.91, 95% CI 1.33-6.36). A dose-response relationship was observed between the daily geomagnetic level (quiet-unsettled, active, or stormy) on the day prior to hospitalization and the risk of mortality or MACE (respectively, 1; 1.98(0.75-5.19); 4.20(1.43-12.3), and 1; 2.41(1.19-4.91); 3.45(1.55-7.71)). Solar flares occurring 0-2 days before the admission increased the risk of MACE by over 1.9 times. Among high-risk patients admitted one day after active-stormy geomagnetic level, in-hospital death occurred in 10.8% and MACE – in 15.3% cases; among patients hospitalized one day after quiet-unsettled geomagnetic level, the respective percentage was 4.8 and 7.9.

Conclusions: The heliophysical conditions during hospital admission affect the risk in-hospital lethal outcome and MACE, adjusting for clinical variables; these effects were stronger in high risk patients.

1. INTRODUCTION

Ischemic heart disease (IHD) is one of the major causes of death in Europe. In order to decrease mortality from IHD, numerous studies have been undertaken to identify factors and mechanisms that cause IHD and promote its progression, and to clarify the relationships of these factors with the clinical course of the disease, its treatment, and prognosis. The principal aim of most scientific clinical studies evaluating patients' survival and prognosis was the assessment of the compound risk of adverse health events (e.g. death or myocardial infarction) or the assessment of the survival function on the basis of the indicators of patients' condition [1,2,3]. Different scores are now available based on initial clinical history, ECG, and laboratory tests, allowing for early risk stratification on admission.

Some authors state that physical conditions – such as geomagnetic activity (GMA) or cosmic ray activity (CRA) – also have an effect on sudden cardiac death (SCD) and the etiology of myocardial infarction (MI). Studies [4] showed that SCD was higher in the presence of the highest and the lowest daily levels of GMA, and days with SCD were accompanied by higher CRA. During high GMA, more SCD occurred at one hour and with agony time > 1-24h, when the element of arrhythmic death was mostly excluded [5]. Some authors stated that the localization of MI was related to the presence of GMA and CRA at the time of admission. At low GMA and higher CRA, left anterior descending coronary artery was the culprit artery in MI [6].

There is evidence that increased solar-geomagnetic activity affects some cardiovascular parameters. Stormy GMA is associated with decreased heart rate variability [7,8], increased blood pressure [9], reduced arterial baroreflex sensitivity and microcirculation [10], elevated tissue perfusion and amplitudes of neurogenic and myogenic oscillations, and increased variability of blood flow [11]. GMA and CRA variations are associated with variations of heart rate and arterial blood pressure [12,13]. It is plausible that the solar-geomagnetic activity

during hospital admission may affect cardiovascular outcomes in patients with myocardial infarction.

The aim of this study was to evaluate the risk of in-hospital death or major adverse cardiovascular event (MI, stroke, cardiac death, and death) in patients with myocardial infarction, depending on the patients' condition on hospital admission and the heliophysical environment during hospital admission and on the first subsequent days.

2. MATERIALS AND METHODS

The study was conducted in Kaunas city, Lithuania from January 1, 2005 to September 30, 2006 (638 days). Data on hospital admissions due to acute coronary syndromes were obtained from the Clinic of Cardiology, Hospital of Lithuanian University of Health Sciences (formerly - Kaunas University of Medicine). We used data on 1,579 patients who were treated for acute myocardial infarction (I21) and survived for more than one day after hospitalization. Myocardial infarction (MI) was diagnosed according to the WHO guidelines: angina pain and equivalent, ischemic signs on ECG (Q wave, ST, and T changes), and an increase in troponin I level (>0.05 μg/L). We analyzed the associations between environmental variables during and after admission and the risk of death and major adverse cardiovascular event (MACE) – MI, stroke, cardiac death, and death – during the hospitalization period. The analysis included data on patients who experienced MACE later than one day after admission.

Data of solar flares, solar proton events (SPE), and geomagnetic activity were used as environmental data. Daily Ap indexes were used as the measure of the level of geomagnetic activity. The Ap index is defined as the geomagnetic disturbance index measured over 24-hour intervals at the surface of the Earth. In the analysis the geomagnetic activity was classified as either quiet (Ap<8), unsettled-active (8≤Ap<30), or stormy (Ap≥30). According to the NOAA (National Oceanic and Atmospheric Administration) classification, a minor geomagnetic storm (GS) occurs when 30≤Ap<50 and a major storm - when Ap≥50. As a measure of the level of solar flares (SF), we used daily north flare index coded in binary values: "no flare" (daily north flare index=0), and "yes flare" (north flare index>0). Ap and flare indexes were downloaded from the joint USA/European Solar and Heliospheric Observatory (web site ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/). During the study period, minor GS were observed on 27 (4.2%) days and major GS – on 16 (2.5%) days; on 75 (11.8 %) days, the north solar flare index was over 0.

The SPE determined by solar proton fluencies in >10 MeV energy interval are routinely measured with the space environment monitor system onboard the Geostationary Operational Environmental Satellites (GOES). The high proton >10 MeV energy fluencies are defined as proton >10 MeV fluency over 86.4×10^{4} protons/(cm^{2}-day-sr), which amounts to the daily average of proton flux of over 10 proton/(cm^{2}-s-sr). Data of daily proton fluencies and SPE were downloaded from the National Geophysical Data Center web site ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SATELLITE_ENVIRONMENT/. SPE was observed on 26 (4.1%) days.

2.1 Statistical Analysis

The evaluation of the complex risk of a MACE or lethal outcome was conducted by applying the multivariate logistic regression model. At first, the model included significant variables

identified using the χ^2 test; subsequently, variable with standardized OR not exceeding 1.5, and *P* exceeding 0.2 were excluded from the model one by one. According to the tertiles of the probability of lethal outcome and MACE evaluated using the logistic model, the patients were distributed into low, moderate, or high risk groups for lethal outcome or MACE.

Unfavorable environmental events such as geomagnetic storms may affect health not only on the day of the event, but on subsequent days as well. There is a plausible presumption that the environmental variables existing on the day of hospital admission or during the two previous days may affect human health on the following day. Therefore, we investigated the lag effect of environmental variables on the risk of lethal outcome or MACE – we used the lag of 0-2 days (lag>0 – before admission, and lag<0 – after admission). To assess the impact of environmental variables on the risk of death or MACE, we used the odds ratio with 95% confidence interval, adjusted by clinical variables. Statistical analysis was performed using SPSS 13 software.

3. RESULTS AND DISCUSSION

3.1 Association between Patients' Characteristics and the Risk of Lethal Outcome or MACE

Among 1,579 patients, recurrent MI occurred in 11 (0.7%) patients, stroke – in 6 (0.4%), cardiac death – in 25 (1.6%), and death - in 35 (2.2%) patients. During hospitalization, 60 (3.8%) cases of MACE were registered. In total, 60.4% of the patients were men and 38.7% were older than 70 years of age. One-fourth (28.3%) of the participants had a history of myocardial infarction and 71.9% had arterial hypertension (Table 1). During hospitalization, 81.3% of patients underwent coronary angiography. Stenosis ≥50% in more than 1 coronary artery was detected in 60.1% patients who underwent coronary angiography.

Considering the influence of other informative factors, it can be stated that the risk of death in patients over 70 years of age was by over 4.5 times greater than in younger patients. A history of stroke, heart failure, and diabetes nearly doubled the risk of lethal outcome and MACE during hospital stay. In patients who used beta blockers, the risk of MACE was by about 2 times lower, compared to that in patients who did not use these medications. Significant risk factors for in-hospital mortality in our study corresponded to risk factors most commonly reported in literature [14]. A history of stroke is an independent factor significantly increasing mortality from acute MI [15,16,17] and risk for MACE [18]. The U-shape effect of heart rate on lethal outcome was assessed by the beautiful study group [19]. In our study, the U-shape effect of heart rate on death and MACE was observed as well.

The limits of low, moderate, and high risk for lethal outcome and MACE and the distribution of adverse events in these groups in Table 2 are presented. In the groups of patients with high risk, death occurred in 32 (6.2%) cases and MACE - in 51 (9.8%) patients.

Table 1. Patients' baseline characteristics and multivariate logistic model for the assessment of the risk for lethal outcome and MACE (adjusted OR and 95 % CI) (*P* value of χ^2 test)

Clinical variable	All	Lethal outcome			MACE		
	N(%)	N(%)	*P*	OR(95% CI)	N(%)	*P*	OR(95% CI)
Age: 20-60 years	501(31.7)	2(5.7)	<.001	1	10(16.7)	.001	1
61-70 years	466(29.5)	7(20.0)		2.38(0.47-12.1)	13(21.7)		
71-80 years	463(29.3)	16(45.7)		4.63(1.01-21.3)	25(41.7)		1.85(1.04-3.29)
> 80 years	149(9.4)	10(28.6)		8.63(1.77-42.0)	12(20.0)		
Males	954(60.4)	17(48.6)	.15		32(53.3)	.25	
Medical history							
MI	47(28.3)	18(51.4)	.002	1.73(0.79-3.82)	28(46.7)	.001	1.73(0.94-3.16)
Heart failure	503(31.9)	21(60.0)	<.001	2.34(1.07-5.12)	34(56.7)	<.001	2.27(1.27-4.05)
Stroke	100(6.3)	8(22.9)	<.001	2.61(1.02-6.70)	13(21.7)	<.001	3.04(1.45-6.39)
AH	1135(71.9)	25(71.4)	.91		41(68.3)	.75	
Pulmonary disease	78(4.9)	5(14.3)	.01		6(10.0)	.07	
PTCA	71(4.5)	4(11.4)	.05		7(11.7)	.01	
Diabetes	232(14.7)	10(28.6)	.02	1.85(0.81-4.26)	15(25.0)	.02	1.61(0.83-3.12)
Clinical data							
Atrial fibrillation	129(8.2)	11(31.4)	<.001	2.24(0.97-5.15)	15(25.0)	<.001	1.79(0.89-3.58)
Heart rate ≤50 bpm	74(4.7)	5(14.3)	<.001	2.88(0.82-10.1)	6(10.0)	<.001	2.80(0.81-9.67)
51-70	556(35.2)	5(14.3)		1	8(13.3)		1
71-80	440(27.9)	6(17.1)		1	13(21.7)		2.16(0.85-5.44)
81-90	245(15.5)	3(8.6)		1	8(13.3)		1.91(0.68-5.42)
>90	264(16.7)	16(45.7)		2.75(1.21-6.24)	25(41.7)		3.99(1.67-9.52)
Killip class III-IV	204(12.9)	22(62.9)	<.001	6.38(2.94-13.8)	32(53.3)	<.001	5.85(1.90-6.47)
Troponin I level >10 *µ*g/L	490(31.0)	19(54.3)	.003	1.76(0.83-3.74)	28(46.7)	.008	
Beta blockers used	547(34.6)	9(25.7)	.26		13(21.7)	.03	0.46(0.23-0.90)

AH - arterial hypertension; PTCA – percutaneous transluminal coronary angioplasty.

Table 2. The distributions of lethal outcome and MACE in low, moderate, and high risk groups

Risk	Lethal outcome		MACE	
	Limits of the probability*	**N(%)**	**Limits of the probability***	**N(%)**
Low	0.00068-0.00283	1(0.2)	0.00195-0.00920	5(0.4)
Moderate	0.00284-0.01010	2(0.4)	0.00921-0.02330	7(1.3)
High	0.01011-0.65545	32(6.2)	0.02331-0.7802	51(9.8)

the risk groups determined by tertiles of the probability in the logistic model

3.2 The Effect of Heliophysical Conditions during Hospital Admission on the Risk of Lethal Outcome and MACE during Hospitalization

In total, 51.6% of patients were hospitalized on days with quiet geomagnetic field (GMF), 28.2% – on days with unsettled GMF, and 12.9% of patients – on days with active GMF; 115 (7.3%) patients were hospitalized on days with GS, and 45 (2.8%) patients – on days with major GS; 190 (12.0%) patients were hospitalized on solar flare days, and 115 (7.3%) patients – during days with SPE.

The importance of clinical surveys for assessing the risk of in-hospital death or MACE has been highlighted in many clinical studies were analyzed, while no analysis was conducted on the additional effect of the heliophysical environment during hospitalization on the risk of in-hospital adverse events. After adjusting for clinical variables, the analysis showed that among patients, admitted one day after GS, the risk of lethal outcome and MACE was by over 3 times higher, compare to patients who were admitted after quiet-unsettled GMA. A dose-response relationship was observed between the GMA level one day prior to admission and the risk of in-hospital mortality or MACE. GS that occurred one day after hospital admission by over 2 times increased the risk of lethal outcome and MACE. SF occurring 0-2 days before admission increased the risk of MACE by over 1.9 times. GS occurring one day before the admission, accompanied by SF (SPE, occurring on the previous day), increased the risk of lethal outcome and MACE by, respectively, 9.68 (9.04) and 5.21 (4.90) times (Table 3).

In high-risk group of patients who were admitted one day after GS accompanied by SF, lethal outcome was registered in 22.2% (6) cases; when GS occurred on day after or before hospital admission, lethal outcome among such patients was registered in 13.3% (10) cases (Fig. 1A). MACE occurred in 28.6% (8) high risk-group patients who were hospitalized one day after GS accompanied by SF (Fig. 1B). Among high-risk patients admitted one day after active-stormy GMF, in-hospital death occurred in 10.8% and MACE – in 15.3% cases; among patients hospitalized one day after quiet-unsettled GMF, the respective percentage was 4.8 and 7.9.

Table 3. The distribution of in-hospital deaths and MACE and adjusted OR of heliophysical variables (only OR with *P*<0.2 are presented)

Heliophysical variable	Lag	N(%)	OR*(95% CI)	*P*	N(%)	OR**(95% CI)	*P*
		In-hospital deaths			**MACE**		
GS	1	5(14.3)	3.69(1.29-10.5)	.02	10(16.7)	2.91(1.33-6.36)	.01
	0				6(10.0)	2.07(0.77-5.78)	.15
	-1	7(20.0)	2.35(0.84-6.54)	.10	11(18.3)	2.69(1.21-5.98)	.02
GMA: Quiet-unsettled	1	22(62.9)	1		36(60.0)	1	
Active		7(20.0)	1.98(0.75-5.19)	.17	14(23.3)	2.41(1.19-4.91)	.02
Stormy		6(17.1)	4.20(1.43-12.3)	.01	10(16.7)	3.45(1.55-7.71)	.003
GMA: Quiet-unsettled	0				38(63.3)	1	
Active					16(26.7)	3.16(1.61-6.19)	.01
Stormy					6(10.0)	2.66(0.96-7.35)	.06
SF index>0	2				14(23.3)	1.92(0.96-3.82)	.07
	1	7(20.0)	2.70(1.05-6.95)	.04	14(23.3)	2.55(1.28-5.09)	.01
	0				14(23.3)	1.96(0.98-3.93)	.06
GS after SPE	1	4(11.4)	9.04(2.56-31.9)	.001	5(8.3)	4.90(1.65-14.5)	.004
GS with SF	1	6(17.1)	9.68(3.28-28.6)	.001	8(13.3)	5.21(2.13-12.8)	.001
	0				4(7.7)	3.94(1.14-13.6)	.03

*adjusting for age; MI, heart failure, diabetes, stroke in anamnesis; heart rate, atrial fibrillation, Killip class, and troponin I level >10 µg/L at admission;

**adjusting for age; MI, heart failure, diabetes, stroke in anamnesis; heart rate, atrial fibrillation, Killip class, and for use of beta blocker in the anamnesis.
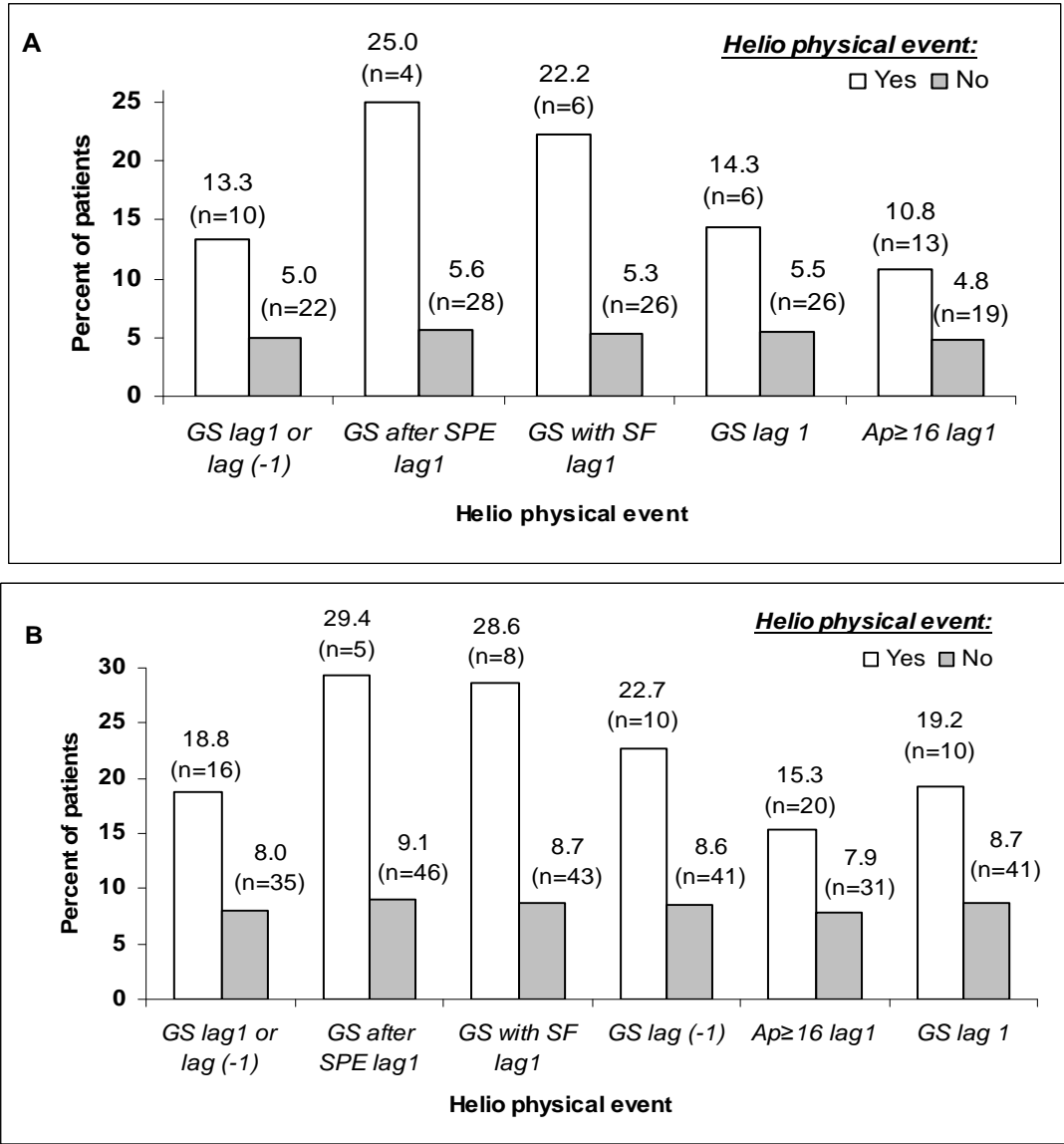
Fig. 1. The risk for in-hospital death (A) and MACE (B) among high-risk patients with respect to heliophysical conditions before (lag 1) and one day after (lag (-1)) hospital admission

According to our results, the addition of heliophysical variables 0-2 days before or one day after hospitalization improved the prognostic characteristics of the risk models. Our study showed that the geomagnetic storms that occurred one day before or one day after hospital admission increased the risk of in-hospital death and MACE; besides, the risk due to GS was observed after standardization by patients' age, anamnesis, and condition during hospital admission. It is likely that during GS or one day after GS, patients with more severe myocardial damage were hospitalized. Results obtained by a number of authors confirm this presumption. According to Stoupel et al. [20], during periods of high GMA, more cases of

anterior wall myocardial infarction and higher outpatient mortality were registered, and a trend towards higher in-hospital mortality from acute myocardial infarction was observed. Most of patients with ischemic cardiac disease at the onset of GS demonstrated significant changes in ECG, a sudden jump of arterial blood pressure, a deceleration of blood flow, and an increased blood viscosity in arteries [21]. The main phase of severe GS was followed by destruction and degradation of mitochondria in cardiomyocytes of rabbits [22]. GS sharply disturbs the rhythm of the external synchronizer of biological rhythms, and is therefore accompanied by an adaptation stress reaction of the organism, which is most pronounced in the case of an unstable state of adaptation system [23]. The unstable state of adaptation may provoke adverse health effects in patients with impaired cardiovascular function. A number of authors indicated the negative effect of GS on cardiovascular markers associated with unfavorable prognosis following MI. An inverse relationship has been reported between heart rate variability and geomagnetic activity [7,8].

Some authors stated that the effects of geomagnetic storms on patients with impaired function of the cardiovascular system are very strong, compared to the corresponding effects on healthy people [21,24,11]. Most of our studied patients had previous cardiovascular problems, and therefore they were likely more sensitive to GMA variations, and, as a result, higher GMA increased the risk of in-hospital death and MACE. According our results, the effect of heliophysical variables also was stronger in high-risk patients.

Because of the aforementioned effect, increased GMA on the day before hospital admission could cause more extensive infarction, thus increasing the likelihood of unfavorable prognosis. Besides, the cardiovascular condition of patients on the day following MI remains complicated, and therefore the effect of GS that occurred at that time is rather significant. GS occurring on day after hospital admission could result in arrhythmias and heart failure, which would impair recovery after myocardial infarction and might cause complications resulting in MACE.

In order to avoid the adverse effects of intense geomagnetic activity, and especially geomagbetic storms, we recommend intensifying the therapy in patients with myocardial infarction, for those were admitted on 1-2 days after geomagnetic storms or the X class solar flares, especially when GS occurred after SPE or solar flare. The daily of solar flares, geomagnetic activity level and its prognosis can be found in NGDC (National Geophysical Data Center) or SPIRD (Space Physics Interactive Data Recourse) home page.

4. CONCLUSIONS

The study showed that after adjustment for clinical variables geomagnetic storms occurring one day before hospital admission or on the first day after hospitalization significantly ($p < 0.05$) increased the risk of death and MACE.

The effect of GS on the risk of death or MACE was increased by solar flares or SPE occurring in conjunction with GS. The effect of GS, solar flares, and SPE were stronger in high-risk patients.

CONSENT

Not applicable.

ETHICAL APPROVAL

We also state that study ethics comply with the Declaration of Helsinki.

ACKNOWLEDGEMENTS

COMPETENTING INTERESTS

Authors have declared that no competenting interests exist.

REFERENCES

1. Van De Werf F, Bax J, Betriu A, Blomstrom-Lundqvist C, Crea F, Falk V, et al. Management of acute myocardial infarction in patients presenting with persistent ST segment elevation. Eur Heart J. 2008;9(23):2909–45.
2. Yan AT, Yan RT, Tan M, Casanova A, Labinaz M, Sridhar K, et al. Risk scores for risk stratification in acute coronary syndromes: Useful but simpler is not necessarily better. Eur Heart J. 2007;9(28):1072–8.
3. Umbrasiene J, Jankauskiene E, Kupstyte N, Babarskiene RM, Vencloviene J, Gustiene O. Prognostication of long-term outcomes for patients with ischemic heart disease. Medicina. 2010;10(46):700–6.
4. Stoupel E, Babayev ES, Mustafa FR, Abramson E, Israelevich P, Sulkes J. Clinical cosmobiology - sudden cardiac death and daily/monthly geomagnetic, cosmic ray and Solar activity the Baku study (2003-2005). Sun and Geosphere. 2006;1(2):13-6.
5. Stoupel E, Domarkiene S, Radishauskas R, Abramson E. Sudden cardiac death and geomagnetic activity: links to age, gender and agony time. J Basic Clin Physiol Pharmacol. 2002;13(1):11-21.
6. Stoupel E, Assali A, Teplitzky I, Israelevich P, Abramson E, Sulkes J, Kornowski R. The culprit artery in acute myocardial infarction in different environmental physical activity levels. Int J Cardiol. 2008;23(2):288-90.
7. Watanabe Y, Corne´lissen G, Halberg F, Otsuka K, Ohkawa SI. Associations by signatures and coherences between the human circulation and helio- and geomagnetic activity. Biomed Pharmacother. 2001;55(Suppl 1):76–83.
8. Cornelissen G, Halberg F, Breus T, Syutkina EV, Baevsky R, Weydahl A, et al. Non-photic solar associations of heart rate variability and myocardial infarction. J Atmos Sol-Terr Phys. 2002;64:707–20.
9. Dimitrova S, Stoilova I, Cholakov I. Influence of local geomagnetic storms on arterial blood pressure. Bioelectromagnetics. 2004;25:408-414
10. Gmitrov J. Geomagnetic disturbances worsen microcirculation impairing arterial baroflex vascular regulatory mechanism. Elektromag Biol Med. 2005;24:31-37.
11. Zenchenko TA, Poskotinova LV, Rekhtina AG, Zaslavskaya RM. Relation between Microcirculation Parameters and Pc3 Geomagnetic Pulsations. Biophysics. 2010;55(4):646–51.
12. Dimitrova S. Possible heliogeophysical effects on human physiological state. Proc IAU Symp. 257:65-7.

13. Mavromichalaki H, Papailiou M, Dimitrova S, Babaev ES, Loucas P. Space weather hazards and their impact on human cardio-health state parameters on Earth. Nat Hazards. 2012;64:1447-59.

14. Lee KL, Woodlief LH, Topol EJ, Weaver WD, Betriu A, Col J, et al. Prediction of 30-days mortality in the era of reperfusion for acute myocardial infarction. Circulation. 1995;91(6):1659-68.

15. Touzé E, Varenne O, Chatellier G, Peyrard S, Rothwell PM, Mas J-L. Risk of Myocardial Infarction and Vascular Death After Transient Ischemic Attack and Ischemic Stroke: a Systematic Review and Meta-Analysis. Stroke. 2005;36(12):2748-55.

16. Dhamoon MS, Tai W, Boden-Albala B, Rundek T, Paik MC, Sacco RL, et al. Risk of Myocardial Infarction or Vascular Death After First Ischemic Stroke.The Northern Manhattan Study Mandip. Stroke. 2007;38:1752-8.

17. Mulder M, Gitt A, Domburg R, Hochadel M, Seabra-Gomes R, Serruys PW, et al. EuroHeart score for the evaluation of in-hospital mortality in patients undergoig percutaneous coronary intervention. Eur Heart J. 2011;32:1398-408.

18. Abtahian F, Olenchock B, Ou FS, Kontos MC, Saucedo JF, Scirica BM, et al. Effect of prior stroke on the use of evidence-based therapies and in-hospital outcomes in patients with myocardial infarction (from the NCDR ACTION GWTG registry). Am J Cardiol. 2011;15;107(10):1441-6.

19. Fox K, Ford I, Steg PG, Tendera M, Robertson M, Ferrari R, et al. Heart rate as a prognostic risk factor in patients with coronary artery disease and left-ventricular systolic dysfunction (BEAUTIFUL): a subgroup analysis of a randomized controlled trial. Lancet. 2008;372(9641):817-21.

20. Stoupel E. Effect of geomagnetic activity on cardiovascular parameters. J Clin Basic Cardiol. 1999;2:34-40.

21. Gurfinkel' YuI, Lyubimov VV, Oraevskii VN, Parfenova LM, Yur'ev AS. Effect of Geomagnetic Disturbances on the Capillary Blood Flow in Patients with Coronary Heart Disease. Biofizika. 1995;40(4):793–9 (In Russian).

22. Chibisov SM, Breus TK, Levitin AE, Drogova GM. Biological effects of planetary magnetic storms. Biofizika. 1995;40(5):959–68 (In Russian).

23. Breus TK, Baevskii RM, Chernikova AG. Effects of geomagnetic disturbances on humans functional state in space flight. J Biomed Sci Eng. 2012;5:341-55.

24. Zenchenko TA, Dimitrova S, Stoilova I, Breus TK. Individual responses of arterial pressure to geomagnetic activity in practically healthy subjects. Klin Med. 2009;4:18-23.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=205&id=12&aid=1394