GEOMAGNETIC ACTIVITY VARIATIONS OF SOLAR ORIGIN AND DYNAMICS OF SUDDEN CARDIAC DEATHS

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Резюме: *Preliminary results of collaborative studies on revealing possible effects of geo-effective solar events, estimated by geomagnetic activity (GMA) variations, on the dynamics of sudden cardiac deaths at middle latitudes are described. Medical data were taken from all of Emergency and First Medical Aid Stations of grand Baku area with millions of inhabitants for a period of 4670 days from 16 November 2002 to 31 December 2018. In total 5490 SCD cases were analyzed. Results revealed that the number of this type fatal cardiac incidences prevailed on the days of very low GMA and quiet GMA.*

ВАРИАЦИИ НА ГЕОМАГНИТНАТА АКТИВНОСТ ОТ СЛЪНЧЕВ ПРОИЗХОД И ДИНАМИКА НА СЛУЧАИТЕ НА ВНЕЗАПНА СЪРДЕЧНА СМЪРТ

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Abstract: *Представени са предварителни резултати от продължаващите съвместни изследвания на гео-ефективните слънчеви събития, оценявани чрез вариациите на геомагнитната активност (ГМА), върху динамиката на броя случаи на внезапна сърдечна смърт. Медицинските данни са от всички Центрове за Спешна и Първа Медицинска Помощ от областта на гр. Баку за период обхващащ 4670 дни от 16.11.2002 г. до 31.12.2018 г. Анализирани са общо 5490 случая. Резултатите показаха, че този тип фатални сърдечно-съдови инциденти преобладават в дните на много ниска ГМА и спокойна ГМА.*

Introduction

The number of studies establishing effects of geomagnetic activity (GMA) on different functional systems and in particular cardiovascular and nervous system has been steadily increasing in the last decades [1–3]. Studies revealed that GMA could affect blood pressure, worsen the baro-reflective sensitivity and microcirculation, may alter the capillary blood flow and heart rate variability. The enumerated established effects on the circulation and cardiovascular parameters indicate that GMA variations may be related to the dynamics of cardiac arrhythmias, cases of myocardial infarction, sudden cardiac deaths and other cardiovascular diseases. This hypothesis has been supported by different studies [4–13].

Myocardial infarctions, more commonly known as heart attacks, occur when there is a blockage in one or more of the coronary arteries, preventing the heart from receiving enough oxygen-rich blood. If the oxygen in the blood cannot reach the heart muscle, the heart becomes damaged.

In contrast, sudden cardiac death (SCD) is a lethal outcome resulting from an abrupt loss of heart function (cardiac arrest). Sudden cardiac arrest occurs when the electrical system to the heart malfunctions and suddenly becomes very irregular. The heart beats dangerously fast. The ventricles may flutter or quiver (ventricular fibrillation), and blood is not delivered to the body. Death follows unless emergency treatment is begun immediately. SCD is described as death of cardiac origin occurring in *one hour* time limit, without preliminary symptoms [14, 15].

In this study we investigated the potential effects of GMA variations of solar origin, estimated by geomagnetic indices, on SCD mortality analyzing a period of 4670 days regarding medical data taken from middle-latitude geographical location.

Material and methods

Daily medical database was created for deaths from all causes registered according to WHO standards in 22 Emergency and First Medical Aid Stations (EFMAS) spread on big urban area (the Absheron Peninsula located at middle latitudes (40°23' N, 49°51' E), including Baku capital city of Azerbaijan with more than 3 million of inhabitants) as well as in the Central Emergency and First Medical Aid Station in Baku.

Emergency calls were subjected to the "cleaning" from deaths due to non-cardiovascular reasons, cancer, traffic/road and other accidents, suicide, stroke, etc., and remaining data (cardiovascular related deaths) were analyzed. Deaths due to diagnosed acute myocardial infarction are not considered in this paper.

Time span covered by the data was from 16 November 2002 to 31 December 2018 with gaps for the following periods: 24.12.2008-01.01.2009; 01.01.2010-01.12.2012 and 01.11.2017-25.03.2018. This period corresponds to the period of socio-economic stability and development in Azerbaijan.

Planetary *Ap*-index and daily disturbance storm time *Dst*-index were used to evaluate different effects of GMA. Data were handled from Goddard Space Flight Center, NASA's Space Physics Data Facility (SPDF): https://omniweb.gsfc.nasa.gov/form/dx1.html

The effect of GMA variations on SCD dynamics was studied by dividing both geomagnetic indices into six intervals to represent the level of GMA (Table 1).

Table 1. Gradation of GMA levels

GMA Index (nT)	I0 very low GMA	I quiet GMA	II weak storm	III moderate storm	IV major storm	V severe storm
Dst	Dst ≥ 0	(0 ÷–20)	[–20 ÷–50)	[–50 ÷–100)	[–100÷–150)	Dst ≤ –150
Ap	Ap < 8	[8 ÷ 15)	[15 ÷ 30)	[30 ÷50)	[50 ÷ 100)	Ap ≥ 100

"Cleaned" from social and other factors data were subjected to medical and mathematical/statistical analysis.

Analysis of variance (ANOVA) was applied to check the significance of GMA variations effect on SCD mortality.

The effect of geomagnetic storms before and after their development on SCD dynamics was investigated by ANOVA and superposed epoch method. GMA impact up to 3 days before and 3 days after sharp changes of geomagnetic conditions was studied.

The chosen level for statistical significance was $p \leq 0.05$.

Results

The number of days with different GMA levels according to Ap- and Dst-index values and the respective number of SCD cases for the period under consideration are shown in Table 2.

Table 3 shows significance levels (*p*-values) obtained by ANOVAs applied to study GMA effect, estimated by geomagnetic indices under consideration (Ap and Dst) on SCD number for the days before ("–"), during ("0") and after ("+") geomagnetic storms. It reveals statistically significant effect ($p < 0.05$) of GMA variations according to Ap-index on all of the days preceding and following the geomagnetic storms except on the 0 day (the day of the occurrence of the storm) and statistically significant effect of GMA fluctuations regarding Dst-index on -3^{rd}, -2^{nd}, $+2^{nd}$ and $+3^{rd}$ day.

Results obtained from ANOVA on the days of the geomagnetic storms occurrence were not statistically significant but revealed that the number of SCD cases were largest on the days of very low

GMA activity regarding both Ap-index values (Fig. 1) and Dst-index-values (Fig. 2) and lowest on the days of highest GMA (severe storms). Vertical bars in the figure denote 0.95 confidence intervals (CI).

Fig. 3 shows SCD number for the different GMA levels regarding Ap-index from –3rd to +3rd day. The largest number of SCD cases was on the days and around the days of very low GMA and quiet GMA. SCD number was less around the days of geomagnetic storms in comparison to I0 and I GMA level. It can be seen on the Fig. 3 that despite the increase of fatal incidences on the days of major and severe geomagnetic storms development (0 day) and on the second day after them, the number of SCD remained less in comparison to the periods of very low GMA and quiet GMA.

Similar dynamics of SCD number was revealed taking into consideration Dst-index (Fig. 4). The difference was an increase of SCD on +2nd and +3rd day of major geomagnetic storms (IV GMA level), which might be due to small number of data as referred to Table 2.

Table 2. Number of days for the different GMA levels and SCD

Parameters / GMA Levels	Ap		Dst	
	Days	**SCD**	**Days**	**SCD**
I0 very low GMA	2585	3078	1191	1429
I quiet GMA	1152	1358	2485	2931
II weak storm	681	779	856	990
III moderate storm	181	203	114	120
IV major storm	54	56	16	18
V severe storm	17	16	8	2

Table 3. Significance levels (p-values) of the effect for GMA (Ap and Dst-indices) on SCD number in Baku for the days before, during and after geomagnetic storms

Day	*p*-values	
	Ap	Dst
–3	0.02*	0.00*
–2	0.00*	0.03*
–1	0.01*	0.16
0	0.78	0.26
+1	0.004*	0.13
+2	0.01*	0.00*
+3	0.001*	0.00*

** - statistically significant result*

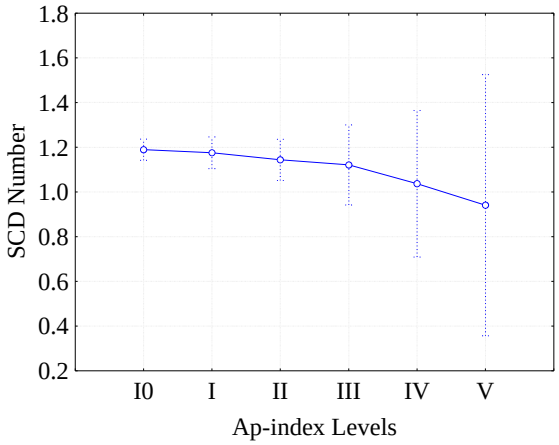

Fig. 1. GMA effect, estimated by Ap-index, on SCD number (±95 % CI)

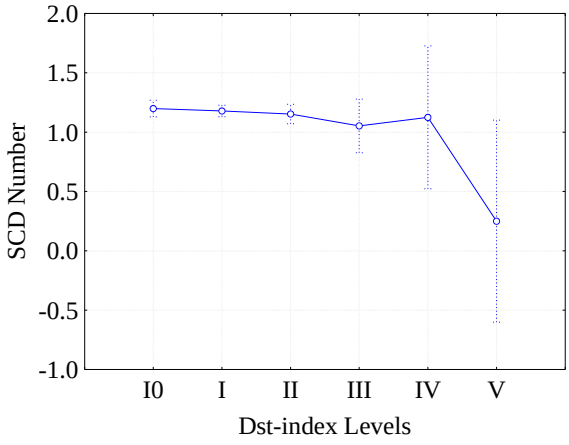

Fig. 2. GMA effect, estimated by Dst-index, on SCD number (±95 % CI)

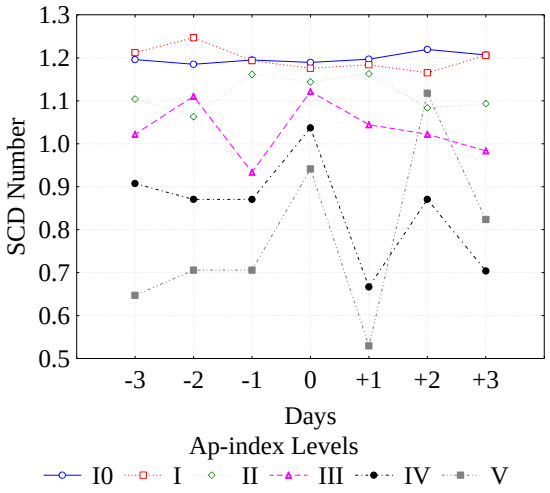

Fig. 3. GMA effect, estimated by Ap-index, on SCD number before, during and after geomagnetic storms

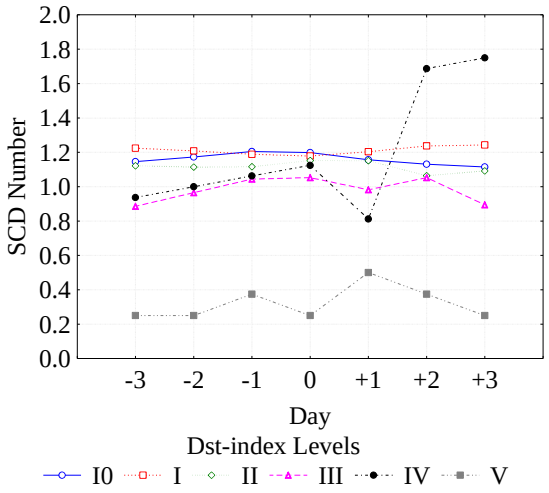

Fig. 4. GMA effect, estimated by Dst-index, on SCD number before, during and after geomagnetic storms

Discussion and conclusions

In this work we continued our earlier studies concerning the space weather effects on SCD dynamics at middle latitudes. The conducted investigations showed that SCD could be affected by GMA variations. It was obtained that the most threatening conditions for that kind fatal cardiac incidences were the periods of very low GMA and quiet GMA. Similar results were obtained by other studies as well [16, 17, 18].

Most sudden cardiac deaths are caused by abnormal heart rhythms called arrhythmias. The most common life-threatening arrhythmia is ventricular fibrillation (VF), which is an erratic, disorganized firing of impulses from the ventricles (the heart's lower chambers). When this occurs, the heart is unable to pump blood and death will occur within minutes, if left untreated. Different studies performed by Stoupel's team have also shown an inverse relationship between SCD and cardiac rhythm disturbances and GMA levels. The development of the implantable cardioverter defibrillator (ICD) introduced a new approach to the management and prevention of sudden death. Stoupel et al. [19] used the data provided by automatic ICD discharges regarding the onset of VF and ventricular tachycardia (VT) to link these events to GMA level. Close to half of all discharges occurred on days of lowest GMA level. There was a significant inverse correlation between GMA level and number of discharges and a significant difference between ICD discharges on days of lowest GMA and the rest of the days with increased GMA. The higher number of ICD discharges on days of lowest GMA is explained by authors by a possible anti-arrhythmic effect of GMA. They conclude that environmental arrhythmogenic factors that act inversely to GMA may be activated at times of low GMA and these results provide additional support of the association of cardiac arrhythmias and low GMA levels. Based on these results, the authors suppose that artificial magnetic fields may serve as a tool to prevent serious arrhythmic events and SCD in high-risk patients.

This study was continued [20, 21] and the authors established that neutron activity was significantly higher on the days of ICD discharges in patients with damaged heart muscle and heart failure. Whether this relation is a direct consequence of low GMA or is mediated by as yet unknown factors induced by low GMA, or whether neutrons play an independent role in the pathogenesis and timing of cardiac arrhythmias, remains to be determined.

Later, it was established in a large scale cohort analysis performed by Ebrille et al. [22], that ICD therapies were delivered less frequently on days of higher GMA, confirming the previous pilot data and suggesting that higher GMA does not pose an increased risk of arrhythmias using ICD therapies as a surrogate marker. Further studies are needed to gain an in-depth understanding of the underlying mechanisms.

The results show that human cardio-vascular function can be potentially affected by GMA variations of solar origin. It seems that an optimal level of geomagnetic field fluctuations is required to prevent fatal cardiac incidences. The role of the possible adverse effect of environmental physical factors, becoming more active at low GMA, like cosmic ray activity should be taken into consideration as well. Long-period and detailed studies must be carried out for confirmation and clarifying the results obtained.

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