GEOMAGNETIC VARIATIONS AND DYNAMICS OF SUDDEN CARDIAC DEATHS

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Abstract: *The results of the ongoing joint studies of influence of changes in space weather, assessed by indices of geomagnetic activity (GMA), on the dynamics of the number of cases of sudden cardiac death are presented. The medical data are for the big urban area of Baku for the period from 16.11.2002 to 31.12.2018. The preliminary results showed that this type of fatal cardiovascular accident prevails in the days of very low GMA and calm GMA. The deepening of the analyses, considering the gender factor, also reveals an increase in this type lethal cardio-vascular incidence from one to three days after the registered major and severe geomagnetic storms, and for males a higher percentage of increase is observed.*

ГЕОМАГНИТНИ ВАРИАЦИИ И ДИНАМИКА НА СЛУЧАИТЕ НА ВНЕЗАПНА СЪРДЕЧНА СМЪРТ

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Резюме: *Представени са резултати от продължаващите съвместни изследвания на промените в космическото време, оценявани чрез индекси на геомагнитната активност (ГМА), върху динамиката на броя случаи на внезапна сърдечна смърт. Медицинските данни са за областта на гр. Баку за периода от 16.11.2002 г. до 31.12.2018 г. Предварителните резултати показаха, че този тип фатални сърдечно-съдови инциденти преобладават в дните на много ниска ГМА и спокойна ГМА.Задълбочаването на анализите разкриват нарастване на разглежданите летални инциденти и от един до три дни след регистрираните силни и много силни геомагнитни бури, като за мъжете се наблюдава по-голям процент на нарастване.*

Introduction

A number of researchers have studied how variations on the Sun, solar wind and cosmic ray intensity can influence the terrestrial magnetosphere and how they can affect the human cardiovascular health state. Reviews covering studies performed during the last several decades on the effects of solar activity (SA) and geomagnetic activity (GMA) on human cardiovascular health can be found in [1–4]. Consistent with these effects, the study of potential influence of SA and GMA on the number of sudden cardiac death incidences is of scientific interest.

Sudden cardiac death (SCD) is the largest cause of natural death and responsible for almost half of all heart disease deaths [5–6]. It is described as death of cardiac origin occurring in one hour time limit, without prodromes (preliminary symptoms) [7–8]. It 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. The incidence of SCD increases with age in both men and women [9–10].

In this study we investigated the potential effects of GMA variations of solar origin, estimated by geomagnetic indices, on SCD incidences, analyzing a period of 4670 days regarding medical data taken from middle-latitude geographical location. Data was analyzed taking into account gender factor.

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 ($40^0$23' N, $49^0$51' E), including Baku capital city of Azerbaijan with more than 3 million inhabitants) as well as in the Central Emergency and First Medical Aid Station in Baku.

All 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 analysed. 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 some gaps covering the following periods: 24.12.2008–01.01.2009; 01.01.2010–01.12.2012 and 01.11.2017–25.03.2018. In total, 5490 SCD cases were analyzed for 4670 days. The whole considered period corresponds to the period of socio-economic stability and rapid development in Azerbaijan.

Planetary *Ap*-index and daily disturbance storm time *Dst*-index were used to evaluate different effects of GMA. Data was 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 of the geomagnetic indices into six intervals to represent the level of GMA depending on the geomagnetic field variations (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

Analysis of variance (ANOVA) was applied to check the significance of geomagnetic field intensity changes' effect on SCD dynamics. ANOVA, as a collection of statistical models and their associated estimation procedures (such as the "variation" among and between groups), used to analyse the differences among group means in a sample.

Factorial ANOVA (2-way) was applied to study gender effects.

Superposed epoch method was used to estimate SCD dynamics up to 3 days before ("-") and 3 days after ("+") changes of geomagnetic conditions.

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.

As it was shown in our preliminary studies [11], analyses revealed statistically significant effect (probability $p<0.05$) of GMA variations estimated by 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 considering 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 and Dst-index values, and lowest on the days of highest GMA (severe storms) [11].

Results from 2-way ANOVA revealed that males in general are more predisposed to SCD. However, both genders have similar trends in SCD dynamics on the days of sharp GMA intensity variations. For both males and females SCD incidences decrease on the days of GMA increment irrespectively of GMA index: Ap-index (Fig. 1) or Dst-index (Fig.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

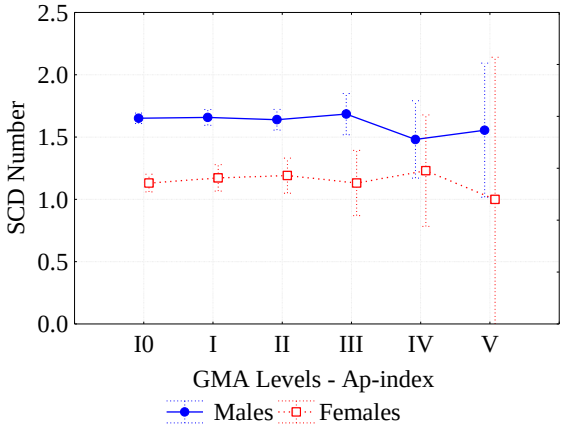

Fig. 1. GMA effect, estimated by Ap-index, on SCD number regarding gender (±95% CI)

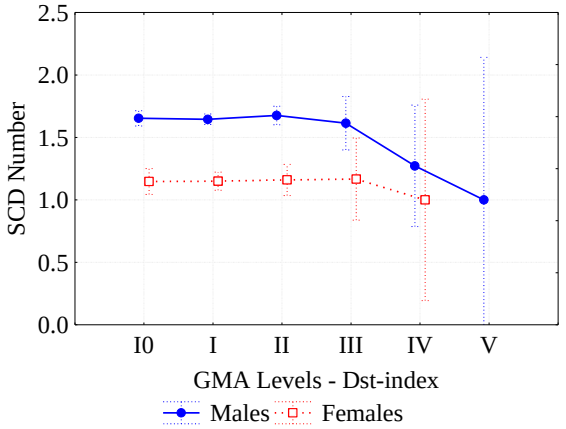

Fig. 2. GMA effect, estimated by Dst-index, on SCD number regarding gender (±95% CI)

Superposed epoch method was used and 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 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 levels. One can see on the Fig. 3 that despite the increase of fatal incidences on the days of major (IV GMA level) and severe (V GMA level) 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).

Further analyses were performed to study reactions of both genders to geomagnetic storms on days preceding and following different levels of GMA variations.

Fig. 5. and Fig. 6 show the dynamics in SCD incidence for males on days before, during and after GMA variations considering respectively Ap- and Dst-index. Results revealed 30% increase in incidences of SCDs in males on second day after severe geomagnetic storms, estimated by Ap-index (Fig. 5). With regard to the Dst-index, an increase in the number of SCD cases was found on the second day after the registered major geomagnetic storms by 47% and by 90% on the second day after the registered severe storms.

The dynamics of SCD incidences in females on days around geomagnetic storms is shown in Fig. 7 (taking into account Ap-index) and Fig. 8 (considering Dst-index). The results showed an increase in the number of incidences in women by 18% on the second day after major storms and by 38% on the third day after severe storms, assessed by Ap-index. Regarding the Dst-index, there was an increase in the cases on the first and third day after major storms by 20% and 40%, respectively.

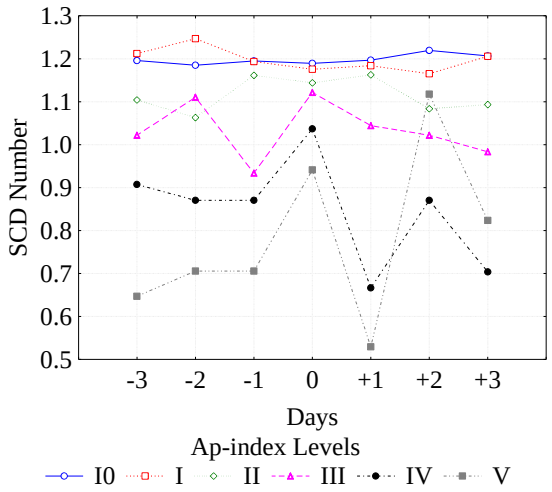

Fig. 3. GMA effect, estimated by Ap-index, on SCD number before, during and after geomagnetic storms

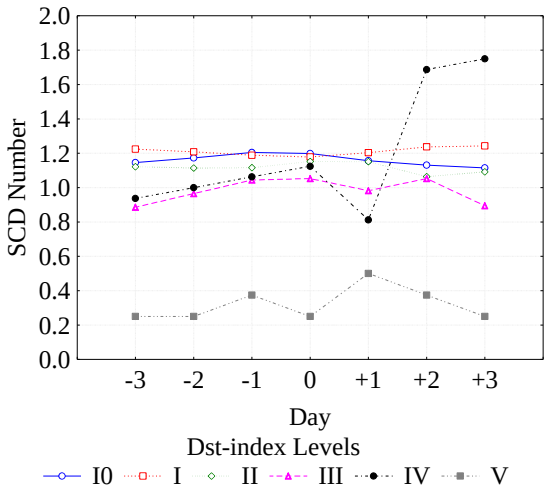

Fig. 4. GMA effect, estimated by Dst-index, on SCD number before, during and after geomagnetic storms

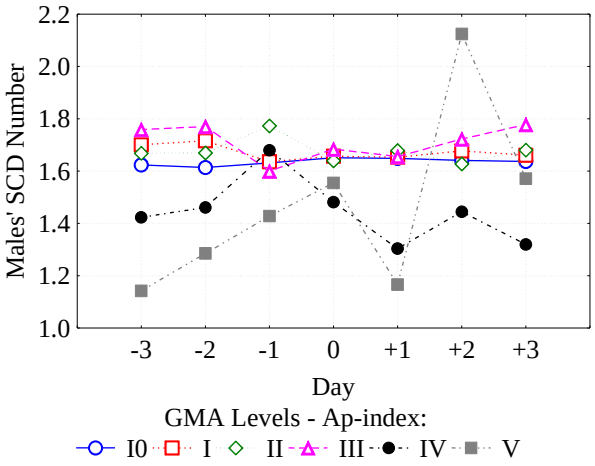

Fig. 5. GMA effect, estimated by Ap-index, on SCD number in males before, during and after geomagnetic storms

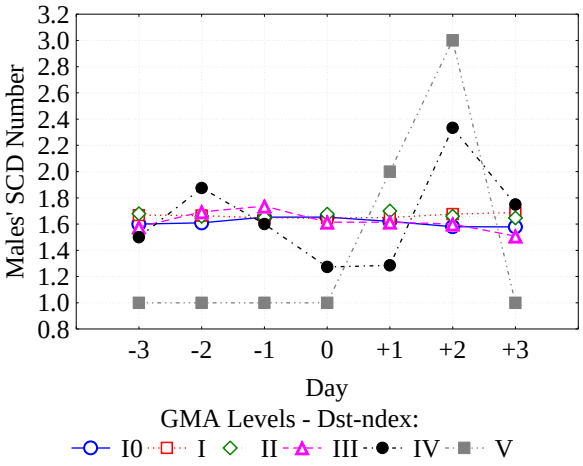

Fig. 6. GMA effect, estimated by Dst-index, on SCD number in males before, during and after geomagnetic storms

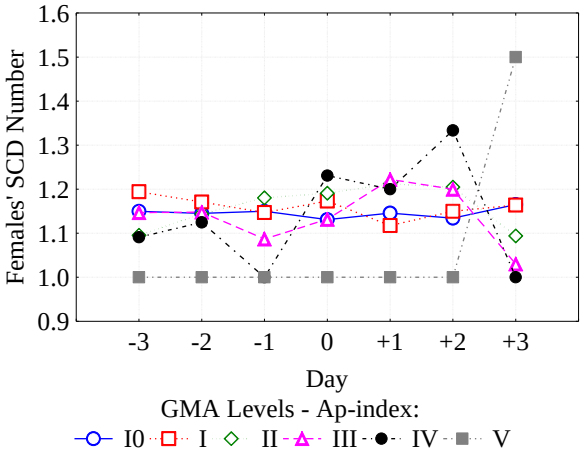

Fig. 7. GMA effect, estimated by Ap-index, on SCD number in females before, during and after geomagnetic storms

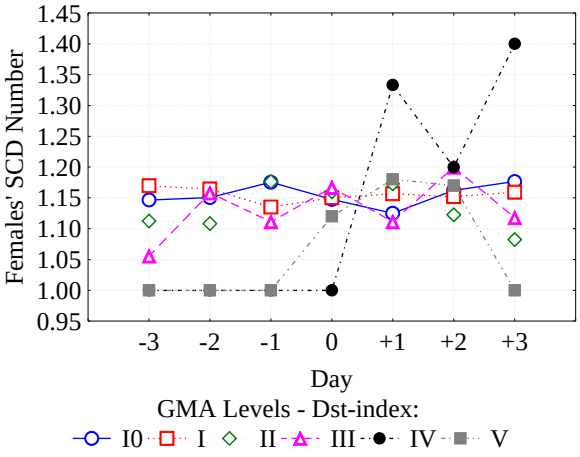

Fig. 8. GMA effect, estimated by Dst-index, on SCD number in females before, during and after geomagnetic storms

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. Our preliminary results revealed that the most threatening conditions for that kind fatal cardiac incidence were the periods of very low GMA and quiet GMA. Similar results were obtained by other studies as well [12–14].

More detailed analyses revealed that males in general are more susceptible to SCD incidence, more specifically on the days after intense geomagnetic storms. It turned out that on the days after major and severe geomagnetic storms SCD number also increased significantly both for males and females, however it was displayed by different days for men and women and total result for the whole group is not so apparent. It might be due also to the small volume of data for such geophysical events. Obviously, further studies should be performed for proving these results.

Most sudden cardiac deaths are caused by abnormal heart rhythms called arrhythmias. The most common life-threatening arrhythmia is ventricular fibrillation. The development of the implantable cardioverter defibrillator (ICD) introduced a new approach to the management and prevention of sudden death. Stoupel et al. [15] used the data provided by automatic ICD discharges regarding the onset of ventricular fibrillation and ventricular tachycardia 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.

Later, it was established in a large-scale cohort analysis performed by Ebrille et al. [16], that ICD therapies were delivered less frequently on days of high level GMA, confirming the previous pilot data and suggesting that high GMA level 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 system functioning 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. Long-period and detailed joint studies must be carried out for confirmation and clarifying the results obtained.

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