Possible Effects of Solar and Geomagnetic Activity on Sudden Cardiac Death in Middle Latitudes

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Abstract. In this paper results revealing potential effects of solar activity (SA) and geomagnetic activity (GMA) on the dynamics of sudden cardiac death (SCD) in 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 the time period 2003-2005. In total 788 SCD cases were analyzed. ANalysis Of VAriance (ANOVA) was applied to study the significance of GMA influence, estimated by different geomagnetic indices, and the type of geomagnetic storms (caused by the solar origin magnetic clouds (MC) and by high speed solar wind streams (HSSWS)) on SCD. Correlation analysis was carried out and relevant coefficients were calculated. Obtained results revealed strong negative correlation between monthly averaged GMA and SCD in Baku for the considered period. ANOVA revealed that SCD number was largest on the days of low GMA, on the days of highest geomagnetic field variations and even on +2nd day after them. It was established that SCDs increased on the days of storms caused by HSSWS and remained higher till +2nd day after they finished.

Keywords: solar activity, geomagnetic activity, sudden cardiac death, magnetic clouds, high speed solar wind streams

Introduction

"Space weather – human health" relations have global implications nevertheless the relevant researches are also important for human beings living at any geomagnetic latitudes. Unfortunately, limited comparison of results of investigations on possible effects on humans from solar activity (SA) and geomagnetic activity (GMA) exists between studies conducted in high, middle and low latitudes. Knowledge about the relationship between SA and GMA and human health would allow to get better prepared beforehand for any future space weather event and its impacts anywhere. These measures will be successful only if we better understand the basic processes of space weather impacts on the Earth and humans. There are signs that abrupt changes in heliogeophysical situation could be a destructive factor in respect to vital activity of the biological systems including human beings, particularly, their cardio-health state. The individual state is very important to physiological stability of the organism. When it is disturbed, as A.L. Tchizhevsky said, "even not a big impulse can provoke a gradual or an instant increase of the instability and organism could die. Such an impulse could be sharp changes in meteorological and geophysical factors" [1].

Sudden cardiac death (SCD) is described as death of cardiac origin occurring in one hour time limit, without prodromes (preliminary symptoms) [2, 3]. The incidence of SCD increases with age in both men and women.

In this study we investigated the influence of geomagnetic field (GMF) intensity, estimated by different geomagnetic indices and the type of geomagnetic storms (those caused by magnetic clouds (MC) and high speed solar wind stream (HSSWS)) on SCD mortality on the basis of three years daily 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 21 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 millions of inhabitants) as well as in the central emergency and first medical aid station in Baku.

TABLE 1

Gradation of GMA levels

GMA indices	I quiet GMA	II weak storm	III moderate storm	IV major storm	V severe storm
Dst, nT	Dst>-20	-50<Dst≤ -20	-100<Dst≤-50	-150<Dst≤-100	Dst≤-150
Ap	Ap < 15	15 ≤ Ap < 30	30 ≤ Ap < 50	50 ≤ Ap < 100	Ap ≥ 100
Am	Am < 15	15 ≤ Am < 30	30 ≤ Am < 50	50 ≤ Am < 100	Am ≥ 100

Results of monitoring carried out as joint work in the Baku city railway polyclinic No2 and in the Research Institute for Cardiology under the Ministry of Public Health of the Republic of Azerbaijan were partially involved in these studies.

It is evident that database created by the help of above-mentioned sources can not be absolutely ideal and may contain some per cent of discrepancy which in turn is admissible for population-based statistical data. This, in our opinion, does not significantly affect the general picture of the considered problem. Besides, it must be taken into account that according to the domestic legislative rules almost all of deaths must be registered by EFMAS services which allows considering this data as comparatively reliable.

More than 1 000 000 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 (cardio-vascular related deaths) were analyzed. EFMAS services register all cases of sudden deaths accurately, including the un-witnessed ones. It is very difficult and sometimes impossible work. Even classifications based on clinical circumstances can be misleading and often impossible, because 40% of sudden deaths can be un-witnessed [2]. We relied on the final diagnosis established by EFMAS services using relevant medical and other methods.

Time span covered by the data was chosen from January 2003 to December 2005 (continuous data). This period corresponds to the period of socio-economical stability in Azerbaijan.

SCD data was separated from the initial data on cardiovascular-related deaths in accordance to the International Classification of Diseases and Related Health Problems, 10-th revision (ICD-10, 2006), Code I46.1 (http://www3.who.int/icd/currentversion/fr-icd.htm). Deaths due to diagnosis acute myocardial infarction (AMI) are not considered in this paper.

GMA indices were handled from:

- World Data Center for Geomagnetism, Kyoto (daily *Dst*-index);
- Space Weather Prediction Center at the National Oceanic Atmospheric Administration - NOAA, Boulder (planetary Ap-index and the index Am derived for the middle latitudes).

For this considered task, GMA was divided into five levels (see: Table 1).

"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 GMF intensity and the type of geomagnetic storms (MC- and HSSWS-caused storms) effect on SCD mortality;
- The effect of geomagnetic storms before and after their development on SCD dynamics was also investigated by ANOVA. GMA impact up to 3 days before and 3 days after sharp changes in geomagnetic conditions was studied;
- Relevant correlation coefficients were calculated;
- The chosen level for statistical significance was $p \leq 0.5$.
- Statistical package STATISTICA (StatSoft Inc., version 6, 2001) was used for data visualization and statistical analyses.

Results

The number of days with different GMA levels according to Ap, Am and Dst-index values and different types of geomagnetic storms (MC- or HSSWS-caused storms) and the respective SCD cases for the period under consideration are shown in Tables 2 and 3.

TABLE 2

Number of days for the different GMA levels and SCD

Parameters / GMA Levels	Ap		Am		Dst	
	Days	SCD	Days	SCD	Days	SCD
I quiet GMA	678	513	847	619	607	429
II weak storm	301	181	212	135	418	308
III moderate storm	89	69	26	24	59	45
IV major storm	17	16	6	5	8	4
V severe storm	11	9	5	5	4	2

TABLE 3

Number of days for types of storms (TS) and SCD

GMA-levels	Days	SCD
Quiet GMA	951	689
HSSWS-caused storm	95	72
MC-caused storm	50	27

Fig. 1 shows geomagnetic indices dynamic (Dst, Am and Ap) and distribution of SCD for the averaged monthly data.

Negative statistically significant correlation coefficients between the averaged monthly GMA indices (Am, Km-sum, Ap and Kp-sum) and averaged monthly SCD number were established (Table 4). Km-sum and Kp-sum indices are the sums of the eight 3-hourly Km and Kp values per a day.

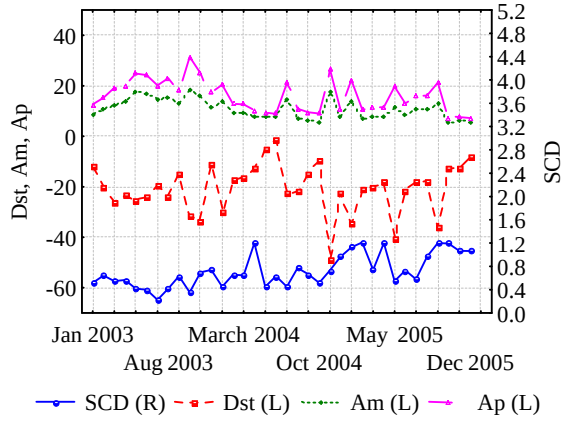

Fig. 1. Monthly averaged geomagnetic indices (Dst, Am and Ap) and monthly SCD number; (L) denotes Left axis while (R) – Right axis.

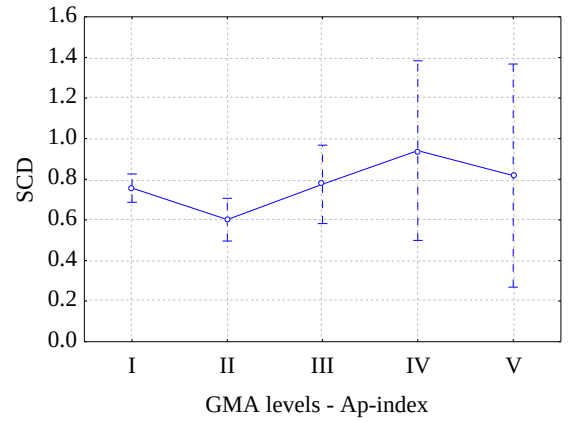

Fig. 2. GMA effect, estimated by Ap-index, on SCD number (±95% CI).

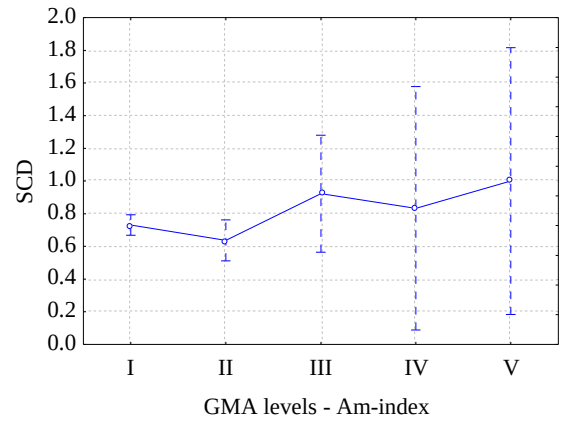

Fig. 3. GMA effect, estimated by Am-index, on SCD number (±95% CI).

TABLE 4

Significant correlation coefficients and their significance levels for monthly averaged data

GMA index	Correlation coefficient *r*	Significance level *p*
Am	-0.51	0.002
Km-sum	-0.57	0.000
Ap	-0.46	0.005
Kp-sum	-0.63	0

TABLE 5

Significance levels (p-values) of the effect for GMA (Am, Ap and Dst-indices) and type of storm (TS) on SCD number in Baku for the days before, during and after geomagnetic storms for the period 2003-2005

Day	*p*-values			
	Am	Ap	Dst	TS
-3	0.19	0.15	0.30	0.99
-2	0.29	0.07	0.28	0.58
-1	0.44	0.09	0.28	0.03*
0	0.47	0.12	0.90	0.36
+1	0.12	0.68	0.57	0.13
+2	0.02*	0.06	0.88	0.51
+3	0.16	0.12	0.88	0.36

** - statistically significant result*

Table 5 shows significance levels (*p*-values) obtained by ANOVAs applied to study GMA effect, estimated by geomagnetic indices under consideration (Am, Ap and Dst) and types of storms (TS) on SCD number for the days before ("-"), during ("0") and after ("+") geomagnetic storms. It reveals statistically significant effect of the type of storm on -1st day, significant effect of GMF intensity according to Am-index on +2nd day and a trend for influence ($p<0.1$) of GMF intensity according to Ap-index on -2nd, -1st and +2nd day.

ANOVA revealed a trend in SCD mortality to increase at major storms and decrease at weak storms according to Ap-index values (Fig. 2). The number of SCD cases did not differ significantly on the days of lowest and highest GMA levels (quiet GMA and severe storms) as well as on the days of moderate storms (Fig. 2). Vertical bars in the figure denote 0.95 confidence intervals (CI). The increment at GMA IV level in comparison with GMA II level was 57%.

According to Am-index SCD dynamics is very similar – SCD number was largest on the days of highest GMA and relatively high on the days of low GMA (Fig. 3).

Surprisingly, GMA effect, estimated by Dst-index, showed that SCD number decreased during major and severe storms (Fig. 4). It can be due to the small number of days: 8 days with major storms and 4 days with severe storms regarding Dst-index in total for 2003-2005 (Table 2) but it could also due to different biophysical mechanisms "activated" by different levels of GMA (there appeared papers stating about

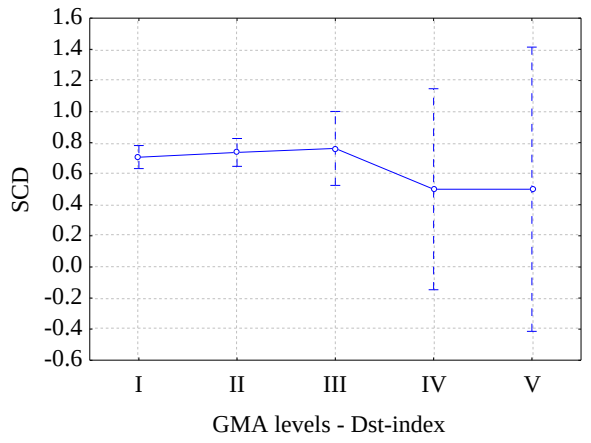

Fig. 4. GMA effect, estimated by Dst-index, on SCD number (±95% CI).

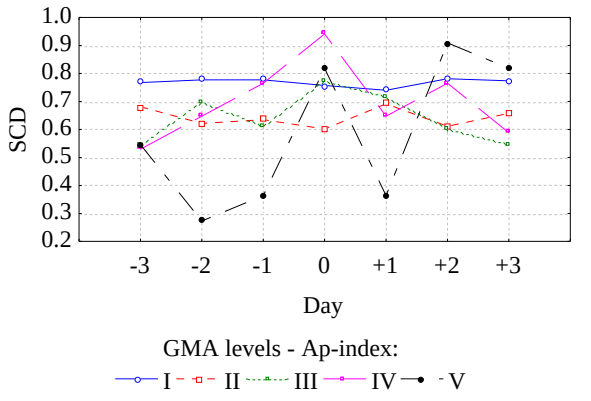

Fig. 5. GMA effect, estimated by Ap-index on SCD number before, during and after geomagnetic storms; "I - V" denote different levels of GMA (Table 1).

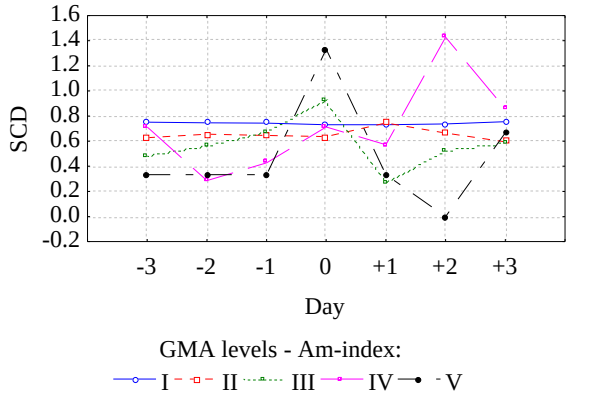

Fig. 6. GMA effect, estimated by Am-index on SCD number before, during and after geomagnetic storms; "I - V" denote different levels of GMA (Table 1).

significant influence of weak geomagnetic fields) or because of impulsive (described by Dst) and background (described by Ap) character of GMA indices impact. For establishing this fact there is a need of detailed and long-period investigations.

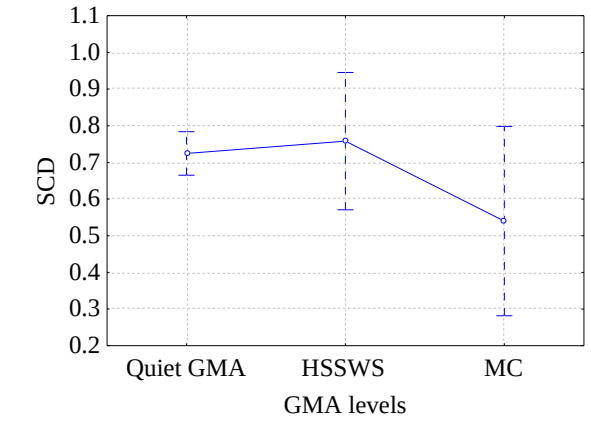

Fig. 7. GMA effect, estimated by the types of geomagnetic storms (Table 3), on SCD number (±95% CI).

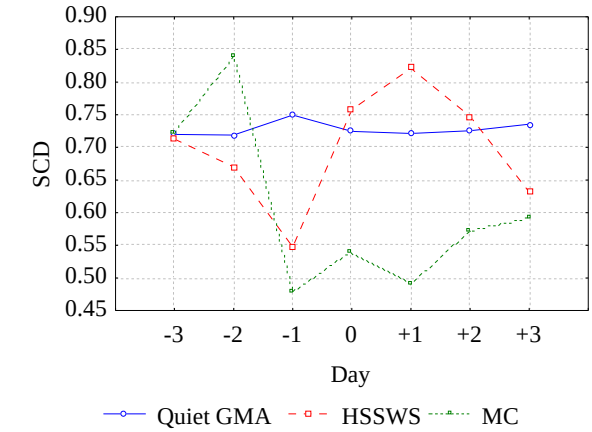

Fig. 8. GMA effect, estimated by the types of geomagnetic storms (Table 3), on SCD number before, during and after geomagnetic storms.

Fig. 5 shows SCD number for the different GMA levels according to Ap-index from -3rd to +3rd day. The largest SCD cases were on the days of quiet GMA, on the days of moderate, major and severe storms development, on +2nd and +3rd day after severe storms and on -1st and +2nd day of major storms.

SCD dynamics under changes of GMA, estimated by Am-index is very similar (Fig. 6). It was observed again that SCD number was high on the days of quiet GMA and on the days of development of the storms with different GMF intensity as well as there was statistically significant increment on +2nd day of major storms (Table 5).

It was established that SCD number decreased by 34%, although the result was not statistically significant, during geomagnetic storms caused by MC and increased by 5% during storms caused by HSSWS in comparison with quiet GMA (Fig. 7).

Dynamics of SCD cases before, during and after the both considered types of storms is shown in Fig. 8. It showed that SCD number was largest from 0 to +2nd day of storms caused by HSSWS, on -2nd day of MC's storms and on the days with quiet GMA. SCD mortality decreased from -1st to +3rd day of storms caused by MC. Table 5 shows that SCD number decreased significantly on -1st day prior to both types of geomagnetic storms.

Discussions

The conducted investigations showed that SCD could be affected by GMF variations and studies in that direction should be continued.

It was obtained that both low and highest GMA are related to increase of that kind fatal cardiac incidences. Long-period and detailed studies must be carried out for confirmation and clarifying the results obtained. It seems that the both types of geomagnetic storms (MC- and HSSWS-caused) affect cardio-health state of humans by different ways. Different characters of GMA indices should be taken into consideration also. It is possible that some of the electromagnetic field changes, which accompany geomagnetic storms, have favorable and stimulating effects [4]. At the same time it should not be neglected the possible adverse effect of very low GMA on cardio-vascular diseases. [5-9] suggested that the role of environmental physical factors becoming more active in low GMA, like cosmic ray (neutron) activity, should be object of further studies.

A disadvantage of this study is that data cover short time period, which was only at the descending phase of 11-year SA cycle, but GMA was comparatively high. A team-work is to clarify the possible biophysical mechanisms through which different GMA indices and different GMA levels affect SCD.

Conclusions

In this paper results of collaborative studies on revealing possible effects of solar and geomagnetic activity on the dynamic of sudden cardiac death (SCD) in middle latitudes are described for the relative socio-economical stability in Azerbaijan and for the descending phase of the 11-year solar activity cycle (2003-2005). ANalysis Of VAriance (ANOVA) was applied to study the significance of the influence of geomagnetic activity, estimated by different geomagnetic indices, and the type of geomagnetic storms (caused by the solar origin magnetic clouds (MC) and by high speed solar wind streams (HSSWS)) on SCD. Results are outlined:

- This study revealed that geomagnetic field (GMF) variations can potentially affect SCD incidences;
- The results revealed strong negative correlation between monthly averaged GMA indices (Am, Km-sum, Ap and Kp-sum) and averaged monthly number of SCD or considered data;
- It was established that SCD number increased on the days of low GMA, on the days of development of geomagnetic storms with higher intensity and on +2nd day after them;
- SCD incidences increased on the days of storms caused by high-speed solar wind streams and immediately after them.

Acknowledgments

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