Cerebral Infarction Versus Solar and Geomagnetic Activity: A Cross-Regression Study

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Abstract

Background: In the course of occurrence of cerebral infarction, cerebral hemorrhage and subarachnoidal hemorrhage episodes, periodicities resembling those found in the solar and geomagnetic activity were observed by Kováč and Mikulecký in 2005.

Objectives: To investigate putative relationships between two indices of solar activity and one index of geomagnetic activity on one side and the occurrence of cerebral infarction on the other.

Methods: In addition to the 192 monthly cases out of 6100 new cases of cerebral infarction that occurred between January 1989 and December 2004, monthly averages for Wolf numbers, solar flares index and Ap index were included in the analysis. The cross-correlation between each cosmo-geophysical variable on the one hand and the number of new cases of the disease on the other was computed. The quadratic regression with the chosen time delay was also studied using, separately, the Wolf numbers, solar flares and Ap index as the explanatory variable and the number of cases of cerebral infarction as the responding variable.

Results: Significantly negative correlation coefficients between the monthly means of the Wolf numbers, of solar flares and of Ap index on the one hand and monthly numbers of new cases of the disease on the other were found for the delays between -6 and +17 months. The cross-regression results for the delay of +5 months (infarction delayed after each cosmo-geophysical variable by 5 months) displayed a linear decrease except for the Wolf numbers where the parabolic decrease of cases was significant.

Conclusions: An increased intensity of the studied cosmo-geophysical parameters appears to be significantly connected with decreased occurrence of cerebral infarctions, and vice versa. This effect seems to last up to 17 months. The results are supported by a few similar findings in the literature. Putative cosmo-biomedical connections warrant further study to verify them in larger samples and longer time scales. If confirmed, their mechanisms should be elucidated.

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The recent national survey of acute cerebrovascular disease in Israel [1] revealed the high burden of this disease and associated problems in current practice. This has led to the study of a broad range of possible environmental links in the hope of finding and developing better prevention measures against the disease. While it may seem rather unusual to suggest possible links between human pathology and events in the heavens – for example between cerebral accidents and solar or geomagnetic activity – as far back as 1934 a study reported the effects of sudden solar flares on health [2]. In recent years, this phenomenon has gained interest among a few groups in the United States [3,4], Japan [5], France [6] and particularly in Israel, partly using the Lithuanian data from the original study [7,8]. In the last year, other etiopathogenetic factors of ischemic cerebral stroke, such as cardiac arrhythmia [9], atherosclerotic plaques, blood coagulation, thrombosis, embolism, immunity and inflammation [10,11], have been added to this new field of research – the effect of cosmo-geophysical variables.

In the time course of occurrence of cerebral infarction, cerebral hemorrhage and subarachnoidal hemorrhage episodes, periodicities resembling those found in the solar and geomagnetic activity were observed [12]. The present study is extending this approach with the same 6100 patients by searching for putative relationships between two indices of solar activity and one index of geomagnetic activity on the one hand, and the occurrence of cerebral infarction on the other.

Patients and Methods

In addition to the 192 monthly number out of 6100 new cases of cerebral infarction that occurred between January 1989 and December 2004 [12], monthly averages for Wolf numbers, solar flares index [13] and Ap index [14] were included in the analysis.

The patients were hospitalized at the Neurologic Clinic of St. Ladislaus Faculty in Nové Zámky in southern Slovakia. This hospital serves a population of 180,000 in an area with a 70 km radius. The diagnosis was made with the aid of up-to-date imaging procedures, such as brain computed tomography, magnetic resonance imaging, CT and MRI angiography, as well as ultrasonography of extra- and intracranial arteries. In the majority of cases, thrombosis of extracranial arteries with possible embolization into intracranial arteries, or primary thrombosis of intracranial arteries was found.

The sample can be considered as representative of the whole population of Slovakia. The complete Slovakian data are officially available since 1994, showing an average of 11,500 new cases per

year, while in our sample there was an average of 380 new cases per year, i.e., 3.3% of the whole Slovakian incidence. This agrees roughly with the fact that 180,000 inhabitants of the source area represent 3.6% of the population of Slovakia – 5 million. The numbers of male and female cases were almost exactly the same. This means a somewhat lower incidence among females as there are slightly more females than men in Slovakia. The majority of cases occurred in people between the ages of 55 and 84.

The present sample displays some similarities with the data from Israel [1]: there were 47% of women in Israel versus 50% in Slovakia; 89% of the correctly diagnosed Israeli cases with acute cerebral disease had ischemic stroke while the remaining 11% had intracerebral hemorrhage; corresponding numbers in our sample are 93% and 7%. The data files can be obtained from either author by email. The cross "correlation" [15,16] between each cosmo-geophysical variable on one hand and the number of new cases of the disease on the other was computed. The procedure takes into account the successively increasing positive (disease later than cosmo-geophysical index) and negative (opposite) time shifts. The quadratic regression [17] with a typical time delay was calculated by using, separately, the Wolf numbers, solar flares and Ap index as the explanatory variable (on the horizontal axis) and the number of cases of cerebral infarction as responding variable (on the vertical axis). The level of the statistical significance was set at $\alpha = 0.05$, corresponding with the 95% (=100.[1-α]) confidence or tolerance probability.

Results

Significantly negative coefficients of correlation were found (with *P* values 0.05–0.002) between the monthly means of the Wolf numbers, solar flares and Ap index on one hand and monthly number of cerebral infarctions on the other, generally for the delays between -6 and +17 months.

The results are shown graphically for the cross-correlation with Wolf numbers in Figure 1. The numerical values of the point and 95% confidence estimates of the statistically significant correlation coefficients are shown with the corresponding time delays for solar flares and for Ap index in Table 1. The cross-regression for the delay of +5 months (the time of occurrence of infarction episodes was delayed after the time of each cosmo-geophysical

Table 1. Correlation between occurrence of cerebral infarction and solar flares or Ap index, calculated for separate mutual time lags

	Solar flares			Ap index		
Lag	r	r_{low}	r_{upp}	r	r_{low}	r_{upp}
-6	-0.33	-0.65	0.00			
-5	-0.38	-0,68	–0,08			
-4	-0.39	-0.70	-0.09			
-3	-0.39	-0.69	-0.08			
-2	-0.40	-0.71	-0.08			
-1	-0.44	-0.74	-0.14			
0	-0.44	-0.74	-0.13			
+1	-0.44	-0.74	-0.14	-0.29	-0.58	0.00
+2	-0.46	-0.76	-0.16	-0.34	-0.63	-0.05
+3	-0.48	-0.79	-0.17	-0.35	-0.62	-0.08
+4	-0.48	-0.78	-0.18	-0.36	-0.65	-0.08
+5	-0.49	-0.79	-0.18	-0.33	-0.63	-0.04
+6	-0.49	-0.80	-0.18	-0.31	-0.62	0.00
+7	-0.49	-0.81	-0.17			
+8	-0.47	-0.82	-0.11			
+9	-0.47	-0.80	-0.13			
+10	-0.45	-0.81	-0.10			
+11	-0.47	-0.82	-0.12			
+12	-0.47	-0.86	-0.09			
+13	-0.47	-0.85	-0.09			
+14	-0.45	-0.86	-0.04			
+15	-0.46	-0.86	-0.07			
+16	-0.44	-0.87	-0.02			
+17	-0.42	-0.85	0.00			

L = time delay (months) of infarction (positive) or of either geophysical variable (negative), r, r_{low}, r_{upp} = correlation coefficient with its lower and upper confidence limits

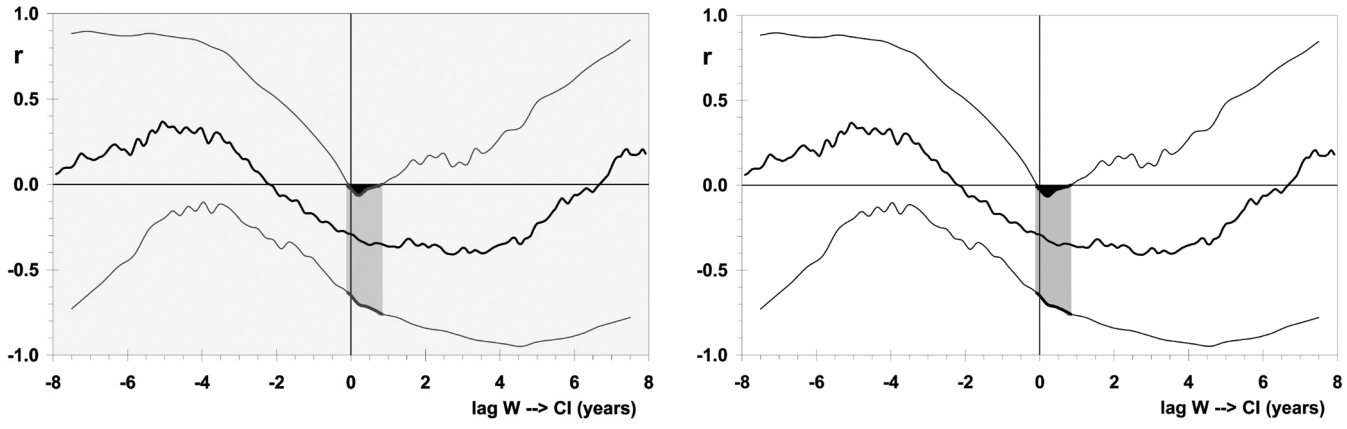

Figure 1. Cross-correlation coefficient r (the vertical axis) versus the lag (years, horizontal axis), i.e., a time delay of the frequency of cerebral infarction (CI) after Wolf numbers (W), representing a positive lag, and an opposite time delay representing a negative lag. The point estimate of r (the middle line) is accompanied by its 95% confidence corridor between the upper and lower line. The non-overlapping of this corridor by the horizontal axis indicates a significant correlation and is marked by shadowing, extending from the -1 month delay to the +11 months delay.

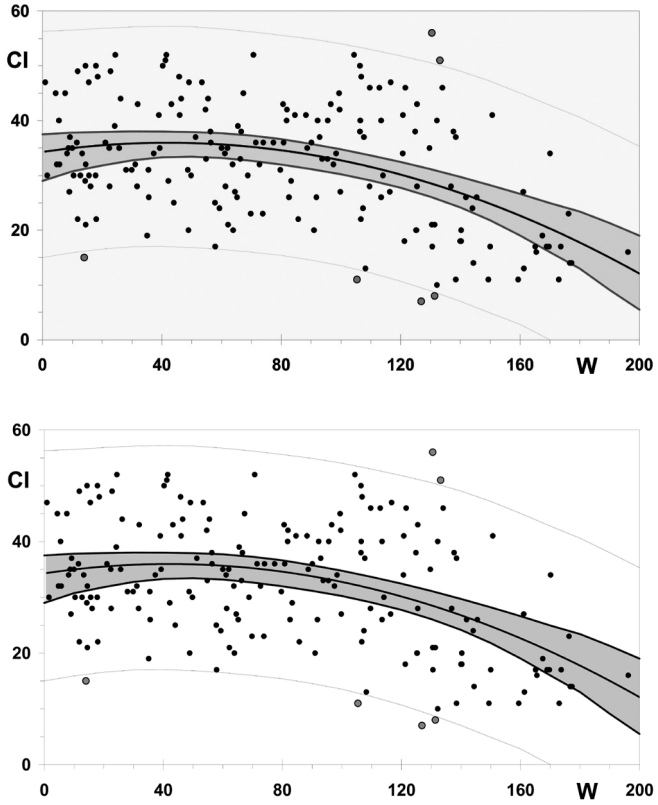

Figure 2. Significant parabolic regression of the frequency of cerebral infarction (vertical axis, number per month) versus the Wolf numbers (horizontal axis). The point estimate (middle parable) is accompanied by the 95% confidence (narrower, shadowed) and tolerance (wider) corridor. The heavy dots are the tolerance outliers.

Table 2. Numerical results of the regression of the number of cases of cerebral infarction versus the three geophysical variables

Coefficient	Wolf numbers	Solar flare index	Ap index
Linear	0.081	-1.133*	-1.056*
	(-0.022, +0.184)	(-1.838, -0.428)	(-1.880, -0.232)
Quadratic	-0.0010*	0.0085	0.0120
	(-0.0015, -0.0004)	(-0.0260, +0.0430	(-0.0084, +0.0323)

The values of coefficients are given as their means (with 95% confidence intervals).
* Significant

variable by 5 months) demonstrated a significant linear decrease except for the Wolf numbers where the parabolic decrease of cases was significant [Figure 2]. The regression coefficients of the corresponding approximating equations for each cosmo-geophysical variable are shown in Table 2.

Discussion

A marked increase in each of the studied cosmo-geophysical parameters appears to be significantly connected with a decrease in occurrence of cerebral infarctions, and vice versa. This effect seems to last for up to 17 months.

A similar relationship with the occurrence of cerebral infarction for all three cosmo-geophysical parameters is intriguing. The Wolf numbers and solar flares are strongly mutually correlated. A similarity of putative effects of either of them on human health is therefore not surprising. On the other hand, the correlation between solar and geomagnetic activity is a little poorer. Often the maximum in geomagnetic activity appears 1–2 years after the maximum of solar activity, as seen clearly from the data and mentioned already by Chapman and Bartels [18].

The reciprocal relationship between cosmo-geophysical activity and disease occurrence that we found, with the aid of cross-correlation, was obvious also from detailed inspection of the approximated chronogram of the occurrence of cerebral infarction in Nové Zámky in 1989–2004 [12] where the data were identical to those in the present study [Figure 1]. A significantly decreased morbidity (by shaded area), as compared to the general trend, was identified in the years 1989–1992 and 2002–2003, i.e., around the peaks of the solar activity in cycles 22 and 23, and significantly increased morbidity (by another shaded area) in the years 1996–1997, i.e., at the time of the solar minimum between cycles 22 and 23.

We found similar results in the literature. Thus, solar activity and deaths from stroke correlated mutually adversely [8]. A low daily flare index was connected with the occurrence of cerebral thrombo-embolisms [6]. Also, a negative correlation was found between geomagnetic activity and paroxysmal atrial fibrillation as well as stroke, the latter only in males aged 65 years and less [7].

For statistical analysis we used the inferential approach [19], connecting the predicted probabilities with the measured data, as shown in Figure 2: the confidence (for mean) and tolerance (for one case) prediction of expected monthly numbers of disease cases for a given Wolf number value is therefore possible. Thus, for example, we predict that the upper and lower confidence interval limits from the disease cases with a Wolf number of 10 will be decreased to 91% and 96% for a Wolf number of 100 and to 50% and 16% with a Wolf number of 200 [Figure 2]. This documents the direct usefulness of the inferential statistics in practice.

Conclusions

Putative cosmo-biomedical connections warrant further study to verify them in larger samples and a longer time frame. If confirmed, their mechanisms should be elucidated. They should then be applied in medical practice, e.g., for predicting the development of morbidity. In that case, it would be useful to attempt to predict the course of solar activity cycling [20].

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