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Influence of Meteorological Conditions on the Incidence of Chronic Subdural Haematoma, Subarachnoid and Intracerebral Haemorrhages – the "Bleeding Weather Hypothesis"

Elisabeth ILLY[1], Joachim GERSS[2], Bernhard R. FISCHER[1], Walter STUMMER[1], Benjamin BROKINKEL[1*], Markus HOLLING[1*]

[1]University Hospital Münster, Department of Neurosurgery, Albert-Schweitzer-Campus 1, Münster, Germany
[2]Institute of Biostatistics and Clinical Research, University of Münster, Schmeddingstraße 56, Münster, Germany

*Equally contributed authors.

Corresponding author: Markus HOLLING ✉ hollingm@ukmuenster.de

ABSTRACT

AIM: To elucidate possible causal relationships on climate change and intracranial haematomas.

MATERIAL and METHODS: In a retrospective study we examined all patients (N=1169) treated for subarachnoid haemorrhage (SAH; n=484), intracerebral haemorrhage (ICH; n=417) or chronic subdural haematoma (CSDH; n=268) in our department over a 7-year-period between 1st June 2005 until 31th May 2012. The date of admission was correlated with the corresponding meteorological parameters which included; mean daily temperature (°C), relative humidity (%), vapor pressure (hPa), barometric pressure (hPa), cloud amount (/8), and wind speed (m/s).

RESULTS: Incidence of SAH tended to increase in April, ICH in January and CSDH in July, respectively, but χ^2 test did not reveal any statistical significance in seasonality for the three bleeding pathologies. Comparing the arithmetic average of meteorological key parameters of uneventful and eventful days by using student's t-test within the three groups (SAH, ICH, CSDH) we could not demonstrate any statistical significance ($p>0.05$). For SAH, logistic regression analyses revealed an increased risk associated with a decrease of barometric pressure ($p=0.021$).

CONCLUSION: Although our data suggest seasonal variabilities of SAH, ICH and CSDH, the single weather parameters do not demonstrate causal relationships with the incidence of cerebrovascular events. However, incidence of SAH tended to increase with changes of barometric pressure which confirms previously published results and might indicate a possible underlying relationship.

KEYWORDS: Chronic subdural haematoma, Subarachnoid haemorrhage, Intracerebral haemorrhage, Weather, Season, Atmospheric pressure

INTRODUCTION

In daily neurosurgical practice, clustering of patients with cerebral haemorrhage around certain days or seasons leads to the impression that a specific weather condition could be correlated with an increased incidence of cerebrovascular events. Previous published research has demonstrated that in the northern and southern hemisphere, a possible causal relationship between climate conditions and the occurrence of subarachnoid or intracerebral haem-

Elisabeth ILLY : 0000-0002-6297-0307
Joachim GERSS : 0000-0003-3489-683X
Bernhard R. FISCHER : 0000-0002-9298-729X
Walter STUMMER : 0000-0002-3460-0640
Benjamin BROKINKEL : 0000-0003-3462-3479
Markus HOLLING : 0000-0002-2167-0789

orrhage exists, with however controversial results. Whereas, seasonal variation in the occurrence of SAH and ICH has been examined extensively, whereby the results are inconclusive (11,12,14,21,32). Several studies describe a peak incidence in spring and winter and a trough in summer for both SAH and ICH (1,2,8,9,11,13,16,22,31,34,35), in other investigations, no seasonal trend could be found. On the other hand, selected weather parameters such as air temperature (1,4,5,10,14,18,24,29,31), and atmospheric pressure (1,3,8,16,17,19,22,24,32,34) have been discussed as risk factors for the occurrence of bleeding events like SAH or ICH. Previous studies tried to prove weather as a possible influencing factor on cerebrovascular events like SAH or ICH with partially inconclusive results (1-3,5,7,10,14,16,19,22,25,27,32). In contrast corresponding research on chronic subdural haematoma's is still lacking. Although CSDH are usually driven by minor trauma's, decompensation might have been associated with weather parameters. The aim of our study was to detect a probable correlation for the three bleeding entities in a large patient collective over a long study period retrospectively.

MATERIAL and METHODS

Study Area

Münster is located in ***North Rhine - Westphalia,*** in a warm temperate rain zone and with cool summer and mild winter due to predominantly maritime influence. The region can be influenced by continental climate with prolonged phases of higher air pressure causing higher temperature's in the summer and dry warm weather whereas in winter, continental climate leads to cold spells.

Data Collection

In a retrospective study from the 1st June 2005 until the 31th May 2012 we collected the following patient data; date of admission, gender, and age of all patients treated for subarachnoid (SAH), intracerebral haemorrhage (ICH) or chronic subdural haematoma (CSDH) in the Department of Neurosurgery of the ***University Hospital Münster***. Weather conditions being available for each day over the whole period were obtained from the meteorological office of the German Weather Service (Deutscher Wetterdienst (DWD)) situated at the International Airport of ***Münster/Osnabrück***. Weather parameters included mean daily temperature (°C), minimal and maximal daily temperature (°C), relative humidity (%), vapor pressure (hPa), barometric pressure (hPa), cloud amount (/8) and wind speed (m/s). Furthermore, for these values the daily changes as well as the difference between minimal and maximal daily temperatures were calculated. Ethical committee approval or patient consent for an anonymized retrospective analysis is not compulsary at our institution.

Statistical Methods

To analyze the seasonal distribution of the incidence of SAH, ICH and CSDH we defined 4 seasons based on meteorological reports: spring (March to May), summer (June to August), autumn (September to November) and winter (December to February). The monthly and seasonal variation were analyzed by χ^2-test.

To detect differences in weather parameters on eventful and uneventful days for the three different bleeding entities we compared the mean values of mean daily temperature (°C), relative humidity (%), vapor pressure (hPa), barometric pressure (hPa), cloud amount (/8) and wind speed (m/s) of days with or without inpatient admission by student's t-test.

Additionally, in a multivariate analysis, a logistic regression model was carried out for each bleeding subtype to determine if there were independent predictors among the meteorological parameters for the occurrence of SAH, ICH and CSDH.

Statistical significance was defined as $p<0.05$. Data analyses was carried out by SPSS PASW Version 18.0.0 for Windows.

RESULTS

Patients' Characteristics

During the study period from the 1st June 2005 to the 31h May 2012, a total of 1169 patients were treated in our department for one of the three bleeding entities, among them 623 males (53.3%) and 546 females (46.7%). SAH occurred in 484 patients (211 males [43.6%], 273 females [53.4%]), ICH in 417 patients (227 males [54.4%], 190 females [45.6%]) and CSDH in 268 patients (185 males [69.0%], 83 females [31.0%]) (Table I). Median age was 55 years for SAH, 66 years for ICH and 74 years for CSDH.

Weather Parameters

In total, data for 2556 days were registered, which included 1601 uneventful and 955 eventful days. Tables II, III and IV show the mean value and the standard deviation of each weather parameter for eventful days concerning SAH, ICH or CSDH cases, and uneventful days. t-test has been carried out for these values to find out differences in eventful and uneventful days, but no significant result for any weather parameter which would establish a potential relationship was obtained.

Seasonal Distribution

Figure 1 shows the distribution for each of the three bleeding entities over time. The incidence of SAH was highest in April (n=49, 10.1 % of all SAH cases) and tended to peak in winter with a trough in summer. The occurrence of ICH was highest in January (n=44, 10.6 % of all ICH cases) with a trough in summer. Moreover, the highest incidence of CSDH occurred in July (n=31, 11.6 % of all CSDH cases) with its lowest

Table I: Number of Patients with SAH, ICH and CSH and Sex Distribution

		Gender		Total
		male	female	
Diagnosis	SAH	211	273	484
	ICH	227	190	417
	CSDH	185	83	268
Total		623	546	1169

Table II: Mean and Standard Deviation for Weather Parameters on Eventful and Uneventful Days for SAH

	SAH				
	No event		Admission		t-test
	Mean	Standard Deviation	Mean	Standard Deviation	p
Cloud amount	5.4	1.9	5.3	2.0	0.194
Relative humidity (%)	78	12	78	12	0.496
Vapor pressure (hPa)	10.3	3.9	10.1	3.9	0.320
Air temperature (°C)	10.4	7.0	10.1	7.1	0.448
Air pressure (hPa)	1009.2	9.5	1009.2	9.7	0.886
Wind speed (m/s)	3.2	1.5	3.2	1.5	0.540
Minimal ground temperature (°C)	3.9	6.6	3.5	6.7	0.179
Minimal temperature (°C)	6.1	6.4	5.7	6.5	0.265
Maximal temperature (°C)	14.6	8.3	14.4	8.4	0.631
Wind peak value (m/s)	9.7	3.8	9.9	3.6	0.523
Change in cloud amount	.00	1.81	-.01	1.76	0.903
Change in relative humidity (%)	-.08	8.52	.27	7.56	0.393
Change in vapor pressure (hPa)	-.02	1.69	.04	1.47	0.477
Change in air temperature (°C)	.00	2.23	-.01	1.89	0.919
Change in air pressure (hPa)	.10	5.67	-.35	5.55	0.134
Change in wind speed (m/s)	1.39	37.81	.14	1.22	0.487
Difference between minimal and maximal air temperature (°C)	8.50	3.99	8.66	4.13	0.431

Table III: Mean and Standard Deviation for Weather Parameters on Eventful and Uneventful Days for ICH

	ICH				
	No Event		Admission		t-test
	Mean	Standard Deviation	Mean	Standard Deviation	p
Cloud amount	5.4	2.0	5.4	2.0	0.912
Relative humidity (%)	78	12	79	13	0.969
Vapor pressure (hPa)	10.2	3.9	10.3	3.9	0.793
Air temperature (°C)	10.4	7.1	10.3	7.0	0.933
Air pressure (hPa)	1009.1	9.6	1010.1	9.1	0.086
Wind speed (m/s)	3.2	1.5	3.1	1.5	0.527
Minimal ground temperature (°C)	3.8	6.6	3.9	6.6	0.923
Minimal temperature (°C)	6.0	6.4	6.0	6.3	0.919
Maximal temperature (°C)	14.6	8.3	14.4	8.1	0.934
Wind peak value (m/s)	9.8	3.8	9.5	3.9	0.258

Table III: Cont.

	ICH				
	No Event		Admission		t-test
	Mean	Standard Deviation	Mean	Standard Deviation	p
Change in cloud amount	-.01	1.80	.05	1.78	0.336
Change in relative humidity (%)	-.06	8.36	.29	8.38	0.413
Change in vapor pressure (hPa)	-.03	1.65	.11	1.62	0.060
Change in air temperature (°C)	-.01	2.18	.08	2.08	0.395
Change in air pressure (hPa)	-.03	5.69	.40	5.37	0.459
Change in wind speed (m/s)	.90	29.93	3.11	56.79	0.389
Difference between minimal and maximal air temperature (°C)	8.54	4.02	8.40	3.98	0.995

Table IV: Mean and Standard Deviation for Weather Parameters on Eventful and Uneventful Days for CSDH

	CSDH				
	No Event		Admission		t-test
	Mean	Standard Deviation	Mean	Standard Deviation	p
Cloud amount	5.4	2,0	5.3	2.0	0.232
Relative humidity (%)	78	12	80	12	0.435
Vapor pressure (hPa)	10.2	3,8	10.3	4.3	0.938
Air temperature (°C)	10.4	7,0	9.9	7.3	0.409
Air pressure (hPa)	1009.2	9,6	1009.2	8.9	0.885
Wind speed (m/s)	3.2	1,5	3.3	1.6	0.947
Minimal ground temperature (°C)	3.9	6,6	3.6	7.4	0.455
Minimal temperature (°C)	6.1	6,4	5.8	6.9	0.353
Maximal temperature (°C)	14.6	8,3	14.2	8.4	0.672
Wind peak value (m/s)	9.8	3,8	9.8	3.6	0.841
Change in cloud amount	-.01	1,80	.08	1.77	0.804
Change in relative humidity (%)	-.01	8,37	-.05	8.24	0.657
Change in vapor pressure (hPa)	-.02	1,64	.07	1.74	0.578
Change in air temperature (°C)	-.01	2.17	.09	2.13	0.400
Change in air pressure (hPa)	-.01	5.65	.38	5.69	0.521
Change in wind speed (m/s)	1.27	35.76	.04	1.45	0.581
Difference between minimal and maximal air temperature (°C)	8.54	4.02	8.39	3.97	0.542

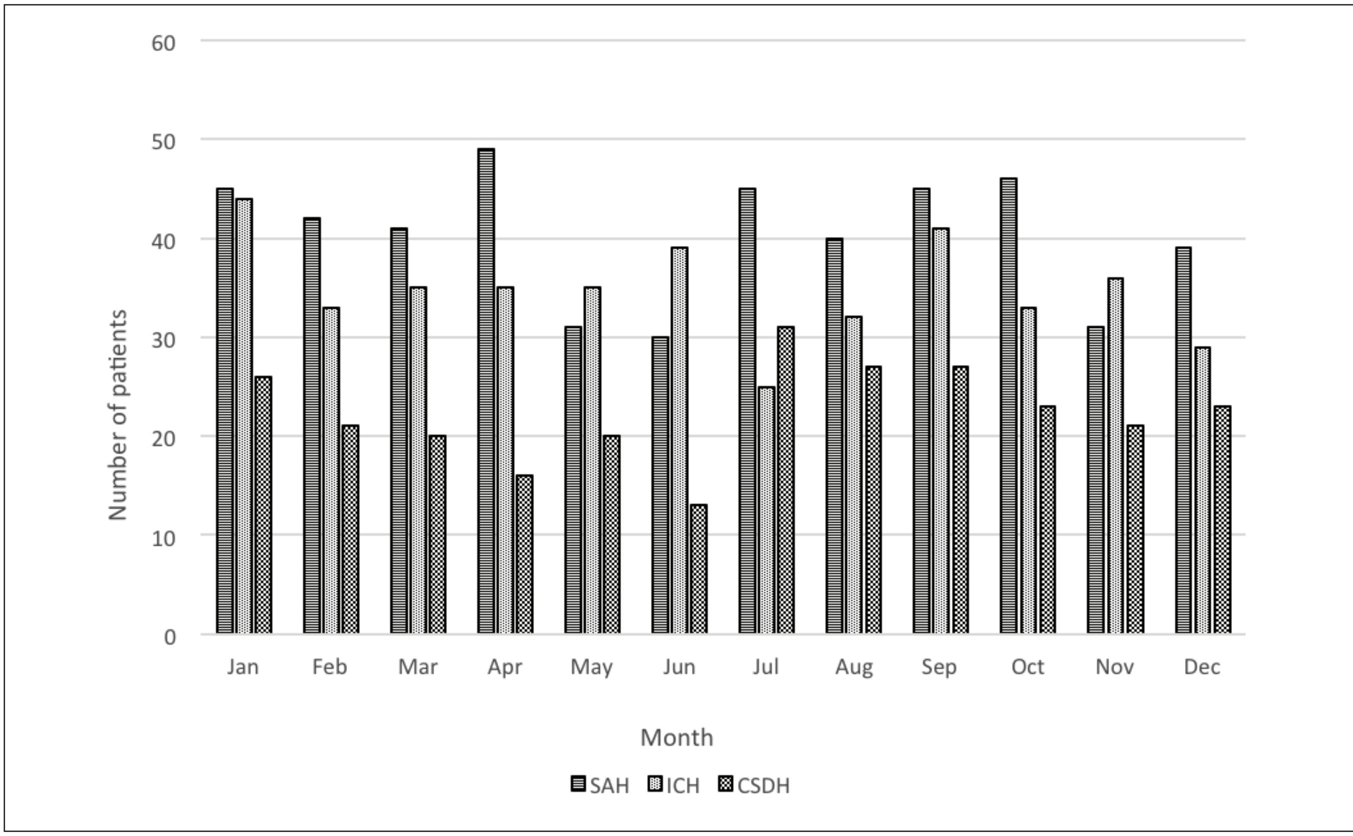

Figure 1: Number of patients with SAH, ICH and CSDH per month.

incidence in spring, but all these findings where without statistical significance when performing χ^2-test.

Logistic Regression

In a multinomial regression model, a decrease of barometric pressure correlated with an increased occurrence of SAH independent from all the other meteorological variables (p=0.021). For ICH and CSDH, multinomial regression analyses could not identify any of the metrological parameters as an independent predictor for their incidence.

DISCUSSION

Although our data suggests a variation in seasonal distribution, we could not statistically prove this from our study group. The incidence of SAH tended to peak in April and showed an additional peak in winter and a trough in summer, which corresponds partially to the results of previous studies. Although some previous published reports did not observe any statistical significance in seasonal distribution of SAH (7,15,27,31), the majority of published articles on this area do agree about the diversity in seasonal distribution, admittedly with inconsistent observations. For instance, studies in the United States, Japan, China and Australia showed a peak in winter (1,13,16,28,36), in winter and spring (9), or in winter and autumn (10). Other studies in Japan, Germany, Denmark, England and Switzerland found an increased incidence in spring (2,14), or respectively in spring and autumn (12,21,26,30,32). Hence results concerning the seasonality of peak incidence of SAH vary markedly, although there is a consensus about a trough in incidence in summer (8,12-14,16,21,25,36). Moreover, gender-based differences can be found in some studies: a study in the United States found an increased incidence of SAH in late fall for men and in late spring for women (6), another study in Japan found a peak in spring in men and in winter in women (33).

It is important to bear in mind that all these results related to seasonal peaks suffer from a lack of comparability, as the characteristic meteorological conditions for each season clearly differ in the various study countries all over the globe. For example, in northern latitudes distinct seasons prevail whereas near to the equator weather underlies less seasonal fluctuations.

However, the results of studies in Central Europe with a continental temperate climate are reasonably comparable. It is particularly interesting that a study from Düsseldorf in Germany, which is located in a comparable geographical region to ***Münster*** and is climatically quite similar, arrived at almost the same findings. Here, the highest incidence for SAH was found in spring (for the month of April), and none of the meteorological parameters could be identified as an influencing factor (2).

In our study, there were indications that a decrease in atmospheric pressure was associated with increased incidence of SAH, but no relevant difference in weather parameters between eventful and uneventful days was found. Other papers have also came to the result that atmospheric pressure could influence the occurrence of SAH, for example, a study in Frankfurt am Main in Germany pointed out that a change in air pressure of more than 10 hPa is an independent predictor for clustering of patients with SAH (32). A study in South Africa came to the same conclusion (22). The underlying mechanism might be elevated blood pressure due to altered atmospheric pressure. On one hand, the majority of vascular events lead to an initially elevated blood pressure so relationship between causation and outcome remains complicated. On the other hand, Kaminski et al. (20) demonstrated an inverse relationship between atmospheric pressure and blood pressure, which supports our findings.

Furthermore, the results from Jehle et al. (16), and Law et al. (23) also indicate a correlation between changes in air pressure and the occurrence of SAH, as they observed a higher incidence of SAH on days with changes in air pressure ("change days") (16), or respectively mean daily atmospheric pressure change was significantly higher on days with SAH than on uneventful days (23). The influence of changes in air pressure could be a reason for the increased occurrence of SAH in the spring, as spring months are known to be especially associated with frequent weather changes caused inter alia by changing air pressure levels.

Concerning ICH, our results are also similar to previous studies. In our survey, the highest incidence of ICH was found in January with a trough in summer, but these findings were without statistical significance. Numerous studies on the northern and southern hemisphere also found an increased incidence of ICH in winter (11,14,15,28,35,36), in winter and spring (34) or in winter and autumn (19). Similarly to SAH, many investigations agree about a trough in the occurrence of ICH in summer (15,25,34-36). Whereas in our study none of the weather parameters could be identified as a risk factor for the incidence of ICH. Air temperature as a possible influence on the incidence of ICH was demonstrated in numerous other studies (4,5,14,18,25,29,31), particularly low temperatures (29,31) or a decrease in temperature (29) correlated with an increased incidence in ICH. This, in turn, could explain the suspected seasonal distribution of ICH with a peak in winter with low air temperature and a trough in summer with mild climate conditions.

At present, corresponding studies for CSDH are still lacking thus we have no data to compare to. In our survey, the highest incidence of CSDH was found in July with a trough in the winter. It remains to be determined whether the increased incidence of CSDH in the summer months could result from a higher number of minor traumas to the head caused by augmentation of sports and leisure accidents during good weather conditions. A limitation in our study is the fact that between the initial trauma and the hospital admission patients exhibit a symptom-free interval, so that a correlation between admission day and weather data is somewhat difficult. Finally, CSDH related symptoms occur at a specific point which then leads to hospitalization and could possibly be influenced by different factors as well as certain weather conditions.

A further limitation is the complex interplay of weather on human behaviour that is difficult to reduce to single weather parameters.

Concerning our data, we acknowledge that weather conditions may change throughout the day. These alterations could not be detected with our dataset. Nevertheless, the extent of changes in the parameter described do not correlate with the incidence of the named pathologies.

CONCLUSION

In summary, our data does indicate seasonality in the incidence of SAH, ICH and CSDH, although this was not of statistical significance. Furthermore, single weather parameters do not allow us to draw conclusions as to incidence of cerebrovascular events. However, in our study the incidence of SAH tended to increase with changes of barometric pressure which is coherent with previously published investigations and might indicate a possible underlying relationship. In total, contrary to numerous presumptions the subjective feeling of a "typical bleeding weather" could not be objectified in our study.

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