

Impact of gravitational interaction between the Moon and the Earth on the occurrence of episodes of cardiogenic pulmonary edema in the field

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ABSTRACT

While circadian variation of occurrence of cardiovascular emergencies has been described, it has not been assessed whether fluctuations of gravitational interaction between the Earth and the Moon may induce other types of its variation in time have the similar impact. Therefore, we decided to evaluate whether there is an association between the occurrence of pre-hospital cardiogenic pulmonary edema (CPE) episodes treated by Emergency Medical Services (EMS) and fluctuations in the intensity of gravitational interaction between the Earth and the Moon.

Methods. We extracted all dispatches to CPE episodes from the EMS database of the Central Bohemian Region, Czech Republic, between 2.11.2008 and 1.7.2014. For each episode, the intensity of gravitational interaction between the Moon and the Earth was calculated. The study period was divided into 11 sections of equal duration according to the different intensity of gravitational interaction, and occurrence of CPE was compared among the groups. **Results.** We observed up to 4,744 episodes of CPE during the study period. Occurrence of CPE episodes was highest in the periods with the weakest intensity of gravitational interaction ($\leq 1.80e1026$ N), while in the periods of the most intense gravitational interaction ($\geq 2.26e1026$ N), the lowest proportion of CPE cases was

observed (23.44 vs. 3.79 %, $p < 0.001$).

Conclusions. We identified a significant association between the intensity of gravitational interaction between the Earth and the Moon and occurrence of CPE, treated by our EMS. The weakest intensity was associated with its increased occurrence and vice versa. Further research is required for potential use of this phenomenon in a chronotherapeutic approach to secondary prevention of CPE.

Key words: cardiogenic pulmonary edema, gravitational interaction

INTRODUCTION

Interaction of two celestial bodies, the Earth and the Moon, has long been the subject of mystical speculation but also of serious research. There have been many published reports of the impact of the Moon's phases on the occurrence of cardiovascular diseases, psychiatric disorders, rheumatologic disorders, birth rates, the risk of sudden cardiac death and the number of emergency department visits or hospital admissions. (1–11)

In the vast majority, a link was not identified. Even the shifts of lunar phases are often considered a marker of oscillation of the gravitational field of the Moon; in fact, there is no direct relationship between these natural phenomena. Moreover,

rather than gravitational field of the Moon itself, we should consider the gravitational interaction between the Moon and the Earth. It has a significant impact on the hydrosphere, atmosphere and the Earth's core. Research on its potential effect on regular variation of occurrence of diseases in time may be important not only for a detailed understanding of its pathophysiology but it also can have practical implications for the operation of emergency medical systems and emergency departments and for a chronotherapeutic approach to the management of diseases. However, a very limited number of studies concerning this topic have been published. (8,12)

One of the frequent and well defined cardiovascular emergencies with well-defined circadian variation is cardiogenic pulmonary edema (CPE). Therefore, we selected CPE as a model disease to evaluate whether there is an association between the occurrence of CPE episodes and fluctuations in the intensity of the gravitational interaction between the Earth and the Moon in a defined region for a specified time period and if so, whether there is a difference between the patterns of interaction in clinical types of CPE. A secondary aim of the study was to assess whether there is an association between the occurrence of CPE episodes and moon phases. We hypothesized that there is no significant association between the occur-

rence of CPE episodes and the intensity of the gravitational interaction between the Earth and the Moon.

MATERIALS AND METHODS

We performed a retrospective study, conducted in accordance with the Declaration of Helsinki. The Emergency Medical Service of the Central Bohemian Region is the exclusive provider of primary pre-hospital emergency care in the Central Bohemian Region, Czech Republic. The region includes both the rural and urban population, representing a total of 1 315 299 inhabitants on a total area of 11 015 km². A computer search of patients treated for dyspnea between 2.11.2008, 02:38 and 1.7.2014, 12:03 was conducted. Only those with CPE were entered in the study. Each patient was managed by a physician in the field. Criteria for considering the patient having CPE were leading complaint of shortness of breath, presence of bilateral pulmonary rales on the pre-hospital physical examination and the absence of another explanation for the clinical setting. The criteria were evaluated by two investigators independently. The results of their analysis were compared with the diagnosis established by the physician in the field. In the case of full accordance with the diagnosis of CPE, the patients were selected for analysis. In the case that both investigators and the physician in the field excluded pulmonary oedema, the patient was not included. If there was a partial mismatch, the case was carefully re-evaluated including personal consultation with the EMS physician and in-hospital documentation.

Patients with missing data were not included in the study. According to the first measured systolic blood pressure (SBP) in the field, we assigned the patients into three clinical subgroups for further analysis: CPE with hypertension (SBP >140 mm Hg), CPE with normotension (SBP ≥90 and ≤140 mm Hg) and CPE with hypotension (SBP <90 mm Hg). Initial blood pressure measurement was performed following the guidelines by oscillometric automatic sphygmomanometer validated according to standardized protocol and checked periodically through calibration. (13) In those patients with more than one initial blood pressure measurement available, the average value was calculated for further analysis.

The time of occurrence of the CPE episode was defined as the time the call was received by the dispatch centre and determined with

an accuracy of 1 minute. While the distance from the centre of the Earth to the centre of the Moon regularly fluctuates, it was calculated for each CPE episode separately. Intensity of the gravitational interaction (F) between the Moon and the Earth for each CE event was calculated using the formula (g gravitational constant; m_1 weight of the earth, kg; m_2 weight of the Moon, kg; r distance from the centre of the Moon to the centre of the Earth, m). The study period was divided into 11 sections of equal duration according to the different intensity of gravitational interaction, from weakest to strongest. Occurrence of CPE was compared among the subgroups.

We also compared the number of CPE episodes in the time points of apogee and perigee (the points in the orbit of the Moon at which it is farthest or nearest to the Earth, respectively) ± 36 hours during the whole survey period. For that purpose, events from the time period 12.11.2008, 16:56 to 04.06.2014, 16:26 were used to maintain the same number of apogee and perigee (74 of each).

The exact date and time of moon phases in the reporting period were obtained from NASA sources. Each synodic month (the period of a complete revolution of the Moon around the Earth, as the period between successive new moons equal to 29.531 days) was divided into four equal periods lasting 7.383 days with a particular phase of the moon in the middle of the period. Each period has been named by the corresponding phase of the moon. For each of the four types of periods we calculated the number of CPE events and compared the differences among the groups.

STATISTICAL ANALYSIS

For the statistical analysis, mean values ± SD or frequencies (percentages) were calculated as necessary. Differences between groups were compared using the χ^2 test, and statistical significance was calculated by the Fischer exact test for alternative variables. Statistical significance for continuous variables was determined by the paired Student t-test. The collected occurrence numbers were compared using Poisson distribution and regression. Comparison of subgroups according to systolic blood pressure was performed by ANOVA analysis. Data were analyzed using Microsoft Excel 2007 (Microsoft, Redmond, WA, USA) and JMP 3.2 statistical software (SAS Institute, Cary, NC, USA). A p value of < 0.05 was considered statistically significant.

RESULTS

For the period 2.11.2008, 02:38 till 1.7.2014, 12:03, a total of 14985 EMS dispatches for dyspnea was identified; 4981 were classified as CPE, of these 4744 complete datasets were available and underwent further analysis. Table 1 shows baseline clinical characteristics of the patients. As much as 51.9 % CPE episodes were associated with arterial hypertension, 5.9 % with hypotension and 40.3 % were accompanied by normotension ($p < 0.050$). In 89 patients blood pressure values were not available.

Figure 1 shows the distribution of CPE episodes in separate intervals according to the intensity of the gravitational interaction. Occurrence of CPE episodes was highest in the periods with the weakest intensity of gravitational interaction (1.76 to 1.80e1026 N), that means when the Moon's distance from the Earth was highest, while in the period of the most intense gravitational interaction (2.26 to 2.30e1026 N) we observed the lowest proportion of CPE episodes (23.44 vs. 3.79 %, $p < 0.001$). Moreover, we observed two peaks of CPE incidence. After a steep decline in incidence with increasing gravity, we observed the next peak when gravitational interaction was 2.11 - 2.15e1026 N.

We identified different patterns of association of gravitational interaction and CPE occurrence in the groups of CPE patients with hypertension, normotension and hypotension (figure 2). While CPE patients with hypertension and normotension followed a two-peak profile, patients presenting with hypotension exhibited maximal incidence of CPE in the period with lowest intensity of gravitational interaction, but then followed a fluctuating profile of occurrence to a minimum in the period with the strongest gravity.

During the period of apogee, we observed significantly more CPE episodes than during perigee (672 versus 594, $p = 0.002$).

Breath rate, heart rate, presence of atrial fibrillation, diabetes mellitus, chronic pulmonary obstructive disease and peripheral oxygen saturation had no significant impact on CPE variation.

We did not observe any significant difference in the incidence of CPE episodes during the various lunar phases in the whole group or in the groups of CPE episodes with hypertension, normotension or hypotension (figure 3).

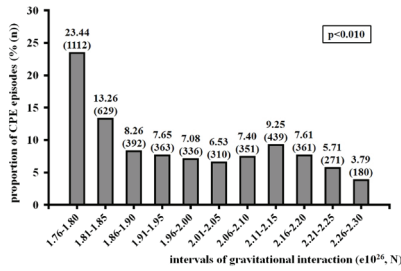


Figure 1. Association between the occurrence of CPE episodes and the intensity of the gravitational interaction between the Earth and the Moon. CPE, cardiogenic pulmonary edema.

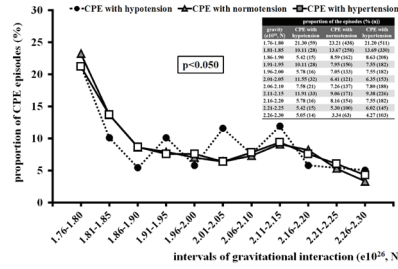


Figure 2. Association between the occurrence of CPE episodes and the intensity of the gravitational interaction between the Earth and the Moon in the groups of CPE patients with hypertension, hypotension and normotension. CPE, cardiogenic pulmonary edema. $p<0.05$ for the difference between CPE with hypotension and other groups

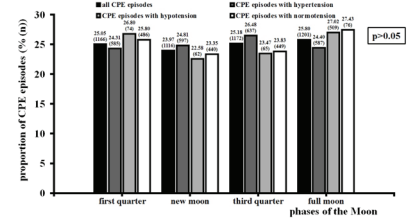


Figure 3. Proportion of CPE episode incidence during various phases of the moon. CPE, cardiogenic pulmonary edema.

Table 1. Baseline clinical characteristics of patients.

VARIABLE	all CPE episodes	CPE with hypertension	CPE with normotension	CPE with hypotension	p
Number of cases (n)	4744	2463	1914	278	
age (years, mean±SD)	75.0±10.5	75.2±10.3	74.5±10.7	73.4±11.1	0.006
men / women (%)	49 / 51	49 / 51	49/51	47 / 53	>0.050
Diabetes mellitus (n / %)	1424 / 30.0	726 / 29.5	615 / 32.1	83 / 29.5	>0.050
COPD / asthma (n / %)	513 / 10.8	263 / 10.7	219 / 11.4	31 / 11.0	>0.050
initial heart rhythm					
sinus rhythm (n / %)	2668 / 56.2	1379 / 56.0	1131 / 59.1	158 / 56.2	>0.050
atrial fibrillation (n / %)	1239 / 26.1	643 / 26.1	522 / 27.3	74 / 26.3	>0.050
other rhythm / not known (n / %)	840 / 17.7	441 / 17.9	350 / 18.3	49 / 17.5	>0.050
number of STEMI patients (n / %)	222 / 4.7	74 / 3.0	97 / 5.1	51 / 18.3	<0.001
systolic arterial blood pressure (mm Hg, mean±SD)	149±39	178±25	124±14	81±9	<0.001
diastolic arterial blood pressure (mm Hg, mean±SD)	84±22	97±16	74±12	46±19	<0.001
mean arterial blood pressure (mm Hg, mean±SD)	105±26	124±17	91±12	57±12	<0.001
heart rate (beats/min., mean±SD)	99±26	101±24	97±25	97±31	0.010
SpO2 (% , mean±SD)	85±13	85±11	87±12	80±17	<0.001
breath rate (breaths/min., mean±SD)	24±6	24±6	22±7	23±7	0.015

p value was calculated for the differences between the subgroups of CPE with hypertension, normotension and hypotension COPD, Chronic Obstructive Pulmonary Disease; CPE, cardiogenic pulmonary edema; SpO2, peripheral capillary oxygen saturation; STEMI, ST-elevation myocardial infarction.

DISCUSSION

The main finding of our study is that, in a large number of cases, we identified a significant association between the intensity of gravitational interaction between

the Earth and the Moon and occurrence of cardiogenic pulmonary edema treated by EMS. The pattern of association was found different for CPE with hypertension and hypotension. On the other hand, we did not find any effect of the lunar phases

during the synodic lunar cycle on the incidence of CPE. Variation of biological processes in time is a natural characteristic of living organisms. These events oscillate under the influence of exogenous environmental oscillators

which are monitored by an endogenous system comprising peripheral and central biological clocks. (14) Among the main sources of exogenous oscillations are the Earth's rotation around its axis, rotation of the Moon around the Earth and the Earth's rotation around the sun. Interaction of the Earth and the Moon is expressed by a significant influence on the hydrosphere, atmosphere and Earth's crust in the form of tidal force. A reliable lunar cycle is also seen in living organisms, especially in marine animals. (15) It is not a surprise that the occurrence of cardiovascular emergencies such as stroke, acute aortic syndrome, acute coronary syndromes, sudden cardiac death, pulmonary embolism and cardiogenic pulmonary edema have been shown to be closely related to circadian, circaseptan and circaannual variation. (16–20) The potential impact of the Moon and the Earth's interaction on human biorhythms may be mediated by the periodic fluctuations of night glow between a new moon and full moon. However, it has been repeatedly demonstrated that cyclic alternation of lunar phases has no significant effect on the occurrence of cardiovascular emergencies. (1,2,9,10) This observation was confirmed also in our survey. Another influence on human biorhythms can be due to regular variation of intensity of gravitational interaction on the basis of fluctuations in the distance between the Earth and the Moon. This happens regularly due to orbital excentricity of the Moon, with the distance between the Moon and Earth varying from around 356 334 km to 405503 km. (21) Wake et al. published an investigation of the effect of Moon gravity on the occurrence of acute myocardial infarction at 5 hospitals. They found, in 1369 consecutive patients, that there was an increase in incidence when the distance between the centre of the Moon and the Earth was more than 399864 km, or in other words, when the gravity of the Moon was the least intensive. (12) An identical association was found in a retrospective cohort analysis of 1007 consecutive births performed by the same research group. (8) There are two major limitations in both studies. The authors performed in-patient cohort analysis and it may not represent all cases in the geographic region. Second, the authors did not use an appropriate formula for gravity calculation. They included in it only the weight of the Moon. However,

the formula described the gravitational interaction between two celestial bodies and therefore, it is necessary to consider the product of weight of both the Moon and the Earth, which results in a force higher by 15 orders. Nevertheless, in principle, Wake et al. found a similar profile to the occurrence of myocardial infarction and number of births, as was the major finding in our study, i.e., that the occurrence of CPE episodes significantly increases during weaker gravitation periods and vice versa. We want to emphasize that we are not able to explain the described phenomena in more detail. It is likely that there is no direct causal relationship but it is rather a series of more intermediary events directly or indirectly affecting the final biological phenomenon. Anyhow, we assume that it is not a random association. Similar results were observed in two very distant geographical regions, and in our study, more than 4000 episodes of CPE were enrolled, which we consider a sufficiently large sample to be reliable. Interestingly, we identified different patterns of CPE occurrence variation in different clinical types of CPE. This should be the subject of further research.

Research on the phenomena affecting rhythmic fluctuation of the occurrence of cardiovascular emergencies is of major importance for several reasons. First, it allows a deeper understanding of its pathophysiology with respect to chronobiology. Second, monitoring variability of occurrence of emergencies in the field may help optimize operation of emergency medical systems, particularly in the allocation of occupancy of day and night shifts and in preparedness for the increased workload. Third, it may be of great importance in the secondary prevention of emergencies, which incidence is subject to regular occurrence of variability in time. CPE is one of the candidate diseases for such a chronotherapeutic approach. Pronounced circadian variation has been demonstrated for CPE occurrence and a casual relationship with hypertension, particularly with non-dipper/riser profile and with the presence of excessive morning surge. (22,23) Moreover, our results indicate that the chronobiological approach may be considered even beyond the horizon of the twenty four hour cycle. Although the causal relationship between gravitational interaction between the Earth and the Moon and the

occurrence of CPE has not been detected so far, it is easy to automatically calculate the periods with increased risk of CPE occurrence in advance. Especially in patients with congestive heart failure and in those patients who have already suffered from a CPE episode, it can be considered wise to concentrate maximum preventive effort in terms of avoiding excessive physical activity, reduced salt intake, strict infection prevention and careful home blood pressure monitoring on these days, especially in unstable and decompensated patients.

STUDY LIMITATIONS

The major limitation of the presented study is that it is a retrospective and not prospective survey with all general limitations. Another limitation lies in the selection of the patients with CPE. It was based on the prehospital clinical assessment. However, careful retrospective stepwise re-evaluation of each event was performed to exclude all cases in which the cause of shortness of breath was other than CPE or the cause was unclear, to maximize homogeneity of selected patients. The patients who died of CPE before contacting EMS were not included. However, the latter is the common limitation of epidemiological studies. Finally, the data were collected from one central European region and the results should not automatically be applied to other geographic and socio-economic regions.

CONCLUSIONS

We conclude that a significant association of intensity of gravitational interaction between the Earth and the Moon and occurrence of cardiogenic pulmonary edema treated by EMS has been identified in a large cohort of cases in our study. A prospective approach in future research is warranted. Recognition and understanding of chronobiological features of cardiovascular emergencies may optimize emergency medical service operation, and imbedding a chronotherapeutic pattern into secondary prevention measures may improve long term management of these diseases.

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