Oceanic Meteorological Conditions Influence Incidence of Aneurysmal Subarachnoid Hemorrhage

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Objective: Publications concerning the weather pattern of occurrence of the subarachnoid hemorrhage have produced controversial results. We chose to study subarachnoid hemorrhage occurring in oceanic climate with deep variations focusing on partial oxygen volume (pO_2) and patient history. *Methods:* Seventy-one patients had been successively recruited from a single center 45 km from the Atlantic shore. Climate conditions had been analyzed from 72 hours before subarachnoid hemorrhage to 24 hours after. According to Dalton's law, climate conditions influence pO_2, recalculated with Dupré's formula, and patient history analyzed and scored according to the induced oxidative stress. *Results:* Subarachnoid hemorrhage risk is highest during spring and autumn, lowest between midnight and 6:00 a.m. Risk is highest after a period of atmospheric pressure higher than 1010 hPa (83%) and high pO_2 and lowest for atmospheric pressure lower than 990 hPa and pO_2 lower than 20.6. According to the medical history, 2 groups of patients could be identified: patients without history (22%), women (62%), high atmospheric pressure, and relatively lower pO_2; and patients with a medical history, relatively lower atmospheric pressure, and higher pO_2. Atmospheric pressure decreased significantly before disruption (994 hPa) but with a constant pO_2. Subarachnoid hemorrhages during high atmospheric pressure were preceded by a decrease of pO_2 despite a highly stable period of high atmospheric pressure. *Discussion:* Atmospheric O_2 changes and the subsequent oxidative stress could be the local ultimate trigger of subarachnoid hemorrhage that could result in the "ideal" fit of patient's health conditions with the meteorological environment. **Key Words:** Subarachnoid hemorrhage—weather—atmospheric pressure—atmospheric oxygen pressure—pO_2—intracranial cerebral aneurysm.

Introduction

Spontaneous subarachnoid hemorrhages (SAHs) account for about 5% of all strokes and are a major contributor to the stroke-related loss of productive life years, have an overall mortality of 45%, and thus represent a strong economic burden. Despite intense research, causes of intracerebral aneurysms (ICAs), accounting for 85% of SAH, remain largely unknown as are causes leading to their disruption. Periodically, studies aimed at correlating meteorological conditions, seasons, and disruptions are published[1-4] as medical doctors (MDs) in charge often have the feeling that some periods of time seem more favorable than the others.[5] Results of such studies appear controversial and heterogeneous as they are issued from very different areas around the world having each a preeminent weather regimen, i.e., continental, oceanic, or subtropical. Also, large cohorts of patients for epidemiological survey gather patients from different areas within a country, "diluting" the potential identification of meteorological influences.[6] On the other hand, oxidative stress, the imbalance between reactive oxygen species (ROS) production and neutralization, is often cited among causes

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Received January 6, 2017; accepted February 9, 2017.
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1052-3057/$ - see front matter

http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2017.02.031

of aneurysm.[7] Our hypothesis is that O_2 (oxygen) could be the link between aneurysm disruptions in patients and patient environment, and that neither time nor location or patient general health status is alone able to provoke an SAH. Only the best combination of these parameters might modify Henry's law parameters in such a way that an oxygen-related cascade of events could occur, leading to SAH. If such a hypothesis were true, the oxidative patient "profile" might have to match with the weather conditions to create an unfavorable situation leading to this given patient and this precise moment to SAH. The aim of this study was to analyze the weather conditions and patient characteristics of all and only-patient aneurysm-related SAH, recruited from a single intensive care unit over 1 year, located in an area with deep atmospheric changes. The medical history of each patient had thus been recorded in addition to the SAH "classical risk factors". Our unit is located in Nantes, France, 47°13′N; 1°33′W, a 300,000 inhabitants city located 45 km from the Atlantic Ocean shore and thus submitted to marked seasonal oceanic climate. There are no hills higher than 70 meters 100 km around, likely to interfere with weather conditions. Patterns of this geographical situation are moderate temperature variations but strong atmospheric pressure (AP) changes, even daily, including wind and relative humidity (RH) variations. In addition, partial oxygen volume (pO_2) had been calculated from recorded data. Analyzing such weather conditions at time of disruption as well as during the 48 hours before could accurately indicate if a characteristic weather profile for SAH may exist, including changes in available O_2. We expected to find a relationship between the general health conditions of patients and weather conditions synergistically leading to a SAH.

Materials and Methods

Eighty-three patients had been consecutively admitted to the intensive care unit from January 1, 2013, to December 31, 2013, and data had been fully completed for 71 patients concerning the SAH circumstances as well as patient medical history. Diagnosis of SAH, and origin and number of ICAs had been confirmed by nuclear magnetic resonance. Patients were living at a maximum of 60 km around Nantes (n = 64) and 7 patients were secondarily transferred from 80 to 100 km away when SAH occurred. Time of SAH was obtained from relatives, from the patient, and from emergency teams, and recalculated for each patient. Clinical histories had been found extremely rich and we gathered and scored diseases according to the oxidative stress imbalance that they generated. According to literature data,[8] we attributed arbitrarily a score of 2 for each acute or chronic vascular disorder, as for cancers or cancer treatments, 1 for each other disease not specially known to generate oxidative stress (i.e., orthopedic surgery). Thus, each patient's score represents a sum of various events. Only patients unable to provide any

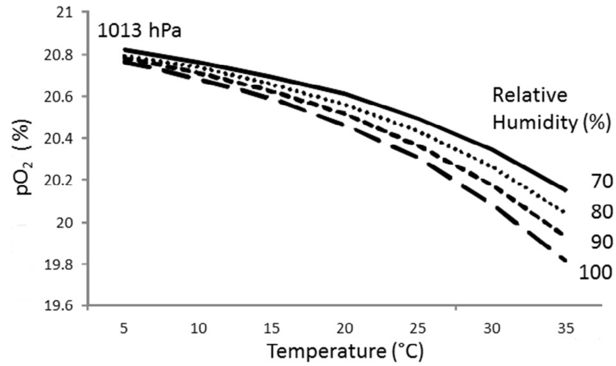

Figure 1. *Influence of temperature and relative humidity on calculated atmospheric partial oxygen pressure (pO_2) for an atmospheric pressure of 1013 hPa.*

marked souvenir of disease and without any clinical file were scored as 0.

Seasons were limited by March 20 equinox (11:00 a.m.), June 21 solstice (5:03 a.m.), September 22 equinox (8:44 p.m.), and December 21 solstice (5:11 p.m.). Weather conditions had been obtained from the websites www.meteociel.fr and www.meteobretagne.fr, publishing maps, and data issued from the National Centers for Environmental Prediction/National Oceanic and Atmospheric Administration as well as METAR files.[1] All data had been checked for accuracy from 2 different sources. AP, wind speed, temperature, and RH had been obtained every 6 hours over a period of 48 hours before and after the stroke. A high AP (HP, high pressure) was above or equal to 1013 hPa a low pressure (LP) under. Effects of a given gas[9] depend on Henry's law, thus resulting from Dalton's law saying that AP results from oxygen pressure exerted by its volume plus nitrogen plus water vapor. Effect of oxygen would thus vary according to AP, RH, and temperature (Fig 1) in addition to diurnal variations,[2] influenced in Nantes area by tides and thus wind and temperature. Partial oxygen pressure that may influence oxidative stress had been recalculated from these data using the Dupré's formula approximated by Rankine (pN_2 being constant):

$$\text{Vapor pressure (VP)} = \text{Saturating pressure (psat)} \times \text{relative humidity in which psat is obtained from:}$$
$$\ln \text{psat} = 13.7 - 5120/T, \text{ T being the temperature in °K}$$

$$pO_2 = (AP - VP) \times 20.95$$

$$PpO_2 = (pO_2/AP) \times 100$$

Weather conditions of year 2013 had been compared to national conditions and to Nantes recordings over the period 1961-2010 to eliminate a year 2013 artifact. Considering by hypothesis that the real weather conditions

[1] http://www.meteociel.fr/previsions/15569/nantes.htm, http://www.meteobretagne.fr.

[2] i.e., measured in 2004 in Germany, https://fr.wikipedia.org/wiki/Pression_atmosph%C3%A9rique).