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Meteorological Factors Affecting Aneurysmal Subarachnoid Hemorrhage in the Philippines

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Rationale/Objective: Aneurysmal subarachnoid hemorrhage (aSAH) may be associated with meteorologic factors in temperate countries. The authors aimed to investigate the relationship between meteorologic factors and aSAH admissions in the Philippines, a tropical country with two seasons: rainy and dry.

Methods: A census review of aSAH admissions from 2015 to 2019 at a tertiary hospital was performed. Meteorologic data were collected for the same time period, and statistical analysis was performed.

Results: A total of 660 patients were admitted for aSAH, 275 and 385 during the rainy and dry seasons, respectively. August and October had the greatest number of mean admissions (13.2) while February had the least (6.2). There was a moderate positive correlation between aSAH admissions and mean temperature. Negligible to weak negative correlations were seen between aSAH admissions and humidity, barometric pressure and precipitation. However, there was no correlation on regression analysis.

Conclusion: There were no significant differences in aSAH admissions between rainy and dry seasons. The authors found an increase in aSAH admissions during months with higher temperatures and HI, and weak to negligible negative correlations between aSAH admissions and humidity, barometric pressure, and precipitation. These findings may inform health care facilities in terms of readiness for aSAH admissions.

Key words: subarachnoid hemorrhage (SAH), aneurysm, meteorology, weather, tropical

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Aneurysmal subarachnoid hemorrhage (aSAH) has an estimated incidence of 7.9 per 100,000 person-years.[1] Associated morbidities include neurologic deterioration and other deficits, with an estimated all-cause mortality of 30%.[2] Due to its significant morbidity and mortality rates, numerous risk factors for aSAH have been investigated, including meteorological conditions.[3]

There are conflicting reports about the association of aSAH and meteorological factors.[4–8] Some authors reported that seasonal variations were associated with increased rates of aSAH.[4-8] Majority of the studies that investigated these found that there were increased consults for aSAH during colder months,[8–16] but there were also some series that found no correlation.[17,18] Increase in humidity[19] and decrease in barometric pressure associated with colder temperatures have also been reported to correlate with aSAH.[20] However, most of these studies were conducted in temperate regions. In a systematic review by De Steenhuijsen Piters et al., all 24 countries included in the review had a temperate climate.[21] To the authors knowledge, there have only been two previously published studies on the correlation of weather and aSAH in a non-temperate country. The first is a single-center study from India, which described a surge in the number of aSAH cases in areas with a mean 1.1˚C drop in temperature in the preceding 2 days prior to admission.[22] The second study, a retrospective review of a single-center experience in Hong Kong, found that the mean atmospheric pressure was significantly higher on days with aSAH admissions compared to those without.[23]

The Philippines is a tropical country with two main seasons: rainy from June to October, and dry from November to May.[24] It is an archipelago that is characterized by a relatively high mean temperature,

high humidity, and abundant rainfall.[24] Given the high temperature and humidity of Philippine climate, actual temperature differs from felt temperature and is measured by the heat index (HI) in daily use.[25] The capital city of Manila has monthly mean temperatures ranging from 25 to 32˚C, heat indices ranging from 26 to 43˚C, annual humidity of 77%, annual barometric pressure of 1011 mbar, and annual precipitation of 1667 mm.[26] During the rainy season, temperature ranges from 24.6 to 31.4˚C and HI from 25 to 42˚C, while in the dry season, they range from 22.6 to 34.3˚C and 23 to 48˚C, respectively.[26] This tropical climate is different from most of the published literature on the subject. In this paper, the authors aimed to investigate the relationship between meteorologic factors and aSAH admissions in our setting, which is the largest tertiary hospital in Manila.

Methods

The authors conducted a review of the monthly number of admissions of patients with aSAH from the censuses of the Divisions of Neurosurgery and Adult Neurology at the Philippine General Hospital from January 2015 to December 2019. Meteorologic data such as mean, maximum and minimum temperatures (in degrees Celsius), humidity (in percent), barometric pressure (in mbar), average rainfall (in mm), and days of rain for every month were taken from the website of the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA)[26] and www.worldweatheronline.com.[27] The mathematical formula for heat index (HI) incorporated temperature and humidity as data points, and was computed as follows: HI = -42.379 + 2.04901523*T + 10.14333127*RH - .22475541*T*RH - .00683783*T*T - .05481717*RH*RH + .00122874*T*T*RH + .00085282*T*RH*RH - .00000199*T*T*RH*RH; where HI is heat index, T is temperature, and RH is relative humidity.[28] This was computed for mean, maximum and minimum temperatures. Descriptive statistics were used to assess the individual variables, and the statistical software used was R (R Project for Statistical Computing, Vienna, Austria). Statistical analysis between rainy and dry months was performed using an independent sample t-test. The Pearson correlation between the monthly number of aSAH admissions and meteorological factors was performed, as well as multiple regression analysis. Alpha level was set at 0.05.

Results

Aneurysmal SAH Admissions and Meteorological Data

A total of 660 patients with aSAH were admitted at the institution from January 2015 to December 2019. Annually, aSAH admissions ranged from 72 to 176 (mean 132 $\pm$ 45.6), while 2 to 25 patients (mean 11 $\pm$ 2.3) were seen monthly. August and October had the greatest number of mean admissions (13.2 $\pm$ 6.3) while February had the least (6.2 $\pm$ 3).

There were 275 aSAH admissions (mean 55) during the rainy season (June to October), and 385 (mean 55) during the dry season (November to May). Mean temperatures ranged from 25.3 to 31.1˚C and mean HIs ranged from 26.2 to 40.8˚C during the rainy season. On the other hand, mean temperatures had a slightly wider range during the dry season (24.2 to 31.6˚C), and the mean HIs ranged from 25 to 39.4˚C. It was significantly more humid during the rainy season (79.9% vs 70.2%, $p=0.0038$), and barometric pressure was also significantly lower (1008.2 mbar vs 1011.6 mbar, $p<0.001$). There was also significantly more rain during the rainy season (298.4 mm vs 77.7 mm, $p<0.001$; 13.6 vs 3.3 rainy days, $p<0.001$). (Table 1)

If monthly data were considered, the mean recorded temperatures ranged from 26 to 29.8˚C, with a maximum of 30 to 33.8 and minimum of 23 to 26.2. Mean HIs ranged from 27 to 35˚C, with maximum at 36 to 45˚C and minimum at 23 to 28˚C. Mean relative humidity ranged from 62.8 to 82.2%, and barometric pressures from 1007 to 1013.8 mbar. Mean monthly precipitation ranged from 29.3 to 394.1 mm, while the average days of rain per month ranged from 1 to 17. (Table 2)

Statistical Analysis

Based on the t-test, there were no significant differences between total and mean aSAH admissions for the rainy and dry seasons (Table 1). Pearson's R was used

to examine the correlation between each meteorological factor and the number of monthly admissions for aSAH. Weak, moderate and strong correlations were defined as a correlation coefficient of <0.3, 0.3 to 0.6, and >0.6, respectively.[29] There was a moderate positive correlation between aSAH admissions and mean temperature (r(11)=0.41, p=0.18). Weak positive correlations were seen between aSAH admissions with the mean (R=0.409), maximum (R=0.259) and minimum temperatures (R=0.265), and mean (R=0.273), maximum (R=0.254), and minimum (R=0.228) heat indices. Negligible to weak negative correlations were seen between aSAH admissions and humidity (R=-0.073), barometric pressure (R=-0.236), precipitation (R=-0.075), and days of rain (R=-0.044). On multiple regression, no associations were found between monthly aSAH admissions and the meteorologic factors assessed (R^2=0.858, F=0.604, df=10, p=0.776). (Table 3)

Table 1. Comparison of rainy and dry seasons from 2015-2019.

	Rainy Season (June to October)	Dry Season (November to May)	p-value
Mean Temperature (˚C)	28.2	27.7	0.2386
Mean Maximum Temperature (˚C)	31.1	31.6	0.2161
Mean Minimum Temperature (˚C)	25.3	24.2	*0.0464*
Mean Heat Index (˚C)	32.4	30.3	*0.0452*
Mean Maximum Heat Index (˚C)	40.8	39.4	0.1771
Mean Minimum Heat Index (˚C)	26.2	25	0.0528
Humidity (%)	79.9	70.2	*0.0038*
Barometric Pressure (mbar)	1008.2	1011.6	*<0.001*
Annual Precipitation (mm)	298.4	77.7	*<0.001*
Annual Days of Rain	13.6	3.3	*<0.001*
Total aSAH Admissions	275	385	0.5
Mean aSAH Admissions	55	55	0.5

Table 2. Monthly SAH admissions and meteorological factors, PGH, January 2015-December 2019.

Month	Total aSAH admissions	Mean monthly aSAH admissions	Mean temperature (mean maximum, mean minimum; in C°)	Heat index (mean maximum, mean minimum; in C°)	Mean relative humidity (%)	Barometric pressure (mbar)	Mean precipitation (in mm)	Mean number of days of rain
January	54	10.8	26 (30, 23)	27 (36, 23)	73.8	1012.8	59	2
February	31	6.2	26.2 (30.8, 23.4)	28 (37, 24)	68.6	1013.8	29.3	1
March	64	12.8	28 (32.2, 24.5)	30 (39, 25)	64	1012.6	36	2
April	61	12.2	29.4 (33.8, 25.7)	32 (43, 26)	62.8	1010.8	75.2	4
May	59	11.8	29.8 (33.5, 26.2)	35 (45, 28)	70.2	1009.6	159.1	8
June	60	12	29 (32.1, 25.9)	34 43, 27)	76.8	1008.8	269.1	12
July	46	9.2	27.8 (31, 25.3)	32 (41, 26)	81.2	1008	394.1	17
August	66	13.2	28 (30.6, 25.2)	32 (40, 26)	82.2	1007	295.8	14
September	37	7.4	28 (30.7, 25.2)	32 (40, 26)	81	1008.4	317.3	15
October	66	13.2	28 (30.9, 25)	32 (40, 26)	78.4	1008.8	215.6	10
November	52	10.4	27.6 (30.8, 24.4)	31 (39, 25)	75.4	1010.6	101.3	3
December	64	12.8	27 (30.1, 23.6)	29 (37, 24)	76.6	1011.2	84	3

Table 3. Summary of correlative and associative statistical analysis.

	Monthly aSAH admissions	
	Pearson R (p-value)	**Regression Analysis (p-value)**
Mean Temperature	0.41 (p=0.18)	0.18
Max Temperature	0.26 (p=0.41)	0.81
Min Temperature	0.27 (p=0.40)	0.44
Mean Heat Index	0.27 (p=0.39)	0.15
Max Heat Index	0.25 (p=0.43)	0.76
Min Heat Index	0.23 (p=0.48)	0.59
Humidity	-0.07 (p=0.81)	0.48
Barometric Pressure	-0.23 (p=0.46)	0.84
Mean Precipitation	-0.07 (p=0.81)	0.65
Mean Days of Rain	-0.04 (p=0.89)	0.54

Discussion

The current study found positive correlations between aSAH admissions and increasing temperatures and HI. There were weak to negligible negative correlations with humidity, barometric pressure and precipitation, but they were not statistically significant. When aSAH admissions were analyzed according to rainy and dry season, there was no significant difference between the two seasons. This study illustrates the relationship between aSAH admissions and meteorological conditions from the perspective of a tropical country, and possible implications are discussed.

Temperature and Heat Index

In the current study, there were more aSAH admissions during months with higher temperatures and heat indices. This differed from what was reported by the majority of the literature,[4-12] but was similar to the findings of two studies. Han et al. reported that higher environmental temperatures were correlated with an increase in aSAH admissions especially for male patients,[30] while Hughes et al. observed the same phenomenon in aSAH from anterior communicating artery aneurysms.[31] A possible explanation for this finding may be the physiological effects of increasing temperature on blood pressure (BP), since high temperatures have been correlated with increases in BP.[32] It is postulated that with increasing temperature, there is increased discomfort, which may lead to stress and hypertension due to increased adrenergic stimulation.[33] The sudden increase in BP during hot weather may predispose a patient with an unruptured aneurysm to have SAH.[33] In temperate countries, increased aSAH admissions during warm weather may occur due to increase in exercise and other strenuous activities on sunny days.[30,31] For example, a relatively sedentary person who is not accustomed to outdoor exercise may be encouraged to do so during a warm day, leading to increased stress, hypertension and aSAH.[30] Since the relationship between temperature and HI is linear, it was not surprising to see that an increase in HI was positively correlated with SAH admissions, along with increased temperature.

Most papers that investigated the relationship between weather and SAH found that lower temperatures and changes in barometric pressure were associated with increased admissions for aSAH.[8–16] Physiological responses, specifically an increase in sympathetic response due to colder temperatures, support an increase in the number of aSAH admissions for cooler months.[21] Decreasing temperature leads to vasoconstriction, resulting in increased BP, which is a risk factor for aneurysmal rupture.[11] Another possible explanation for

increased aSAH prevalence in winter is the increased rate of systemic infections during this time.[30] Certain patient activities may also predispose to aSAH. Huang et al. found an increase in aSAH admissions during winter and attributed it to increased patient smoking and alcohol consumption in an effort to keep warm, suggesting that these social behaviors may be risk factors for aneurysmal rupture.[15]

Humidity, Barometric Pressure, and Precipitation

There was only a weak to negligible correlation between aSAH admissions and humidity and barometric pressure in the current study, unlike several papers that reported that changes in barometric pressure were associated with increased aSAH admissions.[8–16]

For barometric pressure, it has been found that acute hypobarbia, at pressures of 0.8, 0.65 and 0.5 atmospheres, may cause a decrease in cerebral oxygen levels, leading to compensatory vasoconstriction to improve cerebral blood flow through autoregulation.[34] Although hypoxia and its effect on cerebral autoregulation (i.e., consequent increase in BP) may seem a plausible explanation for increased aSAH admissions, this phenomenon was observed in the acute phase and not in a chronic setting.[34]

The authors found that there were decreased aSAH admissions in the months with more rainfall, although the correlation was only weak to negligible. The months with the greatest amount of precipitation, July and September, also had some of the lowest aSAH admissions throughout the year. In tropical countries where increased rainfall may be accompanied by environmental hazards such as flash floods, access to health care facilities may also be hampered; hence, a decrease in admissions may be seen.[36]

Implications for Health Systems in the Philippines

This is the first paper that explored relationships between meteorological factors and aSAH admissions in the country, which has a different climate compared to most of the literature on weather and aSAH. The Philippines is located in the typhoon belt, an area in the Western Pacific Ocean where about one-third of the world's tropical cyclones form.[37] It is beset by an average of 20 typhoons a year, 5 of which may be destructive.[38,39] The monsoon months of July and August, in particular, have the highest incidence of typhoons and floods.[39] Aside from their destructive effects on agriculture and infrastructure, floods and resulting landslides may also hinder access to healthcare. In a time-sensitive disease such as aSAH, meteorological factors may contribute to a delay in treatment, which is associated with a poorer outcome.[40] Thus, it is imperative that disaster preparedness measures and inter-hospital referral systems should be in place, especially during typhoon season.[41]

Based on current findings, there were more aSAH admissions during the warmer months, so hospitals throughout the city should be prepared to admit more aSAH patients when the temperature and HI are higher. Neurosurgical centers should also increase their readiness in terms of intensive care unit beds, angiography/endovascular facilities, and operating rooms to cater to the increased case load of aneurysm patients. (Figure 1)

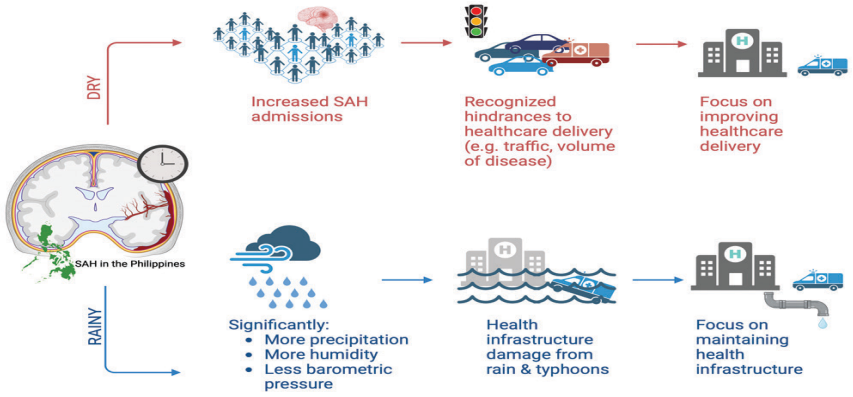

Figure 1. Graphical illustration of the implications of meteorologic factors for SAH patients in the Philippines separated by the seasons

Limitations

The current study has several limitations. First, this was a retrospective review with all its inherent biases. Second, the authors' retrospective analysis only encompassed 5 years. Third, they only included the number of admissions for aSAH and not specific patient or aneurysm characteristics. Lastly, their meteorological data was limited to temperature, heat index, humidity, barometric pressure, and precipitation.

Conclusions

This was the first study examining the relationship between meteorological factors and admissions for aSAH in the Philippines. There were no significant differences in aSAH admissions between rainy and dry seasons. The authors found an increase in aSAH admissions during months with higher temperatures and heat indices, and weak to negligible negative correlations between aSAH admissions and humidity, barometric pressure and precipitation. These findings may inform health care facilities in terms of readiness for aSAH admissions.

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