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Barometric pressure and the incidence of benign paroxysmal positional vertigo☆

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ABSTRACT

Objectives: To investigate the relationship between barometric pressure and the incidence of benign paroxysmal positional vertigo (BPPV).

Methods: 181 patients diagnosed with classic BPPV seen between 2011 and 2016 were identified. Demographic information, data of onset, and date of presentation were recorded. Historical barometric data for each of the 60 months were recorded. In addition, monthly counts of other atmospheric, infectious, and allergic variables for that time period were recorded. Correlation analysis compared monthly incidence of BPPV with absolute and relative changes in atmospheric conditions.

Results: The incidence of BPPV onset demonstrated a statistically significant positive correlation with barometric pressure, where every one-unit increase in barometric pressure leads to an expected increase of 6.1 diagnoses ($p = 0.0008$). The correlation coefficient (r) between barometric pressure and BPPV diagnoses was 0.66 (95% CI 0.14–0.90) with a p-value of 0.0131. Other seasonal variables demonstrated correlation, though none as strong as barometric pressure.

Conclusions: Barometric pressure has been long been associated with conditions of the inner ear, though its relationship to the pathogenesis of BPPV has not been investigated. Monthly changes in barometric pressure, rather than the absolute value, may be responsible for the observed changes in incidence. These findings demonstrate a clear association between barometric pressure and BPPV that may help to explain both the etiology of BPPV and its possible connection to migraine-related conditions.

1. Introduction

Benign Paroxysmal Positional Vertigo (BPPV) is a disorder of the inner ear characterized by recurrent bouts of positionally-triggered spinning vertigo that last roughly 15 s to 1 min. Its prevalence has been estimated at 2.4% [1], with trauma, infection, and other associated inner ear pathologies among the known associated causes [2–5]. However, the true underlying pathogenesis is poorly understood and no clear causative factor is identified in 50–97% of cases [6]. Recent studies have demonstrated a possible seasonality to BPPV, with fewer cases occurring during the summer months. Theories behind this trend propose calcium homoeostasis to play a key role as serum Vitamin D levels surge with increasing daylight [7–10]. However, the correlative evidence is weak, and recent evidence suggests such associations to be purely coincidental [11].

One factor not yet thoroughly explored in the pathogenesis of BPPV is barometric pressure. Known to be associated with other inner ear pathologies such as Meniere's disease [12] and sudden sensorineural hearing loss [13], barometric pressure variations impact on neurotologic conditions is evident, if not clear [14–18].

The aim of this study is to determine the temporal relationship between monthly barometric pressure levels and incidence of BPPV. Additional seasonal variables (atmospheric, allergic, and infectious), are explored for the basis of comparison in seasonal trends. For those variables that do demonstrate seasonality, potential rationale will be explained.

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2. Methods

2.1. Patients

We retrospectively reviewed the charts of adult patients presenting to our tertiary ambulatory academic neurotology clinic between 2011 and 2016 for symptoms of positional vertigo. Patients were identified based on ICD-9 codes for new onset BPPV (386.11) who were diagnosed by otolaryngologists within the department. 654 consecutive patients were initially identified. Otolaryngology clinic notes were examined for patient symptoms, demographics, month of symptom onset and pertinent exam findings. Patients were included in the study if they had symptomatic episodes of positional vertigo clinically consistent with BPPV coupled with a positive Dix-Hallpike maneuver (rotatory or horizontal nystagmus). Patients were excluded if unable to recall symptom onset or the onset date was unclear from the clinical note, patients with a pre-existing diagnosis of BPPV (recurrent BPPV), or if patients had a negative Dix-Hallpike or canalith repositioning maneuver despite clinical suspicion by history alone.

Average monthly atmospheric data for the Richmond, Virginia metropolitan area were obtained through www.usclimatedata.com. These including barometric pressure, average, high and low temperatures, humidity, UV index and average hours of daily sunshine [19]. Averages were calculated for each individual month across the 5 year study period. Allergen data included grass and mold pollen counts and were obtained through daily counts at the Science Museum of Virginia. Infectious disease data included the influenza-like illness (ILI) activity indicator available through the Center for Disease Control (CDC) [20]. This standardized scale grades influenza-like illness activity on a monthly basis from 1 to 10, based on the number of outpatient visits to healthcare providers for influenza-like symptoms across each state in the nation. The data for Virginia were recorded.

2.2. Statistical analysis

Measurements were summarized with means, standard deviations, minimum and maximum values. Associations between environmental measurements and the number of monthly BPPV diagnoses were assessed with a linear mixed model. Models were fit separately for each environmental measurement, included as a fixed effect, with a random month effect included to account for seasonality, which is modeled with an unstructured covariance pattern. Associations between two indices UV index and sunshine hours with total monthly BPPV diagnoses (over 5 years) are estimated with Spearman rank correlations. The MEANS, CORR and GLIMMIX procedures were used for summaries and analyses, respectively, in the SAS statistical software (version 9.4, Cary, NC, USA).

The study protocol was approved by the Virginia Commonwealth University Institutional Review Board.

3. Results

There were 181 patients with BPPV who met inclusion criteria. Patient age ranged from 26 to 89 with an average age of onset of 64.4 years old. Patients presented between 1 day and 4 years after symptom onset, averaging 116 days prior to seeing a neurotologist (though many had seen different clinicians prior and were referred for further evaluation). Patients with longstanding clinical disease prior to presentation had a specific date, such as hospitalization, procedure, trauma, or event to attribute to their symptom onset. Fig. 1 shows the BPPV diagnoses on a monthly basis during the study period. Estimated regression slopes and Spearman correlation coefficients for all variables are presented in Tables 1 and 2 respectively.

Of all the variables studied, barometric pressure demonstrates the strongest statistically significant positive correlation, where every one-unit increase in barometric pressure leads to an expected increase of 6.1

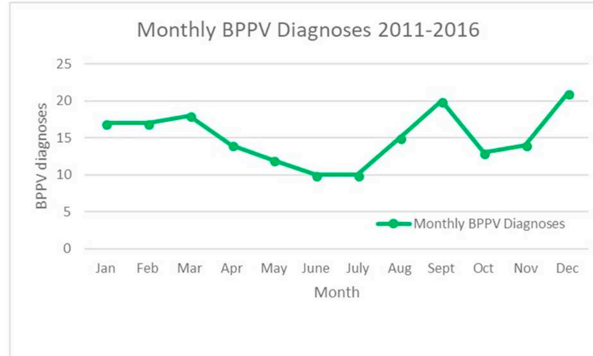

Fig. 1. Average monthly diagnoses of BPPV over the 5-year study period.

Table 1
Estimated regression slopes between environmental measurements and monthly BPPV diagnoses. SE = standard error.

	Estimated slope	SE	t-Value
Barometric pressure	6.10	1.32	4.61
Average temperature - high	−0.04	0.01	−6.10
Average temperature - low	−0.04	0.01	−6.04
Average temperature	−0.04	0.01	−6.10
Precipitation	−0.14	0.05	−3.06
Humidity	−0.02	0.02	−0.93
ILI Activity	0.25	0.05	5.45
Average tree pollen count	−0.23	0.56	−0.41
Average mold pollen count	−0.23	0.04	−5.36
Average grass pollen count	−0.12	0.02	−6.13
Average ragweed count	0.08	0.03	2.70

Table 2
Estimated Spearman correlations between environmental measurements and monthly BPPV diagnoses.

	Estimated Correlation	95% CI	*p*-Value
Barometric pressure	0.66	0.14–0.90	0.0131
Average temperature - high	−0.57	−0.86–0.01	0.0438
Average temperature - low	−0.57	−0.86–0.00	0.0418
Average temperature	−0.57	−0.86–0.00	0.0418
Precipitation	−0.25	−0.72–0.38	0.4311
Humidity	−0.06	−0.61–0.53	0.8490
ILI Activity	−0.55	−0.03–0.86	0.0509
Average tree pollen count	−0.18	−0.68–0.44	0.5650
Average mold pollen count	−0.58	−0.87 to −0.02	0.0368
Average grass pollen count	−0.41	−0.80–0.21	0.1676
Average ragweed count	−0.15	−0.67–0.46	0.6267
Allergy index	−0.05	−0.61–0.54	0.8740
UV index	−0.62	−0.88 to −0.07	0.0235
Average daily sunshine	−0.68	−0.90 to −0.90	0.0099

diagnoses ($r = 0.66$ [95% CI 0.14–0.90], $p = 0.0131$). This indicates a moderate to strong correlation. The line of best fit for the association between BPPV and barometric pressure is presented in Fig. 2.

For other atmospheric variables explored, temperature demonstrate a significantly negatively correlation with BPPV diagnoses ($r = -0.57$, p-value 0.0418) where the number of expected BPPV diagnoses decreases by 0.4 for a ten-degree increase in high, low or average temperature. Similarly, both UV index (correlation coefficient: −0.62, $p = 0.0235$) and sunshine index (correlation coefficient: −0.68, $p = 0.0099$) demonstrate negative correlation, implying that as UV light and sunshine increase, the number of BPPV diagnoses decreases. No statistically significant correlation with BPPV diagnoses is seen for humidity.

For allergens, mold pollen is significantly and negatively associated with the number of diagnoses (correlation coefficient: −0.58, $p = 0.0368$, with expected diagnoses decreasing by 0.2 as mold pollens

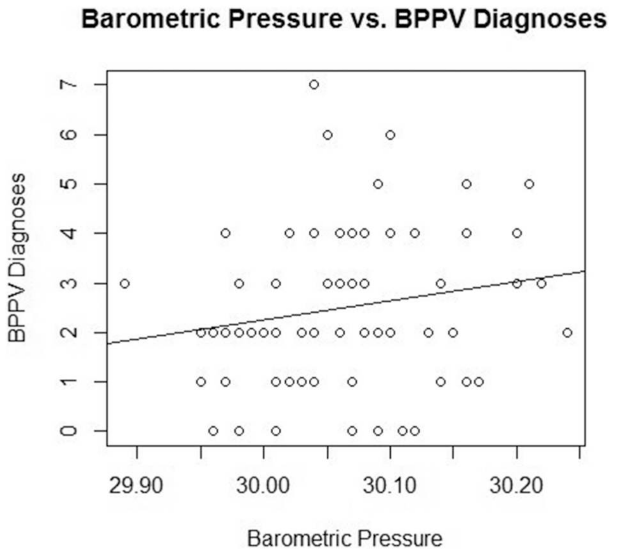

Fig. 2. Correlation between Barometric pressure and monthly BPPV diagnoses across the study period.

increase by 1000, while grass pollen is statistically insignificant ($p = 0.1676$). For the infectious variable studied, no statistically significant relationship was observed ($p = 0.0509$).

4. Discussion

The relationship between a disease and its variable incidence throughout the year has been long and widely recognized. Conditions such as rotavirus [21], stroke [22], myocardial infarction [23], infectious mononucleosis [24], Hodgkin's disease [24], Kawasaki Disease [25], Crohn's exacerbations [26], tuberculosis [27] and duodenal ulcer exacerbations [28] have all been associated with variable incidence throughout the year.

Over the last decade, similar investigations of the seasonal variations in inner ear disease have been undertaken. Gerceker found that idiopathic sudden sensorineural hearing loss (ISSHL) occurred more frequently in the winter months, with the authors suggesting a possible viral origin [29]. Yet Jourdy et al. found no seasonality behind ISSHL in their study [30]. Similarly, vestibular neuronitis demonstrated minimal evidence of seasonality when examined [31]. In other studies, vertigo symptoms were associated with higher incidence during the winter to early spring months, but dizziness occurred more frequently during the summer [32]. Although Meniere's Disease has been definitively linked to allergens [33], studies have failed to demonstrate a proven seasonal association [34]. Other authors' findings have led them to suggest associations between barometric pressure and Meniere's disease [12].

For BPPV, several investigators have studied seasonal variations in the incidence, often hypothesizing physiologic processes when any correlations were found. The first study to describe this relationship was Whitman et al., studying a population in Boston, Massachusetts. They authors reported that the incidence of BPPV was significantly higher in early spring months (March, April, May) [35]. Their retrospective study of 956 patient visits over 5 years identified patients via billing records, thus using encounter date, rather than patient history, as the month of symptom onset. Because of the variable duration patients take to seek care, this most likely does not represent true symptom onset. Saeed et al. then retrospectively reviewed 207 patients across 3 years in Iraq and found a negative correlation between BPPV and temperature but a positive correlation with atmospheric pressure [13]. Although they similarly showed a decrease in diagnoses across summer months, their chart review used date of presentation rather than date of symptom onset for association.

When examining possible contributing factors, some have suggested the role of Vitamin D and calcium homeostasis in the pathophysiology of BPPV [7–10,36]. Meghji et al., in their retrospective study of 339 patients across 4 years in Norwich, UK, demonstrated that BPPV incidence was significantly higher in the first half of the year (January to June) or what they considered "low Vitamin D months" [37]. (In that study high and low Vitamin D levels were based on previously reported monthly standards within the UK, and not from the study patients themselves). Despite recent increased interest in calcium homeostasis in the pathogenesis of BPPV, Karatas and colleagues performed a case-controlled study of 78 patients with BPPV and 78 matched controls finding no correlation between Vitamin D deficiency (and osteoporosis) and BPPV [11].

The present study suggests that the variable with the single strongest correlation between BPPV and seasonal variations is not sunlight or UV index, but rather barometric pressure. Such findings confirm the association first reported by Saeed et al. [14]. The strong correlation between BPPV and atmospheric pressure, coupled with the documented association between atmospheric pressure and Meniere's Disease [12,14], suggests a possible pathophysiologic link between the clinically observed coincidence of BPPV and Meniere's Disease. Endolymphatic hydrops has been suggested as the primary pathophysiologic mechanism of Meniere's Disease and previous studies have demonstrated the pressure-sensitive nature of vestibular receptors and the presence of a valve-like structure that regulates endolymphatic pressure in the inner ear [38–40]. The dysfunction of this valve prevents endolymphatic outflow and thus the regulation of inner ear pressure with changes in atmospheric pressure [41]. Transmission of this increased pressure throughout the inner ear space may lead to dislodgement of otoconia crystals leading to symptomatic BPPV and/or coexisting Meniere's Disease.

Alternatively, current thinking may point towards the association between BPPV and migraine, as both are subject to changes in barometric pressure. In 2015, Okuma and colleagues found that relatively small changes in atmospheric pressure (6–10 hPA) were sufficient to trigger attacks in patients with known migraine [42]. Likewise, Chu et al. identified 8266 patients with known migraines and an age matched 8266 patients without migraines via ICD codes through their national database. They found that over a ten-year period, individuals with migraines were 2.03 times more likely to develop BPPV [43]. The link between BPPV and migraines, coupled with the association between both processes and barometric pressure support a possible causative mechanism for BPPV. Nonetheless, stronger prospective epidemiologic studies are needed.

Additional variables explored in this study demonstrate statistically significant correlations, though none as strong as barometric pressure. Temperature, UV index, sunshine hours are all very closely related (higher in summer and lower in winter) and therefor nearly impossible to parse out individually. The correlations observed corroborate previously published associations, though it remains unclear if sunlight somehow offers some protective factor in BPPV pathogenesis [14,35,36]. Although the correlations with some allergens reach statistical significance, the relationship between BPPV and allergens deserves further study. The reasons why a significant positive relationship with mold pollen exists, but does not with grass pollen is likewise unclear as these two allergens generally peak at different times throughout the year. We suspect that although statistical significance was found, the correlations were relatively weak and the evidence insufficient to support an allergic etiology to BPPV. However, as previous studies demonstrated an association between allergens and Meniere's Disease, further study is warranted [33].

This study is among the first to investigate viral infection as a potential etiology of BPPV. In a previous study of 944 patients, Hanci et al. examined the potential role of infection in the etiology of BPPV. Examining viral serology levels after diagnosis, significantly higher titer values were found in patients diagnosed with BPPV when compared to controls. Furthermore, the study demonstrated seasonality and found the elevated titers primarily during spring and autumn months [44]. Our study used the influenza like illness (ILI) activity indicator as a method of monitoring upper respiratory infections but found no correlation between ILI activity and BPPV diagnoses, suggesting infection may not play a prominent role in BPPV pathogenesis. However, by using historical population data not matched directly to our patients, our findings may fall short when compared to the methods used by Hanci et al. in finding correlations.

While this study has strengths, it is not without its limitations. Variations in atmospheric measurements, allergen counts, and viral activity can occur from year to year. We attempted to obviate this by analyzing five years of data. In addition, some of the data sets collected were specific for the Richmond metropolitan area, though the practice catchment area is such that some (though few) patients may live throughout or beyond the state. Atmospheric pressure fluctuations were not examined on a day to day basis with the frequency of attacks, but rather in correlation to symptom onset. Further studies should aim to examine changes in attack frequency with day to day pressure fluctuations. As our practice is a tertiary/quaternary referral practice, longer time elapsed between onset of symptoms and office visit may lead to potential recall bias, though we attempted to mitigate this by eliminating hundreds of patients who could not accurately recall the onset of their symptoms. Furthermore, because patients were seen at a tertiary, rather than primary care setting, this cohort may include more cases of atypical BPPV. Therefore it may differ slightly from the patient population seen by a general otolaryngologist or primary care physician. Ultimately, caution must be exercised in interpreting correlation. A statistically significant coefficient of correlation does not imply any degree of causation over association, no matter how compelling the physiologic rationale.

5. Conclusion

While previous studies have shown a seasonal variation for BPPV diagnoses, this study is among the first to look specifically at variation in atmospheric pressure (among other atmospheric data) and the potential link with BPPV incidence. BPPV diagnoses were observed to be lowest during the summer months (June through August) with a moderate to strong, statistically significant positive correlation between BPPV diagnoses and barometric pressure observed throughout the year. Such a finding may shed insight into pathophysiology of BPPV and its observed coincidence with migraine.

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