# Drops in Barometric Pressure Are Associated with Deep Intracerebral Hemorrhage

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*Background and purpose:* The objective of this study is to assess the effects of changes in barometric pressure and outdoor temperature on the incidence of different subtypes of intracerebral hemorrhage (ICH). *Methods:* Consecutive patients with primary supratentorial ICH were included. All patients resided in the same geographic area. We compared patients with subcortical ICH to those with cortical ICH. Meteorological data were continuously accrued. High-risk ICH days were defined as those on which 1 or more patients with ICH were admitted and compared to non–high-risk days. We analyzed the relationship between spontaneous ICH location and averaged daily atmospheric pressures and temperatures. *Results:* We included 206 patients (147 with deep ICH and 59 with lobar ICH). Patients with deep ICH were younger ($P < .001$), more often had histories of diabetes, smoking and previous lacunar strokes, and were more often male ($P < .01$ for all). Drops in mean air pressure 2 days prior to the ictus were associated with deep but not lobar ICH ($P = .006$). Deep ICH clustered during February months in parallel with larger changes in barometric pressures ($P < .001$). *Conclusions:* Drops in daily atmospheric pressures were associated with deep but not cortical ICH, suggesting a link to hypertensive etiology. Changes in barometric pressures were also associated with higher monthly frequencies of ICH. **Key Words:** Barometric pressure—intracerebral hemorrhage—hypertension—acute stroke—stroke treatment—rapid improvement—thrombolysis—stroke outcomes.


## Introduction

Spontaneous intracerebral hemorrhage (SICH) is associated with very high morbidity and mortality rates. Previous epidemiological studies investigated the relationship between seasonal and meteorological variations and SICH, but the findings were inconsistent.[1-6] Some studies found a higher incidence of SICH in winter and spring,[5,6] but others failed to prove such a relationship.[1,2,4] One study found a higher incidence of SICH in winter and spring, specifically in patients with known hypertension and hypercholesterolemia.[7] Another study found that SICH rates were increased on days with higher air pressures, days during which a typhoon was approaching, and days with west or southwest wind.[3] However, previous studies did not examine whether these meteorological parameters affect different subtypes of SICH differently. Therefore, the current study investigated the effects of meteorological changes on different SICH locations and etiologies.

## Methods

Consecutive patients with supratentorial SICH admitted over 5 years (2009-2013) were studied. The

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institutional review board authorized approved the study (HMO-13-0633).

Patients admitted to our tertiary care university hospital were included. It is the only medical center designated as a stroke center and equipped with a stroke unit (out of 3 hospitals in the catchment area). Therefore, emergency medical services (EMS) in the catchment area are instructed to bring patients with suspected stroke to our center. Thus, while we cannot exclude the arrival of several patients to one of the other hospitals in the area, especially if they were not transferred by EMS, it is safe to assume that the majority of intracerebral hemorrhage (ICH) patients in the catchment area were admitted in our center.

All included patients resided in the same geographic area and were exposed to similar meteorological conditions (altitude 570-857 m, mean daily atmospheric pressure 922 ± 3 hPa and average daily temperature 21.5°C; 1 hPa = 1 mbar = 1/1000 atm). Patients transferred from other geographic regions, those with infratentorial SICH and those with secondary ICH etiology (e.g., tumor and arteriovenous malformation) were excluded.

We analyzed the relationship between SICH and average daily atmospheric air pressure and outdoor temperature. Meteorological data were obtained from 3 measurement stations in the catchment area allowing for more accurate data accrual. Measurements of barometric pressure and temperature were performed every 10 minutes from which averaged daily temperature and barometric pressure were calculated. High-risk SICH days were defined as those with 1 or more SICHs.

Patients with SICH were first divided according to ICH location: deep versus lobar. Selective patients in the latter group underwent susceptibility-weighted imaging (SWI) studies. Those with evidence of cortical-only microbleeds were defined as having probable cerebral amyloid angiopathy (CAA), while patients who had biopsy-proven CAA were classified as having definite CAA.[8] Patients with nonhypertensive cortical SICH who did undergo magnetic resonance imaging (MRI) or biopsy (e.g., due to contraindications for MRI) were categorized as having possible CAA.[8]

A second analysis was made according to SICH probable etiology. Patients with SICH were divided according to ICH etiology. Hypertensive SICH was defined as any deep or lobar SICH when the patient had a history of known hypertension and blood pressure recording of 160/100 or higher at presentation. Patients with lobar SICH and no history of hypertension or elevated BP at presentation were categorized as nonhypertensive.

Different sets of deltas of mean barometric pressure and outdoor temperature were calculated for each day over the study in relation to each of 4 previous days. The calculation formula was derived from the change in the mean daily barometric pressure between the intended day and the day of ICH onset. The same calculation formula was performed for outdoor temperature. The data set of each day interval was analyzed independently. We used hectopascal units for every change in the barometric pressure and degree Celsius for every change in the outdoor temperature.

Univariate comparisons between groups were performed with the Student *t*-test for continuous variables and with $\chi^2$ analysis for categorical variables. Comparison of mean weather changes between days with and without SICH was performed using *t*-test.

## Results

Over 5 years, 249 consecutive patients with supratentorial SICH were admitted. Of those, 206 patients sustained SICH in the same geographic area and were included (147 with deep ICH and 59 with lobar ICH). Reasons for exclusion were the occurrence of the ictus or patient residence outside the predefined geographic area (n = 26), infratentorial ICH (n = 16), and cavernoma discovered on follow-up MRI (n = 1).

Patients with deep SICH were younger (mean age 70.32 ± 12 versus 76.62 ± 10, $P < .001$) and more often were male (65% versus 37%, $P < .001$), had diabetes mellitus (38% versus 20%, $P = .01$), were smokers (27% versus 10%, $P = .007$), and had previous lacunar strokes (29% versus 10%, $P = .004$; Table 1).

Selective patients underwent SWI and several brain biopsies were performed during emergent decompressive craniectomies. In the lobar ICH group, all 13 SWI examinations performed fulfilled criteria for probable CAA and 2 biopsies showed CAA pathology.[8] Overall, 15 of 59 lobar patients had evidence for probable or definite CAA.

When analyzed according to etiology, 25 of 59 lobar ICH patients had both a history of hypertension and an elevated blood pressure higher than 160/100. None of these 25 patients had cortical microbleeds on MRI.

From the 26 SWI examinations of the deep SICH patients, only 2 examinations showed a mixed pattern of deep and lobar microbleeds, supporting a tentative diagnosis of hypertensive bleed in the vast majority of deep SICH.

Comparison of mean air pressure drops at 1, 2, 3, or 4 days prior to the ictus (between days without SICH and high-risk ICH days) was performed. Drops in barometric pressures 2 or 3 days prior to the ictus emerged as a statistically significant predictor of deep SICH ($P = .006$ and $P = .012$, respectively; Table 2). Moreover, in deep SICH, the mean drop in barometric pressure was significantly higher prior to days with multiple patients presenting with SICH ($P < .01$).

However, no correlations were identified between barometric changes and lobar ICH. Similarly, no correlation was identified between high-risk ICH days and either increased barometric pressures or changes in outdoor temperatures.