Prognostication of incidence and severity of ischemic stroke in hot dry climate from environmental and non-environmental predictors

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ABSTRACT Background: Recently, rapid fluctuations of ambient temperature were found to be associated with hospital admission for cardiovascular diseases in general and the ischemic stroke in particular. Objective: to test if climatic factors predict the incidence of stroke reliably and to study the predictive potential of risk factors for a stroke. Materials and methods: In a retrospective design, we studied 566 patients admitted to the stroke unit in 2016-2019. A distributed lag nonlinear model was used to explore immediate and delayed effects of weather and clinicodemographic risk factors on the stroke incidence. Supervised machine learning was used to build models predictive of the mRS score. We assessed model performance by calculating R², mean absolute error and root-mean-square error. Results and conclusions: We found a non-correlation between the weather parameters and statistics on stroke. The disparities in their trends lead us to investigate behind time effects of the environment with distributed lag models and a concordant impact of all the settings - with machine learning models. If categorized into two classes by severity and functional outcomes, the cases have few disparities in the weather parameters within a week before the stroke onset. In contrast to the groups classified by severity, the ones grouped by outcomes have a significant difference in age, nationality, the presence of background diseases and smoking status. We ranked environmental and individual risk factors by the information gain that they provide to the models. Inclusion of the weather parameters into the machine learning model predicting the mRS score provides a slight boost in performance.

INDEX TERMS Ethnicity, Ischemic stroke, Machine learning classification model, Middle East, Risk, Sex, Weather
I. INTRODUCTION

Stroke is one of the top 20 diseases contributing to life expectancy with disabilities. Over 7 million people die annually from cerebrovascular diseases worldwide. Half of them die of the ischemic stroke (IS) [1]. Arterial hypertension, atherosclerosis, atrial fibrillation, diabetes mellitus and smoking are commonly studied risk factors for IS [2], [3], [4], [5], [6], [7]. The time of the stroke onset and the meteorological factors refer to additional risk factors which have not been studied well. In recent years, there has been a rise in interest to the impact of meteorological factors on public health because of the climate changes, observed and projected [8], [9], [10].

Ambient temperature as a risk factor of IS. The effect of temperature on the population has received a particular attention of researchers [10]. Studies on its delayed effect (up to 7 days) have evidenced an impact of extreme cold weather on the risk of IS [11]. Relevant findings for hot dry climate are missing. Studies have provided discrepant findings onto whether an increase [12]–[14] or decrease [15]–[17] in the air temperature triggers IS.

It is challenging to elucidate pathogenic mechanisms of extreme heat or cold because of their cumulative effect and a lag of response to them [18], [19]. Furthermore, the perception of temperature changes according to relative humidity and wind power. Socioeconomic factors may also interact with the weather to affect the prevalence of IS. It is also necessary to consider the financial availability of air conditioners or heaters. Today the information on this issue is missing [20].

Temperature variance. Large-scale shifts in the weather patterns may put a burden on society as individuals are maladjusted to them. This increases the occurrence of cardiovascular disasters [21] and risk of mortality [22]. The temperature variance also has attracted particular attention of epidemiologists. They found that rapid fluctuations of ambient temperature are positively associated with hospital admission for cardiovascular diseases in general [23] and for IS in particular [24].

Relative humidity (RH) as a risk factor of IS. RH changes the thermal conductivity of the air and thus contributes to the impact of ambient temperature [25]. An association between IS and ambient temperature is shown to be stronger on the days with high RH levels [16]. There is little evidence on the relationship of low partial pressure of oxygen and high RH levels with IS risk in summer [26]. Some authors examined the effects of changes in RH without considering other weather parameters. A meta-analysis of such studies done in Switzerland, Portugal, Russia, South Korea and Taiwan showed no association of the occurrence of IS with air humidity [27]. In support of these findings, a study conducted on different age groups in Slovenia did not show significant correlation [28]. So, the effects of RH, considered either apart or in combination with other meteorological findings, remain disputable for different geographic locations.

Atmospheric pressure (AP) as a risk factor of IS. A supposed effect of AP on IS is that it exerts some stress on an atherosclerotic plaque and may contribute to its rupture [29]. Researchers have reported conflicting findings: while some studies did not find a significant relationship between AP changes and the IS occurrence [27], [28], [30] the others showed that a drop in AP increased the IS incidence within the next 24 hours [31]. This IS rate was consistent with the maximal and minimal values of AP [32]. Unfortunately, these data are not fully reliable. First, the authors carried out single center-based studies limited to a specific climatic zone. Second, the number of patients was also limited. Third, they did not take into consideration that the time of the IS onset may not coincide with hospitalization.

Wind speed (WS) as a risk factor of IS. The impact of wind speed on IS has not been studied well. Some authors collected facts that the number of IS cases increases when the maximum WS is low 3 days before the stroke [31]. An exploration found an association between the increased WS and a high prevalence of IS in the elderly [33]. Some authors did not consider confounding risk factors. In another observation, IS count was associated with the WS range and wind chill [34]. A later study justified an effect of age, sex, and smoking status on the IS morbidity [34]. Some scientists analysed changes in the air masses due to the wind and justified that dry polar air was associated with a lower IS risk [35]. Further studies are required to get an insight if the weather parameters interact with individual risk factors to influence the IS incidence in distinct geographic locations.

II. OBJECTIVES

We wanted to test if climatic factors predict the incidence of IS reliably and to study the predictive potential of IS risk factors. The hypothesis of the study was that harsh desert climate of the UAE is an additional environmental IS risk factor, worsening the disease course and outcomes. The primary objective was to estimate the associations of the IS incidence with weather parameters and clinicodemographic risk factors in the desert climate. We explored if climatic factors contribute to IS severity (second objective). We also built a regression model to predict the outcome of IS at discharge (third objective).

III. MATERIALS AND METHODS

A. DATASET DESCRIPTION

The data on de-identified IS cases was collected from the hospital information system in the city of Al Ain, Abu Dhabi Emirate. The dataset was labeled the PRAS_IS dataset after the project title “Prognostication of Recovery from Acute Stroke”. The following weather parameters were obtained from the National Oceanic and Atmospheric Administration: daily ambient temperature (TEMP), relative humidity (RH), wind speed (WDSP) and AP. The number of days between the stroke onset and a given weather event was measured and expressed by a number after the acronym, e.g., WDSP7 is the wind speed 7 days before the stroke onset. We
also calculated the humidity index (humidex) from ambient temperature and RH. From these data, we calculated the derivative parameters characterizing the weather. The daily change was calculated for air temperature (TDIF), pressure (PDIF), wind speed (WDIF), relative humidity (RHDIF) and humidex (HDIF).

We also analyzed the following possible clinicodemographic predictors of the IS incidence and outcomes: age (DEMOGRAPHY_age), sex (DEMOGRAPHY_sex), ethnicity (DEMOGRAPHY_ethnicity), body mass index (BMI), history of a stroke (History_OldStroke), history of smoking (History_Smoking), current diabetes mellitus (History_DM), arterial hypertension (History_HyperTension), ischemic heart disease (History_IschemicHeartDisease), arterial hypertension (History_ArterFibrillation), and hyperlipidemia (History_HyperLipidaemia), year of the stroke onset (year), day of the onset (ONSET_Date), time of day at the onset (ONSET_LKW_time), National Institutes of Health Stroke Scale (NIHSS) score at hospital admission (Screening_tools_NIHSS), final diagnosis (Diagnosis_Final), and mRS at discharge (Discharge_Plan_Modified_Rankin_Score). To classify the cases, we added DEMOGRAPHY_agerange as a categorical variable (age groups 18–44, 45–59, 60–74, 75–89 and >90 years).

**B. STUDY DESIGN AND SUBJECTS**

The primary outcome was the number of daily emergency hospital admissions for IS. We analyzed the records of the IS patients admitted to the stroke unit of Al Ain Hospital from January 1, 2016 to December 31, 2019 (tertiary level care). The final study cohort included 566 patients (see Table I). In accordance with the national healthcare standards, all the patients were examined by a neurologist; underwent brain CT, a complete etiologic review and other tests to fulfill the IS diagnostic criteria. The inclusion criteria were absence of intracranial bleeding on CT on admission and conformation of IS with diffusion restriction found on MRI [163 in International Classification of Diseases (ICD-10) and 434.91 in ICD-9].

**C. METHODOLOGY**

To examine associations between the IS incidence and the weather parameters, we constructed plots (Fig. 1) representing the regional circannual weather changes and IS morbidity rates. We also examined the immediate and delayed effects of the weather and its daily changes on the IS incidence with distributed lag nonlinear model (DLNM) analysis (Fig. 2).

Working on the second objective, we aimed to find out how clinicodemographic and the weather factors impact IS severity. We conducted a comparative analysis of the groups classified by NIHSS score with a threshold of 4 (362 minor vs 204 moderate and severe cases) and by mRS with a threshold of 2 (371 absent or slight disability vs 195 cases of moderate to severe disability and deaths). As the variables had non-normal distribution, we utilized non-parametric tests. The relationships between the continuous features were assessed with Kruskal-Wallis test.

The idea of the third objective was to build a machine learning model prognosticating the IS early outcomes (mRS score). By selecting the top 20 informative features to train the regression model in the 10-fold cross-validation technique, we highlighted the importance of the weather conditions in the ethyopathogenesis. We compared the strength of associations between the input variables and the values of NIHSS and mRS with Pearson’s correlation. Fig. 3A-B show the ranked variables. With MAE, RMSE and R², we compared the performance of the prediction from different sets of predictors (see Table V). For details on the models see Supplemental Material.

**D. STATISTICAL ANALYSIS**

We calculated descriptive statistics for the groups with different levels of severity on admission and outcomes at discharge in a standard way. The discontinuous variables were presented as Mean±SD, while for the categorical ones the percentage was calculated. We resorted to Pearson’s correlation to show the associations between the factors. This allowed us to reduce the “noise” from useless variables, thereby improving the model outcome metrics with the top valuable features: "NIHSS_score", "DEMOGRAPHY_age", "Lab_Investigation_C-reactive protein", "History_OldStroke", "History_DM", "History_IschemicHeartDisease", "History_HyperTension", "DEMOGRAPHY_nationality", "History_ArterFibrillation", "WDIF3", "RH", "Lab_Investigation_Creatinine", "TDIF4", "RH1", "WDSP2", "TDIF5", "isMultiple", "History_HyperLypidAemia", "WDSP1", "Hemorrhagic transformation".
FIGURE 1. Plots of average monthly air temperature, average daily changes, mean relative humidity, and incidence of ischemic stroke by month.
TABLE I. Incidence of ischemic stroke in Al Ain stratified by sex and age group

| Variable       | Total number | Mean number per annum | Mean per 100,000 people | City population |
|----------------|--------------|-----------------------|-------------------------|-----------------|
| IS cases       |              |                       |                         |                 |
| female gender  | 125          | 31.25                 | 25.76                   | 249'940         |
| male gender    | 441          | 110.25                | 139.86                  | 315'310         |
| totally        | **566**      | **141.5**             | **100.13**              | **565'250**     |
| in 2016        | 135          | -                     | 25.76                   | 524'000         |
| in 2017        | 113          | -                     | 20.40                   | 554'000         |
| in 2018        | 146          | -                     | 24.96                   | 585'000         |
| in 2019        | 172          | -                     | 28.76                   | 598'000         |
| Age groups     |              |                       |                         |                 |
| 0-34 years     | 21           | 5.25                  | 5.40                    | 389'057         |
| 35-44 years    | 86           | 21.50                 | 82.22                   | 104'595         |
| 45-54 years    | 160          | 40.00                 | 330.29                  | 48'443          |
| 55-64 years    | 139          | 34.75                 | 827.09                  | 16'806          |
| 65-74 years    | 95           | 23.75                 | 2001.69                 | 4'746           |
| ≥75 years      | 65           | 16.25                 | 4054.90                 | 1'603           |

TABLE II. Associations between meteorological factors and ischemic stroke incidence

| Variable                | Mean ± SD | Median [IQR] | Min - Max | Correlation with IS incidence | p-value |
|-------------------------|-----------|--------------|-----------|-------------------------------|---------|
| Temperature, °C         | absolute  | 29.36 ± 7.146| 30.389    | -0.003 ± 1.59                | -0.03   |
|                        | daily change | -0.003 ± 1.59| 0.056     | -0.722 ± 0.889               | 0.004   |
| Air pressure, mbar      | absolute  | 979.45 ± 7.007| 980.5     | -0.002 ± 1.406               | 0.014   |
|                        | daily change | -0.002 ± 1.406| 0         | -0.8 ± 0.7                   | 0.018   |
| Wind speed, knot        | absolute  | 7.745 ± 1.952| 7.5       | -0.001 ± 1.885               | 0.009   |
|                        | daily change | -0.001 ± 1.885| 7.5       | 6.5 ± 8.7                    | 0.719   |
| Relative humidity, %    | absolute  | 37.869 ± 14.939| 36.216    | -0.022 ± 9.137               | 0.044   |
|                        | daily change | -0.022 ± 9.137| 0.067     | 5.244 ± 5.018                | 0.461   |
| Humindex, °C            | absolute  | 32.081 ± 8.476| 32.544    | -0.002 ± 1.847               | 0.019   |
|                        | daily change | -0.002 ± 1.847| 0.037     | -0.895 ± 1.093               | 0.799   |

B. IMPACT OF WEATHER PARAMETERS AND INDIVIDUAL RISK FACTORS ON STROKE SEVERITY

Fig. 2 displays the immediate and delayed outcomes of ambient temperature, perceived temperature (humidex), air pressure, wind speed and their daily changes in terms of the IS risk. Contour plot 2A shows that a decrease in the risk follows extremely low and especially high levels of ambient temperatures with a 3- to 6-day lag.

From Fig. 2B, the risk reduces for a day after considerable changes of the air temperature. There is a rise in risk with a 3- to 5-day lag after a temperature drop by -5°C and more. This may reflect maladjustment of the population living in the desert climate to a dramatic drop in ambient temperature. Both a rise in humidex above 35°C leads to a decreased IS risk, and the effect lasts 3-4 days. Negative changes in humidex below -5°C/day reduce the incidence of IS up to 3 days. Conversely, the positive changes in humidex result in the opposite trend lasting a day (see Fig. 2C-D). A week after the day of exposure IS risk falls back to the baseline for the major weather events. A decline in RH fosters a decreased IS risk values and vice versa.

An increase in air pressure above 980 mbar is associated with a slight rise in IS risk on the day of exposure (see Fig. 2E-F). From day 1 to 7 after the event, we see the opposite tendency. Both high and low absolute values of WS have a positive impact on the number of IS cases. The DLNM diagram for WD looks similar to the one on TD (see Fig. 2G-H). Fig. 2I-J present data for relative humidity.
|TABLE III. Comparison of clinidemographic parameters among ischemic stroke cases classified by severity and early outcomes |
|---|---|---|---|---|---|---|---|---|---|
| | Total | n=566 | NIHSS Score | modified Ranking Score |
| | | | n₁=362(63.96%) | n₂=204(36.04%) | P₁<2 | n₁=371(65.55%) | n₂=195(34.45%) | P₁<2 |
| | Year | | | | | | | | |
|2016 | 135(23.85%) | 75(20.72%) | 60(29.41%) | 0.120496 | 82(22.1%) | 53(27.18%) | 0.046502 |
|2017 | 113(19.96%) | 78(23.51%) | 35(17.16%) | 65(17.52%) | 48(24.62%) | 0.000597 |
|2018 | 166(25.8%) | 96(26.52%) | 50(24.51%) | 103(27.76%) | 43(22.05%) | 0.000293 |
|2019 | 172(30.39%) | 113(31.22%) | 59(29.82%) | 121(32.61%) | 51(26.15%) | 0.000194 |
|NIHSS score | mRS score | 1.62±1.36 | 9.68±4.94 | 1.75±88 | 3.11±3.88 | 7.21±5.98 | 1.26±20 |
|2016 | 1.41±1.34 | 2.85±1.55 | 3.89±24 | 0.9±0.72 | 3.89±0.62 | 2.63±90 |
| | | | | | | | | |
|NIHSS group | modified Ranking Score | 0.23±2.48 | 8.35±0.23 | 6.2±3.45 | 6.23±3.48 | 51(26.15%) | 0.000194 |
|low | high | 371(65.55%) | 39(6.89%) | 96(26.52%) | 94(31.07%) | 59(30.26%) | 25(12.82%) | 0.000194 |
|0.23±2.48 | 8.35±0.23 | 6.2±3.45 | 6.23±3.48 | 51(26.15%) | 0.000194 |
| | | | | | | | | |
|MRS group | modified Ranking Score | 0.23±2.48 | 8.35±0.23 | 6.2±3.45 | 6.23±3.48 | 51(26.15%) | 0.000194 |
|low | high | 371(65.55%) | 39(6.89%) | 96(26.52%) | 94(31.07%) | 59(30.26%) | 25(12.82%) | 0.000194 |
|0.23±2.48 | 8.35±0.23 | 6.2±3.45 | 6.23±3.48 | 51(26.15%) | 0.000194 |

|Age, years | | | | | | | | |
|BMI | | | | | | | | |
|362(63.96%) | | 204(36.04%) | | | | | | |
|NIHSS | score | modified Ranking Score | low | high | 371(65.55%) | 39(6.89%) | 96(26.52%) | 94(31.07%) | 59(30.26%) | 25(12.82%) | 0.000194 |
|low | high | 371(65.55%) | 39(6.89%) | 96(26.52%) | 94(31.07%) | 59(30.26%) | 25(12.82%) | 0.000194 |
|0.23±2.48 | 8.35±0.23 | 6.2±3.45 | 6.23±3.48 | 51(26.15%) | 0.000194 |

|Sex | | | | | | | | |
|male | | | | | | | | |
|female | | | | | | | | |
|364(63.65%) | | 38(6.89%) | | | | | | |
|0.23±2.48 | 8.35±0.23 | 6.2±3.45 | 6.23±3.48 | 51(26.15%) | 0.000194 |

|Nationality | | | | | | | | |
|Asian | | | | | | | | |
|Arab | | | | | | | | |
|UAE | | | | | | | | |
|63(11.3%) | | 38(6.89%) | | | | | | |
|0.23±2.48 | 8.35±0.23 | 6.2±3.45 | 6.23±3.48 | 51(26.15%) | 0.000194 |

|Smoking | | | | | | | | |
|cigarette | | | | | | | | |
|44.9±14.9 | | 30.1±14.9 | | | | | | |
|0.23±2.48 | 8.35±0.23 | 6.2±3.45 | 6.23±3.48 | 51(26.15%) | 0.000194 |

|Old Stroke | | | | | | | | |
|Diabetes mellitus | | | | | | | | |
|Hypertension | | | | | | | | |
|Ischemic heart disease | | | | | | | | |
|Arterial libration | | | | | | | | |
|Hyperlipidemia | | | | | | | | |
|Smoking | | | | | | | | |
|Tropinone | | | | | | | | |
|C-reactive protein | | | | | | | | |
|Total cholesterol | | | | | | | | |
|Low density lipoprotein | | | | | | | | |
|Atherogenic index | | | | | | | | |
|POC: Random blood sugar | | | | | | | | |
|Creatinine | | | | | | | | |
|MBR FINDINGS | | | | | | | | |
|Hemorrhagic transformation | | | | | | | | |
|Lacunar stroke | | | | | | | | |
|Multiple lesions | | | | | | | | |
|Side of lesion | | | | | | | | |
|Vascular territory | | | | | | | | |

*If the variance of a variable differs significantly (p < 0.05) from other cases taken together, its Mean ± SD is marked with an asterisk. The significant differences between cohorts are marked in bold.*
FIGURE 2. Contour exposure–lag-response plots and three-dimensional exposure–lag-response plots of hemorrhagic stroke risk versus ambient temperature (a, b), perceived temperature (c, d), atmosphere pressure (e, f), wind speed (g, h), relative humidity (i, j) and daily changes in them (lag = 7 days)

If categorized into two classes by NIHSS and mRS values, the cases have few disparities in the weather parameters within a week before the stroke onset (see Table IV). Two classes of NIHSS values differ substantially in RH two days before IS (p = 0.02 - 0.04), and two classes of mRS values - in WS on the 4-th and 7-th day (p = 0.01 - 0.04), and in WD the day before (p = 0.016 - 0.013).

C. EARLY OUTCOMES OF STROKE

Fig. 3 shows environmental and individual risk factors ranked by the information gain they provide to the model predicting NIHSS value. The top valuable predictors are background diseases: arterial fibrillation, hypertension, diabetes mellitus and smoking. They are followed by the weather parameters and the Cat2Vec-encoded data on the onset of the stroke in the calendar year [cos(day of year), sin(month), sin(day of year)]. Hyperlipidemia is the top-rank biochemical predictor as it is a marker of atherosclerosis.
**TABLE IV. Comparison of weather parameters on days preceding ischemic stroke of distinct severity and early outcomes**

| Days before stroke | Total n=566 | NIHSS Score | modified Ranking Score |
|--------------------|------------|-------------|------------------------|
|                    | n ≤ 36 (23.98%) | n > 36: 204 (36.04%) | P1 = 2 | mRS ≤ 2: 371 (65.55%) | mRS > 2: n=185 (34.45%) | P3 = 4 |
| 0                  | 29 (7.2% ±0.36) | 30.02±4.75 | 29.12±6.99 | 0.071713 | 29.58±6.08 | 29.92±6.86 | 0.304969 |
| 1                  | 29 (6.55% ±0.36) | 29.96±7.17 | 29.08±7.02 | 0.084130 | 29.53±7.19 | 29.87±6.98 | 0.27604 |
| 2                  | 29 (6.65% ±0.36) | 29.91±7.1 | 29.21±6.92 | 0.13143 | 29.51±7.13 | 29.94±6.86 | 0.244159 |
| 3                  | 29 (6.53% ±0.36) | 27.73±19 | 28.01±16.99 | 0.096489 | 29.28±17.35 | 29.67±17.25 | 0.206273 |
| 4                  | 29 (7.42% ±0.36) | 28.97±17.3 | 28.66±17.08 | 0.05725 | 29.18±17.27 | 29.78±17.27 | 0.351478 |
| 5                  | 29 (6.22% ±0.36) | 29.72±17.3 | 29.06±26.97 | 0.15488 | 29.34±27.24 | 29.76±27.77 | 0.34864 |
| 6                  | 29 (6.22% ±0.36) | 29.72±17.3 | 28.89±26.97 | 0.10553 | 29.71±27.32 | 29.66±26.86 | 0.28464 |
| 7                  | 29 (7.55% ±0.36) | 29.54±17.8 | 28.44±26.32 | 0.013111 | 29.75±27.62 | 29.91±27.62 | 0.306852 |

**WEATHER PARAMETERS WITHIN A WEEK BEFORE STROKE**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Temperature, °C | 29.72±0.36 | 0.01 | 29.12±0.36 |

**Atmospheric pressure, mbar**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Pressure | 29.72±0.36 | 0.01 | 29.12±0.36 |

**DAILY CHANGES OF WEATHER WITHIN THE SAME WEEK**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Temperature, °C | 29.72±0.36 | 0.01 | 29.12±0.36 |

**Relative humidity, %**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Humidity | 29.72±0.36 | 0.01 | 29.12±0.36 |

**DAILY CHANGES OF WEATHER WITHIN THE SAME WEEK**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Temperature, °C | 29.72±0.36 | 0.01 | 29.12±0.36 |

**Relative humidity, %**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Humidity | 29.72±0.36 | 0.01 | 29.12±0.36 |

**DAILY CHANGES OF WEATHER WITHIN THE SAME WEEK**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Temperature, °C | 29.72±0.36 | 0.01 | 29.12±0.36 |

**Relative humidity, %**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Humidity | 29.72±0.36 | 0.01 | 29.12±0.36 |

**DAILY CHANGES OF WEATHER WITHIN THE SAME WEEK**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Temperature, °C | 29.72±0.36 | 0.01 | 29.12±0.36 |

**Relative humidity, %**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Humidity | 29.72±0.36 | 0.01 | 29.12±0.36 |

**DAILY CHANGES OF WEATHER WITHIN THE SAME WEEK**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Temperature, °C | 29.72±0.36 | 0.01 | 29.12±0.36 |

**Relative humidity, %**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Humidity | 29.72±0.36 | 0.01 | 29.12±0.36 |

**DAILY CHANGES OF WEATHER WITHIN THE SAME WEEK**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Temperature, °C | 29.72±0.36 | 0.01 | 29.12±0.36 |

**Relative humidity, %**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Humidity | 29.72±0.36 | 0.01 | 29.12±0.36 |

**DAILY CHANGES OF WEATHER WITHIN THE SAME WEEK**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Temperature, °C | 29.72±0.36 | 0.01 | 29.12±0.36 |

**Relative humidity, %**

| Parameter | Value | Standard Deviation | Reference |
|-----------|-------|--------------------|-----------|
| Humidity | 29.72±0.36 | 0.01 | 29.12±0.36 |
A negative association of arterial hypertension with IS severity can be explained by the medications prescribed. The total number of background diseases is positively associated with the metric of early outcomes. However, some background diseases may remain misdiagnosed and, therefore, not treated.

To predict the early IS outcomes from different features, we employed six conventional ML regressors (SVM non-linear, Gradient Boosting, AdaBoost, Random Forest, Lasso, and K Nearest Neighbours). The models were trained until convergence. To generalize our solution to the true-rate error, the models were trained in the ten-fold cross-validation technique. The performance of the regression models was expressed in the mean absolute error (MAE), root mean square error (RMSE) and coefficient of determination (R2). We reported the performance metrics averaged over 10 folds. The Python scikit-learn library v. 0.24.2 was used to implement ML models.

Fig. 4 shows correlation feature selection for the regression model trained to forecast mRS value. The model for calculating mRS incorporates the aforementioned predictors of NIHSS and the data received on admission. The top valuable individual risk factors are severity on admission, age, the history of an old stroke. The weather parameters also have a high-performance value in the model. To judge on the additive value of the parameters for the total performance of ML, see Table V. For all regressors, except AdaBoost, the inclusion of the weather estimates improved the accuracy of the final model. After performing feature selection, we received the most accurate prediction with Random Forest algorithm.

V. DISCUSSION
A. ASSOCIATION OF STROKE INCIDENCE WITH WEATHER AND INDIVIDUAL RISK FACTORS
1) Impact of weather on prevalence of IS
The relation between the weather changes and IS has been studied in many papers, but inconsistency in the findings leads to further debate. This inconsistency might rise out of discrepancies among studies in design, methodology, population susceptibility, climate and geographical regions. Similarly to other papers [30], [37], [38] we failed to find a straight-forward correlation between the meteorological factors and the incidence of IS. On the other hand, unlike other papers we did not find either a non-correlation with the relative humidity [15], [27] or a positive association of the IS incidence with temperature variations [19], [39] and barometric pressure [40], [41].

Pathophysiological links between the weather and IS have been discussed recently. Hot weather may initiate IS by increasing blood viscosity, the platelets count and the level of serum cholesterol [42], [43], while cold seasons induce IS because of peripheral vasospasm and an increased blood pressure [44]. Heat stroke is a special case of brain ischemia which typically happens due to exercising in hot environment [45].

A high level of humidity in a hot climate may cause dehydration, which increases the risk of thrombosis [46]. Analogously, in these conditions an association between cold temperature and IS morbidity is also strong [16].

Changes in AP may exert stress on atherosclerotic plaques up to rupturing them [29]. A study found an association between the incidence of non-lacunar IS and the daily decrease in AP [31], [47]. We observed the opposite tendency and found that the IS occurrence increased after the moderate changes of AP within the previous day.

Extreme weather conditions may initiate stress that induces heart arrhythmia and contributes to the formation of thrombi. Additional research is required to confirm and get a new insight into the relationship between IS and the meteorological factors at diverse geographic locations [32].

2) Individual risk factors for IS
Age, sex, obesity, smoking, atherosclerosis, hypertension, low physical activity, atrial fibrillation and diabetes mellitus are the known risk factors for IS [48], [49]. Many studies show that a sedentary lifestyle, a low physical activity, smoking and obesity [50] lead to atherosclerosis, arterial hypertension [51] and diabetes mellitus [52] which are the main risk factors for IS, especially in the young generation [53], [54]. IS morbidity is higher in men [55]–[57]. Many authors believe that the risk of IS doubles each decade after the pivotal age of 55 [58], [59]. An alternative opinion is that the tendency starts at an early age [60], [61]. Particularly, our data suggest that from 45 to 54 the IS morbidity is four times higher than from 35 to 44 (330.29 vs 82.22 per 1000). Starting from 55 years of age, the risk of IS doubles compared to the preceding 10-year interval. The factors that account for the rising IS incidence in young adults - smoking, alcohol and drug abuse, a non-balanced diet promoting atherosclerosis, diabetes mellitus (DM) and obesity - are identical to the risks of developing cardiovascular complications of the disease [6], [62]–[64]. Genetic disorders contributing to cardiovascular pathologies improve the identification of IS at all ages including young adulthood [65]. A high number of pregnancies and childbirths may make young women vulnerable to IS [66], [67]. It is debatable if estrogen in birth-control pills account for IS in young women [68], [69]. Recent facts tell us that the dosage of estrogen is too small to promote IS [70]–[72].

3) Interaction between weather and individual risk factors for IS
Little is known on the interaction between the environmental and individual risk factors. For example, obesity may account for the elevated noradrenaline level which is a risk factor for IS [73]. Researchers observe a pick of noradrenaline and blood pressure in obese men in low temperature conditions [74]. An exposure to low temperatures may increase the blood and pulse pressure [75]. Patients with hypertension and diabetes mellitus are more vulnerable
FIGURE 3. NIHSS score predictors ranked with correlation feature selection method in 10-fold cross-validation technique.

B. ASSOCIATION OF STROKE SEVERITY WITH INDIVIDUAL AND ENVIRONMENTAL RISK FACTORS

Table III and Fig. 3A shows a strong association between individual risk factors and disease severity. From our data, the levels of C-reactive protein, troponin I, glucose, hyperlipidemia and INR are the top valuable laboratory factors reflective of the level of IS severity. These results correlate with the findings of other authors (see Section V-B2).

There was no evident difference in ethnicity of the...
patients stratified with regard to severity (p=0.23). However, the outcomes of IS among the UAE-Arabs were much worse, and in Asians - notably more favourable than in other nations (p<0.001). Presumably, economy-related lifestyle habits rather than genetic factors account for the difference.

Some studies have shown that low temperature may contribute to high IS severity [37], [78]. But in our work, change in RH two consequent days before IS was a predictor of severe IS. Maybe this factor exerts a cumulative effect.

1) Stroke severity and background diseases

Arterial hypertension may cause IS [79], [80], and affect its severity. Hypertension may influence endothelial dysfunction and large artery stiffness that transmits the pulsatile flow to the cerebral microcirculation [81], [82]. Because of vasospasm, hypertension may initiate lacunar IS [83]–[86].

Atrial fibrillation is a strong predictor of IS severity as seen from our data. This matches the results of other studies [87]–[89].

FIGURE 4. mRS score predictors ranked with correlation feature selection method in 10-fold cross-validation technique.
TABLE V. Performance of regression models for predicting early outcomes of ischemic stroke from different features

| Regressor         | Non-weather features |         | All features |         | Selected features* |
|-------------------|----------------------|---------|--------------|---------|--------------------|
|                   | MAE                  | RMSE    | R²           | MAE     | RMSE    | R²     | MAE     | RMSE    | R²     |
| Gradient Boosting | 1.132 ± 0.1100      | 0.181   |              | 1.099   | 1.3857  | 0.213  | 1.046   | 1.3258  | 0.281  |
| AdaBoost          | 1.139 ± 0.3879      | 0.193   |              | 1.177   | 1.3901  | 0.195  | 1.248   | 1.4358  | 0.149  |
| K nearest neighbours | 1.369 ± 0.6295     | -0.082  |              | 1.250   | 1.5171  | 0.056  | 1.156   | 1.4417  | 0.141  |
| Lasso             | 1.159 ± 1.3775      | 0.226   |              | 1.132   | 1.3580  | 0.246  | 1.075   | 1.3216  | 0.280  |
| Random Forest     | 1.106 ± 1.3666      | 0.232   |              | 1.071   | 1.3407  | 0.258  | 1.046   | 1.3166  | 0.285  |
| SVR non-linear    | 1.311 ± 1.5421      | 0.036   |              | 1.237   | 1.5271  | 0.052  | 1.207   | 1.6367  | -0.101 |
| Mean ± std        | 1.2 ± 0.11 ± 0.14 ± 0.12 | 1.16 ± 0.07 ± 0.17 ± 0.08 | 1.13 ± 0.08 ± 0.11 ± 0.17 ± 0.14 |

*Top 20 listed features were identified from correlation feature selection method

2) Laboratory markers of stroke severity

**C-reactive protein** (CRP) is a known marker of an early diagnosis of stroke, its recurrence and severity [90], [91]. A permanent release of the inflammatory mediator occurs because of a persistent irritation of the blood vessel wall by an atherosclerotic plaque. Since the level of CRP reflects atherosclerotic changes of the vessel wall, its high values may be indicative of an atherosclerotic embolus in a brain vessel, development of IS and stroke severity [92].

**Troponin I** is also a biomarker of IS severity, the poor outcomes and a coincidence of IS and the myocardial infarction (MI). Many studies have found a rising level of troponin I in the patients with IS who had neither heart nor kidney failure [93]–[97]. Commonly, the elevation of troponin I in IS does not exceed the level of 2 ng/mL [95]. As an explanation, some authors suggest an association of the elevated level of circulating epinephrine with the increased concentration of serum troponin I in IS [98]. Other studies failed to confirm a link between IS and troponin I [98], [99].

**International normalized ratio** (INR) is an important indicator for monitoring blood clotting in the patients taking anticoagulants for the secondary prevention of IS after an old stroke and transitory ischemic attack or atrial fibrillation. We check the level of INR to control thrombolytic therapy and prevent secondary brain hemorrhage or hemorrhagic transformation. A study of prediagnosis use of warfarin demonstrated an inverse relation between admission INR and volumes of acute IS lesion [100]. In our study the analysis of INR is challenging as the information on the prediagnosis use of blood-thinning medication was missing.

**The blood glucose level** may reflect severity of macro and micro-vascular IS lesions in the patients with DM [101]. As the continuous variables are more accurate than the categorical ones, hyperglycemia on admission indicates IS severity more reliably than the history of DM. Stress increases the level of serum glucose and the area of cerebral ischemia thus worsening the functional outcome [102], [103]. Furthermore, hyperglycemia can activate oxidative stress and damage neurons [102], [103].

3) Vascular territory occlusion and stroke severity

Typically, IS severity depends on the location of brain damage caused by cardioembolic occlusion. Cerebral herniation and concomitant occlusion of several vessels also increase IS severity [104]. Evidently, the larger brain vessel is obstructed the more severe the stroke will be, as small collateral vessels may fail to substitute the blood supply. Cases with MCA stenosis are severe with a high likelihood of stroke-in-evolution and severe disability. At the same time, stenosis of MCA and extracranial internal carotid artery (ICA) has a worse functional outcome and a graver risk of stroke recurrence or death [105].

C. COMBINED EFFECT OF CLINICODEMOGRAPHIC FACTORS AND WEATHER PARAMETERS ON EARLY OUTCOME OF STROKE

Interestingly, age and an old stroke as non-modifiable risk factors and the atherogenic index as modifiable risk are much stronger associated with the IS early outcomes than with its severity. In part, this matches the results obtained by other authors (see Sections V-C1-V-C3)

1) Individual risk factors for unfavourable stroke outcomes

A recent study justified smoking, age and NIHSS score on admission as reliable predictors of mRS score at discharge [106]. Another study showed no link between median mRS scores before the onset and at discharge in smoking patients [107]. The high NIHSS at discharge may indicate a poor prognosis for the patient [19]. In our study we found NIHSS to be a strong predictor of mRs.

Thrombolized patients with IS and AF have worse outcome at discharge, a higher recurrence rate compared to non-AF patients [87], [108]. This assumption requires further study.

Physicians should also consider the impact of DM and hyperglycemia on IS outcomes: patients with diabetes have a higher mortality rate, more severe disability and slower recovery [109], [110]. Perhaps, this is due to the fact that acute IS and stress stimulate the hypothalamus–pituitary–adrenal axis as well as the sympathetic nervous system leading to release of stress hormones, including cortisol and catecholamines, which increase glucose levels [111].
From our data, the strongest predictors of IS prognosis are the value of NIHSS on admission, age, the history of an old stroke and DM as well as the smoking status. The weather parameters also contribute to the IS outcomes.

2) Biochemical markers of unfavourable stroke outcomes

Our study justifies the level of CPR, troponin I, creatinine and atherogenic index (AG) as predictors of the early IS outcomes.

CRP. Our findings are compliant with a study that stated the CRP threshold level for predicting survival after IS to be 10.1 mg/L [112]. Other studies found a link between an increased CRP level and the unfavourable long-term outcomes [113].

Troponin I is another marker of the IS outcomes. Its high level is related to increased stroke scale scores at discharge [114], [115].

The end products of the protein metabolism, such as the level of creatinine and the blood urea nitrogen to creatinine ratio, are also reflective of the poor IS outcomes [116]. Authors suggest that their ratio rises as a consequence of dehydration [117], [118] which could impact the delivery of oxygen to the brain thus worsening the outcomes. There is a positive association of the creatinine level with NIHSS and mRS scores in our study.

Atherogenic index (AI), when elevated, is a marker of early atherosclerosis [119], [120]. Patients with IS may suffer from intracranial atherosclerosis that worsens IS severity and outcomes [121], [122]. In our study, hyperlipidemia and AI are positively correlated with NIHSS on admission. Contrarily, there is a negative association of the total cholesterol and AI with the mRS at discharge. The association of lipids and lipid ratios with stroke is an issue of ongoing research and discussion [123]. Instead of using serum AI, recent studies suggest AI of plasma as a new predictive biomarker for cardiovascular illnesses [124]. Some researchers found an association between atherogenic dyslipidemia and recurrent stroke risk in patients with different IS subtypes [125]. A recent study justifies the low-density-lipoprotein particle size as a biomarker for the prognosis of atherothrombotic stroke [126]. Another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study shows that low triglyceride concentration precisely predicts from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127]. In contrast, another study suggests predicting IS mortality from the cholesterol level [127].

3) Vascular territories occlusion and stroke outcomes

An acute internal carotid artery occlusion (ICAO) is associated with poor clinical outcomes and mortality [129], [130].

A posterior inferior cerebellar artery (PICA) infarction is the most frequent IS type, it is usually atherothrombotic by aetiology. An occlusion in this vascular territory is frequently associated with early (within the first week) severe complications [131].

Posterior circulation strokes have better outcomes than the strokes in the anterior circulation of the brain. Among the posterior circulation strokes, the poorest outcome is observed in the non-treated cases of basilar artery occlusion [102], [132] and middle cerebral artery (MCA) occlusion [105], [133]. In the vascular territory of the posterior cerebral artery (PCA), cardioembolism is a less common reason for IS than in the middle (MCA) and anterior cerebral artery (ACA) [134]. For this reason, lacunar infarction is the most common IS subtype in the PCA territory [134] and the short-term IS prognosis in the PCA is more favourable than that in MCA territory as shown by a higher frequency of symptom-free cases at discharge and shorter hospital stay [135]. Another reason for the disproportion in the outcomes is that a posterior circulation stroke is associated with a lower risk of intracranial hemorrhage after intravenous thrombolysis than an anterior circulation stroke [136].

The acute cerebral infarction in more than one arterial territory (MACI) occurs in patients with cardioembolism [137]. It can be associated with AF or atherosclerosis of brain vessels [138]. A damage to ICA may cause MACI in both the anterior and posterior circulation simultaneously [139]. Another supposed reason for MACI is a lesion of azygos artery which is an unpaired ACA. As it supplies both hemispheres with blood, its occlusion may result in bilateral infarct [140]. Patients with MACI stroke have higher rates of short-term in-hospital complications and worse functional status at discharge compared to patients with single arterial territory stroke [137].

A watershed infarct involves a junction of distal fields of two nonanastomosing arterial systems. For the cases of mildly symptomatic ICA occlusion, the forecast of neurological deterioration after hospitalization depends on whether the watershed infarction is internal (IWI) or cortical (CWI) [141]. IWI is associated with hemodynamic impairment and critical stenosis of ICA, it leads to worse hospital courses, early [142] and midterm [143] prognosis compared to CWI. Supposedly, severity of IWI is related to reduced perfusion altering blood flow currents and prompting microembolism to reach the blood vessels with the least efficient blood flow [144].

A collateral flow through the circle of Willis and anastomotic connections between distal segments of cerebral arteries may facilitate partial reperfusion of ischemic territories after a focal stroke thus sustaining brain tissue for hours after an occlusion of major arteries [145]. Collateral vessels in the brain can weaken the effects of arterial occlusion but the outcomes depend on angiogenesis, age and concomitant diseases. There are leptomeningeal anastomoses and perforating arteries between MCA and accessory MCA, which are observed in over 3% of cases. The collateral flow can provide a sufficient supply to the MCA area [146], [147].

Analyzing the vascular territory of the occlusion, we should also look at the other radiomics data: the size, shape of the lesion. Progressive motor deficits and IS severity are closer associated with tubular than oval lacunae [148].
VI. CONCLUSION

- We found a non-correlation between the weather parameters and statistics on IS. The disparities in their trends encouraged us to investigate behind-time effects of the environment with DLNM and determine a concordant impact of all the settings with machine learning models.

- If categorized into two classes by NIHSS and mRS values, the cases have few disparities in the parameters of the weather within a week before the IS onset. The classes of NIHSS values differ markedly in RH on two consequent days before IS. The classes of mRS values vary in WS on the fourth and seventh day, and in WD - a day before IS.

- We ranked environmental and individual risk factors by the information gain that they provided to the model predicting NIHSS value. The top valuable predictors were the background diseases, the weather parameters, the Cat2Vec-encoded data on the IS onset in the calendar year, and hyperlipidemia.

- In contrast to the classes by NIHSS score, the ones grouped by mRS have a pronounced difference in age ($p = 2.14e-06$), nationality ($p = 0.0008$), presence of background diseases and smoking ($p = 7.53e-07$). The separability with regard to the laboratory findings (levels of troponine I and C-reactive protein) is also more pronounced in the cohorts classified by mRS than NIHSS.

- The model for predicting mRS incorporates the aforementioned predictors of NIHSS and the data received on admission (e.g., the stroke location as per MRI). The top valuable individual risk factors are severity on admission, age, history of an old stroke. Inclusion of the weather parameters into the machine learning model predicting mRS score provides a slight boost in performance.

STRENGTH AND LIMITATIONS

The present study has several limitations. First, for natural reasons we could not study the effects of extreme cold temperatures in Al Ain City. Second, we did not consider a possible effect of the air pollution on IS though it may affect the morbidity in conjunction with other environmental factors [149]–[151]. A research reported the absence of association between air pollutant exposure and a short-term IS risk in Lyon (France) [152]. Because of the economic aspect and controversy of the previous findings, this question should be an issue of a separate study.

Third, the desert climate of the city is not representative of the entire country, the biggest cities of which are located along the Gulf with the prevalence of humid air masses over the dry ones. Thus, the study we did is not reflective of the risks for the entire population of the country, but it covers a large multinational cohort exposed daily to the harsh environment of the desert. Similar studies should be conducted in other regions to evidence the impact of the weather on the IS risk.

On the plus side we have a big study cohort of patients admitted to the IS unit within 4 consecutive years. Each case was verified with MRI diffusion-weighted imaging, which is considered to be the golden standard of the IS diagnostics. This study addressed the limitations of previous studies by analyzing a full set of the climate parameters - ambient temperature, RH, humidex, AP, WS - and the changes in these parameters at various times preceding the IS onset, both individually and in combination. We provided physicians a reliable machine learning model for assessing the risk of severe IS forms and outcomes. To gain an advanced accuracy, the models were trained on both internal (clinicodemographic) and external (climatic) risk factors.

CONTRIBUTIONS

YS, EF and JAK contributed to the conceptual idea of the paper; YS and JAK formulated the objectives; YS and EF wrote the manuscript; VL and TH performed the statistical analysis, prepared the figures and tables for data presentation and illustration; TMA, FAZ, KNVG, ML, MS and AP contributed to the literature review and data analysis.

COMPETING INTERESTS

The authors declare no competing interests.

ETHICAL APPROVAL

The study was reviewed by the Al Ain Hospital Research Ethics Governance Committee (reference number AAHEC-12-19-033) and approved for the retrospective analysis of the data obtained as a standard of care. The procedures followed were in accordance with institutional guidelines.

REFERENCES

[1] Salim S Virani, Alvaro Alonso, Hugo J Aparicio, Emelia J Benjamin, Marcio S Bittencourt, Clifton W Callaway, April P Carson, Alanna M Chamberlain, Susan Cheng, Francesca N Delling, et al. Heart disease and stroke statistics—2021 update: a report from the American heart association. Circulation, 143(8):e254–e743, 2021.

[2] T Wein, MP Lindsay, R Côté, N Foley, J Berlingeri, S Bhogal, A Bourgoin, BH Buck, J Cox, D Davidson, et al. Heart and stroke foundation canadian stroke best practice committees. canadian stroke best practice recommendations: secondary prevention of stroke, practice guidelines, update 2017. Int J Stroke, 13(4):420–443, 2018.

[3] Cristina Sierra, Antonio Coca, and Ernesto L Schiffrin. Vascular mechanisms in the pathogenesis of stroke. Current hypertension reports, 13(3):200–207, 2011.

[4] Fred Stephen Sarfo, John Akassi, Sheila Adamu, Vida Obese, Manolo Agbenorku, and Bruce Ovbiagele. Frequency and factors linked to refractory hypertension among stroke survivors in ghana. Journal of the Neurological Sciences, 415:116976, 2020.

[5] Tanvir Chowdhury Turin, Tomonori Okamura, Arfan Raheen Afzal, Nahid Rumana, Makoto Watanabe, Aya Higashiyama, Yoko Nakao, Michikazu Nakai, Misa Takegami, Kunihiro Nishimura, et al. Hypertension and lifetime risk of stroke. Journal of hypertension, 34(1):116–122, 2016.

[6] Janina Markidan, John W Cole, Carolyn A Cronin, Jose G Merino, Michael S Phipps, Marcella A Wozniak, and Steven J Kittner. Smoking and risk of ischemic stroke in young men. Stroke, 49(5):1276–1278, 2018.

[7] Chirantan Banerjee, Yeseon P Moon, Myunghhee C Paik, Tatjana Rundek, Consuelo Mora-McLaughlin, Julio R Vieira, Ralph L Sacco, and
Mitchell SV Elkind. Duration of diabetes and risk of ischemic stroke: the northern Manhattan study. Stroke, 43(5):1212–1217, 2012.

Nick Watts, Markus Amann, Sonja Ayeb-Karlsson, Kristine Belesova, Timothy Bouley, Maxwell Boykoff, Peter Byass, Wenjia Cai, Durand Campbell-Lendrum, Jonathan Chambers, et al. The lancet countdown on health and climate change: from 25 years of inaction to a global transformation for public health. The Lancet, 391(10120):581–630, 2018.

Anthony J McMichael. Globalization, climate change, and human health. New England Journal of Medicine, 368(14):1335–1343, 2013.

Tihos Gostimirovic, Radmilja Merce, Peter Byass, Raffaele Santilli, Vladimir Djulic, Duško Terzić, Svetozar Putnik, and Ljiljana Gajkovic-Bukarica. The influence of climate change on human cardiovascular function. Archives of environmental & occupational health, 75(7):406–414, 2020.

Yanxia Luo, Haibin Li, Fangfang Huang, Nicholas Van Halm-Lutterodt, Qin Xu, Anxin Wang, Jin Guo, Lixin Tao, Xia Li, Mengyang Liu, et al. The cold effect of ambient temperature on ischemic and hemorrhagic stroke hospital admissions: a large database study in Beijing, china between years 2013 and 2014—utilizing a distributed lag non-linear analysis. Environmental pollution, 232:90–96, 2018.

Jing-hua Chen, Han Jiang, Lei Wu, Xiong Liao, Yuanan Lu, Xue-Qin Tao, Peng-Fei Deng, Yao Long, and He-Jang Huang. Association of ischemic and hemorrhagic strokes hospital admission with extreme temperature in nanchang, china—a case-crossover study. Journal of Clinical Neurology, 14(3):89–93, 2018.

Lijun Zhou, Kai Chen, Xiaodong Chen, Yanshui Jing, Zongwei Ma, Jun Bi, and Patrick L Kinney. Heat and mortality for ischemic and hemorrhagic stroke in 12 cities of jiangsu province, china. Science of The Total Environment, 601:271–277, 2017.

Rupa Basu, Dharshani Pearson, Brian Malig, Rachel Broadwin, and Rochelle Green. The effect of high ambient temperature on emergency room visits. Epidemiology, pages 813–820, 2012.

Quzhou Wang, Cuiyan Gao, Hongchun Wang, Lingling Lang, Tao Yue, and Huihuang Lin. Ischemic stroke hospital admission associated with ambient temperature in jinan, china. PLoS One, 8(11):e80381, 2013.

Elizabeta Mostofský, Elissa H Wilker, Joel Schwartz, Antonella Zanobetti, Diane R Gold, Gregory A Wennellus, and Murray A Mittleman. Short-term changes in ambient temperature and risk of ischemic stroke. Cerebrovascular diseases extra, 4(1):8–18, 2014.

Jiaojiao Gao, Feng Yu, Zihan Xu, Jun Duan, Qiang Cheng, Lilian Bai, Yanwei Zhang, Qianwei Wei, Weizhuo Pan, et al. The association between cold spells and admissions of ischemic stroke in hefei, china: modified by gender and age. Science of The Total Environment, 690:140–147, 2019.

Marco Morabito, Alfonso Crisci, Marco Moriondo, Francesco Profili, Paolo Francesconi, Giacomo Trombi, Marco Bindi, Gian Franco Gensini, Yanwu Zhang, Qiannan Wei, Weizhuo Pan, et al. The influence of climate change on human cardiovascular function. Science of The Total Environment, 441:28–40, 2012.

Yun-Chul Hong, Hyoung-Ho Rha, Jong-Tae Lee, Eun-Hee Ha, Ho-Jang Kwon, and HO Kim. Ischemic stroke associated with decrease in temperature. Epidemiology, 14(4):473–478, 2003.

Xia Wang, Yongjun Cao, Daqing Huang, Xuelian Ge, Sarah Richtering, Zhen Hui Leong, Abdul Salam, Craig Anderson, and Marc L Hackett. Air pressure, humidity and stroke occurrence: a systematic review and meta-analysis. International journal of environmental research and public health, 13(7):675, 2016.

Mirjam Ravilien, Fajko Bajovic, and Damjan Vavpotić. A time series analysis of the relationship between ambient temperature and ischemic stroke in the ljubljana area: immediate, delayed and cumulative effects. BMC meteorology, 21(1):1–6, 2021.

Philip D Houck, Jan E Lethen, Mark W Riggs, D Scott Gantt, and Gregory J Dehmer. Relation of atmospheric pressure changes and the occurrences of acute myocardial infarction and stroke. The American journal of cardiology, 96(1):45–51, 2005.

Matthew C Cowperthwaite and Mark G Burnett. An analysis of admissions from 155 united states hospitals to determine the influence of weather on stroke incidence. Journal of Clinical Neuroscience, 18(5):618–623, 2011.

Harun Gunes, Hayati Kandis, Ayhan Saritas, Suber Dikici, and Ramazan Buyukkaya. The relationship between ischemic stroke and weather conditions in duzce, turkey. World journal of emergency medicine, 6(3):207, 2015.

Adam D Tarnoki, Acar Türker, David L Tarnoki, Mehmet Ș İyisoy, Bianka K Szilagyi, Hoang Duong, and László Miskolczi. Relationship between weather conditions and admissions for ischemic stroke and subarachnoid hemorrhage. Croatian medical journal, 58(1):56–62, 2017.

Laura Tamasesuikene, Daiva Rastyne, Ricardas Radisauskas, Abdonas Tamosiunas, Domantas Tamasesuikas, Vidmantas Vaiciulis, Daina Krunkunaitė-Butykienė, and Eglė Miluviūnaitė. Relationship of meteorological factors and acute stroke events in kaunas (lithuania) in 2000–2010. Environmental Science and Pollution Research, 24(10):9260–9293, 2017.

Jayeon Kim, Kyuhyun Yoon, Jay Choi Choi, Ho Kim, and Jung-Kook Song. The association between wind-related variables and stroke symp- toms: A case-crossover study on jeju island. Environmental research, 150:97–105, 2016.

Michael Ertl, Christoph Beck, Benjamin Kühlbach, Jasmin Hartmann, Gertrud Hammel, Annette Straub, Esther Giemsa, Stefanie Seubert, Andreas Philipp, Claudia Traidl-Hoffmann, et al. New insights into weather and stroke: influences of specific air masses and temperature changes on stroke incidence. Cerebrovascular Diseases, 47(5–6):275–284, 2019.

Prajwal Shreyas. Deep embedding’s for categorical variables (cat2vec): Use of deep learning on tabular data. https://radiauoa.com/articles/neurodegenerative-mri-brain-an-approach?lang=us/, 2019. [Online; accessed 10-July-2021].

Rui Magalhães, M Carolina Silva, Manuel Correia, and Trevor Bailey. Are stroke outcome and outcome related to weather parameters? results from a population-based study in northern Portugal. Cerebrovascular diseases, 32(6):542–551, 2011.

Pan Ma, Ji Zhou, Shiguong Wang, TanShi Li, XinGang Fan, Jin Fan, and Jiajun Xie. Differences of hemorrhagic and ischemic strokes in age spectra and responses to climatic thermal conditions. Science of The Total Environment, 644:1573–1579, 2018.

Abdul Salam, Saadat Kamran, Rubina Bibi, Hesham M Korashy, Aijaz Parray, Abdulla Al Mannai, Abdulrahman Al Ansari, Krishna Kumar Kamikcharla, Arta Jozgai Kashii, and Ashafaq Shauab. Meteorological factors and seasonal stroke rates: a four-year comprehensive study. Journal of Stroke and Cerebrovascular Diseases, 28(8):2324–2331, 2019.

Hsin-Chien Lee, Chau-Jong Hu, Chin-Shyan Chen, and Heng-Ching Lin. Seasonal variation in ischemic stroke incidence and association with climate: a six-year-population-based study. Chronobiology international, 25(9):938–949, 2008.

Florian Rakers, Rene Schiffer, Sven Rupprecht, Anja Brandstädt, Otto W Wittke, Martin Walther, Peter Schlatmann, and Matthias Schwab. Rapid weather changes are associated with increased ischemic stroke risk: a case-crossover study. European journal of epidemiology, 31(2):137–146, 2016.
Diet and prevention of coronary heart disease

Secular trends in stroke incidence and mortality: the Framingham study.

Hydration-dehydration, heat, humidity, and "cool, clear water".

Weather as a trigger of stroke:

Influence of sex difference on distribution of risk factors and symptoms in the Gulf cooperation council countries:

Survival and management in the emergency department.

Use of low-dose oral contraceptives and stroke in young women.

Short-term effects of air temperature on blood pressure and neuroendocrine function among obese and non-obese humans: a pilot study.

Current use of oral contraceptives and the risk of first-ever ischemic stroke: a meta-analysis.

Ischemic stroke risk with oral contraceptives: a meta-analysis.

Prevention opportunities for oral contraceptive–associated ischemic stroke.

Current use of oral contraceptives and the risk of first-ever ischemic stroke: a meta-analysis of observational studies.

Effective of left on norepinephrine in acute ischemic stroke.

Efficacy and safety of low-dose oral contraceptives and stroke in young women.

Practical recommendations for the management of obesity in the united arab emirates.

Use of low-dose oral contraceptives and stroke in young women.

Globalization and health.

The role of heat in the pathogenesis of stroke.

Use of low-dose oral contraceptives and stroke in young women.

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Use of low-dose oral contraceptives and stroke in young women.

Use of low-dose oral contraceptives and stroke in young women.
Elevated cardiac troponins and high sensitivity C-reactive protein in stroke patients — the importance in consideration of stroke recovery: from a vascular to a parenchymal overview. Neural plasticity, 2019, 2019.

M Yu Maksimova and TS Gulevskaya. Lacunar stroke. Zhurnal neirologii i psikhiatrii imeni SS Korsakova, 119(8): Vyp. 2:13–27, 2019.

V Perez, C Scacco, A Bassi, E Bottino, G Giurotto, A Alimondi, A Lunghi, E Ciusani, G Brenna, and A Salmaggi. Outcome in lacunar stroke: A cohort study. Acta Neurologica Scandinavica, 138(4):320–326, 2018.

S Sacco, C Mariní, R Totaro, T Russo, D Cerone, and A Carolei. A population-based study of the incidence and prognosis of lacunar stroke. Neurology, 66(9):1335–1338, 2006.

Ji-Jia Staals, Lisse Begeer Raak, Anne Hilton, and Jan Lodder. Differences in long-term survival in two lacunar stroke types: a 15-year follow-up study in 782 cerebral infarct patients. Cerebrovascular Diseases, 25(1–2):26–31, 2008.

MD Michael Findler, MD Jeremy Molad, M Bornstein MD Natan, and Julie Staals, Lisette Van Raak, Anne Hilton, and Jan Lodder. Differences in long-term survival in two lacunar stroke types: a 15-year follow-up study in 782 cerebral infarct patients. Cerebrovascular Diseases, 25(1–2):26–31, 2008.

Kotaro Watanabe, Shuhei Okazaki, Takaya Kitano, Shintaro Sagiyama, Mariko Ohara, Hideaki Kanki, Tsutomu Sasaki, Manabu Sakaguchi, Hideki Mochizuki, and Kenichi Todo. Stroke severity and outcomes in patients with newly diagnosed atrial fibrillation. Frontiers in Neurology, 10:1240, 2021.

Daniel Prefasi, Patricia Martinez-Sanchez, Ana Rodriguez-Sanz, Blanca Fuertes, D Figueras-Rama, G Ruiz-Ares, BE Sanz-Cuesta, and E Diez-Tejedor. Atrial fibrillation in young stroke patients: do we underestimate its impact? European Journal of Neuroscience, 20(10):1367–1374, 2013.

Dan Xie, Li Deng, Xiao-dong Liu, Ji-mei Li, and Yong-bo Zhang. Role of high sensitivity c-reactive protein and other risk factors in intracranial and extracranial artery occlusion in patients with ischaemic stroke. Journal of International Medical Research, 43(5):711–717, 2015.

Yongqing Zhou, Wei Han, Dandan Gong, Changfeng Man, and Yu Fan. Hs-crp in stroke: a meta-analysis. Clinica chimica acta, 453:26–31, 2016.

Huang Yu, Yue Huang, Xin Yu Chen, Yue Yonglu, and Xiaonian Jiao, Guy L Reed, Weikuan Gu, and Hong Chen. High-sensitivity c-reactive protein in stroke patients—the importance in consideration of influence of multiple factors in the predictability for disease severity and death. Journal of Clinical Neuroscience, 36:12–19, 2017.

Gillian Kerr, Gautamananda Ray, Olivia Wu, David J Stott, and Peter Langhorne. Elevated troponin after stroke: a systematic review. Cerebrovascular diseases, 28(3):220–226, 2009.

Jesper K Jensen, Saren R Kristensen, Saren Bak, Dan Atar, Poul Flemming Haflund-Carlson, and Hans Mickley. Frequency and significance of troponin t elevation in acute ischemic stroke. The American journal of cardiology, 99(1):108–112, 2007.

Jacob VanHouten, Gregory Fricker, Bridget Collins, Ritwik Bhatia, Christopher Ellis, and Matthew Schrag. Circulating troponin i level in patients with acute ischemic stroke. Current neurology and neuroscience reports, 18(6):1–6, 2018.

Han-kyeol Kim, Ji Hwa Kim, and Kyung-Yul Lee. Elevated cardiac troponin-i in acute ischemic stroke (p4. 286), 2015.

Benjamin R Miller, Ayham M. Alkhachroum, Tarek Chamy, and Cathy Sila. Troponin elevations in ischemic stroke are associated with stroke severity and advanced age. Circulation, 132(suppl 3):A19723–A19723, 2015.

M Barber, JJ Morton, PW Macfarlane, N Barlow, G Roditi, and DJ Stott. Elevated troponin levels are associated with sympathoendothelial activation in acute ischaemic stroke. Cerebrovascular diseases, 23(4):260–266, 2007.

Thorleif Etgen, Hansjoerg Baum, Kerstin Sander, and Dirk Sander. Cardiac troponins and n-terminal pro-brain natriuretic peptide in acute ischemic stroke do not relate to clinical prognosis. Stroke, 36(2):270–275, 2005.

Hakan Ay, Ethem Murat Arسا, Levent Gungor, David Greer, Aneesh B Singhal, Karen L Furie, Walter J Kosoroszht, and A Gregory Sorensen. Admission international normalized ratio and acute infarct volume in ischemic stroke. Annals of Neurology: Official Journal of the American Neurological Association and the Child Neurology Society, 64(5):499–506, 2008.

Michael Kushner, Patrizia Nencini, Martin Revich, Mario Rango, Dara Jamieson, Franz Fazekas, Robert Zimmerman, John Chowlak, Abbas Alavi, and Wayne Alves. Relation of hyperglycemia early in ischemic brain infarction to cerebral anatomy, metabolism, and clinical outcome. Annals of Neurology: Official Journal of the American Neurological Association and the Child Neurology Society, 28(2):129–135, 1990.

Tracey A Baird, Mark W Parsons, Than Phan, Ken S Butcher, Patricia M Desmond, Brian M Tress, Peter G Colman, Brian R Chambers, and Stephen M Davis. Persistent poststroke hyperglycemia is independently associated with infarct expansion and worse clinical outcome. Stroke, 34(9):2208–2214, 2003.

Shadi Yaghhi, Seema Delkharghani, Eytan Raz, Mahesh Jayaraman, Omar Arfanweer, Brian Mac Groty, Nils Henninger, Maarten G Lansberg, Gregory A. Albers, and Adam de Havenon. The effect of hyperglycemia on infarct size after reperfusion: an analysis of the defuse 3 trial. Journal of Stroke and Cerebrovascular Diseases, 30(1):105380, 2021.

Cheung-Ter Ong, Yi-Sin Wong, Chi-Shun Wu, and Yu-Hsiang Su. Atrial fibrillation is a predictor of in-hospital mortality in ischemic stroke patients. Therapeutics and clinical risk management, 12:1057, 2016.

You-Shing Feng-Y Hiue, Hsu-Ling Yeh, Wei-Hung Chen, Hsu-Chang Chiu, Sung-Chun Tang, Chung-Hsiang Liu, Huey-Juan Lin, Shih-Pin Hou, Yuk-Keung Lo, et al. Impact of mca stenosis on the early outcome in acute ischemic stroke patients. PloS one, 12(4):e0175434, 2017.

Majdi Al Qawasme, Belal Alabbour, Aimam Momani, Deema Obiedat, Kefah Alhayek, Raid Kofahi, Ahmed Yassin, and Khalid El-Salem. Epidemiology, risk factors, and predictors of disability in a cohort of Jordanian patients with the first ischemic stroke. Stroke research and treatment, 2020, 2020.

Takuya Fukuoka, Yoshihiko Nakazato, Hiroshi Kawasaki, Kei Ikeda, Tohru Hara, Akifumi Mikiya, Tatsuki Matsuji, Yasuo Ito, Kazushi Takahashi, Nobuo Araki, et al. The clinical features of ischemic stroke patients for whom smoking was considered the sole risk factor for ischemic stroke. Internal Medicine, 57(12):1703–1706, 2018.

Shenjun Li, Shucai Wang, Mingming Gu, and Bingzhen Cao. Characteristics and outcome of acute ischemic stroke patients with atrial fibrillation. Zhonghua yi xue ya zhi, 95(43):3509–3513, 2015.

Linda S Williams, J Rotich, R Qi, N Fineberg, A Espay, Askrel Bruno, SE Fineberg, and WR Tierney. Effects of admission hyperglycemia on mortality and costs in acute ischemic stroke. Neurology, 59(1):67–71, 2002.

L Kiers, SM Davis, R Larkins, J Hopper, B Tress, SC Rossiter, J Carlin, and S Ratnake. Stroke topography and outcome in relation to hyperglycemia and diabetes. Journal of Neurology, Neurosurgery & Psychiatry, 54(4):263–270, 1992.

Merel JA Luise, Geert Jan Biessels, Guy EHM Rutten, and L Jaap Kappelle. Diabetes, hyperglycemia, and acute ischemic stroke. The Lancet Neurology, 11(3):261–271, 2012.

Keith W Muir, Christopher J Weir, Wafa Alswan, Iain B Squire, and Kennedy R Lees. Persistent poststroke hyperglycemia is independently associated with infarct expansion and worse clinical outcome. Stroke, 30(5):981–985, 1999.

Reyna L VanGilder, Danielle M Davidov, Kyle R Stinehart, Jason D Huber, Ryan C Turner, Karen S Wilson, Eric Haney, Stephen M Davis, Paule Chantler, Laurie Theske, et al. C-reactive protein and long-term ischemic stroke prognosis. Journal of Clinical Neuroscience, 21(4):547–553, 2014.

Buse Hasirci, Münever Okay, Dilek Ağırçan, and Abdullah K Göz. Elevated troponin level with negative outcome was found in ischemic stroke. Cardiovascular Psychiatry and Neurology, 2013, 2013.

Hwa-Suk Song, Jang-Hyun Back, Dong-Kwan Jin, Pil-Wook Chung, Heun-Soo Moon, Bum-Chun Sub, Yong-Bum Kim, Byung Moon Kim, Hee Yeon Woo, Yong Taek Lee, et al. Cardiac troponin t elevation after stroke: relationships between elevated serum troponin t, stroke location, and prognosis. Journal of clinical neuroscience, 4(2):75–83, 2008.
[116] Jon W Schrock, Michael Glasenapp, and Kristin Dregell. Elevated blood urea nitrogen/creatinine ratio is associated with poor outcome in patients with ischemic stroke. Clinical neurology and neurosurgery, 114(7):861–862, 2012.

[117] Hoon Kim, Kiwon Lee, Huimin A Choi, Soheil Samuel, Jung Hun Park, and Kwang Wook Jo. Elevated blood urea nitrogen/creatinine ratio is associated with venous thromboembolism in patients with acute ischemic stroke. Journal of Korean Neurosurgical Society, 60(6):620, 2017.

[118] Mohammad Dehghani-Firoozabadi, Toba Kazemi, and Omid Mehdipour. Association between blood urea nitrogen/creatinine ratio and mortality in patients with stroke. J Res Med Sci, 91:97–98, 2014.

[119] Haomin Huang, Xiaolong Yu, Lamei Li, Ganwei Shi, Feng Li, Jianqiang Xiao, Zhihua Yun, and Gaojun Cai. Atherogenic index of plasma is related to coronary atherosclerotic disease in elderly individuals: a cross-sectional study. Lipids in health and disease, 20(1):1–9, 2021.

[120] Jadda Lou P Sajo, Anna Marie Sage-Nolido, et al. Atherogenic index of plasma (AIP): A MARKER OF RISK FOR ISCHEMIC STROKE, 69(1):9–9, 2021.

[121] Byung-Su Kim, Pil-Wook Chung, Kwang-Yeol Park, Hong-Hee Won, Oh Young Bang, Chin-Sang Chung, Kwang Ho Lee, and Gyeong-Moon Kim. Burden of intracranial atherothrombosis is associated with long-term vascular outcome in patients with ischemic stroke. Stroke, 48(6):2819–2826, 2017.

[122] Yuehua Pu, Liping Liu, Yilong Wang, Xinying Zou, Yuesong Pan, Yannie Soo, Thomas Leung, Xingquan Zhao, Ka Sing Wong, and Yongjun Wang. Geographic and sex difference in the distribution of intracranial atherosclerosis in china. Stroke, 44(8):2109–2114, 2013.

[123] Xiaojuan Liu, Ling Yaf, and Fuzhong Xue. The associations of lipid and lipid ratios with stroke: A prospective cohort study. The Journal of Clinical Hypertension, 21(1):127–135, 2019.

[124] J. C. Fernández-Álvarez, Angeles Andrade-martínez, José A. Varela-Silva, and Iván N Pérez-Maldonado. Atherogenic index of plasma: novel predictive biomarker for cardiovascular illnesses. Archives of medical research, 50(5):285–294, 2019.

[125] Lu Zhao, Ruizhu Wang, Bo Song, Song Tuan, Yuan Gao, Hui Fang, Jie Lu, and Yuming Xu. Association between atherogenic dyslipidemia and recurrent stroke risk in patients with different subtypes of ischemic stroke. International Journal of Stroke, 10(5):752–758, 2015.

[126] Tae-In Song, Hyun-Ji Cho, Yoonkyung Chang, Minjung Youn, Min-Jeong Shin, Inho Jo, Ji Hoe Heo, and Yong-Jae Kim. Low-density-lipoprotein particle size predicts a poor outcome in patients with atherothrombotic stroke. Journal of Clinical Neurology, 11(1):80–86, 2015.

[127] Richard B Horenstein, Dean E Smith, and Lori Mosca. Cholesterol predicts stroke mortality in the women’s pooling project. Stroke, 33(10):1863–1866, 2002.

[128] Christopher J Weir, Naveed Sattar, Matthew R Walters, and Kennedy R Lees. Low triglyceride, not low cholesterol concentration, independently predicts poor outcome following acute stroke. Cerebrovascular Diseases, 16(1):76–82, 2003.

[129] Maurizio Paciaroni, Valéria Casco, Michele Venti, Paolo Milia, L Jaap Kappelle, Giorgio Silvestrelli, Francesco Palmerini, Monica Acciarresi, Michela Sebastianelli, and Giancarlo Agnelli. Outcome in patients with stroke associated with internal carotid artery occlusion. Cerebrovascular Diseases, 20(2):108–113, 2005.

[130] Steven Buslovich and George L Hines. Spontaneous recanalization of thrombolysis. Internal and Emergency Medicine, 12(4):855–861, 2002.

[131] Tomáš Dorňáč, Michal Král, Martin Hazlinger, Roman Herzig, Tomáš Veverka, Stanislav Buvál, Daniel Šafák, Jana Zapletalová, Kristýna Antalíková, and Peket Kalovský. Posterior vs. anterior circulation infarction: dromodynamics, outcomes, and frequency of hemorhage after thrombolysis. International Journal of Stroke, 10(8):1224–1228, 2015.

[132] V Novotny, L Thomassen, U Waje-Andreasen, and H Naess. Acute cerebral infarcts in multiple arterial territories associated with cardioembolism. Acta Neurologica Scandinavica, 135(3):356–351, 2017.

[133] D Chowdhury, JM Wardlaw, and MS Dennis. Are multiple acute small subcortical infarctions caused by embolic mechanisms? Journal of Neurology, Neurosurgery & Psychiatry, 75(10):1416–1420, 2004.

[134] Yue-Hua Roh, Dong-Wa Xang, Seung-Hoon Lee, Byung-Yoo Yoon, and Kee-Hyun Chang. Significance of acute multiple brain infarction on diffusion-weighted imaging. Stroke, 31(3):688–694, 2000.

[135] Mika Okahara, Hiro Kiyouse, Hiromi Mori, Shuichi Tanoue, Michihumi Samou, and Hirohumi Nagatomi. Anatomic variations of the cerebral arteries and their angiography: a pictorial review. European radiology, 12(10):2548–2561, 2002.

[136] Yuko Amano, Hironosu Sano, Ayatake Fujimoto, Hiroaki Kenmochi, Haruhiko Sato, and Soichi Akamine. Cortical and internal watershed infarcts might be key signs for predicting neurological deterioration in patients with internal carotid artery occlusion with mild symptoms. Cerebrovascular Diseases Extra, 10(2):76–83, 2020.

[137] Joon-Tae Kim, Geum-In Youn, Tai-Seong Nam, Seong-Min Choi, Seung-Han Lee, Man-Seok Park, Byeong-Chae Kim, Myeong-Kyu Kim, and Ki-Hyun Cho. Internal border zone lesions as a predictor of early neurological deterioration in minor stroke patients with severe arterial steno-occlusion. Journal of Neuroimaging, 21(2):173–176, 2011.

[138] Yue Li, Man Li, Xiaoyu Zhang, Shuna Yang, Huimin Fan, Wei Qing, Yi Lei, Junfang Jiang-Yuan, and Wenli Hu. Clinical features and the degree of cerebrovascular stenosis in different types and subtypes of cerebral watershed infarcts. BMC neurology, 17(1):1–8, 2017.

[139] John R Belden, Louis R Caplan, Michael S Pessin, and Eddie Kwan. Mechanisms and clinical features of posterior border-zone infarcts. Neurology, 53(6):1312–1319, 1999.

[140] David S Liebeskind. Collateral circulation. Stroke, 34(9):2279–2284, 2003.

[141] Masaki Komiyama, Misao Nishikawa, and Toshihiro Yasui. The association between air pollutant exposure and short-term risk of ischaemic stroke in lyon, france. International Journal of Stroke, 7(8):669–674, 2012.