Unveiling Weather Impact on Intradialytic Blood pressure: A Multifactorial Analysis on Hemodialysis Sessions

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Abstract

The intricate relationship between environmental factors and human health, particularly in the context of cardiovascular health, is an important area of investigation. This is especially relevant in hemodialysis, where blood pressure levels during dialysis sessions are crucially linked to cardiovascular mortality and morbidity. Notwithstanding, there exists a noticeable gap in literature regarding the impacts of seasonal and meteorological variations on hemodialysis patients. This retrospective and longitudinal cohort study investigated the association between weather variables, dialysate composition, serum electrolyte levels, and intradialytic blood pressure in hemodialysis patients. Data were collected from a hemodialysis unit from a representative hospital. Generalized Estimating Equations (GEE) was applied to analyze outcomes related to intradialytic systolic blood pressure (SBP).

In a cohort of 224 patients, significant correlations were found between meteorological parameters - temperature, humidity, wind speed, and daily precipitation - and mean systolic pressure. It is observed that higher temperatures, increased humidity, and stronger wind speeds, coupled with lower precipitation levels, were associated with lower intradialytic systolic pressure. Contrary to previous studies, factors such as age, gender, and diabetes did not significantly influence intradialytic blood pressure.

This comprehensive four-year analysis reveals significant correlations between environmental factors and intradialytic systolic pressure, challenging conventional wisdom and setting a new paradigm in hemodialysis care. The findings highlight the importance of incorporating a broader range of environmental factors in predictive models for intradialytic blood pressure, offering valuable insights for clinical practice and future research in nephrology.

Keywords: Hemodialysis, Intradialytic blood pressure, Weather, Meteorological factors, Generalized Estimating Equations (GEE)

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以多因素分析探討血液透析過程中天氣對透析中血壓的影響

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摘要

環境因素與人類健康之間複雜的關係，尤其是在心血管健康方面，是一個重要的研究領域。這在血液透析中尤其相關，因為透析期間的血壓水平與心血管死亡率和發病率密切相關。然而，關於季節性和氣象變化對血液透析患者影響的文獻明顯不足。本項回溯性縱向世代研究，旨在探討血液透析患者的天氣變數、透析液成分、血清電解質水平與透析中血壓之間的關聯。數據收集自一家具代表性醫院的血液透析單位。本研究應用廣義估計方程式 (GEE) 來分析與透析中收縮壓 (SBP) 相關的結果。在 224 名患者的世代中，發現氣象參數（溫度、濕度、風速和每日降水量）與平均收縮壓之間存在顯著相關性。研究觀察到:較高的溫度、增加的濕度和較強的風速，加上較低的降水量，與較低的透析中收縮壓相關。此發現與先前研究相反，年齡、性別和糖尿病等因素並未顯著影響透析中血壓。這項為期四年的全面分析揭示了環境因素與透析中收縮壓之間的顯著相關性，挑戰了傳統觀點，並為血液透析護理設立了新典範。研究結果強調了在透析中血壓的預測模型中納入更廣泛環境因素的重要性，為臨床實踐和腎臟病學的未來研究提供了重要的發現。

關鍵字： 血液透析、透析中血壓、天氣、氣象因素、廣義估計方程式 (GEE)

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1. Introduction

The intricate link between environmental factors and human health is an interesting yet vital investigation area. Previous research has established associations between various environmental conditions and cardiovascular events, hospitalization rates, and mortality (Dilaveris et al., 2006; Gerber et al., 2006; Park et al., 2020; See et al., 2021). Specifically, studies have shown that lower environmental temperatures could significantly impact blood pressure and alter the hemodynamics of peripheral and aortic vessels (Adamopoulos et al., 2010; Chen et al., 2013). Another study discussed variations in sunlight duration have been linked to fluctuations in human blood pressure (Aubinière-Robb et al., 2013).

These environmental influences are believed to trigger physiological responses such as activation of the sympathetic nervous system and hormone release, including arginine vasopressin, norepinephrine, epinephrine, and angiotensin II. These mechanisms often lead to endothelial dysfunction, resulting in vasoconstriction and elevated blood pressure (See et al., 2021). The relationship takes on added complexity and significance in the realm of hemodialysis. Blood pressure levels during dialysis sessions, not just daily averages, are crucially linked to cardiovascular mortality and morbidity in these patients (Flythe et al., 2015; Stefánsson et al., 2014). Furthermore, fluctuations in blood pressure during dialysis sessions have been associated with increased risks of hospitalization and mortality (Inrig et al., 2007; Inrig et al., 2009).

Despite these known correlations, a noticeable gap exists in the literature regarding the specific impacts of seasonal and meteorological variations on hemodialysis patients. This gap is particularly significant given the potential for such environmental factors to influence these patients' already delicate balance of blood pressure.

In light of the gap discussed, this work embarks on an exploratory journey to uncover the correlations between weather-related data and clinical outcomes in dialysis patients, focusing on blood pressure variations during dialysis. This study aims to deepen the understanding of the environmental influences on hemodialysis patients. It seeks to provide actionable insights for clinics that could transform patient management strategies, enhance predictive models, and refine therapeutic choices. By bridging this gap, findings might aspire to contribute significantly to the field of nephrology, offering new perspectives on how external environmental factors interact with the health outcomes of dialysis patients.

2. Materials and methods

2.1 Study Design and Population

This retrospective and longitudinal cohort study explored the association between weather variables, dialysate composition, serum electrolyte levels, and intradialytic blood pressure in hemodialysis patients. The clinical data was collected in a hemodialysis unit in a representative general hospital. This unit had 2,000-2,500 hemodialysis sessions per month during the study period. The inclusion criteria were adult patients (age >= 18 years) with end-stage renal disease undergoing chronic hemodialysis between January 2016 and December 2020. Because of the outbreak of COVID-19 in Jan. 2021, the data collection process was suspended thereafter. Patients were excluded if they had a dialysis vintage of less than three months or were over 90 years old.

2.2 Data Acquirement

Data for this study were meticulously extracted from the Hospital Information System, encompassing a comprehensive range of variables. These encompassed demographic details, medical history, laboratory results, medication profiles, and meteorological parameters. Specifically, the demographic data comprised age, gender, and prevalent medical conditions. Laboratory evaluations included parameters such as hemoglobin, potassium, sodium, calcium, phosphate, and albumin levels. Data from individual hemodialysis sessions encompassed metrics like interdialysis weight gain, predetermined target body weight, and intradialytic blood pressure measurements. Meteorological data integral to this study were sourced from the official archives of the Central Weather Bureau. This dataset provided information regarding daily atmospheric pressure, ambient temperature, relative humidity, wind velocity, and recorded precipitation levels.

2.3 Statistical analysis

Generalized Estimating Equations (GEE) was used for statistical analysis and the STATA software package was applied. Specifically, logistic regression within the GEE framework was employed to analyze binary outcomes of the occurrence of IDH (Isolated diastolic hypertension). For continuous outcomes associated with intradialytic SBP, linear regression was the adopted. In all statistical evaluations, a p-value threshold of 0.05 was established as the criterion for statistical significance.

2.4 Hypothesis

The primary postulation was that meteorological variables independently influence intradialytic blood pressure, suggesting a potential intrinsic relationship between these external environmental factors and patient-specific clinical outcomes. It is hypothesized that the meteorological parameters independently correlated to intradialytic blood pressure.

3. Results

3.1 Demographic, Clinical, and Meteorological Characteristics

In this cohort, 224 patients met the inclusion criteria and were subsequently subjected for detailed analysis. The comprehensive breakdown of the demographic and clinical attributes could be found in Table 1. The cohort's mean age was 67.84, with a standard deviation of 11.04. A notable majority of the participants were male, constituting 63.3% (n=143) of the total sample. A significant proportion of the study population, 88.8% (n=199), had been diagnosed with diabetes mellitus—meanwhile, hypertension, which was prevalent in 83.9% (n=188) of the patients. Additionally, dyslipidemia was identified in 60.2% (n=135) of the cohort.

Further examination of the cohort's medical history revealed the presence of several other comorbidities. Specifically, coronary artery disease was diagnosed in 13.8% (n=31) of the patients, hypothyroidism in 8.4% (n=19), a prior incidence of stroke in 9.8% (n=22), and peripheral obstructive artery disease was observed in a smaller fraction, 2.6% (n=6), of the participants.

Table 1. Demographic, Clinical, and Meteorological Characteristics of Hemodialysis Patients

Variables	Description Statistics
Age	67.84±11.04
Male	143(63.3%)

Variables	Description Statistics
Hypothyrodism	19(8.4%)
Diabetes Mellitus	199(88.8%)
Hypertension	188(83.9%)
Peripheral Obstructive artery disease	6(2.6%)
Coronary artery disease	31(13.8%)
Stroke	22(9.8%)
Dyslipidemia	135(60.2%)
Mean of daily atmosphere pressure	1011.49 ± 5.49
Mean of daily temperature	24.7 ± 4.51
Mean of daily humidity	79.73 ± 6.8
Mean of daily wind speed	2.1 ± 0.81
Daily precipitation	5.35 ± 23.08

3.2 Associations Analysis

Employing Generalized Estimating Equation to discern factors influencing the mean systolic pressure, several variables emerged with notable associations (Table 2). Hypertension was directly correlated with the mean systolic pressure, as evidenced by a coefficient of 7.003 (95% Confidence Interval (CI): 1.168 to 12.837, $p = 0.019$). Conversely, the administration dosage of erythropoiesis-stimulating agents (ESA) exhibited an inverse relationship, denoted by a coefficient of -14.123 (95% CI: -22.354 to -5.893, $p = 0.001$). Intradialytic hypotension's duration (or vintage) manifested a positive association, with a coefficient of 4.923 (95% CI: 1.227 to 8.618, $p = 0.009$).

Interdialytic weight gain was inversely correlated, as indicated by a coefficient of -2.525 (95% CI: -3.359 to -1.690, $p < 0.001$). Hemoglobin concentrations also demonstrated a negative association, with a coefficient of -2.117 (95% CI: -3.041 to -1.192, $p < 0.001$). Serum potassium and phosphate levels both displayed inverse relationships, with coefficients of -2.972 (95% CI: -5.072 to -0.873, $p = 0.006$) and -1.149 (95% CI: -1.985 to -0.313, $p = 0.007$) respectively.

Meteorological parameters, such as mean temperature, humidity, wind speed, and daily precipitation, were also significantly intertwined with the mean systolic pressure. Specifically, the mean temperature was associated with a coefficient of -0.206 (95% CI: -0.321 to -0.091, $p < 0.001$), humidity with -0.044 (95% CI: -0.079 to -0.010, $p = 0.011$), wind speed with -0.364 (95% CI: -0.595 to -0.133, $p = 0.002$), and daily precipitation with 0.015 (95% CI: 0.008 to 0.022, $p < 0.001$). Notably, for the other variables which were incorporated into the model, correlations with the mean systolic pressure were statistically insignificant.

Table 2. Associations Between Clinical and Meteorological Factors with Mean Systolic Pressure in Hemodialysis Patients: A Generalized Estimating Equation Analysis

Mean of Systolic Pressure	Coefficient	std. err.	P value	[95% conf.	interval]
Age	-0.140	0.111	0.207	-0.357	0.077
Male	0.719	2.451	0.769	-4.084	5.522
Diabetes	1.563	3.581	0.662	-5.455	8.581
Hypertension	7.003	2.977	0.019	1.168	12.837
ESA dosage	-14.123	4.199	0.001	-22.354	-5.893

Mean of Systolic Pressure	Coefficient	std. err.	P value	[95% conf.	interval]
Vintage of Intradialytic hypotension	4.923	1.885	0.009	1.227	8.618
Interdialytic weight gain	-2.525	0.426	0.000	-3.359	-1.690
Target Body weight	0.202	0.143	0.158	-0.079	0.483
Hemoglobin	-2.117	0.472	0.000	-3.041	-1.192
Serum Albumin	-2.305	2.497	0.356	-7.199	2.590
Serum Sodium	-0.198	0.180	0.272	-0.552	0.155
Serum Pottasium	-2.972	1.071	0.006	-5.072	-0.873
Serum total Calcium	-0.125	0.767	0.871	-1.628	1.378
Serum phosphate	-1.149	0.427	0.007	-1.985	-0.313
Mean of atmosphere Pressure	-0.036	0.042	0.394	-0.118	0.047
Mean of Temperature	-0.206	0.059	0.000	-0.321	-0.091
Mean of Humidity	-0.044	0.018	0.011	-0.079	-0.010
Mean of Wind Speed	-0.364	0.118	0.002	-0.595	-0.133
Daily Precipitation	0.015	0.003	0.000	0.008	0.022

p-value <0.05 was defined as significant.

4. Discussion

This work represents a groundbreaking exploration into the intricate relationships between meteorological conditions and intradialytic blood pressure, uncovering significant links that were previously uncharted. Suggesting the use of the Generalized Estimating Equations (GEE) model, with adjustments for critical variables like hypertension and diabetes, has enabled one to unearth connections between environmental factors—temperature, humidity, wind speed, as well as precipitation and intradialytic systolic pressure. It is found out that higher temperatures, increased humidity, stronger wind speeds, and lower precipitation levels are significantly associated with lower intradialytic systolic pressure. These findings offer interesting insights into patient management, challenging conventional wisdom and might setting a new paradigm in hemodialysis care.

Building on the foundational works (Flythe et al., 2015; Stefánsson et al., 2014; Argilés et al., 1998), this study advances the understanding of the relationship between environmental temperature and intradialytic blood pressure. While corroborating the inverse relationship identified in previous studies (Adamopoulos et al., 2010; Chen et al., 2013), research results delved deeper into its implications for hemodialysis patients. Findings also suggest that this relationship is more pronounced in this patient group, underlining the need for further research to tailor treatment approaches for this vulnerable population.

This analysis revealed no significant correlation between atmospheric pressure and intradialytic blood pressure. This finding, aligning with recent studies (Dilaveris et al., 2006), diverges from earlier hypotheses (Danet et al., 1999) and highlights the unique physiological responses of hemodialysis patients to atmospheric conditions, suggesting a need for more focused research in this specific patient group. Acknowledging the limitations of our study, particularly the reliance on outdoor meteorological data and the potential impact of indoor environmental conditions, it is recognized as an imperative for future research to include these aspects.

5. Conclusion

This comprehensive four-year analysis, integrating clinical and meteorological data, reveals significant correlations between environmental factors and intradialytic systolic pressure. These findings enhance the potential for personalized medical advice in varying weather conditions and underline the importance of incorporating a broader range of environmental factors in predictive models for intradialytic blood pressure. This work contributes significantly to understanding the multifactorial influences on intradialytic blood pressure and offers valuable insights for clinical practice and future research.

Acknowledgments

The Institutional Review Board (IRB) of An-Nan Hospital, Tainan, Taiwan, approved the study (IRB number: TMANH110-REC024). No conflicts of interest have been detected in this study.

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