Albanian Journal of Trauma and Emergency Surgery (2025) 9/2:1808 - 1812
DOI: ***10.32391/ajtes.v9i2.451***

OPEN ACCESS JOURNALS

ORIGINAL ARTICLES

Predicting Mortality in Elderly Patients with Hypertensive Crises: Development and Validation of a Risk Model

Erkan Boga

Received: 14 February 2025 / *Accepted:* 10 May 2025 / *Published online:* 20 July 2025
This article is published with open access at ***https://journal.astes.org.al***

Abstract

Introduction: Hypertensive crises, which are marked by severe increases in blood pressure with or without acute target organ damage, represent a critical condition associated with substantial morbidity and mortality, particularly among older adults. As global life expectancy increases, the prevalence of hypertension and its complications also rises, creating an urgent need for effective strategies for early risk assessment and intervention.

This study aims to develop and validate a risk model for predicting mortality in elderly patients experiencing hypertensive crises. Given the high morbidity and mortality rates associated with hypertensive crises in this population, an accurate risk assessment tool could enhance clinical decision-making and improve patient outcomes.

Materials and Methods: A retrospective cohort study was conducted involving 1,500 patients aged 65 and older who presented to the emergency department with hypertensive crises between January and August 2024. Patients with a confirmed diagnosis and complete medical records were included. Data on demographics, clinical findings, laboratory results, and comorbidities were extracted from electronic health records. Univariable and multivariable logistic regression analyses were performed using SPSS version 25 to identify key predictors of mortality.

Results: The dataset was complete, with no missing values. The mean patient age was 82.5 years (±10.3), and the overall mortality rate was 15%. A risk model was developed that categorized patients into low-risk (0.14% mortality), medium-risk (75% mortality), and high-risk (99.87% mortality) groups. Receiver Operating Characteristic (ROC) analysis indicated excellent model performance, with an Area Under the Curve (AUC) of 0.999.

Conclusion: The proposed risk model demonstrates impressive predictive accuracy for mortality in elderly patients experiencing hypertensive crises. However, its retrospective design may limit external validity. This model can help emergency physicians optimize treatment strategies and improve patient outcomes.

Keywords: Hypertensive Crisis, Elderly Patients, Mortality Prediction, Risk Model, Emergency Medicine

Introduction

Hypertension is the most common cardiovascular disease affecting older adults worldwide and is linked to high rates of morbidity and mortality. The increasing frequency and severity of hypertensive emergencies in this population are associated with age-related physiological changes, vascular stiffness, and the rising prevalence of comorbid conditions [1, 2].

A hypertensive crisis is marked by a sudden and significant rise in blood pressure (BP), which may be accompanied by target organ damage or circumstances requiring intervention without such damage (hypertensive urgency) [3].

Original article, no submission or publication in advance or in parallel

* ***Corresponding author:***
Erkan Boga, MD
drerkanboga@gmail.com

Department of Emergency Medicine, Medipol University, Republic of Türkiye, Ministry of Health, Esenyurt Necmi Kadıoğlu State Hospital, TURKEY

In older adults, these occurrences can lead to serious consequences, including heart failure, stroke, and acute kidney injury, all of which significantly elevate the risk of mortality [4, 5].

The management of hypertensive crises in elderly individuals is complex and challenging due to age-related hemodynamic changes, a high burden of comorbidities, and an unpredictable response to medications. Therefore, accurately and promptly identifying mortality risk is vital for informing clinical decision-making. Nonetheless, few mortality prediction models specifically for the geriatric population have been developed using relevant data and validated in clinical settings.

Most existing studies are population-based and do not adequately represent the unique risk factors associated with older adults.

This study aims to identify the key risk factors that predict mortality in elderly patients experiencing a hypertensive crisis and to create a predictive model based on these easily identifiable factors. Such a model would facilitate more accurate mortality predictions for this patient group. By providing a fresh perspective on the clinical management of hypertensive crises in older individuals, this study also assesses the applicability of a locally developed care model. Recognizing risk factors and constructing a predictive model could lead to more effective, individualized management strategies for hypertensive crises. This study aims to develop and validate a model for predicting mortality in hypertensive crises, thereby facilitating more informed decision-making in the clinical management of geriatric patients. This represents a crucial yet underexplored area of research that addresses a significant gap in the field [10].

Materials and Methods

The study was designed as a retrospective cohort analysis that evaluated data from 1,500 patients aged 65 and older who visited the Emergency Department (ED) of State Hospital due to hypertension between January 1, 2024, and August 31, 2024. The study population comprised individuals diagnosed with a hypertensive crisis and possessing complete medical records.

Inclusion criteria included older patients (age > 65 years) presenting with elevated blood pressure in the ED, a diagnosis of hypertensive crisis (either hypertensive emergency or urgency), and patients with comprehensive clinical, laboratory, and demographic data available.

Exclusion criteria involved patients with incomplete data, those transferred to another facility from the ED or treated at a different institution, and patients in the terminal stage or with end-stage disease at high risk of dying from another lethal condition, such as advanced-stage cancer.

Data were collected using the hospital's electronic health record system, from which the information was retrospectively extracted.

The categories of data analyzed in the study included demographic information *(age and gender)*; clinical findings *(blood pressure, including systolic and diastolic measurements, heart rate, level of consciousness, and duration of symptoms at presentation);* laboratory results *(biochemical parameters such as serum creatinine, troponin, electrolytes, and complete blood count)*, comorbidities *(diabetes, heart disease, chronic kidney disease, coronary artery disease, chronic obstructive pulmonary disease, etc.);* target organ damage *(severe acute kidney injury, hypertensive encephalopathy, pulmonary edema, myocardial infarction);* treatment details *(total antihypertensive therapies, intensive care needs, invasive requirements)*; and outcomes *(length of hospital stay, ICU requirement status, and alive/dead status).*

Statistical analysis was performed using SPSS version 25 software. The Kolmogorov-Smirnov and Shapiro-Wilk tests were applied to assess the normality of continuous variables. Continuous variables that were not normally distributed were reported as medians and interquartile ranges (IQR), while those that were normally distributed were shown as means ± standard deviations. Descriptive statistics were presented as means ± standard deviations or medians with interquartile ranges (IQR) for continuous variables, and categorical variables were shown in frequencies and percentages. Comparative analyses for constant variables included t-tests or one-way ANOVA for normally distributed data and Mann-Whitney U or Kruskal-Wallis tests for non-normally distributed data. Categorical variables were analyzed using the chi-square test or Fisher's exact test for small sample sizes.

Risk factors were identified through univariate and multivariate analyses. Each independent variable was evaluated for its association with mortality in the univariate analysis. A multivariate logistic regression analysis included variables with a p-value < 0.05. Odds ratios (OR) and 95% confidence intervals (CI) were reported. Risk scores were categorized into low, medium, and high-risk groups based on regression coefficients, with mortality rates compared among these groups.

A mortality prediction model was developed using multivariate logistic regression analysis. The model included independent variables with the most significant associations with mortality, and a risk score was created based on logistic regression coefficients.

Internal validation involved randomly dividing the dataset into 70% for training and 30% for testing. ROC analysis was performed to validate the model's performance on the test set. External validation was conducted by testing the model on a different patient group to ensure generalizability.

Ethical approval for the study was obtained from the appropriate local ethics committee. Only anonymized patient data were analyzed, and confidentiality principles were strictly upheld. The study was designed following the Declaration of Helsinki.

Results:

The dataset used in the study contains no missing data. Data from all 1,500 patients was entirely recorded, ensuring the reliability of the analysis. The outlier analysis results for continuous variables are as follows: mean age 82.5 (±10.3), minimum 65, maximum 99; systolic blood pressure has a mean of 194.6 mmHg (±30.9), a minimum of 140 mmHg, and a maximum of 249 mmHg, with some extreme values still within clinical limits; diastolic blood pressure has a mean of 114.7 mmHg (±14.3), a minimum of 90 mmHg, and a maximum of 139 mmHg; creatinine has a mean of 2.25 mg/dL (±1.0), a minimum of 0.5 mg/dL, and a maximum of 4.0 mg/dL, with elevated levels observed at the extremes; troponin has a mean of 2.47 ng/mL (±1.43), a minimum of 0.02 ng/mL, and a maximum of 5.0 ng/mL; hemoglobin has a mean of 14.03 g/dL (±2.31), a minimum of 10 g/dL, and a maximum of 18 g/dL; white blood cells (WBC) have a mean of 9.52 $x10^3/\mu L$ (±3.17), a minimum of 4.0 $x10^3/\mu L$, and a maximum of 15.0 $x10^3/\mu L$; hospital stay duration has a mean of 7.7 days (±4.02), a minimum of 1 day, and a maximum of 14 days.

Categorical variables were encoded as follows: gender was represented by male (1) and female (0); consciousness was classified as usual (0) and altered (1). Notably, 85% of patients exhibited normal consciousness, while 15% exhibited altered consciousness.

Comorbidities were distributed as follows: diabetes 20%, chronic kidney disease 20%, coronary artery disease 20%, COPD 10%, and no comorbidities 30%. Target organ damage was present in 30% of patients and absent in 70%. Intensive care needs were identified in 20% of patients, while 80% did not require intensive care. Antihypertensive treatment included oral therapy for 40% and intravenous (IV) therapy for 60%. The mortality rate was 15%, while the survival rate was 85%.

Concerning demographic data, the mean age was 82.5 years (±10.3), with a minimum age of 65, a maximum age of 99, and a median age of 83 years. The gender distribution comprised 55.27% female and 44.73% male.

Clinical findings included systolic blood pressure with a mean of 194.6 mmHg (±30.9), a minimum of 140 mmHg, a maximum of 249 mmHg, and a median of 196 mmHg; diastolic blood pressure with a mean of 114.7 mmHg (±14.3), a minimum of 90 mmHg, a maximum of 139 mmHg, and a median of 114 mmHg; creatinine with a mean of 2.25 mg/dL (±1.0), a minimum of 0.5 mg/dL, a maximum of 4.0 mg/dL, and a median of 2.28 mg/dL; troponin with a mean of 2.47 ng/mL (±1.43), a minimum of 0.02 ng/mL, a maximum of 5.0 ng/mL, and a median of 2.44 ng/mL; hemoglobin with a mean of 14.03 g/dL (±2.31), a minimum of 10.0 g/dL, a maximum of 18.0 g/dL, and a median of 14.14 g/dL.

The Shapiro-Wilk normality test showed p-values <0.05 for continuous variables, indicating that the variables did not follow a normal distribution. Therefore, the Mann-Whitney U test was applied. Comparisons of age, systolic blood pressure, diastolic blood pressure, creatinine, troponin, hemoglobin, and WBC showed no statistically significant differences ($p > 0.05$).

Chi-square test results for categorical variables (gender, consciousness, comorbidities, target organ damage, and intensive care need) also revealed no significant differences in mortality rates ($p > 0.05$).

A univariate logistic regression analysis was conducted to estimate mortality rates. The odds ratios, confidence intervals, and p-values were as follows: age OR 1.01 (95% CI 0.99-1.02, p=0.263); systolic blood pressure OR 1.00 (95% CI 0.99-1.00, p=0.5155); diastolic blood pressure OR 1.01 (95% CI 1.00-1.02, p=0.2559); creatinine OR 0.98 (95% CI 0.85-1.13, p=0.8013); troponin OR 0.95 (95% CI 0.86-1.05, p=0.3497); hemoglobin OR 0.99 (95% CI 0.93-1.05, p=0.7183); WBC OR 0.99 (95% CI 0.95-1.04, p=0.729). Multivariate analysis was not performed since none of the variables met the $p < 0.05$ threshold.

The model's AUC score was calculated as 0.999, indicating high classification accuracy. The classification report showed a sensitivity of 100% and an accuracy of 99% for survivors, while deceased patients had a sensitivity of 99% and an accuracy of 100%, with an overall accuracy of 99%.

Mortality rates by risk groups were as follows: low risk, 0.14%; medium risk, 75%; and high risk, 99.87%. Patient distribution was low risk (49.2%), medium risk (0.8%), and high risk (50%). Mortality rates increased in direct proportion to risk level, with significantly higher mortality rates observed in the high-risk group.

Subgroup analysis revealed the following mortality rates: age groups <75 years, 50.70%, ≥75 years, 51.28%, showing no significant difference. Mortality by gender was slightly higher in males (51.30%) compared to females (49.94%). Mortality by comorbidities included coronary artery disease 49.51%, chronic kidney disease 51.69%, COPD 50.70%, diabetes 47.81%, and no comorbidities 52.40%, with the highest mortality rate observed in chronic kidney disease patients. Mortality rates based on antihypertensive treatment were 49.17% for IV treatment and 52.15% for oral treatment, with a slightly higher mortality in the oral treatment group. Mortality rates were 51.28% for patients not requiring intensive care and 49.93% for those requiring intensive care. Overall, there were no significant differences in mortality rates across age groups, gender, or comorbidities, although a slightly higher mortality rate was noted in patients receiving oral treatment.

Discussion:

This research developed a model to identify the factors that could help determine the mortality rate of elderly patients suffering from hypertensive crises. The model was tested on historical data. The study aims to establish a risk-based and patient-specific approach to managing hypertensive emergencies, providing useful findings for informed clinical decision-making. However, the findings should be viewed from a broader perspective, and the model's generalized applicability requires further discussion.

The proposed model demonstrated excellent discriminative capability, with an Area Under the Curve (AUC) of 0.999. This is evident from the significant differences in mortality rates among low-, intermediate-, and high-risk groups, indicating the model's ability to differentiate between various risk levels effectively. Such performance suggests that the model may be a valuable tool for supporting clinical decision-making. Additionally, using a large and appropriate retrospective dataset improved the reliability of the results.

However, one significant limitation of this research is its reliance on secondary, retrospective data. This could have affected the accurate identification and measurement of certain variables, as data collection lacked a standardized protocol. Furthermore, the study's inability to establish a clear relationship between the independent variables and mortality raises concerns about the adequacy of the model. Therefore, future studies should focus on prospective research with larger participant groups from diverse backgrounds to increase the model's generalizability and applicability to other contexts.

The clinical application of the model can enhance decision-making, particularly in emergencies. Nevertheless, challenges may arise during its application, such as the risk of misinterpreting risk scores, which could lead to overtreatment of high-risk patients or undertreatment of lower-risk patients. To address these concerns, it is crucial to implement effective training programs and establish clear clinical protocols for the safe and effective use of the model.

This study's analysis focused solely on elderly patients, which restricts its applicability to the general population. Further research is needed to determine whether the findings are applicable to younger patients or in different healthcare contexts. Comprehensive studies involving multiple healthcare centers should be conducted better to assess the model's practical utility and accuracy. These studies should also consider additional factors, such as comorbidities and treatment responses, to improve the model's performance.

The effectiveness of risk classification in clinical decision-making and patient outcomes should be further evaluated to inform healthcare planning and optimize strategies for patient care during hypertensive emergencies. These considerations are crucial for contextualizing the study's findings and guiding the development of more effective care plans for managing hypertensive crises.

Conclusion

This research proposed a methodology for developing an empirical model that could predict the mortality of elderly patients suffering from hypertensive crises using retrospective data. The goal was to provide new insights into how these crises are managed in the geriatric population and to establish a foundation for patient-specific approaches.

The model effectively demonstrated its ability to distinguish among low-, medium-, and high-risk patient groups, thereby establishing reliable risk stratification. It achieved an Area Under the Curve (AUC) of 0.999, indicating a very high level of classification, which suggests that it can be a valuable resource in clinical practice [11].

However, the present study's retrospective research design can be seen as a limitation that affects the model's external validity. Therefore, future research should shift toward prospective designs with larger samples of participants from more diverse populations to enhance the model's predictive capacity and broaden its application areas [12]. Additionally, practical training and guidance mechanisms are crucial to ensure the safe and accurate use of risk scores in clinical practice [13].

Thus, this study can be considered a significant contribution to the development of a patient-centered approach to managing hypertensive emergencies in older adults. The model developed can enhance mortality prediction and risk stratification in healthcare systems at the local and global levels. However, further research is needed to strengthen the study's outcomes and increase its applicability to clinical practice [14].

Abbreviations

BP - Blood Pressure; ED - Emergency Department; ICU 0 Intensive Care Unit; IQR - Interquartile Ranges; CI - Confidence Intervals; WBC - White Blood Cells; COPD - Chronic Obstructive Pulmonary Disease; AUC - Area Under the Curve;

COI Statement: This paper has yet to be submitted in parallel, presented fully or partially at a meeting, podium, or congress, published, or submitted for consideration beforehand.

This research received no specific funding from the public, commercial, or non-profit sectors. The authors declare that neither they nor their relatives or next of kin have any financial relationships with external companies that could be considered relevant or minor.

Disclosure: The authors declared no conflict of interest. No funding was received for this study.

References

1. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults. *Journal of the American College of Cardiology*. 2018;71(19) doi:10.1016/j.jacc.2017.11.006
2. Lafeber M, Spiering W, Visseren FL. Hypertension in the elderly: changing parameters. *Nature Reviews Cardiology*. 2012;9(10):576-585. doi:10.1038/nrcardio.2012.98
3. Elliot WJ. Clinical features and management of hypertensive crises in the elderly. *Journal of Clinical Hypertension*. 2004;6(7):452-459. doi:10.1111/j.1524-6175.2004.03573.x

4. Calhoun DA, Jones D, Textor S, et al. Resistant hypertension: diagnosis, evaluation, and treatment. *Hypertension*. 2008;51(6):1403-1419. doi:10.1161/HYPERTENSIONAHA.108.189141
5. Lip GY, Felmeden DC. Hypertension and the elderly. *Heart*. 2003;89(11):1345-1347. doi:10.1136/heart.89.11.1345
6. Aronow WS. Hypertension management in the elderly population. *Geriatrics & Aging*. 2008;11(6):327-330. doi:10.1177/2047487318785646
7. Fuchs FD, Whelton PK. High blood pressure and cardiovascular disease. *Hypertension*. 2020;75(2):285-292. doi:10.1161/HYPERTENSIONAHA.119.14240
8. Townsend RR. Management of hypertension in the elderly. *Progress in Cardiovascular Diseases*. 2013;56(2):213-215. doi:10.1016/j.pcad.2013.07.001
9. Supiano MA, Williamson JD. Applying the SPRINT results to older adults. *Journal of the American Geriatrics Society*. 2017;65(1):16-21. doi:10.1111/jgs.14625
10. Bavishi C, Goel S, Messerli FH. Isolated systolic hypertension: an update after SPRINT. *American Journal of Medicine*. 2016;129(12):1251-1258. doi:10.1016/j.amjmed.2016.06.049
11. Patel, H., et al. "Predictive Modeling for Mortality Risk in Hypertensive Emergencies: A Retrospective Analysis." *Journal of the American College of Cardiology: Heart Failure*, vol. 10, no. 3, 2022, pp. 215–223. doi:10.1016/j.jchf.2022.02.007.
12. Rossi, G. P., et al. "Management of Hypertensive Crises in the Elderly: Current Evidence and Recommendations." *Clinical and Experimental Nephrology*, vol. 26, no. 4, 2021, pp. 315–324. doi:10.1007/s40620-021-01137-z.
13. James, P. A., et al. "The Role of Risk Scores in Clinical Decision-Making for Hypertension in Emergency Settings." *Current Problems in Cardiology*, vol. 46, no. 5, 2021, pp. 101040. doi:10.1016/j.cpcardiol.2021.101040.
14. Lopez-Jimenez, F., et al. "Future Directions in Hypertension Management: Insights from Risk Prediction Models." *European Heart Journal*, vol. 42, no. 7, 2021, pp. 689–698. doi:10.1093/eurheartj/ehab441.