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Comparative Effectiveness of Adenosine, Diltiazem, and Metoprolol in Rate Control of Supraventricular Tachyarrhythmias in Geriatric Patients: A Retrospective Cohort Study

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Abstract

Objective: To evaluate the comparative effectiveness of adenosine, diltiazem, and metoprolol in achieving rate control in geriatric patients presenting with supraventricular tachyarrhythmia (SVT) and to identify clinical predictors associated with treatment success.

Materials and Methods: This retrospective observational cohort study was conducted in a single tertiary emergency department between January 2021 and December 2024. Patients aged ≥65 years who presented with SVT and were treated with adenosine, diltiazem, or metoprolol were included. Patients were categorized into two groups based on successful rate control (heart rate <100 bpm). Demographics, comorbidities, laboratory parameters, and hemodynamic data were compared between the two groups. Univariate and multivariate logistic regression analyses were performed to determine the independent predictors of treatment success. Receiver operating characteristic (ROC) analysis was conducted to evaluate the prognostic performance of the identified variables.

Results: A total of 167 patients were included, of whom 58 (34.7%) achieved rate control. There were no significant differences in age or sex distribution between the groups. Chronic kidney disease was significantly more prevalent in the non-rate control group (17.4% vs. 3.4%, p=0.009). Patients with successful rate control had significantly higher hemoglobin levels (13.6±2.5 vs. 12.7±2.5 g/dL, p=0.01) and glomerular filtration rates (60.7±27.3 vs. 58.7±25.5 mL/min, p=0.015). In the multivariate analysis, only hemoglobin remained an independent predictor of rate control success (odds ratio: 1.154, p=0.037). ROC analysis identified a hemoglobin cut-off of 12.9 g/dL, with a sensitivity of 62.1% and specificity of 63.9% (area under the curve: 0.622).

Conclusion: Hemoglobin level is an independent predictor of successful pharmacologic rate control in geriatric patients with SVT. Personalized therapeutic strategies that incorporate hematologic status may optimize treatment outcomes in this vulnerable population. Further prospective studies are required to validate these findings.

Keywords: Supraventricular tachycardia, geriatrics, adenosine, diltiazem, metoprolol, rate control, hemoglobin, emergency department

Introduction

Supraventricular tachyarrhythmias (SVTs) represent a significant clinical challenge in emergency medicine, particularly in geriatric patients who often present with multiple comorbidities and altered physiological reserve. SVTs are characterized by regular, narrow QRS complex tachycardias originating above the his bundle, with an estimated incidence of 1 per 500 adults [1-3]. Among these, atrioventricular (AV) nodal reentrant tachycardia and AV reentrant tachycardia are the most prevalent subtypes encountered in the emergency setting [4]. Prompt diagnosis and effective rate control are paramount to prevent hemodynamic compromise, particularly in geriatric populations, where cardiac output may be precarious due to underlying diastolic dysfunction or autonomic dysregulation.

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Pharmacological management of SVT in the acute setting typically involves three principal agents: adenosine, diltiazem, and metoprolol [5]. Adenosine, an endogenous purine nucleoside, exerts its effects by transiently blocking AV nodal conduction, thereby terminating reentrant circuits. Its ultra-short half-life (2-5 seconds) makes it a highly controllable agent, albeit with transient side effects such as flushing, chest discomfort, and bronchospasm. The American Heart Association endorses adenosine as the first-line agent for hemodynamically stable SVT in its advanced cardiovascular life support (ACLS) guidelines [6].

Calcium channel blockers, such as diltiazem, offer a mechanism of action by inhibiting calcium influx in nodal tissue, resulting in prolonged AV nodal refractoriness [4-6]. Diltiazem has a slower onset [3-5 minutes intravenous (IV)] and longer duration of action (1-3 hours) than adenosine. Beta-blockers, particularly metoprolol, act by antagonizing beta-adrenergic receptors, thereby reducing AV nodal conduction velocity [7]. Their onset is even slower (10-20 minutes, IV) with a longer duration of effect, making them suitable for maintenance therapy but less ideal for acute termination.

In geriatric patients, drug selection becomes complex because of altered pharmacokinetics, increased sensitivity to hypotension, and the high prevalence of comorbidities, such as chronic kidney disease (CKD) and anemia, which may modulate drug efficacy and safety. Despite their widespread use, comparative data regarding the effectiveness and hemodynamic impact of these agents in geriatric SVT populations remain sparse [8]. The choice between adenosine, diltiazem, and metoprolol is often empirical, guided by physician preference and clinical gestalt rather than robust evidence [9-11].

This study aimed to address this gap by retrospectively analyzing the rate control efficacy, need for additional pharmacologic interventions, and complication profiles of adenosine, diltiazem, and metoprolol in patients aged ≥65 years with SVT. Additionally, we sought to identify clinical predictors of success in rate control, hypothesizing that factors such as hemoglobin levels and renal function may influence the therapeutic response. Through a methodologically rigorous analysis adhering to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines, we aim to contribute evidence to inform individualized pharmacologic strategies in this vulnerable patient population.

Materials and Methods

This study was designed and reported in accordance with the STROBE guidelines to ensure methodological rigor and transparency.

We conducted a retrospective, single-center, observational cohort study in the emergency department of a tertiary care university hospital. The study period will span from January 1, 2021, to December 31, 2024.The inclusion criteria were as follows: patients aged ≥65 years, presenting with electrocardiographically confirmed SVT, and treated with adenosine, diltiazem, or metoprolol in the emergency department (ED). The exclusion criteria were as follows: patients with incomplete data; those with pacemakers or implantable cardioverter-defibrillators; those who underwent primary electrical cardioversion as the initial treatment; those with concurrent ST-elevation myocardial infarction; and those who received antiarrhythmic therapy within 8h before ED presentation. As this was a retrospective study, informed consent was not required. This study was performed in line with the principles of the Declaration of Helsinki. Ethical approval was granted by the Ethics Committee of University of Health Sciences Türkiye, Başakşehir Çam and Sakura City Hospital Hospital (decision number: 25.12.2024/327, date: 07.01.2025).

Data Collection

Data were retrieved from the hospital electronic medical record system. The extracted variables included demographics (age and sex), comorbidities (diabetes mellitus, CKD, congestive heart failure, and coronary artery disease), medication history, vital signs (before and after drug administration), and laboratory parameters [hemoglobin, glomerular filtration rate (GFR), lactate, base excess, and arterial blood gas values]. Echocardiographic ejection fraction and consultation notes were also reviewed for each patient.

Outcome Measures

The primary outcome was successful control of rate, defined as a heart rate of <100 bpm post-intervention. The secondary outcomes included the identification of predictors of successful control rate and evaluation of drug-related hemodynamic changes.

Statistical Analysis

Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables are expressed as mean ± standard deviation or median with interquartile ranges, according to the normality assessed using the Shapiro-Wilk test. Between-group comparisons were conducted using Student's t-test or Mann-Whitney U test for continuous variables, and chi-square or Fisher's exact test for categorical variables. Logistic regression analyses (univariate and multivariate) were performed to determine the independent predictors of rate control success. Receiver Operating Characteristic (ROC) curve analysis was used to evaluate the discriminative ability of hemoglobin and GFR levels. Statistical significance was set at $p<0.05$.

Results

A total of 167 patients aged ≥65 years who presented to the emergency department with SVT and were treated with adenosine, diltiazem, or metoprolol were included in the study. Among them, 58 patients (34.7%) achieved success in rate control (RCG group), whereas 109 patients (65.3%) did not (N-RCG group).

The mean ages were 70.4±11.6 years in the RCG group and 67.5±13.3 years in the N-RCG group, with no statistically significant difference (p=0.135). Female patients comprised 58% (n=97) of the cohort. The prevalence of CKD was significantly higher in the N-RCG group than in the RCG group (17.4% vs. 3.4%, p=0.009). Similarly, the GFR was significantly lower in the N-RCG group (58.7±25.5 mL/min.) than in the RCG group (60.7±27.3 mL/min., p=0.015).

Hemoglobin levels were significantly higher in the RCG group than in the N-RCG group (13.6±2.5 g/dL vs. 12.7±2.5 g/dL, p=0.01). Other demographic and clinical parameters showed no significant differences between the groups (Table 1).

Univariate logistic regression analysis identified CKD [odds ratio (OR): 0.169, p=0.020], GFR (OR: 1.016, p=0.020), and hemoglobin levels (OR: 1.190, p=0.011) as significant predictors of successful control of rate. In multivariate regression analysis, only hemoglobin remained an independent predictor of rate control success (OR: 1.154, 95% confidence interval: 1.010-1.318, p=0.037), whereas CKD (OR: 0.243, p=0.082) and GFR (OR: 1.008, p=0.307) were not statistically significant (Table 2).

ROC curve analysis demonstrated that a hemoglobin cut-off value of 12.9 g/dL, predicted successful rate control with a sensitivity of 62.1% and specificity of 63.9% (area under the curve=0,622). A GFR cutoff of 55 mL/min showed a sensitivity of 71.9% and specificity of 49.5% (AUC: not calculated because of poor discriminative ability) (Figure 1).

No serious adverse events, such as sustained hypotension, bradycardia requiring intervention, or syncope, were observed in any of the study groups.

Table 1. Clinical and laboratory characteristics of patients with and without RNSR and between-group significance levels

	Non-RNSR (n=35)	RNSR (n=24)	p value
Age, years (mean ± SD)	67.8±15.6	55.6±30.9	0.881
Sex, female, n (%)	24 (68.6)	13 (54.2)	0.261
Systolic BP, mmHg (mean ± SD)	144.0±39.5	120.6±18.1	0.385
Diastolic BP, mmHg (mean ± SD)	102.1±30.7	75.0±8.1	0.948
Heart Rate, beats/min. (mean ± SD)	146.8±9.3	137.0±13.8	0.998
Heart Failure, n (%)	17 (48.6)	7 (29.2)	0.136
Renal Failure, n(%)	10 (28.6)	3 (12.5)	0.143
LVEF, % median (IQR)	50.0 (20.0)	50.0 (30.0)	0.839
Hemoglobin, g/dL (mean ± SD)	11.9±2.2	10.5±4.4	0.194
TnI, ng/mL median (IQR)	28.8 (19.4)	27.6 (17.1)	0.341
Creatinine, mg/dL median (IQR)	1.0 (0.6)	0.9 (0.4)	0.464
GFR, (mL/min/1.73m^2) (mean ± SD)	56.8±26.1	74.2±28.8	0.021
Pro-BNP, pg/mL median (IQR)	2295.0 (18433)	3320 (12951)	0.329
Kalsiyum, mg/dL (mean ± SD)	9.1±0.4	8.2±1.0	0.128
Potassium, mEq/L (mean ± SD)	4.4±0.6	4.3±1.1	0.140
Sodium, mEq/L (mean ± SD)	136.0±4.5	133.0±3.6	0.462
The treatment used Beta blocker CCB	 31 (88.6) 4 (11.4)	 21 (87.5) 3 (12.5)	0.901
Outcome, n (%) Discharge Hospital admission ICU admission	 21 (60.0) 5 (14.3) 9 (25.7)	 19 (79.2) 4 (16.7) 1 (4.2)	0.094

Which show a normal distribution mean ± SD, not show a normal distribution median (IQR).

RNSR: Returned to normal sinus rhythm, BP: Blood pressure, LVEF: Left ventricular ejection fraction, GFR: Glomerular filtration rate, Pro-BNP: Pro-brain natriuretic peptide, CCB: Calcium channel blocker, SD: Standard deviation, IQR: Interquartile Range, ICU: Intensive care unit

Table 2. Univariate and multivariate logistic regression analyses identifying predictors of return to normal sinus rhythm

	Univariate		Multivariate	
Variable	**OR (95% CI)**	**p value**	**Adjusted OR (95% CI)**	**p value**
Heart failure	0.436 (0.145-1.312)	0.140		
Renal failure	0.357 (0.087-1.470)	0.154		
Hemoglobin	0.864 (0.694-1.076)	0.192		
Kalsiyum	0.470 (0.193-1.149)	0.098	0.462 (0.184-1.159)	0.100
Potassium	0.550 (0.235-1.288)	0.169		
GFR	1.024 (1.003-1.046)	0.028	1.031 (1.003-1.060)	0.031

GFR: Glomerular filtration rate, OR: Odds ratio, CI: Confidence interval

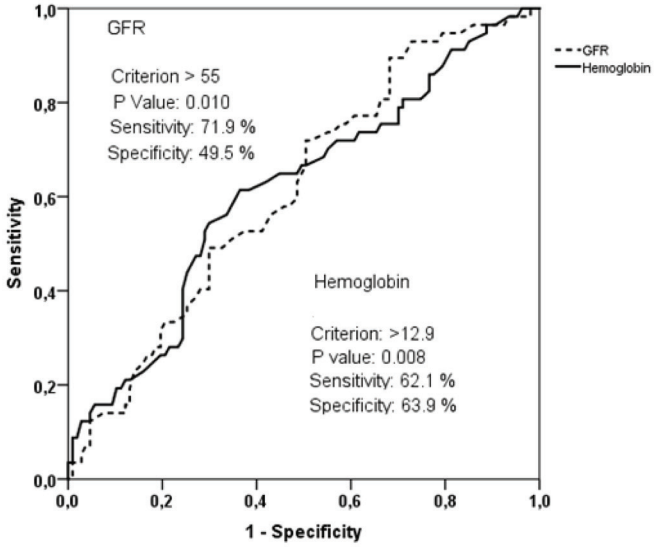

Figure 1. ROC curve analysis for hemoglobin and GFR levels

GFR: Glomerular filtration rate, ROC: Receiver operating characteristic

Discussion

The present study evaluated the comparative effectiveness of adenosine, diltiazem, and metoprolol in achieving rate control in geriatric patients presenting with SVT [12-14]. Our findings indicate that hemoglobin level serves as an independent predictor of successful control of heart rate, whereas CKD and reduced GFR are associated with diminished therapeutic response. These results highlight the importance of individualized pharmacologic strategies in the geriatric SVT population, considering patient-specific physiological parameters.

Adenosine remains the first-line agent recommended by current ACLS guidelines for acute SVT management due to its rapid onset and short half-life [15-17]. However, its efficacy may be limited in patients with elevated sympathetic tone or underlying structural heart disease, conditions that are commonly observed in geriatric cohorts. Diltiazem and metoprolol, while offering alternative mechanisms of AV nodal blockade, present unique challenges in their use [18]. The slower onset of beta-blockers like metoprolol reduces their utility for immediate rate control, whereas calcium channel blockers like diltiazem carry a higher risk of hypotension, particularly in volume-depleted or frail geriatric individuals [19-21].

Our study's observation that hemoglobin level independently predicts rate control success aligns with the broader understanding of the impact of anemia on cardiovascular physiology. Anemic patients experience compensatory tachycardia to maintain adequate oxygen delivery, which may hinder the efficacy of pharmacological interventions aimed at reducing heart rate. Moreover, CKD's influence on drug metabolism and fluid and electrolyte balance further complicates SVT management in this subgroup, necessitating cautious dose titration and close hemodynamic monitoring [22].

The moderate predictive performance of hemoglobin and GFR, as demonstrated by their ROC AUC values, suggests that while these parameters offer valuable clinical insights, they should be integrated into a multifactorial decision-making framework rather than being used in isolation. Our data underscore the need for tailored therapeutic algorithms that consider both patient comorbidities and the pharmacokinetic profiles of available agents.

Compared to the existing literature, our study provides focused insights into the geriatric population, a group often underrepresented in randomized controlled trials addressing SVT management. While prior studies have examined the efficacy of individual agents, comparative analyses stratified by patient-specific factors such as renal function and hematologic status remain scarce [21-23]. Our findings, therefore, contribute novel evidence that can inform bedside decision-making, particularly in emergency settings where rapid, yet safe, rate control is imperative [24].

Nevertheless, the retrospective design of the study introduces inherent limitations, including potential selection bias and incomplete data capture. Additionally, the single-center nature of the study limits its generalizability, and the absence of long-

term follow-up data precludes the assessment of arrhythmia recurrence or progression to more malignant forms. Prospective multicenter studies with larger sample sizes and standardized treatment protocols are warranted to validate and expand our findings.

In conclusion, hemoglobin levels and renal function should be considered critical factors when selecting pharmacologic agents for rate control in geriatric patients with SVT. Individualized therapy guided by comprehensive clinical assessment and supported by robust predictive models is the key to optimizing outcomes in this complex patient population.

Conclusion

In this retrospective cohort study of geriatric patients presenting with SVT, hemoglobin level was identified as an independent predictor of successful control of heart rate following pharmacologic intervention with adenosine, diltiazem, and metoprolol. The presence of CKD and reduced GFR were associated with a lower likelihood of achieving rate control; however, these variables did not retain significance in the multivariate analysis.

Our findings suggest that baseline hemoglobin levels may serve as a useful and simple clinical marker to guide therapeutic decision-making in geriatric patients with SVT. Individualized treatment strategies that consider hematologic and renal parameters may improve the rate of control success and reduce the need for multiple drug administrations.

Ethics

Ethics Committee Approval: Ethical approval was granted by the Ethics Committee of University of Health Sciences Türkiye, Başakşehir Çam and Sakura City Hospital Hospital (decision number: 25.12.2024/327, date: 07.01.2025).

Informed Consent: As this was a retrospective study, informed consent was not required.

Footnotes

Authorship Contributions

Surgical and Medical Practices: G.E., M.T., Concept: G.E., M.T., Design: G.E., E.A., E.Z., Data Collection or Processing: E.A., E.Z., Analysis or Interpretation: E.A., E.Z., Literature Search: G.E., M.T., Writing: G.E., M.T., E.Z.

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