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ORIGINAL RESEARCH

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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

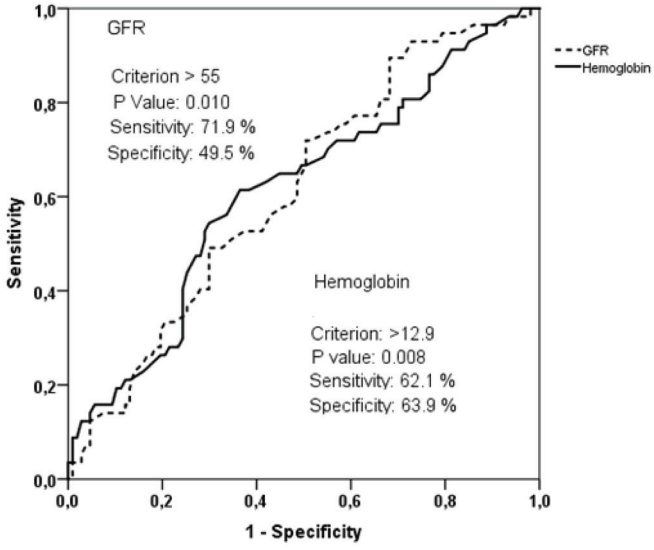

Figure 1. ROC curve analysis for hemoglobin and GFR levels

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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ORIGINAL RESEARCH

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The Effect of Secondary Transfer Distance on Outcomes for Patients with Acute Ischemic Stroke: A Retrospective Cohort Study

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Abstract

Objective: The efficacy of mechanical thrombectomy (MT) and intravenous thrombolytic therapy (IVT) in patients with acute ischemic stroke (AIS) is time dependent. In this study, we investigated the effect of interhospital distance on outcomes for patients who received secondary transfer and were treated with MT and IVT to a comprehensive stroke center (CSC).

Materials and Methods: We included patients with AIS who were secondarily transferred by road to our center, which is considered a CSC, between January 7, 2023, and January 7, 2024. We compared patients based on their distance from the treatment facility: those who were closer or further than 30 km and those who were closer or further than 90 km, in terms of the treatment they received (MT/IVT), three-month mortality, intracranial hemorrhage within 36 hours, and good neurological outcome.

Results: The study included 259 patients who were secondarily transferred from 29 different hospitals. In the <30 km group, the number of patients who received at least one MT/IVT therapy was at least one MT/IVT therapy in the ≥30 km group, 11 patients (7.6%) received at least one MT/IVT therapy (p=0.005). In multivariate analysis, patients transferred within 30 km were twice as likely to receive IVT/MT, compared to those transferred from longer distances.

Conclusion: The need to travel greater distances in the secondary transfer of patients with AIS decreases the chance of these patients receiving MT/IVT. Although three-month mortality, intracranial hemorrhage within 36 hours, and a good neurological outcome did not differ between near and far patients, increasing the number of CSC centers will increase the number of stroke patients who can access MT/IVT treatment options.

Keywords: Acute ischemic stroke, thrombectomy, thrombolytic therapy, emergency medicine

Introduction

Time plays an important role in the treatment of acute ischemic stroke (AIS) as it determines treatment options, and timely access to treatment options for AIS patients is very important in reducing mortality and morbidity. Intravenous thrombolysis (IVT) and mechanical thrombectomy (MT) are treatment options with proven benefits in patients with AIS [1,2]. For patients to benefit from IVT and MT, they need to arrive at the right center at the right time. Different management models are used to ensure that these treatments are provided at the appropriate time. Decisions are made to transfer a patient with suspected stroke to the nearest comprehensive stroke center (CSC) with MT facilities (the mothership model) to the nearest primary stroke

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center (PSC) with acute stroke care where IVT treatment can be administered and thentransfer MT candidates tsso the CSC (drip-and-ship model) [3].

It has not yet been determined which model is superior-the mothership model or the drip-and-ship model [4]. Both models have some disadvantages. While the mothership model creates a serious patient burden on the main center, in the drip-and-ship model, patients may be delayed in receiving MT [5]. Patient outcomes in both models depend on many factors, including the type of health insurance system, the geographical distribution of the population, geographical conditions, and the distance from and accessibility to stroke centers. Geographical constraints result in inequalities in access to centers where MT is available as patients in rural areas can be significantly disadvantaged [6].

Previous studies have compared the mothership and the drip-and-ship models. In this study, we aimed to investigate the effect of transfer distance on the treatment and outcomes of patients with AIS who were secondarily transferred to our CSC. We hypothesized that patients who were transferred to our CSC from more distant hospitals would show a lower rate of IVT and MT treatment and would have higher mortality.

Materials and Methods

Patients and Study Design

This is a single-center retrospective cohort study conducted in a tertiary care emergency department (ED). All patients over 18 years of age with a clinical and neuroimaging diagnosis of AIS who were secondarily transported by road from a PSC to our CSC between January 7, 2023, and January 7, 2024, were included in the study. The study was approved by the, University of Health Sciences Türkiye, Ankara Etlik City Hospital Scientific Research Evaluation and Ethics Committee (decision number: 2024-824, date: 04.09.2024). The study was conducted in accordance with the Declaration of Helsinki, and the patient data collected by the researchers were kept confidential. Pregnant patients, patients with missing data, and patients brought to the study center with cardiac arrest were excluded. Among cases of interhospital transfers, we excluded those who were diagnosed with AIS at the first facility but not at the CSC.

The ED of our 24-hour CSC hospital has a stroke unit and an intensive care unit with the capacity to provide emergency neuroimaging, IVT, and MT. The hospital is the most important and largest stroke center in the city. It is integrated into the country's healthcare system, and all healthcare services provided at the hospital are free of charge.

Stroke Management Strategy

The stroke management strategy used in our region is as follows. Patients with suspected stroke are brought to the nearest hospital. The patient with possible AIS is transferred to the CSC bypassing the nearest center if it will not lose more than 15 minutes of time. There is a pre-planned CSC center stroke on-call for each day, and patients are referred to the on-call CSC during off-hours. The stroke center where the study was conducted is considered a CSC and has 10-12 stroke on-call days per month. MT and IVT is not applied in the hospitals where patients are initially taken. Because the first hospitals patients entered were primary hospitals. In the secondary center where they are brought, IVT and/or MT are administered to eligible patients based on radiological imaging, clinical status, and the amount of time that has elapsed since the onset of symptoms. Patients are followed up in the stroke unit or ward after treatment.

Data Collection

Data were collected using the hospital's information system. Data including sociodemographic characteristics, neurologic complications, treatment modalities, stroke duration, and outcomes were collected. National Institutes of Health Stroke Scale scores (NIHSS) and modified rankin scores (mRS) were calculated using electronic patient records [7,8]. Three-month mortality, mRS after three months, and the day of the week when patients were transferred were recorded using the electronic patient records.

In addition, the hospitals from which the patients were also transferred to our CSC were recorded. Using the addresses of the hospitals and the Google Maps application programming interface, we calculated the distance in kilometers between these hospitals and our CSC.

Intracranial hemorrhage was defined as the occurrence of hemorrhagic transformation (parenchymal hematoma type 1-PH1 or type 2-PH2) within the first 36 hours, according to the ECASS II classification [9]. Good neurological outcome was defined as a 3-month mRS ≤2.

MT and IVT treatments were recorded independently of procedural success. Symptom onset to groin puncture and symptom onset to thrombolysis times were noted in minutes. For the MT procedure, the symptom-to-groin time was calculated as the time from symptom onset to the start of the procedure. Likewise, the symptom-to-needle time was calculated as the amount of time that elapsed from symptom onset to the time of the thrombolytic treatment. The time of symptom onset and the time of treatment initiation were taken from the electronic patient records.

Comparison Groups

After analyzing the distances between the hospitals from which the patients were transferred and the CSC, the patients were divided into the following groups: closer than 30 km and farther than 30 km, and closer than 90 km and farther than

90 km. The closer than 30 km and further than 30 km groups were compared with each other, and the closer than 90 km and further than 90 km groups were compared with each other.

Outcomes

The primary outcome of the study was the effect of administering IVT and MT therapies. The secondary outcomes included three-month mortality, intracranial hemorrhage within 36 hours, and good neurologic outcome.

Sample Size

To determine a significant difference in IVT treatment between patients transferred over different distances, a 5% margin of error and 95% power were required. Therefore, a total of 188 patients were included in the study: 94 patients who were transferred less than 50 km, and 94 patients who were transferred more than 50 km.

Statistical Analysis

Data analysis was performed using the Statistical Package for the Social Sciences for Windows version 26 (IBM Corp., Chicago, Illinois, USA). The conformity of the data to normal distribution was evaluated using the Kolmogorov-Smirnov test and histograms. Normally distributed numerical data were presented as mean ± standard deviation, and non-normally distributed numerical data were presented as median and interquartile range (IQR) (25-75%). Categorical variables were presented as number (n) and frequency (%). Categorical variables were compared using the chi-squared test or Fisher's exact test. Continuous variables were compared with the Student's t-test or the Mann-Whitney U test. The statistical significance level was accepted as $p<0.05$ for all tests.

A multivariate logistic regression model was used to estimate the adjusted odds ratios (OR) and 95% confidence intervals (CI) for the association between the distance variable and outcome (MT, IVT, MT + IVT). The following covariates were included in the model based on their clinical relevance and potential for confounding: age, NIHSS, and a measure of 30 km. Statistical significance was determined using Wald tests, with a p-value <0.05 considered significant. The model fit was assessed using the Hosmer-Lemeshow goodness-of-fit test and the akaike information criterion.

Results

Three hundred and ten patients met the inclusion criteria. After the exclusion of pregnant patients and patients with incomplete data, 259 patients were enrolled in the study. Of these patients, 144 (55.6%) were male. The median age of the patients was 68 years (IQR) 58-78. The median distance patients were transferred to the study center was 40 km (IQR 25-75; 15-80 km). Figure 1 shows the number of patients receiving IVT/MT according to the distance they were transferred.

When comparing patients who received thrombectomy (n=33) with those who did not (n=226), significant differences were observed in several key variables. Patients in the thrombectomy group were significantly younger, with a median age of 60 years (IQR: 54-71), compared to 69 years (IQR: 59-79) in the non-treated group (p=0.011).

Transfer distance significantly affected treatment rates. Treated patients had a median transfer distance of 18 km (IQR: 7-47), compared to 40 km (IQR: 17-81) in the non-treatment group (p=0.002). Thrombectomy was performed in 67% of patients transferred ≤30 km, versus 41% for those >30 km (p=0.005). Strikingly, none of the patients transferred from >90 km (p=0.004) received treatment, highlighting the negative impact of long transfer distances on timely intervention (Table 1). Age was significantly higher in the ≥30 km group than in the <30 km group, with a median age of 69 years (IQR 25-75; range 60-80 years) (p=0.030). Twenty-two patients in the <30 km group (19.3%) and 11 patients in the ≥30 km group (7.6%) (p=0.005) received at least one IVT or MT treatment. Other outcome parameters did not differ significantly between the groups.

The number of patients who received at least one IVT or MT treatment was 33 (15.6%) in the <90 km group, while no patients in the ≥90 km group received these treatments (p=0.004) (Table 2).

Multivariate regression analysis identified age, NIHSS score, and a transfer distance ≤30 km as independent predictors of receiving IVT/MT. Older age was associated with lower odds of treatment (OR=0.948, 95% CI: 0.917-0.980, p=0.002), while higher NIHSS scores increased the likelihood of thrombectomy (OR=1.083, 95% CI: 1.042-1.124, p<0.001). Patients transferred from within 30 km were more than twice as likely to receive IVT/MT than those from farther distances (OR=2.3, 95% CI: 1.02-5.187, p=0.045) (Table 3).

Discussion

The results of this study showed that patients who were transferred more than 30 km from a PSC to the CSC were less likely to receive IVT or MT than patients who were transferred less than 30 km. MT and IVT procedure onset times being similar between the groups seems to indicate the reduced chances of receiving IVT and MT treatments for patients who are transferred further than 30 km or 90 km, regardless of the time of the initiation of the procedure. It has been shown that patients living closer to the hospital are more likely to receive IVT than those living further away, and this cannot be explained by shorter arrival times [10]. This study also showed that patients whose transfer distance was more than 90 km had a lower chance of receiving IVT or MT treatment than patients with shorter transfer distances. Similarly, Khazen et al. [11] found that as the distance between PSC and CSC increases, the likelihood of receiving IVT decreases.

Patients transferred to a location less than 30 km away were 2.3 times more likely to receive thrombectomy than those transferred further away. This highlights the critical role of proximity to a CSC in determining access to thrombectomy. These findings highlight the importance of optimising regional stroke networks to minimise secondary transfer delays and ensure equitable access to life-saving thrombectomy.

In the current study, which included only patients who were secondarily transferred from a PSC to the CSC, there was no difference in three-month mortality, intracranial hemorrhage, and neurological outcomes between patients transferred from nearby primary centers and those transferred from distant primary centers, although patients from remote areas had less chance of receiving IVT and MT. Similarly, a previous meta-analysis found no differences between patients transferred directly to the main center and those transferred secondarily [12]. Ader et al. [13] found that low socioeconomic status may be associated with delays in emergency medicine system (EMS) activation. In our patient population, the group of patients who were transferred more than 90 km to our CSC mostly reside in rural areas and have a low socioeconomic status. Delayed EMS activation for patients transferred from areas more than 90 km away reduces the chances of these patients receiving time-dependent treatments.

In a comprehensive study conducted in our country on patients with AIS, the rate of IVT was 12%, while the rate of MT was 8.3% [14]. In the current study, which included only secondarily transferred patients, the rate of MT was 8.4%, while the rate of IVT was 5.4%. This shows that in our transfer strategy, AIS patients lose the opportunity to receive IVT treatment for the possibility of MT. The low rate of IVT may be due to transfers from distant hospitals.

Interhospital transfer of AIS patients, even when the distance between the hospitals is short, has been shown to reduce the rate of MT administration [15]. However, unforeseen IVT will result in missed treatment time, creating a serious burden on CSCs. Therefore, algorithms that can predict large vessel occlusion early are being developed [16]. Video support for prehospital stroke consultation seems to be successful [17]. In regions where these facilities are not yet available, efforts should focus on ensuring the primary transfer of more patients to a CSC within the one-hour timeframe recommended by the American Heart Association guidelines for regional stroke plans in rural, suburban, and urban communities [18].

Table 1. Demographic and clinical characteristics of patients: a comparison between those who received IVT and/or MT and those who did not

Variables		Treatment+ n=33	Treatment- n=226	p
Age, years, median (IQR 25-75)		60 (54-71)	69 (59-79)	0.011*
Sex (male) n (%)		20 (60)	124 (55)	0.53
NIHSS[b], median (IQR 25-75)		15 (12-22)	8 (5-14)	<0.001*
mRS[c], median (IQR 25-75)		4 (4-5)	3 (2-4)	<0.001*
Good neurologic outcome, n (%) Poor neurologic outcome, n (%)		13 (39) 20 (61)	140 (62) 86 (38)	0.014*
Distance transferred, km, median (IQR 25-75)		18 (7-47)	40 (17-81)	0.002*
30 km	<30 km[a]	22 (67)	92(41)	0.005*
	>30 km	11 (33)	134 (59)	
90 km	<90 km	33 (100)	179 (80)	0.004*
	>90 km	0 (0)	47 (20)	
Needle onset time, median (IQR 25-75)		-	135 (120-180)	
Groin onset time, median (IQR 25-75)		-	240 (160-360)	
Emergency department outcome	Hospitalization, n (%)	32 (97)	223 (98)	0.422
	Exitus, n (%)	1 (3)	3 (2)	
Intracranial hemorrhage (36 saat), n (%)		3 (9)	2 (1)	0.016*
Length of ICU[d] stay, days, median (IQR 25-75) Length of ward stay, days, median (IQR 25-75)		6 (2-10) 3 (0-7)	0 (0-2) 5 (3-7)	<0.001* 0.02*
mRS replacement		1 (0-2)	0 (0-1)	0.156
3th month mortality, n (%)		5 (15)	16 (7)	0.161

Treatment+: IVT and/or MT, Km[a]: Kilometers, NIHSS[b]: National Institutes of Health Stroke Scale scores, mRS[c]: Modified rankin scores, ICU[d]: Intensive care unit, IQR: Interquartile range

IVT: Intravenous thrombolytic therapy, MT: Mechanical thrombectomy

Table 2. Comparison of demographic and clinical characteristics between transferred kilometer groups

	<30 km[a] n=114	≥30 km n=145	p value	<90 km n=212	≥90 km n=47	p value
Age, years, median (IQR 25-75)	67 (56-75)	69 (60-80)	0.030	68 (58-77)	73 (58-83)	0.146
Gender, n (%) Female Male	43 (37.7) 71 (62.3)	72 (49.7) 73 (50.3)	0.055	94 (44.3) 118 (55.7)	21 (44.7) 26 (55.3)	0.966
NIHSS[b], median (IQR 25-75)	8 (5-16)	10 (5-15)	0.828	10 (5-16)	7 (5-11)	0.074
mRS[c], median (IQR 25-75)	3 (2-4)	3 (2-4)	0.963	3 (2-4)	3 (2-3)	0.040
Needle onset time, median (IQR 25-75)	130 (90-180)	180 (180-240)	0.126	135 (120-180)	-	-
Groin onset time, median (IQR 25-75)	300 (200-380)	220 (120-240)	0.209	240 (160-360)	-	-
IVT[d]/MT[e]	22 (19.3)	11 (7.6)	0.005	33 (15.6)	0 (0)	0.004
Intracranial hemorrhage	4 (3.5)	1 (0.7)	0.102	5 (2.4)	0 (0)	0.288
Good neurologic outcome	66 (57.9)	87 (60)	0.732	125 (59)	28 (59.6)	0.938
3 month mortality	13 (11.4)	8 (5.5)	0.085	18 (8.5)	3 (6.4)	0.632

Km[a]: Kilometers, NIHSS[b]: National Institutes of Health Stroke Scale scores, mRS[c]: Modified rankin scores, IVT[d]: Intravenous thrombolytic therapy, MT[e]: Mechanical thrombectomy

Table 3. Factors associated with treatment in univariate and multivariate models

Variable	Univariate OR (95% CI)	Univariate p-value	Multivariate OR (95% CI)	Multivariate p-value
Age	0.966 (0.940-0.993)	<0.01	0.948 (0.917-0.980)	<0.005
NIHSS[a]	1.060 (1.027-1.095)	<0.001	1.083 (1.042-1.124)	<0.001
<30 km[b]	2.91 (1.348-6.297)	<0.005	2.3 (1.02-5.178)	<0.05

NIHSS[a]: National Institutes of Health Stroke Scale scores, Km[b]: Kilometers

OR: Odds ratio, CI: Confidence interval

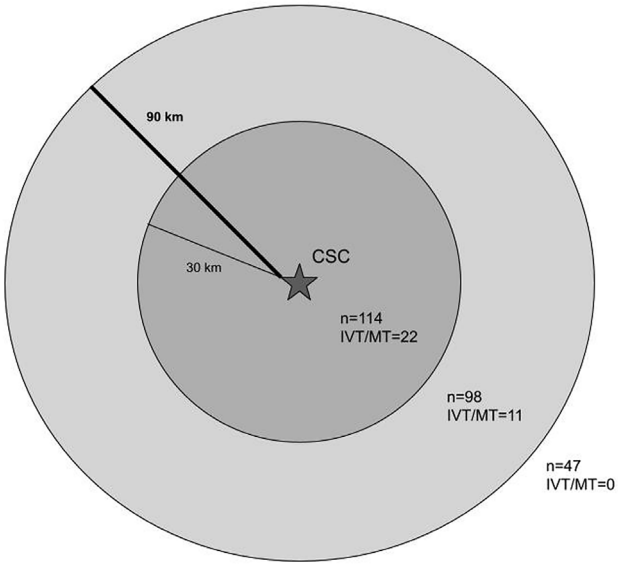

Figure 1. Number of patients treated with IVT/MT according to patients' secondary transfer distance from the CSC

IVT/MT: Intravenous thrombolytic therapy/mechanical thrombectomy, CSC: Comprehensive stroke center

In our region, if AIS patients who can reach the CSC within one hour were taken directly to the CSC, we think that they would have more opportunities to receive MT and IVT.

Study Limitations

Several possible limitations should be considered when interpreting the results of this study. First, the study is retrospective. Therefore, patients with missing data in their electronic patient records were excluded. Second, the management of AIS patients may be different in each country and in different regions within a country. Therefore, the results of this study may not be applicable to other countries or regions within our country. In addition, transfer times for patients may have been impacted by traffic density , indirectly affected the opportunities for patients to receive MT and IVT treatments. Finally, our study was conducted in a single center, and future studies should focus on multiple centers conduct more complex transfer analyses.

Conclusion

In patients with AIS who are secondarily transferred to a CSC, the rate of MT/IVT treatment decreases as transfer distance increases. However, there is no difference between patients whose transfer distances were shorter compared with those whose transfer distances were longer distances in terms of three-month mortality, intracranial hemorrhage, and good neurologic outcome. Our IVT administration rates are quite low for both groups, although our results revealed the negative impact of longer secondary transfers on the likelihood of patients receiving MT/IVT treatment. Increasing the number of centers where MT/IVT treatment is offered and CSCs to reduce secondary transfer distances will contribute to the stroke management strategy in our region.

Ethics

Ethics Committee Approval: The study was approved by the, University of Health Sciences Türkiye, Ankara Etlik City Hospital Scientific Research Evaluation and Ethics Committee (decision number: 2024-824, date: 04.09.2024).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

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

Conflict of Interest: No conflict of interest was declared by the authors.

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ORIGINAL RESEARCH

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Comparative Validation of Blood Gas Analysis, Perfusion Index, and AKIN and RIFLE Scoring Systems in the Diagnosis of Acute Kidney Injury

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Abstract

Objective: This study aimed to evaluate the potential role of the Peripheral Perfusion Index (PI) and arterial blood gas parameters as early indicators of acute kidney injury (AKI) and to compare their diagnostic utility with the Acute Kidney Injury Network (AKIN) and RIFLE scoring systems. We hypothesized that the PI is proportional to the severity of AKI and may aid in early diagnosis and prognosis of the disease.

Materials and Methods: This prospective study included patients who received a new diagnosis of AKI in the emergency department (ED) of two tertiary hospitals based on AKIN and RIFLE criteria. Focusing on ED-diagnosed AKI ensures that the findings reflect early diagnostic decision-making in a time-sensitive setting, where rapid identification of AKI can impact immediate patient management and disposition. The PI of patients with confirmed AKI was measured using the necessary device, and a case report form was completed. This form recorded demographic characteristics, blood gas values, renal function tests, and AKIN and RIFLE scores.

Results: A total of 264 patients were included in this study. The study was divided into two groups: 132 cases (50%) and 132 controls (50%). A statistically significant difference was found between the case and control groups in terms of hypertension ($p=0.001$), coronary artery disease ($p=0.009$), pH ($p=0.015$), HCO_3 ($p=0.001$), sodium ($p=0.001$), PI ($p=0.001$), urea ($p=0.001$), and creatinine ($p=0.001$). A statistically significant difference was found between AKIN score stages and RIFLE index stages regarding pH, CO_2, HCO_3, perfusion index, urea, creatinine, and potassium levels ($p<0.05$).

Conclusion: Our findings suggest that PI and blood gas analysis may serve as valuable adjuncts to conventional AKI classification, providing earlier insights into renal dysfunction.

Keywords: Acute kidney injury (AKI), AKIN Index, Perfusion Index, RIFLE score

Introduction

Acute kidney injury (AKI) is a serious condition characterized by a rapid decline in kidney function, leading to metabolic imbalances and increased morbidity and mortality [1]. While serum creatinine and urine output are the primary diagnostic markers, they are delayed indicators of renal dysfunction [2]. To improve early recognition and risk stratification, various classification systems, including the RIFLE (Risk, Injury, Failure, Loss of kidney function, and End-stage kidney disease) and Acute Kidney Injury Network (AKIN), have been developed [3,4]. However, there is still a need for additional, non-invasive biomarkers that can provide real-time insights into renal perfusion and function.

Patients with AKI commonly present to emergency departments (EDs) with symptoms such as abdominal pain, decreased urine output, diarrhea, and nausea-vomiting [2]. To standardize diagnosis, the Acute Dialysis Quality Initiative (ADQI) developed the RIFLE criteria in 2004 [5]. The RIFLE classification defines AKI severity in three stages (risk, injury, failure) and describes two clinical outcomes (loss and end-stage renal disease) [6].

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Another scoring system, the AKIN, was introduced in 2005 [7]. This system, which serves as a modification of the RIFLE criteria, classifies AKI severity into three stages: stage 1, stage 2, and stage 3 [7]. Both diagnostic systems rely on changes in serum creatinine levels and urine output, regardless of etiology [5]. In both staging systems, mortality increases as the stage progresses.

Despite the widespread use of AKIN and RIFLE scoring systems, early non-invasive markers for AKI remain limited. Perfusion Index (PI), a microcirculatory parameter measured via pulse oximetry, reflects peripheral tissue perfusion and may serve as a dynamic, early marker of AKI severity [8]. Blood gas analysis (BGA), which provides insights into acid-base balance and metabolic disturbances, may further aid in assessing kidney function beyond conventional creatinine-based methods [9].

This study aimed to evaluate PI and BGA as potential adjuncts concomitant with the AKIN and RIFLE scoring systems in patients with AKI. We hypothesize that lower PI values and specific ABG abnormalities are associated with AKI severity and can assist in early diagnosis and risk stratification.

Materials and Methods

Ethical Approval and Patient Consent

This study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the Gaziantep İslam Science and Technology University Non-Interventional Clinical Research Ethics Committee (protocol number: 2022/389, decision number: 389.36.03, date: 26.02.2022). As the study involved a retrospective review of medical records without patient identifiers or potentially identifying data, the institutional review board (IRB) waived the requirement for patient consent.

Study Design and Setting

This was a retrospective observational study conducted in the EDs of Gaziantep City Hospital and Gaziantep Training and Research Hospital between February 2022 and February 2025.

All AKI diagnoses were independently verified by an Emergency Medicine Specialist (Assistant Professor with >10 years of clinical experience) using KDIGO criteria. Data were collected by ten emergency medicine residents (PGY-1/PGY-2), who were blinded to the study hypothesis and not involved in the clinical decision-making process.

PI measurements were obtained using Masimo Radical-7 Pulse CO-Oximeter (Masimo Corp., Irvine, CA, USA) with the probe placed on the patient's finger. PI was recorded as a non-invasive, objective ratio of pulsatile to non-pulsatile infrared light absorption, serving as an indicator of peripheral perfusion.

Study Population and Sampling

The study included adult patients (≥18 years) presenting to the participating EDs with a diagnosis of AKI confirmed by KDIGO criteria [10].

Inclusion criteria:

• Complete data on PI, arterial blood gas (ABG), and renal function tests

• Diagnosis of AKI according to KDIGO serum creatinine criteria.

Exclusion criteria:

• Chronic kidney disease stage 4 or 5 or on maintenance dialysis

• Chronic acid-base disorders

• Acute conditions likely to independently alter blood gas or PI (e.g., sepsis, diabetic ketoacidosis, respiratory failure, shock)

• Pregnancy

• Incomplete medical records for key variables.

A sample size calculation was performed using G*Power (version 3.1.9.8). Assuming a medium effect size (Cohen's d=0.5), α=0.05, and 80% power, 64 participants per group were required. A total of 264 participants were included (132 AKI patients and 132 controls), exceeding the minimum requirement.

All patient data were recorded in a dedicated, de-identified Microsoft Excel database created for this study.

Outcomes

• Primary outcome:

Association of PI and ABG parameters with the presence and severity of AKI (staged by AKIN and RIFLE).

• Secondary outcomes:

• Diagnostic and prognostic performance of PI and ABG parameters using receiver operating characteristic (ROC) analysis area under the curve (AUC)

• Independent predictive value of PI and ABG for AKI in multivariate logistic regression.

Definitions and Scoring (AKIN & RIFLE)

AKI diagnosis and staging were based on KDIGO criteria, while AKIN and RIFLE classifications were calculated for all AKI patients:

• AKIN criteria:

• Stage 1: ≥0.3 mg/dL or 1.5–2.0× baseline serum creatinine

• Stage 2: 2.0–3.0× baseline serum creatinine

• Stage 3: >3.0× baseline or initiation of renal replacement therapy

• Urine output <0.5 mL/kg/h for ≥6–12 h was noted where available.

• RIFLE criteria:

• Risk: 1.5× baseline creatinine or urine output <0.5 mL/kg/h for 6 h

• Injury: 2× baseline creatinine or urine output <0.5 mL/kg/h for 12 h

• Failure: 3× baseline creatinine or urine output <0.3 mL/kg/h for 24 h or anuria for 12 h

• Loss and ESRD stages were noted if applicable but were not primary outcomes in this ED cohort.

All scoring and stage assignments were reviewed and validated by the supervising emergency medicine specialist.

Statistical Analysis

All statistical analyses were performed using SPSS version 26 (MacOS).

Data handling and descriptive statistics:

• Continuous variables: mean ± standard deviation (SD) if normally distributed; median (IQR) if non-normally distributed

• Normality: Kolmogorov-Smirnov and Shapiro-Wilk tests, and visual histogram/probability plot assessment.

• Categorical variables: frequency (%).

Comparative analyses:

• Two-group comparisons: Student's t-test (normal) or Mann-Whitney U test (non-normal)

• Multi-group comparisons: ANOVA with Bonferroni post-hoc (normal) or Kruskal-Wallis with post-hoc Mann-Whitney U test (non-normal)

• Categorical variables: Chi-square test or Fisher's exact test as appropriate

• Correlation and predictive modeling: Multivariate logistic regression with odds ratios [OR, 95% confidence interval (CI)]

• Diagnostic performance: ROC curves and AUC with 95% CIs.

Significance: Two-sided $p<0.05$ was considered statistically significant. No significant missing data were observed for key variables.

Results

A total of 264 patients were included in this study. Methodologically, the study was divided into two equal groups: 132 cases (50%) and 132 controls (50%). The average (AVG) age of the patient group (72.35±10.87) was statistically significantly higher than that of the control group (56.13±19.90) ($p=0.001$). Hypertension was significantly more prevalent in the AKI group (65.2%) compared to the control group (30.0%) ($p<0.001$). Similarly, coronary artery disease was present in 40.9% of AKI patients versus 13.3% of controls ($p=0.002$). These differences suggest a higher baseline cardiovascular risk profile in the AKI group.

The difference in gender distribution between the groups was not found to be statistically significant ($p=0.679$) (Table 1).

Hypertension and coronary artery disease were found to be statistically significantly higher in the patient group compared to the control group ($p=0.001$ and $p=0.009$, respectively). No statistically significant differences were observed between the groups for other variables ($p>0.05$) (Table 1).

In the study, statistically significant differences were observed between the "Patient" and "Control" groups in terms of pH ($p=0.015$), HCO_3 ($p=0.001$), sodium ($p=0.001$), PI ($p=0.001$), urea ($p=0.001$), and creatinine ($p=0.001$) values (Table 2).

A total of 132 patients were categorized using the AKIN and RIFLE scoring systems, (Table 3). According to the AKIN Score, most patients were classified as Stage 1 (63.6%), followed by Stage 2 (28.8%) and Stage 3 (7.6%). In the RIFLE classification, the Risk category was the most common (66.7%), followed by Injury (21.2%), with Failure and Loss each comprising 6.1% of the patient group.

Table 4 summarizes the evaluation of AKIN and RIFLE scores in the patient group, providing the mean AVG, SD, median values, statistical significance (p), and post-hoc comparisons for each parameter.

• AKIN Score Findings:

• PI significantly decreased as AKI severity increased (1>2>3, $p=0.001$).

• Urea and creatinine levels were highest in Stage 3 ($p=0.001$, ranking 3>2>1).

• HCO_3 levels progressively decreased, with Stage 3 having the lowest values ($p=0.001$).

• No significant differences were found for potassium, sodium, lactate, or O_2 levels.

• RIFLE Score Findings:

• PI declined progressively, with the lowest values in the failure stage ($p=0.001$: ranking 1>2>4>3).

• Urea and creatinine levels were significantly higher in the Loss stage compared to all other stages ($p=0.001$, ranking 4>3>2>1).

• O_2 levels were highest in the Failure stage ($p=0.015$, ranking 3>1-2-3.1>2-4).

• No significant differences were found for pH, potassium, sodium, or lactate levels.

Table 1. Demographic and clinical characteristics of patient and control groups

		Control		Case		p
Sex	Male	64	(48.5%)	72	(70.60%)	0.679*
	Female	68	(51.5%)	60	(66.70%)	
Age (AVG ± SD)		56.13	±19.90	72.35	±10.87	0.001**
HT	None	62	(77.50)	18	(22.50)	0.001
	Present	70	(38.04)	114	(61.96)	
CAD	None	74	(66.07)	38	(33.93)	0.009
	Present	58	(38.16)	94	(61.84)	
DM	None	82	(56.16)	64	(43.84)	0.097
	Present	50	(42.37)	68	(57.63)	
CHF	None	88	(49.44)	90	(50.56)	0.233
	Present	44	(51.16)	42	(48.84)	
CKD	None	132	(51.16)	126	(48.84)	0.550
	Present	0	(0.00)	6	(100.00)	
COPD	None	100	(45.87)	118	(54.13)	0.697
	Present	32	(69.57)	14	(30.43)	

*Chi-square, **Mann-Whitney U test.

HT: Hypertension, CAD: Coronary artery disease, DM: Diabetes mellitus, CHF: Chronic heart failure, CKD: Chronic kidney disease, COPD: Chronic obstructive pulmonary disease, AVG: Average, SD: Standard deviation

Table 2. Comparison of Perfusion Index, arterial blood gases and laboratory parameters between patient and control groups

	Group	n	AVG	SD	Median	p
pH	Case	132	7.36	0.10	7.36	0.015
	Control	132	7.40	0.03	7.41	
CO_2	Case	132	39.12	8.19	37.35	0.059
	Control	132	42.77	8.25	40.85	
HCO_3	Case	132	22.08	5.40	21.8	0.001
	Control	132	27.01	8.7	25	
Potassium	Case	132	4.11	0.68	4.095	0.383
	Control	132	3.99	0.32	4.02	
Sodium	Case	132	134.18	5.17	135.3	0.001
	Control	132	138.69	2.18	138.8	
Lactate	Case	132	2.13	1.92	1.65	0.559
	Control	132	1.71	0.77	1.415	
O_2	Case	132	73.05	21.18	77.15	0.649
	Control	132	74.93	18.3	84.05	
Perfusion Index	Case	132	1.19	0.57	1.1	0.001
	Control	132	4.07	1.65	3.95	
Urea	Case	132	71.69	46.02	56.5	0.001
	Control	132	33.73	10.4	29.95	
Creatinine	Case	132	2.02	1.77	1.5	0.001
	Control	132	0.92	0.17	0.935	

*Mann-Whitney U test, **Independent Groups t-test.

AVG: Average, SD: Standard deviation

Table 3. Distribution of the AKIN and RIFLE scores in patient group

		n	%
AKIN score	Stage-1	84	63.6
	Stage-2	38	28.8
	Stage-3	10	7.6
	Total	132	100
		n	%
RIFLE score	Risk	88	66.7
	Injury	28	21.2
	Failure	8	6.1
	Loss	8	6.1
	Total	132	100

AKIN: Acute Kidney Injury Network

A multivariate logistic regression analysis was performed to determine whether PI independently predicted AKI. The model included PI, age, and sex as covariates. PI was found to be a statistically significant independent predictor of AKI (odds ratio (OR): 0.05, 95% CI: 0.01-0.21, $p<0.001$), indicating that lower PI values were strongly associated with the presence of AKI. These results suggest a much stronger association between PI and AKI than previously reported, supporting its role as a potential early diagnostic marker.

A comparison of PI values between AKI and control groups revealed a significant difference. As shown in Figure 1, patients diagnosed with AKI had markedly lower PI values compared to the control group ($p<0.001$), highlighting the potential of PI as an early and non-invasive indicator of renal dysfunction.

To further assess the diagnostic value of PI in predicting AKI, a ROC curve analysis was performed. As illustrated in Figure 2, the PI demonstrated excellent discriminative ability, yielding an area AUC of 0.97, indicating that PI can effectively differentiate between AKI and non-AKI patients in the emergency setting.

The model demonstrated excellent discriminative power, with an AUC of 0.97, suggesting that PI can reliably differentiate between AKI and non-AKI patients.

Discussion

This study demonstrates that lower PI values and ABG abnormalities are significantly associated with AKI presence and severity, with PI showing excellent discriminative ability (AUC =0.97).

AKI is commonly diagnosed using serum creatinine and urine output, both of which are delayed indicators of renal dysfunction [11]. This study highlights the

Table 4. comparative analysis of perfusion index, arterial blood gases and laboratory parameters based on the AKIN and RIFLE scores in patient group

Parameter	AKIN stage 1 (n=84)	AKIN stage 2 (n=38)	AKIN stage 3 (n=10)	p value (AKIN)	Post- Hoc (AKIN)	RIFLE risk (n=88)	RIFLE injury (n=28)	RIFLE failure (n=8)	RIFLE loss (n=8)	p value (RIFLE)	Post--hoc (RIFLE)
pH	7.38±0.06	7.37±0.10	7.18±0.19	0.023	1>3	7.38±0.06	7.36±0.10	7.40±0.13	7.1±0.21	0.091	-
CO_2 (mmHg)	41.04±7.53	37.29±8.40	29.88±5.53	0.006	1>3	40.42±7.92	40.26±7.65	30.03±1.87	29.85±6.39	0.007	1-2>3-4
HCO_3 (mEq/L)	23.55±4.69	21.39±4.08	12.32±5.50	0.001	1>3.2>3	23.31±4.74	21.94±4.40	18.93±4.38	12.15±6.33	0.007	1-2>3-4.3>4
Potassium (mEq/L)	4.01±0.51	4.17±0.87	4.74±0.95	0.067	-	3.97±0.52	4.27±0.95	4.47±0.40	4.67±1.08	0.091	-
Sodium (mEq/L)	134.70±5.55	133.81±4.16	131.32±5.17	0.283	-	134.69±5.51	134.89±3.34	130.48±4.96	129.90±4.71	0.116	-
Lactate (mmol/L)	1.93±1.78	2.23±1.41	3.41±4.00	0.436	-	2.03±1.85	2.00±1.10	1.76±1.27	4.07±4.28	0.900	-
O_2 (mmHg)	75.02±20.13	69.5±24.07	69.98±20.44	0.619	-	74.81±19.70	63.21±23.77	95.75±5.22	65.48±20.54	0.015	3>1-2-3.1>2-4
Perfusion Index	1.36±0.56	0.97±0.45	0.59±0.15	0.001	1>2>3	1.37±0.56	0.96±0.40	0.51±0.20	0.65±0.06	0.001	1>2>4>3
Urea (mg/dL)	55.69±30.27	76.58±22.95	187.54±55.49	0.001	3>2>1	56.24±29.67	74.61±22.35	135.45±91.60	167.68±38.39	0.001	4>3> 2>1
Creatinine (mg/dL)	1.39±0.36	2.04±0.43	7.28±3.21	0.001	3>2>1	1.40±0.36	2.05±0.46	3.13±1.69	7.68±3.55	0.001	4>3>2>1

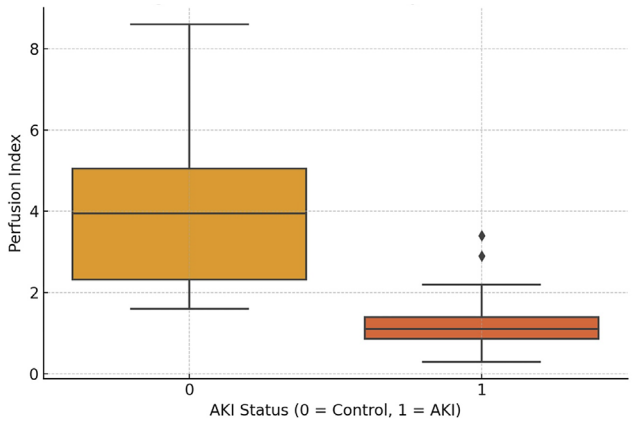

Figure 1. Boxplot of perfusion index in patients with and without acute kidney injury (AKI).

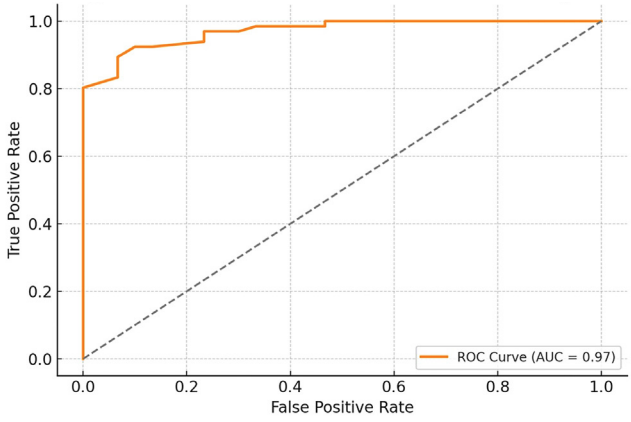

Figure 2. Receiver operating characteristic (ROC) curve of perfusion index for predicting acute kidney injury (AKI)

potential role of PI and ABG The AKI group demonstrated significantly lower perfusion index values compared to controls ($p<0.001$), supporting its role as a strong predictor of renal dysfunction parameters as early, non-invasive markers of AKI severity. Prior to the adoption of the KDIGO classification, the RIFLE (Risk, Injury, Failure, Loss, End-stage) and AKIN criteria were commonly used to define and stage AKI. These systems varied in thresholds and timing for serum creatinine changes, or urine output reduction. The KDIGO classification later harmonized these definitions into a single unified system, improving diagnostic consistency and facilitating comparisons across studies [5,12].

In our cohort, the distribution of AKI severity differed slightly between the AKIN and RIFLE classifications. The RIFLE system identified a greater number of patients in early AKI stages (Risk and Injury), suggesting that its broader creatinine thresholds and the inclusion of more permissive urine output criteria may capture mild renal impairment earlier. In contrast, AKIN classification demonstrated better alignment with patients who progressed to severe AKI as its staging is more sensitive to small but clinically relevant rises in serum creatinine over shorter time intervals. Our findings highlight that using both systems in parallel can provide complementary information, with RIFLE favoring early detection and AKIN better reflecting clinically significant disease progression.

In AKI, the ability of the kidneys to maintain acid-base balance may be impaired, leading to acidosis [13]. Our findings demonstrate a significant decline in pH and bicarbonate (HCO_3) levels in the AKI group, consistent with metabolic acidosis. The mean pH in the AKI group was 7.36, compared to 7.40 in controls ($p=0.015$), while bicarbonate levels were also significantly lower ($p=0.001$). These changes align with previous studies describing impaired acid-base regulation in AKI due to reduced bicarbonate reabsorption and increased acid retention [9]. The worsening of metabolic acidosis with advancing AKI stages further supports its role as an indicator of disease progression [14]. The development of metabolic acidosis may result from the kidneys' inability to excrete acid loads. This was further supported by Hoste al. [6], who stated that kidney failure can lead to decreased serum bicarbonate levels, triggering metabolic acidosis. In advanced stages, CO_2 levels also decreased alongside HCO_3, reflecting progressive metabolic acidosis [15]. These findings emphasize the importance of integrating ABG analysis into AKI assessment, as metabolic disturbances can serve as early warning signs of worsening kidney function.

Additionally, PI was significantly lower in AKI patients compared to controls ($p=0.001$), indicating a reduction in renal perfusion. This aligns with findings from Legrand et al. [8], who reported that AKI is associated with microcirculatory disturbances due to both intrarenal and systemic factors. The correlation between PI and AKI severity suggests that renal hypoperfusion contributes to ischemic kidney injury, further exacerbating cellular damage [16]. As AKI progresses, PI declines, supporting its potential use as a dynamic, real-time indicator of renal microvascular health. This was further supported by a study, which stated that microcirculatory disturbances in AKI could lead to reduced PI [17]. Patients in the most severe AKI stages exhibited lower PI values, indicating worsening renal hypoperfusion, which likely contributes to metabolic deterioration and adverse clinical outcomes [18]. Our findings demonstrated a progressive decline in PI with increasing AKI severity. This suggests that PI may not only serve as a diagnostic marker but also as a potential indicator of disease progression. The observed trend aligns with the pathophysiology of AKI, in which renal microcirculatory dysfunction and impaired perfusion worsen with advancing stages. As ischemia intensifies, tissue oxygen delivery diminishes, which may be reflected by declining PI values. These findings underscore the potential utility of PI as a dynamic biomarker for real-time assessment of renal perfusion

status and AKI severity. Monitoring PI trends could therefore aid in stratifying risk and guiding therapeutic interventions in critically ill patients. Our results suggest that both PI and ABG parameters could serve as valuable adjuncts to traditional AKI classification systems, such as AKIN and RIFLE, by providing earlier and more dynamic physiological insights.

Given the delayed nature of creatinine-based AKI diagnosis, incorporating PI and ABG analysis into routine assessment may facilitate earlier intervention. PI, in particular, may serve as an immediate, non-invasive marker of renal perfusion that reflects real-time changes in kidney function. Clinicians may consider PI and ABG monitoring in emergency and critical care settings to improve risk stratification and guide treatment decisions.

Contrary to previous studies, which reported modest associations between PI and renal outcomes, our analysis revealed a significantly stronger relationship. The multivariate logistic regression and ROC curve, (AUC =0.97), both demonstrate that PI is a highly effective, non-invasive predictor of AKI in emergency settings. This discrepancy may be due to differences in population selection, stricter exclusion of confounding conditions, or more stringent use of a validated pulse co-oximeter device. Further studies with larger, more diverse populations are warranted to validate these findings.

Study Limitations

This study has several limitations. The relatively small sample size may reduce generalizability and limit statistical power. Its cross-sectional design prevents the establishment of causality between PI, ABG parameters, and AKI outcomes. As the study was conducted in tertiary care centers, the findings may not be fully applicable to non-tertiary or outpatient settings. Selection bias is also possible, as mild AKI cases that resolved without hospitalization could be underrepresented.

In addition, physiological confounders that influence PI measurements—such as body temperature, peripheral vascular tone, vasoconstriction, and the use of vasoactive medications, -were not controlled for, which may affect measurement accuracy. Only single time-point measurements of PI and ABG were obtained, limiting the assessment of dynamic trends or progression. Urine output data were not available for all patients, which may reduce the accuracy of AKIN and RIFLE staging. Finally, the heterogeneity of the control group may have introduced unmeasured confounding, as their underlying clinical conditions were diverse.

Conclusion

This study highlights the potential role of PI and ABG parameters as complementary tools for the diagnosis and severity stratification of AKI in the ED. PI independently predicted AKI severity (OR =0.05) and demonstrated excellent discriminative ability (AUC =0.97), underscoring its diagnostic and prognostic utility alongside conventional scoring systems such as AKIN and RIFLE. Integrating PI into AKI risk algorithms may facilitate earlier identification and more informed management decisions, although external validation in larger, multi-center cohorts is warranted to define standardized cutoff values and confirm its clinical impact.

Ethics

Ethics Committee Approval: This study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the Gaziantep Islam Science and Technology University Non-Interventional Clinical Research Ethics Committee (protocol number: 2022/389, decision number: 389.36.03, date: 26.02.2022).

Informed Consent: As the study involved a retrospective review of medical records without patient identifiers or potentially identifying data, the institutional review board (IRB) waived the requirement for patient consent.

Footnotes

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ORIGINAL RESEARCH

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Hand Injuries During Eid al-Adha Celebrations: A Seven-Year Retrospective Analysis

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Abstract

Objective: Eid al-Adha is a significant religious event that involves the ritual slaughter of livestock, leading to an increased risk of hand injuries. This study aims to evaluate the incidence, causes, and severity of hand injuries related to Eid al-Adha over a seven-year period and provide evidence-based recommendations for injury prevention.

Materials and Methods: This retrospective study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the the İstanbul Medeniyet University, Göztepe Training and Research Hospital Clinical Research Ethics Committee. Emergency department records from the İstanbul Medeniyet University, Göztepe Training and Research Hospital covering seven Eid al-Adha celebrations (2017-2022) were analyzed. Patients with hand injuries related to sacrificial activities, including slaughtering and meat preparation, were included. Demographic data, injury characteristics, and treatment modalities were recorded. Statistical analyses were performed using SPSS software, with $p<0.05$ considered statistically significant.

Results: A total of 183 patients were treated for hand injuries related to Eid al-Adha, with a male predominance (75.9%). The mean patient age was 40.09 years. Knife-related injuries were the most common (81%, 148 cases), followed by cleaver injuries (11%, 20 cases) and animal horn trauma (8%, 14 cases). The injuries predominantly affected the upper extremities, with 26% involving the index finger and 20% involving the middle finger. Among all patients, 21.3% required plastic surgery intervention. The highest number of injuries occurred on the first day of Eid (105 cases). A statistically significant difference was found in injury frequency between the first and subsequent days ($p<0.05$).

Conclusion: Hand injuries related to Eid al-Adha remain a public health concern. Most injuries involve knives, affecting the fingers and requiring surgical intervention in a substantial proportion of cases. Promoting safer slaughtering practices, encouraging the use of professional butchers, and improving public awareness are essential strategies to minimize injury risks.

Keywords: Eid al-Adha, hand injuries, sacrificial activities, public health, knife wounds

Introduction

Eid al-Adha, also known as the "Festival of Sacrifice" is a significant religious holiday celebrated by Muslims worldwide. The holiday involves the ritual slaughter of livestock, followed by the distribution of meat among family, friends, and those in need. However, despite its religious and cultural importance, this practice is associated with an increased risk of hand injuries, particularly among individuals with limited experience in animal slaughter and meat preparation [1,2].

Previous studies have shown that knife-related injuries surge during Eid al-Adha, with cases ranging from minor lacerations

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to severe tendon and nerve damage requiring surgical intervention [3,4]. While professional slaughterhouses have been established to minimize these accidents, many individuals still prefer to perform sacrifices themselves, leading to a substantial number of emergency department visits [5,6].

However, most prior studies in Türkiye have been limited to short-term observations, small sample sizes, or single-center experiences. Longitudinal trends, detailed anatomical analyses, and microsurgical outcomes have often been underreported. Our study aims to address these gaps by presenting a seven-year retrospective analysis from a high-volume urban emergency center, focusing on both the frequency and severity of injuries.

We hypothesized that most hand injuries would occur on the first day of Eid al-Adha, primarily involve knife use, and frequently require surgical intervention. By identifying temporal patterns and surgical needs, this study seeks to inform targeted public health measures and trauma preparedness strategies.

This study aims to evaluate the incidence, causes, and severity of hand injuries associated with Eid al-Adha over a seven-year period. By analyzing injury patterns and treatment approaches, we seek to provide evidence-based recommendations for injury prevention and public health interventions.

Materials and Methods

This retrospective study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the İstanbul Medeniyet University, Göztepe Training and Research Hospital Clinical Research Ethics Committee (decision number: 2022/0416, date: 29.06.2022).

Given the retrospective nature of the study, the need for informed consent was waived, and all patient data were anonymized to ensure confidentiality. The study was conducted at a large urban training and research hospital located in a metropolitan area of Türkiye, serving as a regional referral center with a high-volume emergency department.

Study Design and Population

This study retrospectively analyzed emergency department data from İstanbul Medeniyet University, Göztepe Training and Research Hospital, covering seven consecutive Eid al-Adha celebrations from 2017 to 2022. Patients presenting with hand injuries related to sacrificial activities, including slaughtering and meat preparation, were included in the study.

Inclusion Criteria

Patients were included if they sustained hand injuries during animal slaughter or meat preparation activities occurring within the four days of Eid al-Adha and presented to the emergency department of the study hospital for evaluation and treatment.

Exclusion Criteria

Patients with injuries unrelated to Eid al-Adha sacrifices; incomplete medical records; polytrauma; inter-hospital transfers; and repeat admissions were excluded to ensure accurate case identification.

Data Collection

Demographic information, type and severity of injuries, and treatment modalities were extracted from medical records. Data extraction was performed by emergency physicians and plastic surgery residents trained in standardized data entry. All records were anonymized prior to analysis. To minimize bias, data entries were independently cross-checked by two researchers. Data collectors were not blinded to the study hypothesis due to the retrospective design. The injuries were categorized based on anatomical location, depth, and involvement of tendons, nerves, or vasculature. Patients requiring plastic surgery consultation were specifically analyzed.

Statistical Analysis

Descriptive statistics were used to summarize patient demographics and injury characteristics. Continuous variables were reported as means ± standard deviations, while categorical variables were expressed as frequencies and percentages. To compare the distribution of injuries across the days of Eid al-Adha, the chi-square test was applied. Statistical analyses were performed using SPSS software (version 25.0, IBM Corp., Armonk, New York, United States of America). A p-value of <0.05 was considered statistically significant.

Results

Patient Demographics

A total of 183 patients presented to the emergency department with hand injuries related to Eid al-Adha sacrificial activities between 2017 and 2022. The majority of patients were male (139, 75.9%), while 44 (24.1%) were female. The mean age of patients was 40.09 years. Among the 39 patients who required plastic surgery consultation, all were male, with an average age of 36.76 years. The patient distribution by year and demographic data are presented in Table 1.

Injury Characteristics

Knife-related injuries were the most common, accounting for 81% (148 cases) of all cases, while 11% (20 cases) of injuries were due to cleavers and 8% (14 cases) resulted from animal horn trauma. The injuries predominantly involved the upper extremities, with 26% affecting the second digit (index finger), 20% involving the third digit (middle finger), and 13% affecting multiple fingers (Figure 1).

Severity and Treatment Approaches

- Of the injuries, 17% occurred in the upper right extremity, and 22% in the upper left extremity (Figure 2).

• Fifty nine percent of tendon injuries involved extensor tendons, while 38% affected flexor tendons, with 3% requiring amputation (Figure 3).

• Microsurgical repair was necessary in 22% of cases, while 78% of patients did not require microsurgery (Figure 4).

• Tendon injuries were categorized by anatomical zones, with 22% occurring in Zone 3 and 18% in Zone 4 (Figures 5 and 6).

Hospitalization and Surgical Interventions

Among the 183 cases, 144 patients (78.7%) received primary sutures in the emergency department, while 39 (21.3%) required plastic surgery intervention. Among the 39 patients who underwent surgical intervention by the plastic surgery team; 23 (59%) procedures were performed under local anesthesia, 8 (21%) under general anesthesia, and 1 (3%) with axillary block and sedation. The remaining 7 (17%) underwent minor procedures such as primary wound suturing, all performed under local anesthesia.

One patient required drainage due to a hematoma caused by an animal horn impact, and another suffered a distal phalanx fracture.

Comparison Across Years

The number of hand injuries fluctuated over the seven-year study period without a consistent increasing or decreasing trend. However, in every year, the highest number of cases was consistently observed on the first day of Eid al-Adha. Overall, the first day accounted for the majority of injuries (105 cases), followed by the second day (31 cases), third day (25 cases), and fourth day (22 cases) (Table 2).

Statistical Findings

A statistically significant difference was observed in the frequency of injuries between the first and subsequent days of Eid al-Adha ($p<0.05$). No significant difference was found between the right and left hand injury distributions ($p>0.05$).

Table 1. Patient demographic statistics by year, gender, and age group

Year	Total patients	Male patients	Female patients	Minimum age	Maximum age	Male age average (± SD)	Female age average (± SD)
2016	9	9	0	15	72	39.89 (±19.01)	-
2017	28	25	3	27	81	39.57 (±15.89)	56.33 (±16.19)
2018	17	15	2	21	61	41.71 (±16.44)	31.00 (±6.36)
2019	30	27	3	16	72	41.83 (±13.56)	38.00 (±5.48)
2020	44	42	2	25	78	39.57 (±15.86)	46.00 (±5.66)
2021	29	27	2	23	88	42.24 (±17.39)	45.50 (±10.60)
2022	26	14	12	17	67	36.23 (±13.84)	44.67 (±13.40)
Total	**183**	**139**	**44**	**15**	**88**	**39.14 (±13.95)**	**42.73 (±12.81)**

SD: Standard deviation

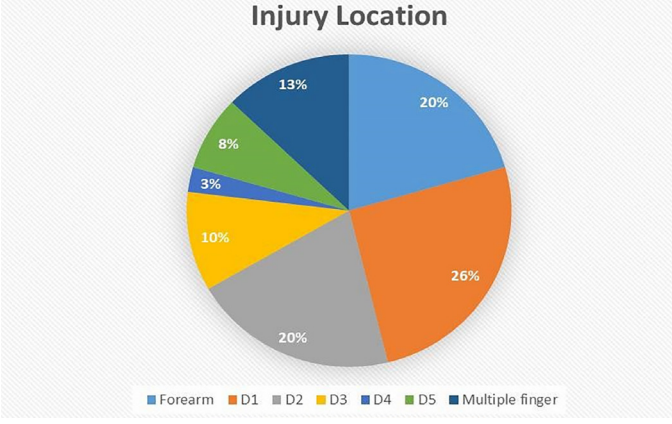

Figure 1. Injury location

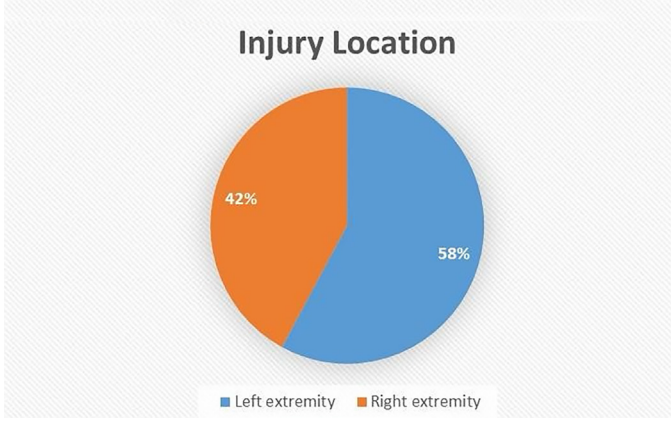

Figure 2. Injury location (right/left hand)

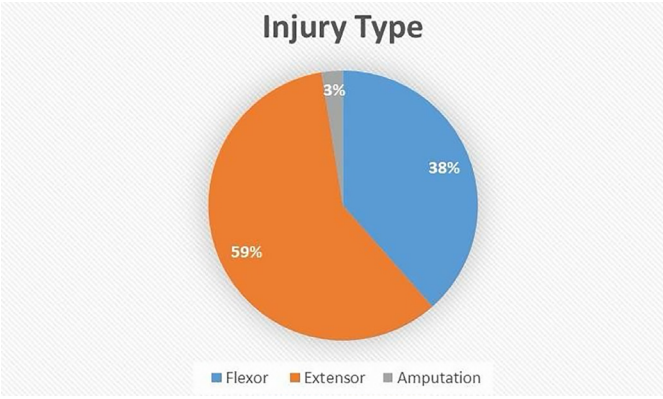

Figure 3. Injury type

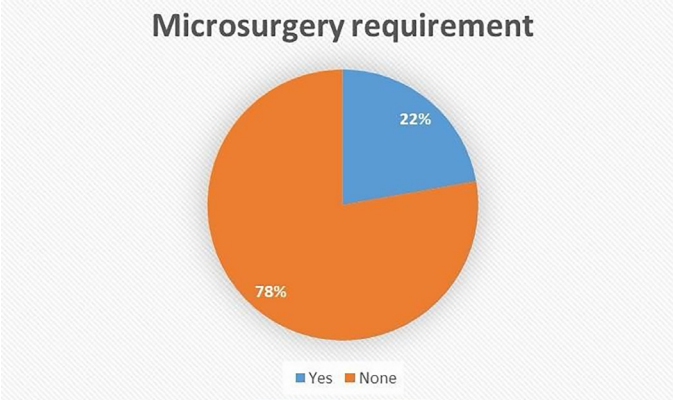

Figure 4. Microsurgery requirements

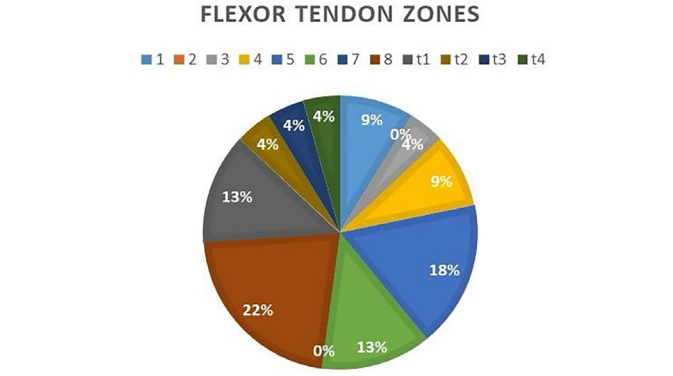

Figure 5. Flexor tendon zones

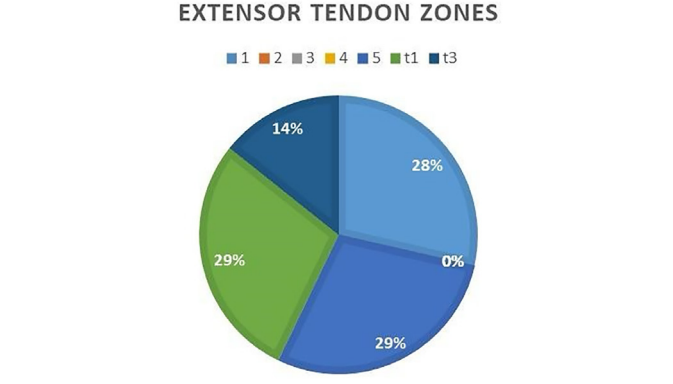

Figure 6. Extensor tendon zones

Table 2. Distribution of cases by the day of the holiday

Holiday day	Number of cases	Male	Female
First	105	92	13
Second	31	21	10
Third	25	17	8
Fourth	22	9	13
Total	**183**	**139**	**44**

Discussion

This study provides a comprehensive analysis of hand injuries related to Eid al-Adha sacrificial activities over a seven-year period. Unlike previous studies that focused on short-term data from a single Eid period, our analysis covers seven consecutive years and includes over 180 patients. This provides a broader and more representative overview of the patterns and severity of injuries sustained during Eid al-Adha. The findings highlight the high prevalence of knife-related injuries, particularly among males, and underscore the risks associated with non-professional slaughtering practices [1-4].

The predominance of injuries among men aligns with prior studies, as men are more frequently involved in the slaughtering process [5,6]. The high rate of thumb and second finger injuries corresponds with the mechanics of knife handling, reinforcing the need for improved safety measures and proper handling techniques. Additionally, the distribution of injuries across both upper extremities suggests that both dominant and non-dominant hands are equally at risk during sacrificial activities [7].

Moreover, the need for microsurgical intervention in over one-fifth of cases underlines the severity and complexity of the injuries. This is consistent with findings from previous reports in Türkiye and other Muslim-majority countries, where similar peaks in hand trauma have been recorded during sacrificial holidays [1,3,5]. These injuries not only require advanced surgical care but also lead to functional impairment, particularly among individuals engaged in manual labor. Our microsurgical intervention rate of 22% and amputation rate of 3% are comparable to findings from previous regional studies [1,5,8], indicating a persistent burden of high-severity hand trauma during the holiday period.

Beyond the clinical burden, these cases increase the pressure on emergency and reconstructive services during short periods. Public health systems should consider implementing temporary resource reallocation plans, such as increasing microsurgical staff availability, during Eid al-Adha. Additionally, future studies should evaluate the long-term functional outcomes and economic consequences of these injuries to fully grasp their societal impact.

A significant finding of this study is the concentration of injuries on the first day of Eid al-Adha, when the majority of sacrifices occur [8]. This aligns with previous research, indicating that peak hospital admissions coincide with the initial surge in slaughtering activities. The fluctuation in annual case numbers may be influenced by several factors, including changes in public awareness, availability of professional slaughtering services, and variability in media coverage regarding injury risks. Nonetheless, the consistently high number of injuries on the first day of Eid highlights a predictable pattern that allows for targeted prevention. Given that professional slaughterhouses have been promoted as safer alternatives, further public awareness campaigns may be necessary to encourage their use and reduce the incidence of self-inflicted injuries [9,10]. Unfortunately, the location of the sacrificial activity (e.g., private vs. professional facility) was not documented in the medical records, limiting our ability to analyze the impact of institutional slaughtering practices. Public health campaigns should go beyond general awareness by offering targeted, culturally appropriate educational content, including visual guides on safe knife use, promotion of certified butchers, and encouraging at-risk populations, to avoid direct participation in slaughtering.

Study Limitations

This study is limited by its retrospective design and single-center setting, which may affect the generalizability of the results. Minor injuries not requiring hospital admission may have been underreported. Additionally, long-term outcomes and functional recovery data were not available. Furthermore, data regarding patients' socioeconomic and educational backgrounds, which may influence both the risk of injury and access to care, were not recorded. The study also includes only individuals who presented to the emergency department, which likely underestimates the true incidence of Eid-related hand injuries in the general population.

Conclusion

Hand injuries related to Eid al-Adha remain a significant public health concern. Our seven-year analysis highlights the high frequency of knife-related trauma (particularly on the first day of the holiday), most often affecting the second and third fingers and frequently requiring surgical or even microsurgical intervention.

In light of these findings, public health authorities should consider implementing targeted educational campaigns that focus on safe knife handling techniques, the use of protective equipment such as cut-resistant gloves, and the promotion of certified professional butchers. Educational materials should be culturally appropriate and delivered through accessible platforms prior to the holiday period.

Additionally, emergency services and plastic surgery departments should anticipate seasonal surges in hand injuries and allocate resources accordingly. Collaboration with religious leaders and municipalities may also help encourage community members to avoid high-risk practices.

By combining preventive education, surgical preparedness, and policy-level advocacy, it is possible to reduce the burden of these preventable injuries during future Eid al-Adha celebrations.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the İstanbul Medeniyet University, Göztepe Training and Research Hospital Clinical Research Ethics Committee (decision number: 2022/0416, date: 29.06.2022).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: O.İ., R.R.B., H.P., Concept: O.İ., R.R.B., Design: O.İ., R.R.B., Data Collection or Processing: R.R.B., H.P., Analysis or Interpretation: O.İ., R.R.B., H.P., Literature Search: R.R.B., H.P., Writing: O.İ., R.R.B., H.P.

Conflict of Interest: No conflict of interest was declared by the authors.

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ORIGINAL RESEARCH

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Testican-1 as a Biomarker for Assessing Disease Severity in COVID-19 Patients

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Abstract

Objective: This study aimed to evaluate the levels of testican-1 in patients diagnosed with Coronavirus Disease-2019 (COVID-19) and to investigate its potential utility in predicting disease severity and clinical progression. Testican-1, a proteoglycan with known associations with sepsis and central nervous system damage, was hypothesized to serve as a biomarker for severe cases.

Materials and Methods: The study was conducted between September 15 and October 15, 2020, at University of Health Sciences Türkiye, Kayseri City Hospital, a designated pandemic center. A total of 89 patients with polymerase chain reaction-confirmed COVID-19 diagnoses were included. Patients were classified as moderate or severe based on clinical criteria. Serum testican-1 levels were measured using enzyme-linked immunosorbent assay. Routine biochemical parameters, C-reactive protein (CRP), procalcitonin, D-dimer, and other inflammatory markers, were analyzed.

Results: Testican-1 levels were significantly higher in patients with severe disease and admitted to intensive care units compared to moderate cases ($p<0.001$). However, no statistically significant correlations were found between testican-1 levels and other clinical markers, including CRP, procalcitonin, and D-dimer. A weak positive correlation with lactate levels and, and a weak negative correlation with basophil percentages.

Conclusion: Testican-1 shows promise as a specific biomarker for assessing the severity of COVID-19, potentially aiding clinicians in prognosis and management. While it does not correlate strongly with other inflammatory markers, its distinct association with severe disease underscores its utility.

Keywords: COVID-19, testican-1, biomarker, disease severity, clinical progression

Introduction

Coronavirus Disease 2019 (COVID-19), which is spreading rapidly around the world, has been declared a pandemic by the World Health Organization [1]; the first case was detected in Türkiye on March 11, 2020. The virus that causes COVID-19 is a member of the severe acute respiratory syndrome coronavirus virus family [2]. The disease can cause severe symptoms in humans, including cough, muscle aches, fever, severe shortness of breath, pneumonia, and sepsis [1].

Current information indicates that the disease is more severe in older people, men, and those with comorbidities [2,3]. The definitive diagnosis of the disease is the detection of the virus by real-time reverse transcriptase-polymerase chain reaction (PCR). However, the demonstration of diffuse lung involvement by computed tomography is also helpful in the diagnosis, especially in patients with or without contact [4].

Although there is no specific laboratory test to diagnose the disease, markers of infection and elevated levels of markers of thrombophilia, such as D-dimer, are present. COVID-19 is also known to cause cytokine storms, leading to conditions sepsis, multi-organ failure, and death [5].

Testican-1 is a proteoglycan carrying chondroitin sulfate and heparan sulfate chains and is originally identified as a precursor of glycosaminoglycan peptide in seminal plasma. It has been

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found to be particularly abundant in the thalamus and upregulated by astroglial cells in the brain [6]. Studies have shown that it can be detected in brain and central nervous system injury and sepsis [6-8].

In this study, we evaluated testican-1 levels along with various parameters in patients diagnosed with COVID-19. Thus, we attempted to determine the utility of testican-1 levels in predicting the clinical course and diagnosis of COVID-19 patients.

Materials and Methods

Study Setting and Population

This prospective study was conducted at University of Health Sciences Türkiye, Kayseri City Hospital between 15.09.2020 and 15.10.2020. Our hospital has been working as a pandemic hospital since March 2020. The study was conducted with the permission of the Ethics Committee of University of Health Sciences Türkiye, Kayseri City Hospital (decision number: 144, date: 03.09.2020). An informed consent form was obtained from all patients.

The patients included in the study were those who applied to the Emergency Department of University of Health Sciences Türkiye, Kayseri City Hospital and, after their first treatment, were admitted to the COVID-19 ward or intensive care units (ICU) with a preliminary diagnosis of COVID-19 after their first treatment. Patients were classified as moderate or severe according to their clinics. Clinically moderate patients were selected from those who were conscious, had oxygen saturation not falling below 85%, did not use assisted respiratory muscles, and were treated with ward follow-up. Patients considered severe were selected from patients who were followed up in the ICU, had an end-tidal oxygen saturation below 85%, were using assisted respiratory muscles, and were in poor general condition. Six patients deteriorated in their clinics during ward follow-up and were transferred to the ICU during the study. Therefore, the data of these patients were considered ward follow-up. The patients' PCR results were monitored, and patients who tested positive for COVID-19 were included in the study.

Data Collection

Testican-1 values were also examined in addition to the blood parameters taken during the routine follow-up of the patients. Blood samples were also obtained in the morning for testican-1 in PCR-positive patients. Routine biochemical parameters, C-reactive protein (CRP), and procalcitonin levels were determined using standard methods with an AutoAnalyzer (Cobas 8000, Roche Diagnostics, Indianapolis, IN, USA). D-dimer and complete blood count AutoAnalyzers (Diagnostica Stago, France and Sysmex XN 1000, Japan); Serum samples were separated after centrifugation at 5000 RPM (NF 400 centrifuge, Türkiye) for 10 minutes. Serum samples of patients were stored at -80 °C until tested. Serum testican-1 levels will be investigated by sandwich enzyme immunoassay using Human Testican-1 Enzyme Immunosorbent Test Kit; Range: 0.156-10 ng/mL, minimum detectable concentration: 0.061 ng/mL, USCN Business Co., Wuhan, China. The testican-1 level was analyzed according to the manufacturer's instructions and expressed in pg/mL. The concentrations of the samples were calculated using calibration curves obtained from operating standards at known levels. The intra-assay and inter-assay coefficient of variation were calculated as <10% for this analysis.

Statistical Analysis

To determine the number of samples in the study, the sample size was calculated using G-Power (3.1) version with a power of 0.80, taking the Lee et al. [6] study as an example and assuming an alpha of 0.05. Descriptive statistics were presented with frequency, percentage, mean, standard deviation, median, 25% quartile (Q1), and 75% quartile (Q3). The assumption of normality was checked using the Shapiro-Wilk test, Skewness and Kurtosis values, and q-q plots. The independent samples t-test (independent two-sample t-test) was used the Mann-Whitney U test was used. Spearman's Correlation test was used because the assumption of normality was not met in the relationship between numerical variables. P-values less than 0.05 were considered statistically significant. The analyses were performed with SPSS 23.0 software.

Results

Eighty nine patients were included in the study. The gender, age, general status, and parameter values of these patients are given in Table 1.

No statistically significant differences have been found between testican-1 concentration levels of women and men, in our study. Testican-1 concentration levels were found to be statistically significantly higher in patients hospitalized in intensive care and in patients with severe general conditions ($p<0.001$) (Table 2).

No statistically significant relationship was found between testican-1 concentration and age, ferritin, fibrinogen, D-dimer, CRP, procalcitonin, and sedimentation variables all patients and patients with moderate and severe conditions ($p>0.05$) (Table 3).

A statistically significant weak negative relationship was found with basophil percentage ($r=-0.226$; $p=0.033$), whereas a statistically significant weak positive relationship was found between testican-1 concentration and lactate in all patients ($r=0.218$; $p=0.041$) (Table 3).

Testican-1 concentration, age, ferritin, D-dimer, CRP, procalcitonin, lactate, white blood cells (WBC), neutrophil,

Table 1. Parameters of patients

		n	Percent	Mean (SD)	Median (Q1-Q3)
Gender	Female	37	42%		
	Male	52	58%		
Ward/intensive care unit	Ward	57	64%		
	ICU	32	36%		
Clinic status	Moderate	51	57%		
	Severe	38	43%		
Age		89			60 (90-74)
Testican-1 concentration (pg/mL)		89		2704.83 (2793.38)	1650 (11360-3480)
Ferritin (µg/L)		89		541.76 (710.18)	275 (4685-592)
Fibrinogen (mg/L)		89		5078.2 (1503.55)	5130 (9300-6160)
D-dimer (µg/L)		89		2291.91 (3724.15)	1110 (23390-2300)
C-reactive protein (mg/mL)		89		61.11 (71.04)	34 (332.5-86.7)
Procalcitonin (µg/L)		89		3.55 (16.32)	0.13 (100-0.32)
Sedimentation (mm/h)		89		49.84 (35.04)	43 (135-73)
Laktat (mmol/L)		89		1.25 (0.66)	1 (4.2-1.2)
White blood cells		89		7.91 (4.43)	6.99 (27.85-9.16)
Neutrophil%		89		65.03 (21.93)	68.2 (94.8-81.1)
Lymphocyte%		89		19.69 (13.1)	17.8 (52.4-29)
Monocyte%		89		7.6 (4.89)	7.5 (34.5-9.7)
Eizinophil%		89		1.3 (1.47)	0.8 (5.6-1.8)
Basophil%		89		0.7 (1.58)	0.3 (15-0.6)
Platelet		89		253.81 (96.88)	247 (600-299)

SD: Standard deviation, ICU: Intensive care unit

Table 2. Comparison of testican-1 concentration with gender, hospitalization, and clinic status (Mann-Whitney U test)

	Testican-1 concentration (pg/mL)	n	Mean (SD)	Median (Q1-Q3)	Test ist	p
Gender	Female	37	2530 (2831.86)	1440 (700-3200)	866.5	0.427
	Male	52	2829.23 (2786.62)	1705 (795-3940)		
Ward/ICU	Ward	57	1741.93 (1557.41)	1110 (580-2410)	454	**<0.001**
	ICU	32	4420 (3609.33)	3215 (1385-7500)		**<0.001**
Clinic status	Moderate	51	1660.59 (1490.33)	1100 (570-2410)	505.5	**<0.001**
	Severe	38	4106.32 (3469.39)	2835 (1330-6130)		**<0.001**

SD: Standard deviation, ICU: Intensive care unit

lymphocyte, monocyte, eosinophil, and basophil values were found to be statistically significantly higher in patients with a severe general condition compared to those with a moderate general condition ($p<0.05$). Fibrinogen, sedimentation, and platelet values were not found to be significant (Table 4).

Testican-1 concentration, age, D-dimer, CRP, procalcitonin, WBC, neutrophil, lymphocyte, and basophil were found to be statistically significantly higher in patients hospitalized in the ICU compared to those hospitalized in the ward ($p<0.05$) (Table 5).

Discussion

COVID-19, which surrounds the world, has become a test for health care systems. Each country has tried to implement its own treatment plans, although the World Health Organization has tried to establish a specific protocol. However, the

Table 3. Comparison of testican-1 concentration with age, ferritin, D-dimer, CRP, procalcitonin, sedimentation, lactate, WBC, NE%, LY%, MO%, EO%, BA%, and platelet (p<0.05, Spearman's correlation test)

Concentration		Age	Ferritin (µg/L)	Fibrinogen (mg/L)	D-dimer (µg/L)	CRP (mg/mL)	Procalcitonin (µg/L)	Sed (mm/h)	
All patient	r	0.098	0.193	0.166	0.174	0.161	0.168	0.141	
	p	0.362	0.07	0.121	0.104	0.131	0.116	0.187	
	n	89	89	89	89	89	89	89	
Moderate	r	0.14	0.235	0.117	0.106	0.058	-0.119	0.14	
	p	0.326	0.097	0.415	0.457	0.686	0.407	0.326	
	n	51	51	51	51	51	51	51	
Severe	r	0.038	-0.127	-0.103	-0.302	-0.133	-0.24	0.038	
	p	0.82	0.446	0.54	0.065	0.425	0.146	0.82	
	n	38	38	38	38	38	38	38	
Concentration		**Lactate (mmol/L)**	**WBC**	**NE%**	**LY%**	**MO%**	**EO%**	**BA%**	**Platelet**
All patient	r	0.218*	0.18	0.06	-0.142	-0.174	-0.1	-0.226*	-0.035
	p	0.041	0.091	0.574	0.185	0.103	0.351	0.033	0.748
	n	89	89	89	89	89	89	89	89
Moderate	r	0.204	0.12	-0.098	-0.033	-0.094	-0.042	-0.088	0.171
	p	0.15	0.401	0.495	0.818	0.511	0.77	0.541	0.229
	n	51	51	51	51	51	51	51	51
Severe	r	-0.072	-0.208	-0.205	0.181	0.015	0.018	-0.035	-0.149
	p	0.666	0.211	0.218	0.278	0.928	0.916	0.835	0.373
	n	38	38	38	38	38	38	38	38

* Correlation is significant at the 0.05 level (2-tailed). WBC: White blood cell, NE%: Neutrophil (%), LY%: Lymphocyte (%), MO%: Monocyte (%), EO%: Eosinophil (%), BA%: Basophil (%), CRP: C-reactive protein

increasing number of patients sometimes exceeded the capacity of the health systems and led to the hospitalization of patients depending on certain criteria. Clinical status, age, and comorbidities, and pulmonary imaging for diagnosis have been prioritized in emergency admissions in Türkiye and many other countries. Treatment has been designed according to the evaluation of PCR positivity [9]. It is known that patients' condition may deteriorate during treatment. In this case, we thought that an examination that could predict the patients' clinical outcomes was important, and we considered using testican-1, which has been shown to be useful in sepsis, although with a small number of publications, for this purpose.

In a study of 82 cases conducted by Lee et al. [6] a correlation was found between testican-1 levels of patients diagnosed with sepsis and the severity of the disease. In our study, we primarily compared testican-1 levels in patients admitted to the ward and ICU, and in patients classified as moderate and severe according to their clinical status. We found higher levels in ICU patients and patients with severe clinical status compared with patients admitted to the ward and those with moderate clinical status. We believe that the difference between these values is not only statistically significant but also important in terms of showing the severity of the disease. We believe that this difference in testican-1 levels may be helpful in assessing the severity of the disease or in clinical prediction in ward follow-up. Therefore, this increase in testican-1 levels may be a warning that the patients are approaching the onset of sepsis.

Wang et al. [10] showed WBC and neutrophil elevation, thrombocytopenia, basophil, eosinophil, and monocyte decrease, especially in patients with severe clinical conditions and ICU admission, similar to our study. Zhang et al. [11] found a relationship between procalcitonin levels and disease severity in their study. Similarly, in our results, procalcitonin levels increased with clinical deterioration. In our study, we did not find a statistical relationship between testican-1 concentrations and age, ferritin, fibrinogen, D-dimer, CRP, procalcitonin, and sedimentation regardless of clinic. However, we believe that this result is important in this way. The testican-1 level can be used to evaluate the severity of the disease, not to diagnose. This sentence is a fragment and requires additional context to form a complete sentence: in addition, there was a positive correlation between testican-1 and lactate level, and a negative correlation between

Table 4. Comparison of parameters according to disease severity

	Clinic status	n	Mean (SD)	Median (Q1-Q3)	Test ist	p
Age	Moderate	51	54.29 (16.67)	53 (43-65)	-4.676[a]	**<0.001**
	Severe	38	69.76 (13.6)	70 (63-78)		
Testican-1 concentration (pg/mL)	Moderate	51	1660.59 (1490.33)	1100 (570-2410)	505.5[b]	**<0.001**
	Severe	38	4106.32 (3469.39)	2835 (1330-6130)		
Ferritin (µg/L)	Moderate	51	378.88 (446.32)	223 (118-434)	681.5[b]	**0.017**
	Severe	38	760.37 (919.09)	425 (178-992)		
Fibrinogen/mg/L)	Moderate	51	4840.39 (1535.98)	4930 (3610-5820)	-1.749[a]	0.084
	Severe	38	5397.37 (1416.33)	5410 (4340-6330)		
D-dimer (µg/L)	Moderate	51	1321.96 (1855.65)	510 (290-1580)	504[b]	**<0.001**
	Severe	38	3593.68 (5029.51)	1810 (1110-3550)		
C-reactive protein (mg/mL)	Moderate	51	38.24 (51.78)	12 (2.8-69.1)	476.5[b]	**<0.001**
	Severe	38	91.8 (81.79)	68.65 (34-117.6)		
Procalcitonin (µg/L)	Moderate	51	0.22 (0.38)	0.06 (0.04-0.16)	467[b]	**<0.001**
	Severe	38	8.03 (24.44)	0.22 (0.13-0.98)		
Sedimentation (mm/h)	Moderate	51	44.39 (32.95)	40 (18-68)	765.5[b]	0.091
	Severe	38	57.16 (36.84)	56 (23-85)		
Lactate (mmol/L)	Moderate	51	1.06 (0.26)	1 (1-1)	547.5[b]	**<0.001**
	Severe	38	1.5 (0.9)	1.2 (1-1.8)		
White blood cells	Moderate	51	6.1 (2.18)	5.59 (4.43-7.44)	432.5[b]	**<0.001**
	Severe	38	10.32 (5.46)	8.73 (6.74-12.24)		
Neutrophil%	Moderate	51	57.91 (20.17)	61.2 (49.1-70.1)	424[b]	**<0.001**
	Severe	38	74.57 (20.75)	81.75 (68.5-88.3)		
Lymphocyte%	Moderate	51	24.92 (13.42)	22.9 (15.8-35.2)	439.5[b]	**<0.001**
	Severe	38	12.67 (8.74)	10.45 (6.6-15.9)		
Monocyte%	Moderate	51	8.51 (5.18)	8.2 (5.8-10.4)	675.5[b]	**0.015**
	Severe	38	6.37 (4.22)	5.25 (3.3-9.2)		
Eizinophil%	Moderate	51	1.52 (1.44)	1.2 (0.3-2.2)	715[b]	**0.035**
	Severe	38	1 (1.47)	0.4 (0.1-1.4)		
Basophil%	Moderate	51	0.78 (2.06)	0.4 (0.2-0.7)	577[b]	**0.001**
	Severe	38	0.28 (0.27)	0.2 (0.1-0.4)		
Platelet	Moderate	51	259.98 (88.45)	247 (198-311)	887[b]	0.496
	Severe	38	245.53 (107.83)	245.5 (175-294)		

[a]Independent two-sample t-test, [b]Mann-Whitney U test

SD: Standard deviation

testican-1 and basophil level. In particular, we believe that the relationship with lactate level supports our hypothesis that it could be a warning to the clinician when the disease changes direction towards sepsis. The negative correlation in basophil levels may also be related to the rate at which basophils change in sepsis.

It was found that those with severe disease in our study were of advanced age, similar to the studies by Guan et al. [12] and Zhou et al. [5]. D-dimer levels were found to be high in severe COVID-19 patients, and the mortality rate was higher in D-dimer-positive patients in the review by Shah et al. [13]. In our study, there was also a significant difference in age, D-dimer, CRP, procalcitonin, lactate, WBC, neutrophil, lymphocyte, basophil, and platelet levels between ICU patients and patients with poor general condition. This is also consistent with previous studies in COVID-19 patients.

In our study, there were no gender differences in testican-1 levels. However, the male sex was predominant in the patients. In our study, COVID-19 disease was seen at a high rate in males, similar to the study by Guan et al. [12].

Table 5. Comparison of patients hospitalized in intensive care unit according to ward patients

	Hospitalization	n	Mean (SD)	Median (Q1-Q3)	Test ist	p
Age	Ward	57	56.05 (17.05)	54 (45-69)	-3.818[a]	**<0.001**
	ICU	32	69.53 (13.83)	70 (60.5-77.5)		
Testican-1 concentration (pg/mL)	Ward	57	1741.93 (1557.41)	1110 (580-2410)	454[b]	**<0.001**
	ICU	32	4420 (3609.33)	3215 (1385-7500)		
Ferritin (µg/L)	Ward	57	501.11 (736.98)	245 (141-552)	793,5[b]	0.311
	ICU	32	614.19 (664.92)	307.5 (166.5-780.5)		
Fibrinogen/mg/L)	Ward	57	4933.33 (1519.11)	5030 (3860-5900)	-1.216[a]	0.227
	ICU	32	5336.25 (1463.33)	5260 (4255-6310)		
D-dimer (µg/L)	Ward	57	1634.21 (2529.45)	650 (310-1580)	566,5[b]	**0.003**
	ICU	32	3463.44 (5059.74)	1810 (865-3115)		
C-reactive protein (mg/mL)	Ward	57	43.02 (55.31)	20.5 (4.1-69.1)	501.5[b]	**<0.001**
	ICU	32	93.33 (84.41)	74.25 (33.5-123.9)		
Procalsitonin (µg/L)	Ward	57	1.98 (13.22)	0.08 (0.04-0.21)	522[b]	**0.001**
	ICU	32	6.35 (20.68)	0.2 (0.13-1.4)		
Sedimentation (mm/h)	Ward	57	47.49 (34)	42 (18-69)	816[b]	0.412
	ICU	32	54.03 (36.99)	52 (23-85.5)		
Lactate (mmol/L)	Ward	57	1.07 (0.3)	1 (1-1)	476.5[b]	**<0.001**
	ICU	32	1.57 (0.95)	1.2 (1-1.95)		
White blood cells	Ward	57	6.38 (2.79)	5.59 (4.43-7.49)	380[b]	**<0.001**
	ICU	32	10.62 (5.45)	8.97 (7.28-12.59)		
Neutrophil%	Ward	57	57.95 (23.05)	62.5 (49.1-72.9)	399[b]	**<0.001**
	ICU	32	77.64 (12.19)	81.75 (69.55-88.25)		
Lymphocyte%	Ward	57	22.89 (14.13)	22.4 (13.9-33.3)	567.5[b]	**0.003**
	ICU	32	13.97 (8.6)	11.65 (7.55-19.25)		
Monocyte%	Ward	57	7.99 (5.34)	8 (5.4-10.2)	766[b]	0.212
	ICU	32	6.9 (3.94)	5.65 (4.3-9.4)		
Eizinophil%	Ward	57	1.37 (1.42)	1 (0.14-2)	805.5[b]	0.361
	ICU	32	1.16 (1.55)	0.55 (0.1-1.55)		
Basophil%	Ward	57	0.72 (1.96)	0.4 (0.2-0.7)	640.5[b]	**0.019**
	ICU	32	0.3 (0.28)	0.2 (0.1-0.45)		
Platelet	Ward	57	258.65 (86.72)	254 (198-305)	814.5[b]	0.404
	ICU	32	245.19 (113.74)	74.5-292.5)		

[a]Independent two-sample t-test, [b]Mann-Whitney U test

SD: Standard deviation, ICU: Intensive care unit

When the correlation between all these values and testican-1 values is examined, we think that the testican-1 level will be useful in predicting the severity of the disease.

Study Limitations

In addition, it is necessary to mention some of our limitations. Our study was conducted on inpatients and patients diagnosed with the disease. Evaluating using a control group without any disease may be significant to determine at least one significant cut-off value.The study was conducted at a single centre (Kayseri City Hospital), which may limit the generalisability of the results to other patient populations or different geographical regions. The sample size of 89 patients is relatively small. This may affect statistical power and limit the ability to detect meaningful differences, particularly in subgroup analyses.

Conclusion

COVID-19 continues to spread and kill all over the world. Prevention and reduction of the spread of this disease are as important as its treatment. The decision of which patients will be hospitalized or taken under outpatient treatment is left to the clinician's experience together with the patient's clinical results. We believe that the testican-1 level is a test that will help the clinician in this case. We hope that our study will pave the way for further studies on this subject in the future.

Ethics

Ethics Committee Approval: The study was conducted with the permission of the Ethics Committee of University of Health Sciences Türkiye, Kayseri City Hospital (decision number: 144, date: 03.09.2020).

Informed Consent: An informed consent form was obtained from all patients.

Footnotes

Authorship Contributions

Surgical and Medical Practices: O.B., Concept: O.B., D.K., Design: O.B., Data Collection or Processing: O.B., Analysis or Interpretation: O.B., Literature Search: O.B., D.K., Writing: O.B., D.K.

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ORIGINAL RESEARCH

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The Practice of Approaching the Clinic of Renal Colic in Pregnant Patients Admitted to the Emergency Department: 5-Years Retrospective Observational Study

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Abstract

Objective: Renal colic in pregnant women; it is a difficult situation to manage in the emergency department. This study aims to examine the emergency service evaluation and approach to kidney stone cases in pregnant women.

Materials and Methods: Pregnant patients who applied to our hospital between 2016-2022 were included in this study. The diagnoses of the patients were made by ultrasonography (USG) and other imaging methods. Demographic data, complaints, laboratory results, and treatment methods of the patients were recorded and analyzed.

Results: Fifty-two pregnant patients presenting with renal colic were included in the study. Patients' presenting symptoms: 46 (88.5%) flank pain, 9 (17.3%) pyuria, 7 (13.5%) nausea and vomiting, 6 (11.5%) macroscopic hematuria, 2 (3.8%) microscopic hematuria. In 49 (94.2%) patients, the diagnosis was made by USG. The diagnosis was made by magnetic resonance imaging in 2 (3.8%) patients and by computed tomography in 1 (1.9%) patient. Conservative treatment was applied to 50 (96.2%) patients; endoscopic surgical treatment, to 2 (3.8%) patients.

Conclusion: Renal colic accompanying pregnant patients admitted to the emergency department it is an important problem that should be evaluated with a multidisciplinary approach due to limitations in diagnosis and treatment steps, and potential complications that may affect maternal and fetal health. USG is a valuable method for detecting complications that may cause loss of kidney function in these patients. These patients are managed in emergency departments. When they are referred to the urology clinic, they are treated conservatively. In cases where conservative treatment fails, patients can be treated effectively and safely with endourological interventions.

Keywords: Pregnancy, renal colic, emergency, ultrasonography

Introduction

Although kidney stones are uncommon during pregnancy, affecting approximately 1 in 200 to 1 in 500 women, they represent the most frequent non-obstetric cause of acute hospitalization in this population [1-4]. Pregnancy-induced physiological changes-including urinary tract dilatation, elevated progesterone levels (which reduce ureteral peristalsis), uterine compression of adjacent organs, hydronephrosis, and increased urinary pH-heighten the risk of stone formation [2-5]. Symptomatic kidney stones during pregnancy are associated with recurrent miscarriage, mild preeclampsia, chronic hypertension, gestational diabetes, premature rupture of membranes, and cesarean delivery [5,6].

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Although conservative methods are mostly sufficient in the treatment, the management of renal colic is difficult in pregnant patients and it is a peculiar situation due to the risk of the fetus being affected by this situation [7]. Although a multidisciplinary approach is recommended in the management of these patients, the diagnosis and treatment of these patients are carried out by emergency room doctors. Therefore, it is important to evaluate pregnant renal colic patients in the emergency department. Our study aims to evaluate pregnant patients who applied to the emergency department and were found to have stones in the urinary system the approach to these patients.

Materials and Methods

The study was designed as a descriptive and retrospective analysis. The study was started after the approval of the University of Health Sciences Türkiye, Prof. Dr. Cemil Taşcıoğlu City Hospital Ethics Committee, (decision number: 76, date: 24.02.2025). Among the pregnant patients who visited our hospital's tertiary emergency department between April 2016 and July 2022, those who were diagnosed with renal colic and stones in the urinary system as a result of the examinations and tests performed in the emergency department were included in the study. Two groups were defined based on hydronephrosis severity: Group 1 (no/mild hydronephrosis, grades 0-2) and Group 2 (moderate/severe hydronephrosis, grades 3-4). Hydronephrosis grading followed the Society of Fetal Urology classification (grade 0: no dilation; grade 4: severe dilation with parenchymal thinning).

Patients

Age, trimester of pregnancy, complaints of admission to the emergency department, blood urea, creatinine values, urine analysis, imaging [ultrasonography (USG), magnetic resonance imaging (MRI), computed tomography] results, and treatments applied (conservative, ureteral stent, wiggly nephrostomy) were scanned from the hospital electronic data system and recorded. Patients under the age of 18, trauma patients, and patients whose pregnancy was terminated for any obstetric reason were excluded from the study. The study complied with the principles of the Declaration of Helsinki.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics software (version 22; IBM Corp., Armonk, NY, USA) under an institutional license held by the University of Health Sciences Türkiye, İstanbul, Türkiye. The suitability of continuous variables for normal distribution was evaluated using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Descriptive statistics are presented as mean ± standard deviation for normally distributed data, median (interquartile range) for non-normally distributed data, and frequency (percentage) for categorical variables. For comparisons between two groups, Student's t-test was used for normally distributed parameters, and the Mann-Whitney U test was used for non-normally distributed parameters. Categorical variables were compared using the chi-square test, Fisher's exact test, Fisher-Freeman-Halton exact test, or Yates' correction test, as appropriate. Spearman's correlation analysis was employed to assess relationships between ordinal variables. A p-value <0.05 was considered statistically significant.

Results

The mean age was 27.25±4.93 years. Most admissions occurred in the third trimester (34.6%), and multiparous patients predominated (65.4%). The number of multiparous patients was more than the number of nulliparous patients (65.4%). The most frequent presenting symptoms were pain (88.5%) and pyuria (17.3%). The most common complaint was right flank pain (67.3%). 75% of the patients had no previous history of urinary tract stones. 96.2% were treated conservatively. The diagnosis was made by USG in 94.2% of the patients. There was no sign of hydronephrosis in 67.3%. The location of the stone was located 51.9% of the time in the ureter. The mean creatinine value was 0.51±0.12 mg/dL, and the mean urea was 18.45±6.12 mg/dL (Table 1). Lower creatinine is expected during pregnancy due to an increased glomerular filtration rate.

No statistically significant correlation was found between the hydronephrosis level and the creatinine and urea levels of the patients (p=0.930, p=0.719) (Table 2). A statistically significant difference was found between hydronephrosis levels and the treatments applied. Medical treatment was applied to 100% of the patients with hydronephrosis 0-1-2, a ureteral stent was applied to one patient with hydronephrosis level 3, and percutaneous nephrostomy was applied to one patient with hydronephrosis level 4 (Table 3).

Discussion

Renal colic in pregnant patients presents a diagnostic and therapeutic challenge in emergency departments, necessitating a multidisciplinary approach due to risks to maternal and fetal health. These patients are managed in emergency departments using the correct diagnostic steps.

Renal USG is the imaging method that should be preferred in pregnant patients with suspected nephrolithiasis [8,9]. MRI and/or low-dose CT are recommended for patients whose stones cannot be visualized on USG but whose symptoms persist [1]. In our study, 94.2% of the patients were diagnosed via ultrasound. Since our study was retrospective and included patients diagnosed through stone visualization, the diagnostic accuracy of USG may be high. In addition to diagnosing, USG

Table 1. Distribution and percentage ratios of the parameters considered in the study among patients

Age mean ± SD (min.-max.)		27.25±4.93 (18-41)
Trimester n (%)	1st trimester	18 (34.6)
	2nd trimester	16 (30.8)
	3rd trimester	18 (34.6)
Parity n (%)	Nullipar	18 (34.6)
	Multipar	34 (65.4)
Obstetric complication n (%)		0 (0.0)
Symptom n (%)	Pain	46 (88.5)
	Pyuria	9 (17.3)
	Nausea-vomiting	7 (13.5)
	Macroscopic hematuria	6 (11.5)
	Microscopic hematuria	2 (3.8)
Side n (%)	Right	35 (67.3)
	Left	13 (25.0)
	Bilateral	4 (7.7)
Treatment n (%)	Conservative	50 (96.2)
	Ureteral stent	1 (1.9)
	Percutaneous nephrostomy	1 (1.9)
Stone story n (%)	Yes	13 (25.0)
	No	39 (75.0)
Diagnostic tool n (%)	USG	49 (94.2)
	USG+MRI	2 (3.8)
	USG+CT	1 (1.9)
Hydronephrosis grade n (%)	0	35 (67.3)
	1	9 (17.3)
	2	6 (11.5)
	3	1 (1.9)
	4	1 (1.9)
Stone localization n (%)	Renal pelvis	6 (11.53)
	Parenchyma	5 (9.6)
	Ureter	27 (51.9)
	Bladder	14 (26.9)
Creatine mean ± SD (min.-max.)		0.51±0.12 (0.12-0.82)
Urea mean ± SD (min.-max.)		18.45±6.12 (8-38)

SD: Standard deviation, min.-max.: Mininmum-maximum, USG: Ultrasonography, MRI: Magnetic resonance imaging, CT: Computed tomography

Table 2. Relationship between hydronephrosis degree and blood urea-creatinine levels

	Hydronephrosis	
	r	p*
Creatine	-0.013	0.930
Urea	-0.052	0.719

*Spearman correlation analysis

is recommended to detect conditions that may cause kidney dysfunction and to decide on the treatment method (10,11). While 67.3% of our patients had hydronephrosis of grade 0, 32.7% had hydronephrosis of grade 1-4. We observed that all patients with hydronephrosis grade 0-1-2 received medical treatment; a ureteral stent was placed in one patient with hydronephrosis grade 3; and a percutaneous nephrostomy was applied to one patient with hydronephrosis grade 4. Surgical indications are rarely required in pregnant patients with renal colic. However, since both the fetus and the mother are at risk, it is important to decide on the treatment method.

Hydronephrosis severity guided treatment: milder cases (grades 0-2), responded to medical therapy, while severe cases (grades 3-4) required intervention. A previous study that evaluated pregnant renal colic patients reported that a ureteral stent was applied to 35 patients and percutaneous nephrostomy was applied to 5 patients [12]. Another study reported that a stent was applied to 13 patients, and percutaneous nephrostomy was applied to one patient [13]. Both studies reported that conservative treatment was sufficient in most of the patients [13]. They recommended that the patients receive analgesic and hydration therapy before surgical intervention and that they be re-evaluated for surgery if no response was observed. Dhangar et al. [13] in their study evaluating the indications for surgical intervention, revealed that surgical intervention is required in patients with prolonged high fever, pain unresponsive to analgesics, long-lasting pain, stones larger than 8 mm, and stones remaining in the ureter [14]. In addition, the study emphasized that the degree of hydronephrosis must be taken into account. Consistent with the findings of these studies, a statistically significant difference was found between the level of hydronephrosis and the treatments applied in our study. Thus, from the results we obtained, we demonstrated the importance of the presence and severity of hydronephrosis in treatment management. In our patients, those who either did not have hydronephrosis or had hydronephrosis at the 0-1-2 level were given medical treatment. 96.2% of our patients responded to medical treatment. Analgesia, antibiotics, and hydration are recommended as medical treatment in pregnant renal colic [1]. McAleer and Loughlin [15] reported that pregnant patients presenting with renal colic mostly responded to medical treatment.

Table 3. The relationship between the degree of hydronephrosis and the treatment method

		Treatment						
		Conservative		Ureteral stent		Percutaneous neph		
		n	%	n	%	n	%	p*
Hydronephrosis	0	35	100	0	0.0	0	0.0	<0.001
	1	9	100	0	0.0	0	0.0	
	2	6	100	0	0.0	0	0.0	
	3	0	0.0	1	100	0	0.0	
	4	0	0.0	0	0.0	1	100	

*Chi-square test

Finally, when we evaluated the demographic characteristics of the patients, the mean age of our patients was 27.25±4.93 years, a figure consistent with studies conducted with pregnant renal colic patients [14]. We mainly determined the application time as the 3rd trimester. In their studies, Abruzzese et al. [12] reported the gestational week as 24.5 weeks, Dhangar et al. [13] as 23 weeks, and in Swartz et al. [16], 2-3. The study emphasized that it is common in the third trimester. In the evaluation of our patients according to the number of previous pregnancies, we found that multiparous patients outnumbered nulliparous patients (65.4%). Conservative management of ureteral stones during pregnancy is the standard approach [17]. Renal colic in pregnancy most commonly occurs during the third trimester, with multiparity emerging as a potential risk factor in our cohort. Gestational hydronephrosis occurs in 90% of cases on the right side and up to 67% on the left side in the third trimester due to the compression of the growing uterus [18]. The predominant complaint was right flank pain (67.3%). Prolonged dilation and high progesterone levels have been identified as the main factors that reduce ureteral peristalsis and lead to stasis. The increased glomerular filtration rate during pregnancy enhances the excretion of uric acid, oxalate, sodium, and calcium, thus increasing the susceptibility to stone formation [11,19]. Our findings are consistent with these studies.

As reported in previous studies, the most common complaints of our patients were pain (88.5%) and dysuria (17.3%). Fever, vomiting, and hematuria may also be seen in patients with renal colic during pregnancy. Renal colic radiating to the groin or severe flank pain is the main symptom [5]. Other symptoms are nausea, vomiting, dysuria, frequent urination, and hematuria. In the presence of fever and pyuria, initiation of appropriate antibiotic therapy and evaluation of the patient in terms of sepsis were recommended [7,14,20].

As a result, diagnosing and managing the pregnant patient with urinary tract stones is difficult and complex. In the emergency department setting, the patient's symptoms and risk factors should be evaluated, and appropriate tests should be conducted to decide the treatment. Appropriate analgesia and, if necessary, appropriate antibiotic therapy and hydration should be administered. Although it is rare, the option and necessity of surgical intervention should be considered.

Study Limitations

This study has several limitations. First, its retrospective design inherently restricts the ability to control for confounding variables. Second, the relatively small sample size, which stems from the inclusion criteria (selecting only patients with imaging-confirmed stones), may introduce selection bias. Moreover, as the data were derived from a tertiary referral center, the cohort might disproportionately represent severe or complex cases, potentially limiting the generalizability of the results to broader populations. Future prospective studies with larger, multicenter cohorts are warranted to validate these findings and mitigate potential biases.

Conclusion

In our cohort, renal colic during pregnancy most commonly occurs in the third trimester, and it is associated with multiparity. USG remains the primary diagnostic tool, effectively detecting stones and guiding management. While conservative treatment (analgesia, hydration, and antibiotics) suffices for most cases, the severity of hydronephrosis (grades 3-4) strongly correlates with the need for endourological interventions such as ureteral stenting or percutaneous nephrostomy. This link between hydronephrosis severity and intervention aligns with existing literature and represents a key contribution of our findings to clinical practice. A multidisciplinary approach is critical in emergency settings to address maternal-fetal risks and tailor trimester-specific strategies. These findings underscore the importance of trimester-specific evaluation and vigilant monitoring of hydronephrosis severity to optimize clinical decision-making in emergency care. The results further emphasize prioritizing hydronephrosis severity in management protocols, while highlighting the need for future studies to explore the causality of parity-related risk associations.

Ethics

Ethics Committee Approval: The study was started after the approval of the University of Health Sciences Türkiye, Prof. Dr. Cemil Taşcıoğlu City Hospital Ethics Committee, (decission number: 76, date: 24.02.2025).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: A.S., A.A., R.K., Concept: A.A., N.U., R.K., Design: A.S., N.U., R.K., Data Collection or Processing: A.S., A.A., R.K., Analysis or Interpretation: A.A., N.U., R.K., Literature Search: A.S., A.A., N.U., Writing: A.A., N.U., R.K.

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ORIGINAL RESEARCH

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Definitions and Treatment of Pulseless Electrical Activity, Pseudo-Pulseless Electrical Activity and Cardiogenic Shock: A Retrospective Video-Based Analysis

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Abstract

Objective: Cardiopulmonary arrest (CPA) rhythms are classified into shockable and non-shockable categories. Pulseless electrical activity (PEA) is a non-shockable rhythm defined as the absence of a palpable pulse despite organized electrical activity on the monitor. However, PEA encompasses a spectrum from complete cardiac inactivity to cardiogenic shock. Pseudo-PEA (p-PEA) represents an intermediate state, marked by electrical activity and varying degrees of myocardial motion. While PEA and p-PEA are treated in a similar manner to asystole, their distinct characteristics suggest a potential need for differential treatment, especially for p-PEA, which may benefit from positive inotropic therapy. This study aims to establish diagnostic criteria for PEA, p-PEA, and cardiogenic shock and assess their responses to inotropic therapy.

Materials and Methods: This retrospective, video-based study was conducted in the emergency department of a university hospital. Archived ultrasound (USG) video recordings from August 2017 to April 2021 were analyzed. Adult CPA patients with documented cardiac activity and positive inotropic therapy during cardiopulmonary resuscitation (CPR) were included. Data on demographic details, CPR characteristics, treatment interventions, and clinical outcomes were collected. Statistical analysis was performed using SPSS v24.0 with a significance level of $p<0.05$.

Results: Out of 94 patients, 12 met the inclusion criteria. Patients were divided into three groups: those with valvular motion alone (n=4), valvular and myocardial motion (n=6), and cardiogenic shock (n=2). Return of spontaneous circulation was achieved in all patients with both valvular and myocardial motion after inotropic therapy ($p=0.002$), but not in those with only valvular motion.

Conclusion: Patients with valvular motion alone were classified as PEA, while those with myocardial activity were defined as p-PEA. Positive inotropic therapy was effective in p-PEA but not in PEA. USG, including carotid and femoral examinations, can aid in differentiating cardiogenic shock from p-PEA, emphasizing the need for specific treatment protocols. Further research is essential to validate these findings.

Keywords: Pulseless electrical activity, pseudo-PEA, cardiogenic shock, positive inotropic therapy, echocardiography

Introduction

Cardiopulmonary arrest (CPA) rhythms are generally categorized into shockable and non-shockable rhythms [1,2]. To date, significantly more research has focused on shockable rhythms, including the development of defibrillation [3], with many guidelines providing more extensive coverage on this topic [4]. Shockable rhythms in CPA are characterized by irregular electrical activity accompanied by the absence of a palpable pulse, and defibrillation forms the cornerstone of their treatment. Non-shockable rhythms, on the other hand, are divided into asystole and pulseless electrical activity (PEA). Unlike shockable rhythms, PEA demonstrates organized electrical activity and frequently a certain degree of regular cardiac activity. However, its treatment follows the same protocol asystole, which lacks both electrical activity and cardiac motion entirely [4].

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PEA is defined as an arrest rhythm characterized by the absence of a palpable pulse despite the presence of an organized electrical rhythm on the monitor [5,6]. However, this definition is rather superficial, as PEA encompasses a wide spectrum ranging from a complete absence of cardiac activity to cardiogenic shock with the return of spontaneous circulation (ROSC), including various degrees of cardiac activity in between. This ambiguity is particularly notable in the absence of cardiac imaging, as routine use of cardiac ultrasound (USG) for rhythm assessment remains a topic of debate [2,7,8]. The intermediate condition, between PEA and cardiogenic shock, where varying degrees of valvular and myocardial activity accompany electrical activity, is often referred to as pseudo-PEA (p-PEA) [9]. p-PEA can only be diagnosed through cardiac USG. It is considered a more severe form of cardiogenic shock, in which perfusion pressure is inadequately maintained, ultimately resulting in an undetectable pulse [10]. As evident, p-PEA shares close ties with both PEA, and cardiogenic shock and lacks clearly defined boundaries. The differentiation among these entities fundamentally revolves around two factors: the presence or absence of a palpable pulse and the existence of cardiac activity. Despite numerous studies on pulse detection [11], manual palpation remains the standard method for assessing the pulse during cardiopulmonary resuscitation (CPR) in routine practice. However, manual pulse checks are subjective, varying between patients and practitioners [11,12]. The debate regarding whether the carotid or femoral artery is the most accurate site for pulse palpation further complicates the matter, as the optimal site may vary depending on the patient [12]. It is evident that a practitioner may not perceive identical pulse intensities in a morbidly obese versus an extremely thin patient, and even two practitioners assessing the same patient may arrive at differing conclusions. The second challenge lies in the confusion surrounding the distinction between PEA, p-PEA, and cardiogenic shock based on cardiac activity, even when cardiac USG is employed. For instance, in a patient with organized electrical activity and no detectable pulse, echocardiography may reveal no cardiac activity, isolated valvular motion, partial myocardial motion in addition to valvular movement, or coordinated myocardial motion involving the entire myocardium. This spectrum blurs the line between where PEA ends and p-PEA begins. In terms of treatment, PEA and p-PEA are currently managed in the same way as asystole. However, p-PEA, given its close relationship with cardiogenic shock, represents a distinct clinical condition that may benefit from adjunctive pharmacological therapies, such as positive inotropes, in addition to CPR, potentially leading to different outcomes [9,13]. Cardiogenic shock, on the other hand, is not a cardiac arrest state but rather a condition with a specific therapeutic approach, primarily involving positive inotropic agents. These entities represent clinical conditions with distinct treatment needs and outcomes, yet they are almost uniformly categorized as PEA in current guidelines [2]. Distinguishing among these definitions has significant implications for treatment, particularly in determining the need for ongoing CPR and the initiation of positive inotropic therapy, both of which are of critical importance.

This retrospective study, based on echocardiographic video recordings, aims seeks to establish the differential diagnosis of PEA, p-PEA, and cardiogenic shock with a treatment-focused approach, as well as to identify patients who may benefit from positive inotropic therapy.

Materials and Methods

Study Design and Setting

This study was conducted as a retrospective video-based analysis in the critical care unit of the emergency medicine department at a tertiary university hospital. The critical care area of this emergency department is equipped with 16 beds for vital monitoring, 6 mechanical ventilators, and USG devices, including two portable units, one fixed unit, and one with a transesophageal probe. All critical patients and those experiencing CPA are managed in this area. Bedside USG examinations of patients in the critical care unit are performed by senior residents under the supervision of five attending physicians or faculty members, and video recordings are systematically archived. The study retrospectively reviewed archived video recordings from August 2017, when regular video archiving began on the USG devices, to April 2021. Ethical approval for the study was obtained from the İzmir Katip Çelebi University Non-Interventional Clinical Research Ethics Committee on April 15, 2021 (decision number:0214, date: 15.04.2021).

Study Population

The study included patients aged 18 years or older who experienced in-hospital or out-of-hospital CPA and had cardiac USG imaging performed during CPR. The study population consisted of patients in whom any degree of cardiac activity was detected on these USG images, and who were subsequently initiated on positive inotropic therapy. Cardiogenic shock was defined as the presence of organized rhythm, echocardiographic evidence of myocardial activity, a weak palpable pulse with hypotension, and hemodynamic instability following ROSC. Patients were excluded if they had incomplete cardiac USG video recordings either before or after the initiation of positive inotropic therapy, if information was missing in physician or nurse observation forms, or if clinical outcome data were unavailable due to transfer to another hospital or incomplete contact information.

Data Collection and Study Protocol

During the study period, all recorded images from the three available USG devices were reviewed. All patients who underwent cardiac USG imaging during CPR were identified.

These patients were cross-referenced with the hospital's patient records; and those who received positive inotropic therapy during CPR were identified. The study population comprised patients with complete video recordings both before and after the initiation of positive inotropic therapy. Demographic data, chronic conditions, laboratory test results, CPR durations and outcomes, rhythms observed during CPR, treatment regimens, and interventions were applied, and, if ROSC was achieved, the return rhythm and vital signs were collected from the hospital's digital patient records and follow-up forms. These details were recorded on patient data forms. Patients who achieved ROSC were followed until hospital discharge or death, and data on 24-hour and in-hospital clinical outcomes were documented.

Statistical Analysis

Descriptive statistics were calculated, including frequency, percentage, median, minimum (min.), and maximum (max.) values. Counts and percentages were reported for categorical variables, while min. and max. values and interquartile ranges were determined for numerical variables The normality of the distribution for continuous variables was assessed using histogram curves, Kurtosis-Skewness values, and the Shapiro-Wilks test. Group comparisons were performed using the chi-square test. All statistical analyses were conducted with SPSS version 24.0 software using a 95% confidence interval, with a significance level set at $p<0.05$.

Results

During the study period, cardiac USG recordings of 94 patients who underwent CPR in the emergency department's critical care area were reviewed. Among these patients, 63 were identified as having received positive inotropic therapy during CPR. Of these, 11 had incomplete observation forms, and 40 lacked either pre- or post-inotropic therapy cardiac USG recordings. Consequently, 12 patients with complete cardiac USG recordings before and after positive inotropic therapy were included in the study. Among the included patients, 5 (42%) were female, and the mean age was 67±16 years. For 10 patients, dopamine and dobutamine were administered at a dose of 20 mcg/kg/min. during CPR, while 2 patients were classified as post-CPR cardiogenic shock and received 10 mcg/kg/min. of dopamine and dobutamine after CPR was completed. Patients in CPA at the initiation of positive inotropic therapy underwent CPR for a max. of an additional 30 minutes.

Of the patients with organized electrical activity on the monitor during CPR but no palpable pulse (Figure 1a-d) 4 (33%) exhibited only valvular motion on cardiac USG imaging obtained before positive inotropic therapy (Video 1a-4a). None of these patients showed significant changes in cardiac activity following inotropic therapy (Video 1b-4b). The general characteristics and CPR details for these patients are presented in Table 1.

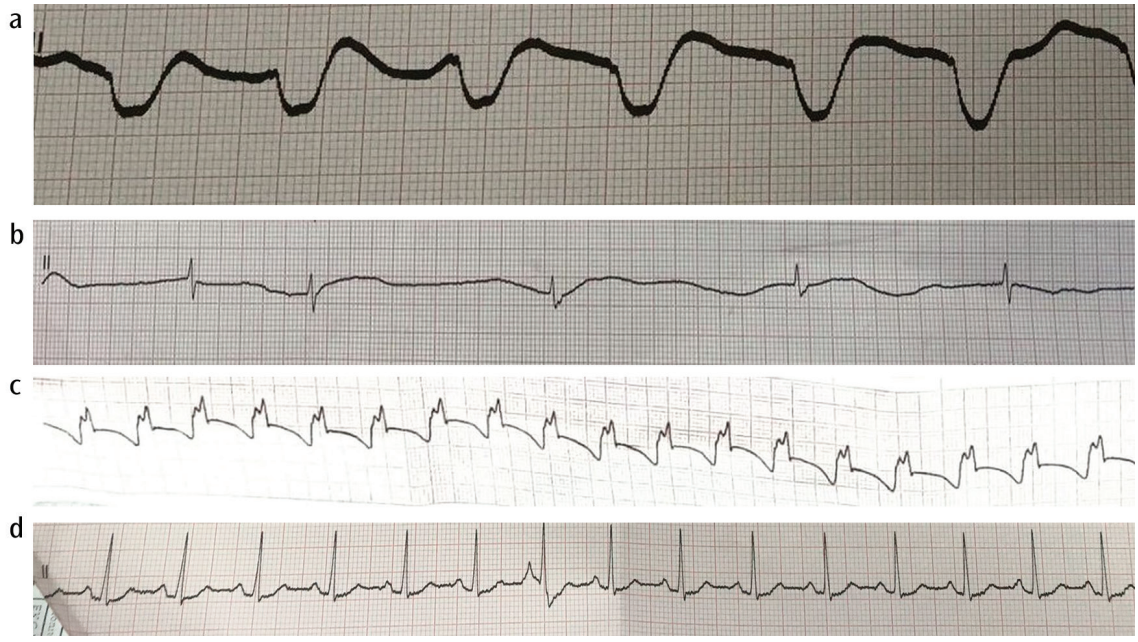

Figure 1 a). PEA rhythm in case 1 with only valvular motion on USG before inotropic therapy. b) Slow AF rhythm in case 2 with only valvular motion on USG before inotropic therapy. c) Wide-QRS SVT rhythm in case 3 with only valvular motion on USG before inotropic therapy. d) PEA rhythm in case 4 with pulmonary thromboembolism and only valvular motion on USG before inotropic therapy

USG: Ultrasound, PEA: Pulseless electrical activity, AF: Atrial fibrillation, SVT: Supraventricular tachycardia

Table 1. General characteristics and CPR data of patients who received positive inotropic therapy at CPR and in whom only valve motion was observed at pre-treatment cardiac USG

Case	Age (y)	♂♀	Clinical presentation	CPR course	Primary cause of CPA	Rhythms monitored in CPR	Cardiac USG (pre-positive inotrope)	Cardiac USG (post-positive inotrope)	Outcome of CPR and 24-hour survival
1	73	♂	This patient with sudden onset, dyspnea and confusion was brought to the hospital in an orthopneic state. CPA occurred 5 minutes after the start of NIMV treatment	At the 20th minute of CPR, a regular rhythm without a pulse was seen on monitor (Figure 1a). At the 20th minute of CPR, a regular rhythm with a wide QRS that did not produce a pulse, was seen on the monitor. Upon detection of cardiac activity at bedside USG, positive inotropes added to the treatment, and CPR continued	Unknown - possible PTE	Asystole -PEA - VF -asystole	Only valve motion (Video 1a)	Decreased valve motion (Video 1b)	ROSC could not be achieved after 30 minute of CPR and the patient was considered ex
2	88	♂	This bedridden patient had aspirated food during feeding. He was found at home with CPA by ambulance crews. He was brought to the hospital with supraglottic airway at the 25th minute of CPR	No pulse could be detected at the first pulse check (27th minute of CPR) in the hospital, but a rhythm compatible with AF with slow ventricular response was observed on the monitor (Figure 1b). A positive inotrope was added to the protocol after cardiac activity was observed at bedside USG and CPR continued	Aspiration pneumonia	Asystole - PEA - Asystole	Only valve motion (Video 2a)	Decreased valve motion (Video 2b)	ROSC could not be achieved after 40 minute of CPR, and the patient was considered ex
3	83	♂	CPA following sudden loss of consciousness at home. Relatives called an ambulance, and the patient was brought to the hospital with ETI at the 16th minute of CPR	After performing CPR for another 6 minutes in the hospital, a wide QRS tachycardic but non-pulsating rhythm was observed on the monitor. This was interpreted as SVT with bundle branch block with old ECGs (Figure 1c). A positive inotrope was added to the protocol after regular cardiac activity was observed at bedside USG, and CPR continued	Unknown	Asystole - PEA - asystole	Only valve motion (Video 3a)	Decreased valve motion (Video 3b)	ROSC could not be achieved after 30 minute of CPR and the patient was considered ex
4	77	♀	This patient, who was bedridden due to previous stroke, was brought to the emergency room due to sudden shortness of breath at home. The patient underwent pulmonary CT angiography after NIMV treatment and experienced CPA minutes later	While the rhythm was present on the monitor, the patient developed respiratory arrest, and no pulse could be detected. The patient was started on the CPR protocol, but there was still no pulse at the first pulse check, although the rhythm was still present on the monitor (Figure 1d). A positive inotrope was added to the treatment because of cardiac activity at bedside USG. Upon detection of PTE at thoracic CT angiography, thrombolytic therapy was started and the CPR protocol was maintained	PTE	PEA - asystole	Only valve motion (Video 4a)	Decreased valve motion (Video 4b)	ROSC could not be achieved after 40 minute of CPR and the patient was considered ex

USG: Ultrasound, CPR: Cardiopulmonary resuscitation, CPA: Cardiopulmonary arrest, PEA: Pulseless electrical activity, CVD: Cerebrovascular disease, NIMV: Non-invasive mechanical ventilation, CT: Computer tomography, AF: Atrial fibrillation, PTE: Pulmonary thromboembolism, VT: Ventricular tachycardia, VF: Ventricular fibrillation, MI: Myocardial infarction, ETI: Endotracheal intubation, GCS: Glasgow Coma Score, ROSC: Return of spontaneous circulation, ECG: Electrocardiogram, SVT: Supraventricular tachycardia

In 6 patients (50%) who exhibited organized electrical activity on the monitor but no palpable pulse during CPR (Figure 2a-g), cardiac USG imaging before positive inotropic therapy revealed valvular motion with varying degrees of myocardial motion (Video 5a-10a). All these patients demonstrated significant improvement in cardiac activity following inotropic therapy (Video 5b-10b); and ROSC was achieved in all cases, allowing CPR to be terminated. However, all these patients experienced recurrent CPA within 24 hours and succumbed in the clinical units where they were admitted. The general characteristics and CPR details of these patients are presented in Table 2. A statistically significant difference was found between the group with only valvular motion and the group with both valvular and myocardial motion in terms of response to positive inotropic therapy (ROSC, p=0.002).

In the remaining two patients, ROSC was achieved during formal CPR, evidenced by the presence of a weak pulse and low blood pressure, in addition to the organized rhythm observed on the monitor (Figure 3a, b). Positive inotropic therapy was initiated after CPR completion. Pre-therapy cardiac USG revealed valvular motion with varying degrees of myocardial motion (Video 11a and 12a). Post-inotropic therapy, the USG showed significant improvement in cardiac activity (Video 11b, 12b). Among these, case 11 achieved 24-hour survival and was discharged without sequelae, while case 12 experienced recurrent CPA but succumbed within 24 hours. The general characteristics and CPR details for patients in cardiogenic shock are presented in Table 3.

The contractile strength comparison of the contractile strength of cardiogenic shock cases (case 11 and case 12) with p-PEA cases (case 6 and case 9) through echocardiographic evaluation, it was observed that their findings were remarkably similar.

The odds of ROSC were 117 times higher in p-PEA patients, with phi coefficient of 0.998, indicating an exceptionally large effect size. Clinically, this strongly supports the importance of identifying myocardial motion via echocardiography during CPR and suggests that p-PEA patients should not be treated identically to PEA patients without myocardial activity. Positive inotropic therapy may have a markedly different and more favorable impact in pseudo-PEA cases (Table 4).

Discussion

Pulse assessment is one of the primary diagnostic tools guiding CPR and is currently performed predominantly through manual palpation, a rudimentary method. However, numerous studies have demonstrated that this technique is practitioner- and patient-dependent, with limited reliability in low-cardiac-output ROSC scenarios and susceptibility to various factors such as cold extremities and obesity [14-17]. For these reasons, although not yet part of routine practice, alternative methods such as carotid USG, femoral USG, and cardiac USG are gaining popularity [11,18]. Even with these instruments, the diagnostic boundaries between PEA, p-PEA, and cardiogenic shock remain unclear. Clinically, these entities exist on a spectrum. According to common understanding, PEA, characterized by a rhythm without any cardiac movement, lies at one end of the spectrum. p-PEA, where rhythm is accompanied by some degree of cardiac activity but no palpable pulse, occupies the middle. At the other end lies cardiogenic shock, characterized by rhythm, cardiac activity, a weak pulse, and low blood pressure [15,19]. However, these broad definitions leave gaps, and no consensus has been established among researchers. For instance, in their study, Wu et al. [18] did not classify patients with only valvular motion observed on cardiac USG into either the PEA or p-PEA groups. Conversely, Devia Jaramillo et al. [20] classified patients with valvular motion alone as p-PEA. Similarly, no clear data exist regarding the threshold at which myocardial contractility transitions from p-PEA to cardiogenic shock. This distinction is typically made using manual pulse palpation, a subjective and potentially unreliable method. Thus, under current definitions, PEA, p-PEA, and even cardiogenic shock are closely related entities with potential clinical overlap [10,21,22]. Furthermore, p-PEA patients with organized rhythm and some degree of myocardial contraction are treated in the same way as asystole patients, who lack rhythm and cardiac activity entirely. To our knowledge, this study is the first to evaluate the differential diagnosis of PEA, p-PEA, and cardiogenic shock, as well as their responses to positive inotropic therapy, through detailed echocardiographic analysis. Among the four patients with only valvular motion observed on cardiac USG, none responded favorably to additional positive inotropic therapy. Conversely, all six patients with valvular motion and varying degrees of myocardial motion demonstrated a positive response to inotropic therapy, achieving ROSC. These findings suggest that patients with only valvular motion should be categorized as PEA and treated accordingly. Meanwhile, patients with both valvular motion and varying degrees of myocardial motion should be classified as p-PEA, and their treatment may benefit from the addition of positive inotropes. Furthermore, carotid and femoral USG could be effective tools for distinguishing between p-PEA and cardiogenic shock in the differential diagnosis.

Importantly, this study does not aim to recommend a specific pharmacological agent, but rather to highlight a subgroup of patients (p-PEA) that may respond to inotropic support, and to stimulate further research in this area.

The most significant secondary finding of this study is the contribution of bedside USG to the diagnosis of patients. particularly in the p-PEA group, where ROSC was achieved with positive inotropic therapy allowing these patients to be accurately diagnosed and provided with specific treatment opportunities.

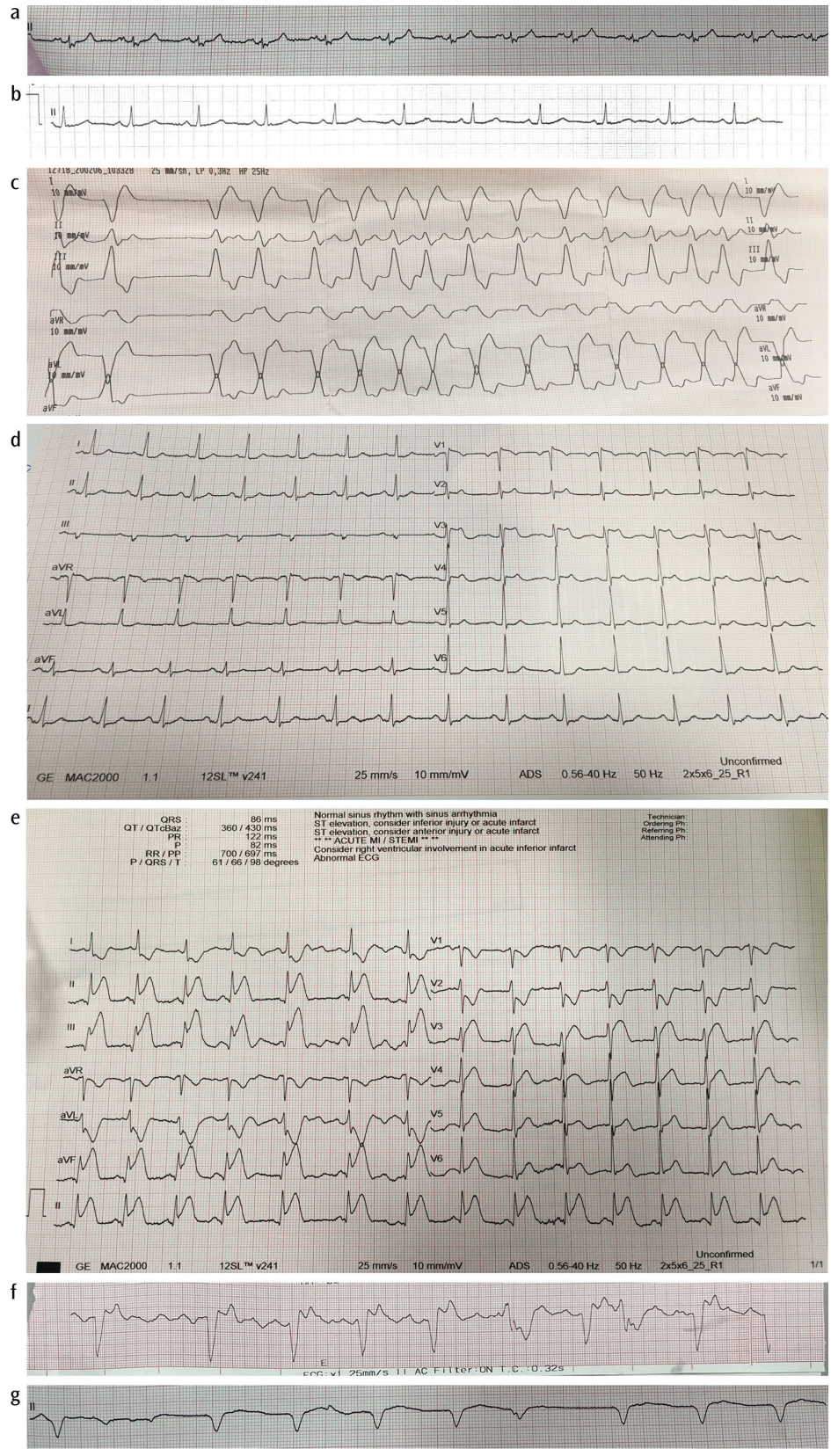

Figure 2. a) PEA rhythm in case 5 with myocardial + valvular motion on USG before inotropic therapy. b) PEA rhythm in case 6 with myocardial + valvular motion on USG before inotropic therapy. c) Wide-QRS tachycardia in case 6 after ROSC. d) PEA rhythm in case 7 with myocardial + valvular motion on USG before inotropic therapy. e) PEA rhythm in case 8 with myocardial + valvular motion on USG before inotropic therapy. f) PEA rhythm in case 9 with myocardial + valvular motion on USG before inotropic therapy. g) PEA rhythm in case 10 with myocardial + valvular motion on USG before inotropic therapy

USG: Ultrasound, PEA: Pulseless electrical activity, QRS:, ROSC: Return of spontaneous circulation

Table 2. General characteristics and CPR data of patients who received positive inotropic therapy at CPR and with myocardial motion in addition to valve motion at pre-treatment cardiac USG

Case	Age (y)	♂	Clinical presentation	CPR course	Primary cause of CPA	Rhythms monitored in CPR	Cardiac USG (pre-positive inotrope)	Cardiac USG (post-positive inotrope)	Outcome of CPR and 24-hour survival
5	76	♀	The patient was admitted to the emergency department with complaints of severe dyspnea and chest pain. The patient was anxious with unstable vital signs and experienced CPA during ETI	At the 12th minute of CPR, cardiac USG was performed on this patient, whose pulse could not be detected despite the rhythm on the monitor (Figure 2a). A positive inotrope was added to the treatment since cardiac activity was observed. At the 16th minute of CPR, the patient's pulse, which was confirmed by carotid USG, was taken, and CPR was stopped. Since thromboembolism was seen in the right structures, thrombolytic treatment was applied	PTE	Asystole - PEA - ROSC with AF with rapid ventricular response	Myocardium and valve motion (Video 5a)	Increase in myocardial and valve motion (Video 5b)	ROSC- ex within 24 hours
6	58	♀	The patient was admitted to an orthopneic state with severe dyspnea. The patient was unable to tolerate NIMV treatment and developed CPA at the 10th minute of admission	Although the rhythm was observed on the monitor (Figure 2b), no pulse was obtained, and CPR was started. Positive inotropic therapy was added to the treatment of this patient with cardiac activity at bedside USG. CPR was terminated when pulse was confirmed by carotid USG at the 12th minute of CPR. The patient stabilized after 1 hour, but experienced CPA again during CT angiography. The patient, who experienced continuous asystole during 20 minutes of CPR, died then	Unknown - possible PTE	PEA - ROSC with tachycardia with wide QRS (Figure 2c)	Myocardium and valve motion (Video 6a)	Increase in myocardial and valve motion (Video 6b)	ROSC- ex within 24 hours

Table 2. Continued

Case	Age (y)	♀♂	Clinical presentation	CPR course	Primary cause of CPA	Rhythms monitored in CPR	Cardiac USG (pre-positive inotrope)	Cardiac USG (post-positive inotrope)	Outcome of CPR and 24-hour survival
7	51	♂	The patient was brought to the emergency room by relatives due to the sudden onset of chest pain and unconsciousness. CPR was started when no pulse or rhythm could be detected at the time of admission. The duration of CPA was unclear	Rhythm was observed on the monitor (Figure 2d) after 8 minutes of CPR, but there was no pulse. A positive inotrope was added to the CPR protocol in this patient with cardiac activity at bedside USG. A pulse confirmed by carotid USG was palpated approximately 6 minutes later. Detailed cardiac ultrasound was performed and aortic dissection was detected (Video 7a). The patient was transferred for surgery	Aortic dissection	Asystole - PEA - ROSC with sinus tachycardia	Myocardium and valve motion (Video 7b)	Increase in myocardial and valve motion (Video 7c)	ROSC - Ex within 24 hours
8	74	♀	This patient was admitted with syncope after severe chest pain. He had a cold, pale appearance and agonal breathing. No pulse could be detected after several minutes, and the CPR protocol was started with advanced airway methods	Rhythm was observed on the monitor (Figure 2e) at the 15th minute of CPR, which was interpreted as asystole. Hemorrhagic pericardial effusion and cardiac activity were detected at cardiac USG performed due to lack of pulse. A pulse which was confirmed by carotid USG, 8 minutes after positive inotrope was added to treatment. The patient was transferred for surgery in an unstablecondition	MI and free wall rupture	Asystole - PEA - ROSC with sinus tachycardia	Myocardium and valve motion (Video 8a)	Increase in myocardial and valve motion (Video 8b)	ROSC- Ex within 24 hours
9	48	♂	This morbidly obese patient underwent 15 minutes of CPR from an external center with a diagnosis of ST elevation MI and was referred as ETI. VF developed while the patient was being received fromy the ambulance team, and the CPR protocol was started	After 10 minutes, a rhythm was seen on the monitor (Figure 2f), but because of doubt about the pulse in this morbidly obese patient, no beat was observed at femoral ultrasound (Video 9a) and CPR continued. Upon detection of cardiac activity at bedside USG, a positive inotrope was added to treatment. ROSC was achieved at the 16th minute, and the patient was transferred to the angiography laboratory	MI	VF- Asystole - PEA - ROSC with sinus tachycardia	Myocardium and valve motion (Video 9b)	Increase in myocardial and valve motion (Video 9c)	ROSC - Ex within 24 hours

Table 2. Continued

Case	Age (y)	♀	Clinical presentation	CPR course	Primary cause of CPA	Rhythms monitored in CPR	Cardiac USG (pre-positive inotrope)	Cardiac USG (post-positive inotrope)	Outcome of CPR and 24-hour survival
10	61	♂	The patient called an ambulance due to severe chest pain that started during exercise. The healthcare team detected elevation in the inferior and lateral leads of the patient's ECG. The patient developed CPA arrest during transport and was brought to the patient with 3 defibrillations and 10 minutes of CPR	After 5 minutes of CPR in the hospital, the rhythm was observed on the monitor (Figure 2g). Since the presence of a pulse was suspected, carotid ultrasound was performed, but no adequate pulse was detected at USG (Video 10a). positive inotrope was added to the CPR protocol due to cardiac activity at bedside USG. After a total of 20 minutes of CPR, ROSC was achieved, and the patient was transferred to the angiography laboratory	MI	VF - asystole-PEA - ROSC with sinus tachycardia	Myocardium and valve motion (Video 10b)	Increase in myocardial and valve motion (Video 10c)	ROSC - Ex within 24 hours

CPR: Cardiopulmonary resuscitation, CPA: Cardiopulmonary arrest, PEA: Pulseless electrical activity, CVD: Cerebrovascular disease, NIMV: Non-invasive mechanical ventilation, CT: Computer tomography, AF: Atrial fibrillation, PTE: Pulmonary thromboembolism, VT: Ventricular tachycardia, VF: Ventricular fibrillation, MI: Myocardial infarction, ETI: Endotracheal intubation, GCS: Glasgow Coma Score, USG: Ultrasound, ROSC: Return of spontaneous circulation ECG: Electrocardiogram, SVT: Supraventricular tachycardia

Bedside USG enabled the diagnosis of pulmonary thromboembolism (PTE) in case 5, aortic dissection in case 7, and free wall rupture in case 8, while also supporting the presumptive diagnosis of PTE in case 6. This study highlights that cardiac USG can be a valuable guide in cases where organized electrical activity is observed on the monitor during CPR, but the pulse is absent. Bedside USG provided these high-mortality patients with a chance for specific treatment, a finding consistent with earlier studies [23].

In this study, carotid and femoral USG, as well as cardiac USG, were utilized alongside manual pulse palpation for the differential diagnosis of p-PEA and cardiogenic shock. This was necessary because distinguishing these conditions based solely on echocardiographic visual assessment proved challenging. For example, no significant difference in contractile strength was observed between cardiogenic shock patients (case 11 and case 12) and p-PEA patients (case 6 and case 9). In morbidly obese patients like case 9, manual pulse detection might be difficult, as previous studies have indicated a high failure rate for manual pulse checks in obese patients [12]. Thus, even echocardiography may be insufficient for distinguishing p-PEA from cardiogenic shock, and combined methods such as carotid USG, femoral USG, or $ETCO_2$ may be necessary. In cases where none of these tools is available and a rhythm is present but no pulse is palpable, adding positive inotropic therapy may be beneficial.

In this study, all p-PEA patients with higher cardiac activity who were treated with positive inotropic agents achieved ROSC, while none of the PEA patients with less cardiac activity did. Väyrynen et al. [15] previously reported that the most significant factors influencing survival in PEA patients were the use of adrenaline and the presence of cardiac activity. These findings are consistent with our results. Mehta and Brady [10] previously reported achieving ROSC in a PEA patient during CPR by administering vasopressin, a vasopressor agent, in addition to standard resuscitation. Similarly, Wenzel et al. [24] demonstrated that vasopressin increased the ROSC rate in PEA patients during CPR. However, these studies did not differentiate between PEA and p-PEA, leaving the group classification of ROSC-achieved patients unclear. Prosen et al. [13] advanced this field by using capnography and USG to distinguish PEA from p-PEA, reporting that vasopressin was more strongly associated with ROSC and survival in p-PEA patients. In our study, consistent with Prosen et al. [13] findings, all p-PEA patients treated with positive inotropes, achieved ROSC, while no PEA patients did. Thus, cardiac activity during CPR may be a key determinant of treatment response. Supporting this, Wu et al. [18] reported that PEA patients with detectable cardiac activity had a 4.09-fold higher likelihood of achieving ROSC, compared to those without. Beyond vasopressin, Myerburg et al. [25] suggested that curcumin might be effective in achieving ROSC in PEA patients. While not all studies differentiated

between PEA and p-PEA, it appears that p-PEA patients with greater myocardial movement may have a higher likelihood of responding to certain drug therapies, warranting further targeted research.

Many experts believe that PEA has been an overlooked entity to date [9]. Extensive studies have been conducted on VF and VT, characterized by pulseless and irregular rhythms, leading to the development of specific therapies like defibrillation [26]. These therapies have significantly improved survival rates in these patients [27]. However, despite also being pulseless, regular rhythms like PEA and p-PEA have no specific therapeutic recommendations and are treated the same as asystole in routine CPR. Given the organized contractility and rhythm, especially in p-PEA patients, the ROSC and survival rates could potentially exceed those of irregular rhythms like VF. However, the superior survival rates of VF are primarily due to the availability of specific treatments like defibrillation. Similarly, the introduction of specific therapies for PEA and p-PEA patients could improve their survival outcomes. This study supports the hypothesis that positive inotropic agents, which are beneficial in cardiogenic shock, may also benefit p-PEA patients, who are in a condition similar to cardiogenic shock. Nevertheless, further research is required before this knowledge can be applied in routine practice

Study Limitations

The primary limitation of this study is its retrospective design, which means that data were accessed retrospectively. However, as these cases were recorded with the intent of being used for future training, detailed patient information and clinical data were systematically documented. This allowed access to most of the data necessary for the study. Another significant limitation is that it was conducted at a single center, which may restrict the generalizability of the findings. Furthermore, due to the retrospective nature and limited sample size, the study groups were not homogenous in terms of age or etiology of cardiac arrest, which may affect the comparability of the groups and limit the strength of conclusions.This missing data represents a significant limitation due to its known impact on survival outcomes.

Conclusion

According to the results of this study, valvular motion and myocardial motion can be used as references for the echocardiographic differentiation of PEA and p-PEA. Based on treatment response and outcomes, the group with valvular motion alone can be classified as PEA, while the group with valvular motion and in addition to varying degrees of myocardial motion can be classified as p-PEA. For the differential diagnosis of cardiogenic shock and p-PEA, carotid or femoral USG may serve as a useful tool. In terms of treatment, adding positive inotropic agents to the routine CPR protocol, may benefit patients with p-PEA, whereas such treatment may be ineffective for those in the PEA group. Further studies are required to validate these findings.

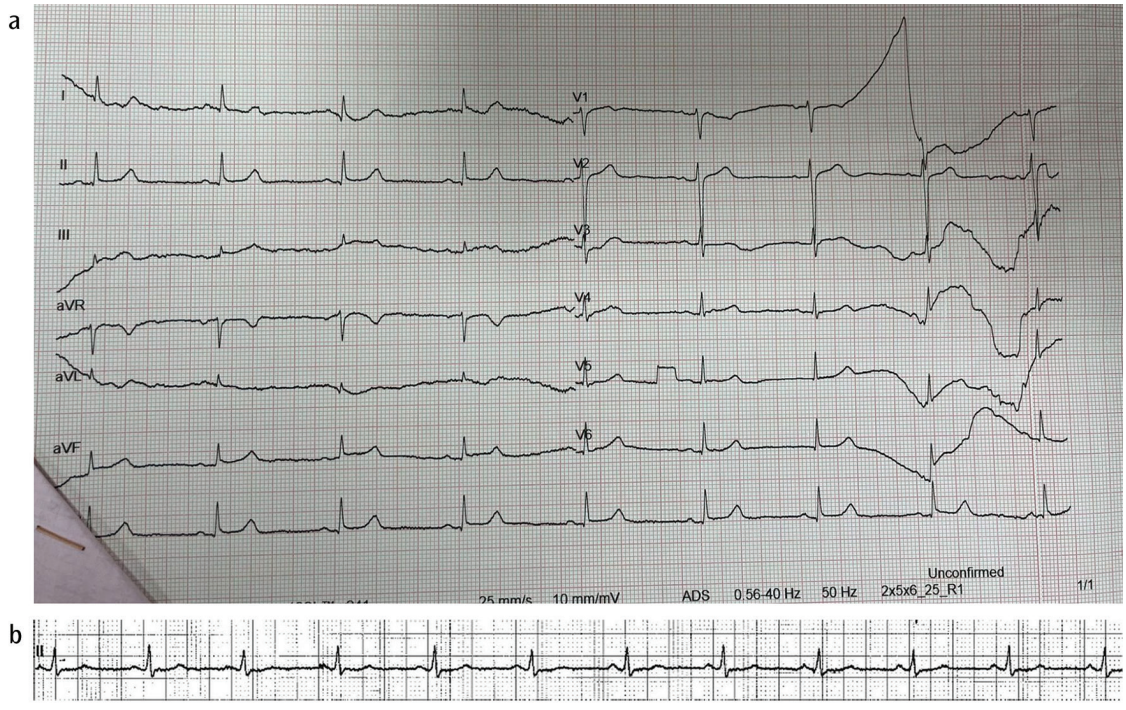

Figure 3. (a) Sinus tachycardia in case 11 with weak pulse and myocardial + valvular motion on USG in cardiogenic shock. b) Sinus rhythm in case 12 with weak pulse and myocardial + valvular motion on USG in cardiogenic shock

USG: Ultrasound

Table 3. General characteristics and CPR data of patients with post-CPR cardiogenic shock

Case	Age (y)	♀	Clinical presentation	CPR course	Primary cause of CPA	Rhythms monitored during CPR	Cardiac USG (pre-positive inotrope)	Cardiac USG (post-positive inotrope)	Outcome of CPR and 24-hour survival
11	27	♂	An ambulance was called by an ambulance by friends of the patient, who lost consciousness after using synthetic cannabinoids. The patient was brought to the emergency room with a GCS of 10 and developed VF 30 minutes later, at which the CPR protocol was initiated	A regular rhythm was observed on the monitor (Figure 3a) after a total of 12 defibrillations and 1.5 hours of CPR. A very weak pulse was detected from the carotid, and the presence of pulse was confirmed by carotid USG. Concomitant arterial blood pressure was 60/40. Cardiac activity was observed at cardiac USG, and the patient was evaluated as being in cardiogenic shock. CPR was terminated, and a positive inotrope was added to the treatment	Intoxication	VF - asystole - ROSC with normal sinus rhythm	Myocardium and valve motion (Video 11a)	Increase in myocardial and valve motion (Video 11b)	ROSC - survived
1 2	78	♀	This obese obese patient was brought to the emergency room by the ambulance team after a sudden onset of syncope at home. ETI was decided on for this unstable patient with deep hypoxia and hypocarbia. Although rhythm was seen on the monitor after ETI, arterial blood pressure could not be measured	CPR was started sine no pulse could be detected. In the third cycle, rhythm Figure 3b was observed, and a weak pulse was palpable. Bedside USG revealed a pulse in the carotid artery, and cardiac activity was present, and a thrombus was detected in the right atrium. The patient's arterial blood pressure was 70/30. CPR was terminated, and positive inotropic agents and thrombolytic therapy were added to the treatment	PTE	PEA - ROSC with normal sinus rhythm	Myocardium and valve motion (Video 12a)	Increase in myocardial and valve motion (Video 12b)	ROSC- ex within 24 hours

CPR: Cardiopulmonary resuscitation, CPA: Cardiopulmonary arrest, PEA: Pulseless electrical activity, CVD: Cerebrovascular disease, NIMV: Non-invasive mechanical ventilation, CT: Computer tomography, AF: Atrial fibrillation, PTE: Pulmonary thromboembolism, VT: Ventricular tachycardia, VF: Ventricular fibrillation, MI: Myocardial infarction, ETI: Endotracheal intubation, GCS: Glasgow Coma Score, ROSC: Return of spontaneous circulation, USG: Ultrasound

Table 4. ROSC Outcomes, effect size and odds ratio for p-PEA vs. PEA

Group	ROSC (+)	ROSC (-)	Total	Odds ratio (95% CI)	p-value	Effect size (φ)
Valvular + myocardial motion (p-PEA)	6	0	6	117.0 (1.35 -10,124.69)	0.002	0.998 (very large)
Valvular motion only (PEA)	0	4	4			

Odds ratios were corrected using the Haldane-Anscombe method. Effect size (phi coefficient) was derived from chi-square approximation with n: 10.0. According to cohen (1988), φ: 0.10 (small), 0.30 (medium), 0.50 (large); values above 0.80 are considered very large.

ROSC: Return of spontaneous circulation, PEA: Pulseless electrical activity, p-PEA: Pseudo-pulseless electrical activity

Ethics

Ethics Committee Approval: Ethical approval for the study was obtained from the İzmir Katip Çelebi University Non-Interventional Clinical Research Ethics Committee on April 15, 2021 (decision number:0214, date: 15.04.2021).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: N.G.Ç.Y., A.Y., M.G.E., Concept: N.G.Ç.Y., A.Y., M.G.E., S.B., Design: N.G.Ç.Y., M.G.E., E.K., S.B., M.Ş., Data Collection or Processing: A.Y., M.G.E., E.K., S.B., Analysis or Interpretation: M.G.E., E.K., M.Ş., Literature Search: N.G.Ç.Y., A.Y., M.G.E., E.K., M.Ş., Writing: N.G.Ç.Y., A.Y., M.G.E.

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Video 1a. Pre-positive inotropic therapy
https://d2v96fxpocvxx.cloudfront.net/2a4f1576-691d-4c9c-9173-1686c7aa9aea/cards/562fc498-4955-4257-b91c-48c2e9952e32.gif
Video 1b. Post-positive inotropic therapy
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Video 2a. Pre-positive inotropic therapy
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Video 2b. Post-positive inotropic therapy
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Video 3a. Pre-positive inotropic therapy
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Video 3b. Post-positive inotropic therapy
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Video 4a. Pre-positive inotropic therapy
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Video 4b. Post-positive inotropic therapy
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Video 5a. Pre-positive inotropic therapy
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Video 5b. Post-positive inotropic therapy
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Video 6a. Pre-positive inotropic therapy
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Video 6b. Post-positive inotropic therapy
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Video 7a. Aortic arch from the suprasternal notch
https://d2v96fxpocvxx.cloudfront.net/2a4f1576-691d-4c9c-9173-1686c7aa9aea/cards/18b57eb8-6f04-452a-8708-c9698f863b2a.gif
Video 7b. Pre-positive inotropic therapy
https://d2v96fxpocvxx.cloudfront.net/2a4f1576-691d-4c9c-9173-1686c7aa9aea/cards/18b57eb8-6f04-452a-8708-c9698f863b2a.gif
Video 7c. Post-positive inotropic therapy
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Video 8a. Pre-positive inotropic therapy
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Video 8b. Post-positive inotropic therapy
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Video 9a. Femoral artery ultrasound
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Video 9b. Pre-positive inotropic therapy
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Video 9c. Post-positive inotropic therapy
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Video 10a. Carotid artery ultrasound
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Video 10b. Pre-positive inotropic therapy
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Video 10c. Post-positive inotropic therapy
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Video 11a. Pre-positive inotropic therapy
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Video 11b. Post-positive inotropic therapy
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Video 12a. Pre-positive inotropic therapy
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Video 12b. Post-positive inotropic therapy
https://d2v96fxpocvxx.cloudfront.net/0fdb9ffe-e838-45c0-b564-25a52c51df96/documents/GECC-42714_(0)_Video_12.gif

ORIGINAL RESEARCH

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Evaluation of the Adequacy of Youtube Videos in Approach to Cardiac Arrest in Pregnant Women

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Abstract

Objective: Pregnant mortality is one of the important health indicators in the country. In the event of cardiovascular arrest, the necessary interventions should be performed in accordance with the guidelines to increase the chances of survival of both the mother and the fetus. The American Heart Association's (AHA) constantly updated cardiopulmonary resuscitation (CPR) guidelines guide us in this regard. YouTube is a frequently used video sharing website for obtaining information in the field of health as well as in many other fields. The aim of this study was to evaluate the adequacy of YouTube videos in terms of information content in the approach to pregnant patients experiencing cardiac arrest.

Materials and Methods: On February 13, 2024, the terms "cardiopulmonary arrest in a pregnant patient" and "basic life support" were entered into the YouTube search bar. The AHA CPR guideline recommendations for pregnant arrest were used as references. Journal of the American Medical Association (JAMA), Video Power Index, Global Quality Score (GQS), Quality Criteria for Consumer Health Information (DISCERN), and like rate were used as review criteria.

Results: A total of 87 videos published in English on YouTube about pregnant arrest were analyzed. Among the videos included in the analysis, 17 videos (45.9%) had a JAMA Score of 3 and GQS Score of 3 12 videos (32.4%) had. AHA CPR guidelines were analyzed.

Conclusion: Intervention for pregnant cardiac arrest patients and education on this subject have an important place. As a result of this study, it was concluded that there is not enough information available on YouTube regarding pregnant CPR training. We recommend that videos on pregnant CPR training posted on YouTube be reviewed and supervised by specialized healthcare professionals in accordance with current guidelines.

Keywords: Pregnant patient, basic life support, YouTube videos, resuscitation guidelines

Introduction

Globally, maternal mortality rates are one of the key parameters used to demonstrate the quality of a country's health system. In 2020, the maternal mortality rate in Organization for Economic Cooperation and Development (OECD), countries was set at 10.9 (per 100,000 live births). While this rate is 3 in countries such as Norway, Poland, and Israel, it is 173 in developing countries such as Indonesia. The rate in Türkiye was found to be higher than the OECD average (17.3) [1].

Management of cardiac arrest in pregnant patients should be aimed at successful rescue of mother and baby, and early perimortem cesarean section should be performed if necessary [2]. The success of the intervention in pregnant pregnancy is enhanced by the application of up-to-date guidelines and information. YouTube is one of the most frequently visited websites by patients and healthcare professionals worldwide. In 2024, YouTube ranked second in the ranking of the most frequently used websites in the world and in Türkiye [3]. In this study, we aimed to investigate the adequacy of the information published on YouTube, in the field of health, in terms of pregnant cardiac resuscitation.

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Materials and Methods

On February 13, 2024, a search of YouTube (https://www.youtube.com) was conducted by entering the terms "pregnant cardiopulmonary arrest", "cardiopulmonary resuscitation (CPR)", and "basic life support (BLS)". The date of upload, duration, number of views, who uploaded the videos (1st healthcare organization, 2nd pharmaceutical company, 3rd website, 4th TV channel, 5th healthcare worker), liking or disliking rate, and the number of comments, written about the video were recorded on a prepared form. Global Quality Scale (GQS), Journal of the American Medical Association (JAMA), and DISCERN scoring mean values were calculated.

Video Power Index (VPI) values [(like rate x view rate)/100], like rate [number of likes x 100 / (number of likes + number of dislikes)], view rate (number of views/days) were calculated to determine the popularity of the videos [4]. The GQS defined by Bernard et al. [5] to assess the informativeness of a video was calculated for each video. The JAMA criteria proposed by Silberg et al. [6] and the Oxford University Consumer Health Quality Criteria (DISCERN) were used to compare the transparency and editorial information of each video [7]. No human or animal data were used in the study. In addition, as in other similar studies, no ethics committee application was made because the study utilized publicly available YouTube videos [8,9].

Video Exclusion Criteria

- Non-medical videos (advertisements, news and interviews)
- Videos made for advertising
- Videos published outside English
- Comedy and entertainment videos
- Duplicated images
- Non-educational videos with real-life examples
- Cardiopulmonary resuscitation images of animals
- Short duration videos

In line with the information in the CPR in the pregnant patient guideline updated by the American Heart Association (AHA), the appropriateness of the video content was evaluated under the following headings.

AHA Algorithm for Advanced Maternal Resuscitation [10]

(1) Ensuring the safety of the patient's area.

(2) Control of patient non-response.

(3) Ensuring airway patency and assessing respiration.

(4) Mobilization of the emergency unit via mobile phone.

(5) C-A-B sequence.

(6) Manual left lateral uterine displacement (one hand/two hands) to ensure blood flow to the heart.

(7) 30:2 chest compression.

(8) Chest compression depth at the desired level (2 inches).

(9) Use of automated external defibrillator (AED) to restart the heart use of AED (was AED mentioned in the video?).

(10) Chest compressions should be 100-120/min.

(11) Use of capnography to confirm endotracheal tube placement and for monitoring.

(12) Advanced airway placement, continuous chest compressions with 1 breath every 6 seconds.

(13) Stabilization of the mother.

(14) Targeted temperature management.

(15) Monitoring of fetal heart rhythm in terms of bradycardia and other complications.

(16) Perimortem cesarean section (within 5 minutes of cardiac arrest).

(17) Internal eligibility for the AHA algorithm for advanced maternal resuscitation.

Journal of the American Medical Association Comparison Scoring (1 Point Per Question)

Authorship: Authors and contributors, their affiliations, and relevant credentials should be provided

Attribution: Fully cite the References and Sources cited in the video content and include the necessary copyright information.

Disclosure: Website "ownership" must be prominently and fully disclosed, such as sponsorship, advertising, underwriting, commercial financing arrangements or support, or potential conflicts of interest.

Currency: Indication of the time of publication of the content published in the video and the dates when it was updated.

Modified DISCERN Scale (Yes: 1, No: 0 Points for Each Question)

(1) Is the video clear, concise and easily understandable?

(2) Is it sourced from reliable sources?

(3) Is the information presented in an unbiased manner?

(4) Does it include additional sources of information for the patient to refer to if needed?

(5) Does the video address controversial or unclear issues?

Global Quality Scale Criteria

(1) Low quality content, poor site flow, majority of information missing, not at all useful for patients.

(2) Mostly poor quality and slow flow, some information listed but many topics missing, very limited for patients to use as an

information resource.

(3) Moderate quality, incomplete flow and some important information is not sufficiently mentioned and the information that is mentioned is poorly discussed, may be of limited use to patients.

(4) Good quality and mostly good flow, most of the necessary information is mentioned but some topics are not covered, in this respect it may be useful for patients.

(5) Very good quality and excellent flow, useful for patients to be able to provide sufficient information for their use.

Statistical Analysis

Data processing was done using SPSS 17.0 software package. Continuous variables were expressed as mean ± standard deviation; categorical variables were shown as numbers or percentages. The Mann-Whitney U test was used to determine the significance of the difference between the means of the groups for continuous variables. The Mann-Whitney U test was used in groups that did not show normal distribution. The Spearman correlation test was used to determine the correlation between the continuous variables. A level of statistical significance was determined at $p<0.05$.

Results

A total of 87 videos published in English on YouTube were analyzed in our study. Fifty videos that did not meet the inclusion criteria were excluded. Analysis of the DISCERN scores of the 37 videos included in the study revealed that more videos scored 1 or 4 points was higher than the others (Figure 1). Among the videos included in the analysis, 17 (45.9%) had a JAMA score of 3 and 12 (32.4%) had a GQS score of 3 (Figures 2 and 3). Of the 37 videos, the mean number of broadcast days was 871.27±661.54 (3-2230) and the mean broadcast duration was 11.04±11.99 minutes. The mean number of views was 57990.59±155671.22 (7-769249), the mean number of comments was 1305.03±4972.89 (0-28958); and the mean number of likes was 28.19±102.28 (0-603). It was observed that no video was disliked. Mean video popularity was

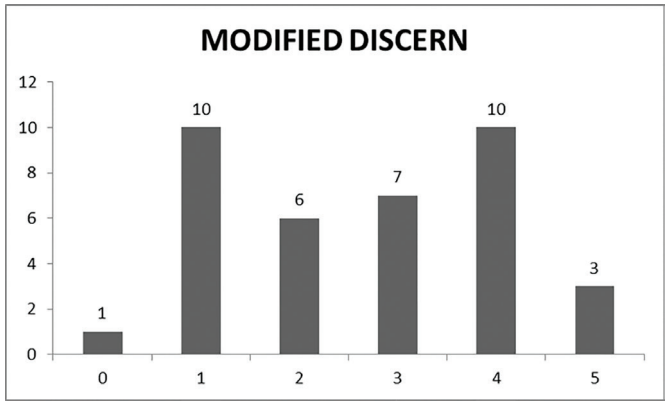

Figure 1. Modified Discern Scale

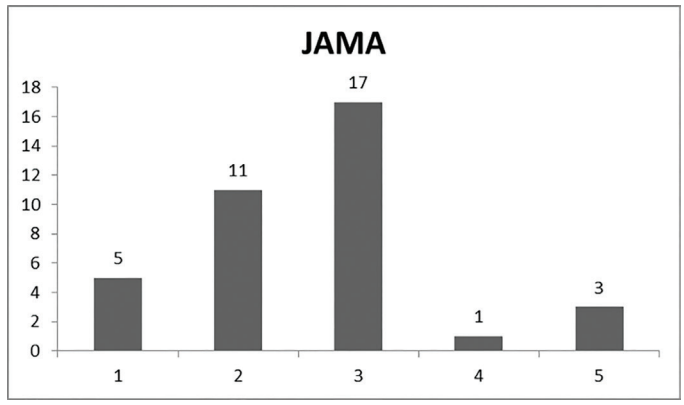

Figure 2. JAMA Scale

JAMA: Journal of the American Medical Association

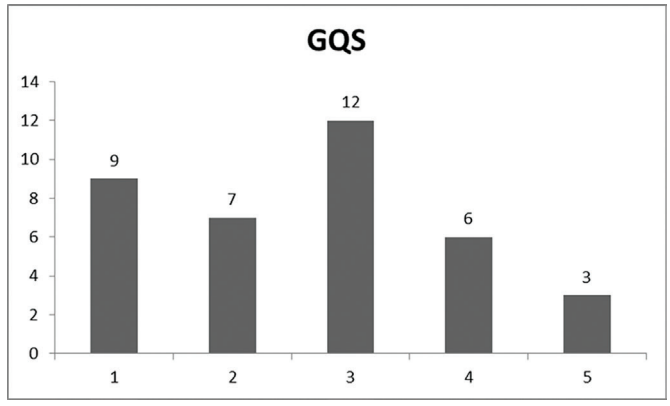

Figure 3. GQS Scale

GQS: Global Quality Score

35.25±69.82 (0-345), and mean VPI was 57990.59±155671.22 (7-769249) (Table 1).

Sixteen of the videos (43.24%) were uploaded by official institutions and organizations (Table 2). In the majority of the videos, 22 videos comprising 59.46%, slides were used as auxiliary material, and only 8 videos (21.6%) used realistic simulation (Table 3).

The parameters by which we evaluated the scope of the videos and which were determined according to the AHA CPR guideline are given in Table 4. In this table, it was seen that the title of the topic and the self-introduction section of the author. It was observed that 75.08% of the videos included manual left lateral uterine displacement, 30:2 chest compressions, 97% adherence to the C-A-B sequence, and emphasis on the chest compression depth required for 100-120 beats per minute (81%). However, we concluded that other parameters we evaluated in the AHA guideline were largely lacking. The rate of AED use was very low in these videos. Information on the use of capnography was included in only 18% of the videos. Perimortem cesarean section recommended in the guidelines was included in only 9 (24%) of the videos, while maternal stabilization after CPR, fetal heart rhythm monitoring, and body temperature monitoring were not mentioned frequently (Table 4).

Table 1. Characteristics of YouTube videos in terms of publication content

	n	Minimum	Maximum	Mean	Standard deviation
Number of broadcast days	37	3	2230	871.27	661.54
Duration (minutes)	37	1	47	11.04	11.99
Number of views	37	7	769249	57990.59	155671.22
Number of comments	37	0	28958	1305.03	4972.89
Liking rate	37	0	603	28.19	102.28
Video popularity	37	0	345	35.25	69.82
Video Power Index	37	7	769249	57990.59	155671.22

Table 2. Distribution of videos according to upload source

	Number	Percentage
Medical personel (doctor, paramedic, etc.)	11	29.73%
Laypeople	4	10.81%
Official institution or association	16	43.24%
Via TV show	3	8.11%
Shooting at BLS course	3	8.11%

BLS: Basic life support

Table 3. Distribution of videos according to resource usage

	Number	Percentage
Realistic simulation	8	21.62%
Writing board	4	10.81%
Model	18	48.65%
Slide	22	59.46%

Table 4. Parameters by which we evaluate the coverage of the videos

		No		Yes	
	n	Number	Percentage	Number	Percentage
Video title	37	1	2.70%	36	97.30%
The author of the video introduces himself (professional/student)	37	8	21.62%	29	78.38%
Do audio and video conflict?	37	17	45.95%	20	54.05%
Are there subtitles?	37	20	54.05%	17	45.95%
Ensuring environmental safety	37	20	54.05%	17	45.95%
Control of patient unresponsiveness	37	18	48.65%	19	51.35%
Ensuring airway patency and assessing breathing	37	18	48.65%	19	51.35%
Activating the emergency medical system with mobile 911	37	15	40.54%	22	59.46%
C-A-B sequence	37	1	2.70%	36	97.30%
Left lateral uterine displacement by hand (one hand/two hands)	37	9	24.32%	28	75.68%
30:2 chest compressions	37	2	5.41%	35	94.59%
Appropriate chest compression depth (2 inches)	37	7	18.92%	30	81.08%
AED use	37	26	70.27%	11	29.73%
Chest compressions should be 100-120/min.	37	7	18.92%	30	81.08%
Capnography	37	30	81.08%	7	18.92%
Maternal stabilization	37	23	62.16%	14	37.84%

Table 4. Continued

		No		Yes	
	n	Number	Percentage	Number	Percentage
Targeted temperature management	37	30	81.08%	7	18.92%
Fetal heart rhythm monitoring	37	28	75.68%	9	24.32%
Perimortem cesarean section	37	28	75.68%	9	24.32%

AED: Automatic external defibrillator, min.: Minimum

DISCUSSION

Maternal mortality is one of an important health indicators of a country. Advanced life support states that the first priority is to save the mother's life; however, measures should be taken urgently to ensure the highest chance of survival for both mother and baby. In particular, physiologic and anatomic changes during pregnancy require special attention during cardiopulmonary resuscitation. It should be kept in mind that the uterus should be shifted to the left lateral side during chest compressions, that there may be a difficult airway, and that postmortem cesarean section preparation should be performed to reduce pressure on the venous system and increase return of spontaneous circulation [10-13].

Since 2005, YouTube, a video sharing site, has been used as a source of information by patients and healthcare professionals [14]. Especially during the COVID-19 pandemic, video sharing sites such as YouTube have become an important source of medical information that can be accessed by a wide audience for free. The presence of low-quality videos containing misleading or incomplete information on YouTube, during the pandemic, has shown the need for videos prepared by experts on the subject [14].

Scales such as JAMA and DISCERN are used in the evaluation of visual publications on the Internet [15]. Therefore, we used the VPI value, GQS, DISCERN, and JAMA scales in our study.

In the study by Tutar et al. [16] very few videos were identified using the descriptive terms "CPR" and "BLS", and the reliability, quality, and information content of the videos were inadequate according to the CPR training guidelines. In the same study, it was found that 36% of all videos listed in a search using descriptive words were completely irrelevant to the field of CPR and BLS [16]. In the evaluation of pediatric CPR and BLS by Tosun et al. [17] only 16.5% of YouTube videos were suitable for inclusion in the study and 83.5% were found to be off-topic. It was concluded that this situation could limit viewers' access to up-to-date information and lead to misleading information. Similarly, in this study, very few videos were found in a search using descriptive terms, and 57.5% of these videos contained inappropriate content.

When we look at the use of AEDs in out-of-hospital cardiac arrest patients in public areas, the rate of AED use in our study was 29.73%, while AED use in the study by Tutar et al. [16] constituted only 5.1% of all videos. Although this rate is thought to be relatively high in our study, it was concluded that AED use has not yet been addressed sufficiently given the time elapsed.

In contrast to the previous study [16] based on the AHA 2015 CPR guidelines, our study was based on the AHA 2020 CPR guidelines, and it was found that the AHA 2020 CPR guidelines were followed and that there was sufficient information on adequate chest compression depth and compression-to-ventilation ratio. However, the videos we reviewed did not include information on the use of capnography, perimortem cesarean section, maternal stabilization, fetal heart rhythm, and temperature monitoring. This led to the conclusion that information on resuscitation of the pregnant woman was provided only as normal CPR and that information necessary for the survival of both the mother and the fetus was missing. In a study by Lynes et al. [18] in 2020, which analyzed 638 videos, only 1.6% of the videos included a female mannequin. The same study found that there was 1 high-quality video teaching a woman modern, hands-only CPR. The results of this study showed that there are few CPR training videos specific to women and that the barriers to providing the necessary training videos should be removed to prevent gender inequality in CPR [18]. There are very few studies in the literature examining the level of knowledge in YouTube videos about resuscitation for pregnant women. In this context, we believe that this study will contribute to revealing the deficiencies in the resuscitation of pregnant women and to their elimination.

Study Limitations

Limitations of our study included the exclusion of video sharing sites other than YouTube and the exclusion of non-English videos.

Conclusion

According to the AHA's current CPR guidelines, it was determined that the videos on YouTube contained incomplete information. This situation limits the use of YouTube videos

as a source of information on the approach to performing CPR during pregnancy. CPR performed during pregnancy in accordance with the guidelines will increase the chances of survival for both the mother and the baby. We believe that YouTube videos regarding pregnancy CPR training should be revised with the help of the updated guidelines.

Ethics

Ethics Committee Approval: Our study was conducted by examining digital data and was analyzed by examining digital data using objective scales and criteria. There are no data sharing or treatment interventions regarding any person or patient. No animals or plants were used for research purposes. For all these reasons, ethics committee approval is not required.

Informed Consent: Patient consent was not required as the study involved no human participants, identifiable data, or interventions.

Footnotes

Authorship Contributions

Surgical and Medical Practices: A.Y., Concept: A.Y., Design: A.Y., Data Collection or Processing: A.Y., Analysis or Interpretation: C.K., Literature Search: C.K., Writing: A.Y., C.K.

Conflict of Interest: No conflict of interest was declared by the authors.

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ORIGINAL RESEARCH

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Psychiatric Comorbidities and Prognosis in Biochemically Screened Substance Using Adults: A Retrospective Emergency Department Cohort Study

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Abstract

Objective: This study examined demographic characteristics, psychiatric comorbidities, and short-term outcomes of substance-using adults with positive urine drug tests in an emergency department (ED) setting.

Materials and Methods: Retrospective cohort of adults (≥18 years) who presented to ED between May 2022 and November 2023 with at least one positive urine test. Data included demographics, psychiatric history, ED diagnosis, disposition, hospital stay, and 1-month mortality. Urine drug screening used a standard biochemical method.

Results: Among 427 patients, the median age was 27 years, and 72.6% were male. The most frequently detected substances were amphetamines, cannabinoids, and benzodiazepines. Psychiatric disorders were identified in 59% of patients based on prior medical records. Hospitalization was more common in those with psychiatric comorbidities. Amphetamine and benzodiazepine users were more often discharged, whereas those who used cannabinoids or synthetic cannabinoids had longer hospital stays.

Conclusion: Psychiatric comorbidities are associated with increased hospitalization among substance-using adults. Substance type appears to influence clinical outcomes: stimulants and sedatives were linked to higher discharge rates, while cannabinoids were associated with prolonged hospitalizations. These findings highlight the importance of integrated psychiatric care and routine screening in EDs.

Keywords: Substance-related disorders, mental health, amphetamine, benzodiazepines

Introduction

Substance use is a widespread issue presenting complex challenges to health care systems globally, including emergency departments (EDs). Rapid, accurate identification of substance use is essential to initiate appropriate clinical management and improve outcomes. Urine drug testing is a standard biochemical method to detect substance exposure [1].

In Europe, approximately 25% of adults aged 15-64 have used illicit drugs at least once in their lives [2,3]. In the United States, large-scale surveys such as the National Survey on Drug Use and Health (NSDUH) and the Monitoring the Future study highlight the persistent prevalence of substance use across various age groups [4,5]. According to the 2022 NSDUH report, tobacco, alcohol, and illicit drug use remain highly prevalent, particularly among adolescents and young adults. These findings also reveal a considerable overlap between substance use disorders (SUDs) and psychiatric conditions, supporting the development of targeted public health policies.

In emergency settings, the incidental detection of substance use through biochemical testing is particularly important. Many individuals who present to EDs for various medical issues may

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not initially disclose their substance use. However, routine biochemical screenings can identify unsuspected cases, revealing a broader scope of SUDs in the population [6,7]. This incidental detection is critical for timely intervention, enabling the identification of at-risk individuals who might otherwise remain untreated. Data from such ED encounters also offer valuable epidemiological insights, helping to inform effective public health strategies [6-8].

Understanding the demographic and clinical characteristics of patients who test positive for substance use is essential for developing tailored medical interventions. Beyond physical health, substance use is closely linked to psychiatric conditions such as depression, anxiety, and psychosis, which complicate clinical management and worsen prognosis [9,10]. In some cases, individuals may begin using substances to self-medicate psychiatric symptoms, which ultimately exacerbates their mental health problems. Conversely, substance use can also trigger or intensify psychiatric conditions by altering brain structure and function [9].

While many studies have addressed various aspects of substance use in emergency settings, comprehensive analyses that include psychiatric and medical comorbidities, hospitalization status, and short-term outcomes remain limited. The intersection of substance use and psychiatric disorders is particularly important, as it shapes both treatment strategies and clinical outcomes in emergency settings.

Although the psychiatric aspects of substance use have been acknowledged in previous research, few studies have systematically examined their joint impact on clinical outcomes in emergency settings. There remains a critical need for integrated approaches that address both substance use and mental health in ED populations. This study seeks to address this gap.

This study aims to address this gap by examining the demographic and clinical characteristics of patients who underwent urine drug testing in an ED. Specifically, it explores the impact of psychiatric comorbidities and substance use on 1-month mortality, hospital length of stay, and hospitalization status. Additionally, the study investigates associations between types of substances used and the presence of psychiatric disorders, internal diseases, or trauma.

The findings are expected to contribute to the existing literature by offering insights into clinical outcomes in substance-using adults and reinforcing the importance of integrated psychiatric and emergency care.

Materials and Methods

Ethics, Study Design, and Data Collection

Ethical approval was obtained from Ankara Bilkent City Hospital, No. 2 Clinical Research Ethics Committee on December 6, 2023 (approval number: E2-23-5864, date: 06.12.2023), and informed consent was waived due to the retrospective design. Informed consent was waived due to the retrospective nature of the study, in accordance with the decision of the ethics board. All procedures were conducted in compliance with data protection regulations and the principles of the Declaration of Helsinki.

The study was conducted in the ED of a tertiary care hospital and included visits between May 1, 2022, and November 30, 2023. Patients were included consecutively based on clinical suspicion of substance use, which prompted a urine drug test. Inclusion required a confirmed positive result for at least one substance. Patients with negative test results or incomplete records were excluded. Patient data were retrieved from the hospital's statistics unit and electronic medical records, in full compliance with personal data protection standards. For cases in which, 1-month mortality data were unavailable from electronic records, follow-up was attempted via telephone contact with the patient or a legal guardian. If follow-up could not be completed, the case was recorded as "mortality data unavailable" and excluded from mortality outcome analysis.

During the study period, 3,500 patients underwent urine drug testing based on clinical suspicion of substance use, and 427 tested positive for at least one substance. Collected variables included age, sex, known psychiatric diagnoses, presenting complaints, ED diagnoses, hospitalization status, hospital stay duration, and 1-month mortality. Psychiatric and medical comorbidities were categorized based on ICD-10 diagnostic codes as recorded in the electronic medical records. Diagnoses included mood disorders (F30-F39), anxiety disorders (F40-F48), psychotic disorders (F20-F29), and SUDs (F10-F19), among others.

Measurement of Substances

Urine drug screening used the Enzyme Multiplied Immunoassay Technique with the Siemens ADVIA Chemistry analyzer, which is a standard biochemical method for verifying substance use. This assay detects commonly used substances including amphetamines, cannabinoids, benzodiazepines, cocaine, opiates, and others. The detection limits for most substances ranged between 50 to 300 ng/mL, depending on the analyte, with detection windows varying from 1 to 5 days post-ingestion. Sensitivity and specificity values were consistent with manufacturer standards, typically exceeding 90% for the substances included. The integrity of urine samples was ensured through established quality control protocols. Only completed test results were included in the analysis.

Outcome Measures

Demographic variables (age, gender), clinical diagnoses (including psychiatric and medical comorbidities), hospitalization status, hospital length of stay, and 1-month

mortality were documented. The types of substances detected via urine screening were recorded and analyzed.

Associations between patient characteristics and clinical outcomes (hospitalization, length of stay, and 1-month mortality) were evaluated. Additionally, the relationship between specific substance types and clinical diagnoses (psychiatric disorders, internal diseases, or trauma) was assessed.

Statistical Analysis

Statistical analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as numbers and percentages. The Shapiro-Wilk test was used to assess the normality of continuous variables. As the data did not follow a normal distribution, non-parametric methods were applied.

Categorical variables were compared using the chi-square or Fisher's exact test. The Mann-Whitney U test was used for comparing two independent groups. For multiple group comparisons, the Kruskal-Wallis test was employed, followed by post hoc pairwise analysis using the Mann-Whitney U test. Correlations between continuous variables were analyzed using Spearman's correlation test. A p-value <0.05 was considered statistically significant.

Results

Demographic and Descriptive Findings

The median age of the patients was 27 years (range: 18-61). Among 427 patients, median age was 27 years (range: 18-61), 72.6% were male, and 70% were single. Psychiatric disorders were identified in 59% of patients (n=252). Among these, 183 patients (42.9%) tested positive for more than one substance. Intensive care unit (ICU) admission occurred in 14.5% of cases; 7 patients (1.6%) died within 1 month. Substance use was considered a contributing factor in 4 of these deaths, based on ED documentation and clinical assessment, while the remaining 3 deaths were attributed to pre-existing medical conditions or trauma. The most frequently detected substances were amphetamines (n=195), followed by cannabinoids and benzodiazepines (Table 1). Additionally, we conducted subgroup analyses by substance type and age group. For example, the median age was 25 years [interquartile range (IQR) 22-29] among amphetamine users, compared to 30 years (IQR 26-35) among cannabinoid users, suggesting a younger profile in stimulant users.

At presentation, the most common complaints were self-harm behaviors (8.7%) and falls from height (4%). Agitation was the predominant psychiatric symptom (16.6%), whereas suicide attempts via drug ingestion were the main reason for internal medicine admissions (14.5%).

Clinical Outcomes and Substance Associations

Hospitalization was significantly more common among patients with a history of psychiatric disorders (p=0.004). Patients using amphetamines and benzodiazepines were more frequently discharged from either the ward or ICU (p=0.002 and p=0.001, respectively). These findings indicate a statistical association, but not a causal relationship. Clinical explanations such as milder intoxication severity, effective symptom control, or less complex medical needs may underlie these higher discharge rates. In contrast, cannabinoid and synthetic cannabinoid use was associated with longer hospital stays (p=0.001 and p<0.001, respectively) (Table 2). This may reflect factors such as behavioral dysregulation, agitation, or delayed recovery often seen with these substances.

When examining the association between diagnosis and substance type, amphetamine users were most commonly diagnosed with psychiatric conditions as 53% (p=0.042). Although other substances such as ecstasy, benzodiazepines, cannabinoids, synthetic cannabinoids, cocaine, heroin, and opiates were also found in patients with psychiatric diagnoses, no statistically significant relationships were observed between these substances and specific diagnosis groups (Table 3).

Discussion

This study investigated the demographic and clinical characteristics, psychiatric comorbidities, and short-term outcomes of adults with substance use detected via urine drug screening in an ED setting. Amphetamines, cannabinoids, and benzodiazepines were the most commonly identified substances. Psychiatric disorders were prevalent among the patient cohort, and agitation and self-harm were frequent presenting complaints. Patients with a known history of psychiatric illness were significantly more likely to be hospitalized. In contrast, patients who used amphetamines and benzodiazepines were more likely to be discharged. This is a statistical association rather than a causal relationship. It may reflect milder clinical presentations, less severe intoxication, or more predictable recovery profiles in these groups. Differences in clinical management strategies and decision-making thresholds may also have played a role. Additionally, cannabinoid and synthetic cannabinoid use was associated with prolonged hospital stays. This may be attributed to clinical and behavioral factors such as acute agitation, psychotic symptoms, or delayed physiological recovery, which often necessitate extended observation and supportive care. From a clinical and hospital resource perspective, longer stays among cannabinoid users may increase bed occupancy and staff workload, suggesting the need for ED protocols to identify, manage, and possibly expedite care for these patients.

These results reflect data-derived observations and are presented separately from interpretive commentary to maintain analytical clarity.

Taken together, the findings contribute to a deeper understanding of the complex interplay between substance use, mental health, and acute care needs in ED populations. SUDs continue to pose a significant public health challenge, as reflected in recent epidemiological surveys [2-5]. Although some data indicate stabilization or slight declines in use among certain populations, emerging substances and shifting usage patterns continue to demand updated clinical and public health responses [4,5,11].

Routine biochemical screenings in emergency settings play a crucial role in detecting hidden substance use. Many patients do not disclose drug use voluntarily, and incidental detection via urine testing provides opportunities for early intervention [6-8]. These data are also valuable for public health surveillance and resource planning.

The high rate of psychiatric comorbidities observed in this study supports previous findings that individuals with SUDs often suffer from concurrent mental health conditions [9,10]. This dual burden complicates diagnosis and management and requires an integrated care approach. Patients may use substances to self-medicate psychiatric symptoms, which may temporarily alleviate distress but often worsens the underlying psychiatric condition over time. Conversely, prolonged substance use may trigger or exacerbate psychiatric illness by altering brain structure and function [9]. These dynamics highlight the need for comprehensive mental health services in emergency settings.

Table 1. Demographic and descriptive data of substance using adults in an emergency department

Age [median years (min.-max.)]	27 (18-61)	
Hospital stay [median hour (min.-max.)]	8 (1-2304)	
Gender	Male [n (%)]	310 (72.6)
	Female [n (%)]	117 (27.4)
Marital status	Single [n (%)]	299 (70)
	Married [n (%)]	90 (21.1)
	Divorced [n (%)]	38 (8.9)
Psychiatric disorder (known before in history)	Schizophrenia [n (%)]	10 (2.3)
	Bipolar disorder [n (%)]	23 (5.4)
	Drug addiction [n (%)]	43 (10.1)
	Depression [n (%)]	15 (3.5)
Other disease (known before in history)	Epilepsy [n (%)]	5 (1.2)
	Hypertension [n (%)]	4 (0.9)
Diagnosis (made in ED)	Traumatic injury [n (%)]	96 (22.5)
	Psychiatric disorder [n (%)]	252 (59)
	Other [n (%)]	79 (18,5)
ED disposition	Discharge* [n (%)]	322 (75.4)
	Service [n (%)]	43 (10.1)
	ICU [n (%)]	62 (14.5)
1-month mortality	Alive [n (%)]	420 (98.4)
	Exitus [n (%)]	7 (1.6)
Detected substance [number of cases and mean blood concentration (µg/L)]	Amphetamine	195, 775.27
	Cannabinoid	143, 64.73
	Benzodiazepine	122, 349.70
	Ecstasy	109, 206.30
	Synthetic cannabinoid	48, 1.98
	Cocaine	21, 28.35
	Heroin	12, 1.22
	Opiate	33, 299.11

*Of the discharged patients, 49 refused treatment and follow-up in the ED, while 50 left the hospital without permission and without notifying the medical team.

min.-max.: Minimum-Maximum, n: number, ED: Emergency department, ICU: Intensive care unit

Table 2. Comparative analysis of hospitalization and hospital stay with descriptive and clinical data in substance-using adults in an emergency department*

Variable	Hospitalization			Hospital stay	
	Discharge	Hospitalized	p	Hours (median)	p
Age (min.-max.)	27 (18-61)	29 (18-59)	0.291		0.303
Marital status[a] (n)	223	76	0.625	10	0.029
Gender[b] (n)	226	84	0.114	7	0.388
Prior psychiatric disorder[c] (n)	250	86	0.438	8	0.213
Psychiatric diagnosis[d] (n)	188	64	<0.001	8	0.233
Amphetamine (n)	159	36	0.004	8	0.387
Ecstasy (n)	84	25	0.554	8	0.122
Benzodiazepine (n)	76	46	<0.001	4	0.130
Cannobinoid (n)	107	36	0.271	8	0.001
Synthetic cannobinoid (n)	38	10	0.626	6	<0.001
Cocaine (n)	17	4	0.515	7	0.735
Heroin (n)	7	5	0.170	8	0.998
Opiate (n)	21	12	0.119	0	0.990

[a]Data refer to divorced patients

[b]Data refer to male patients

[c]Data refer to patients with no previously established diagnosis of psychiatric conditions.

[d]Data refer to patients who received a psychiatric diagnosis during the emergency department visit.

*Some cases had more than one detected substance.

min.-max.: Minimum-Maximum, n: number

Table 3. Distribution of substances used by diagnosis groups in substance-using adults in an emergency department

Variable	Trauma (n, %)	Psychiatric disease (n, %)	Internal disease (n, %)	p
Amphetamine	53, 27%	103, 53%	39, 20%	0.042
Ecstasy	32, 29%	56, 52%	21, 19%	0.122
Benzodiazepine	25, 20%	77, 63%	20, 17%	0.538
Cannobinoid	33, 23%	93, 65%	17, 12%	0.036
Synthetic cannabinoid	12, 25%	28, 58%	8, 17%	0.951
Cocaine	5, 24%	15, 71%	1, 5%	0.237
Heroin	3, 25%	7, 58%	2, 17%	0.969
Opiate	6, 18%	20, 60%	7, 22%	0.807

Another important finding was the association between specific substances and hospitalization characteristics. As noted, patients using amphetamines and benzodiazepines were more frequently discharged likely reflecting lower severity or faster clinical resolution. On the other hand, cannabinoid and synthetic cannabinoid users had longer hospital stays. These differences suggest that the type of substance used can influence both care pathways and resource utilization in the ED. Clinicians should consider these variations when triaging and managing patients with suspected or confirmed substance use.

Lastly, although this study did not find statistically significant associations between most individual substances and specific diagnostic categories, amphetamine use was more frequently observed in patients diagnosed with psychiatric disorders. This trend is consistent with literature suggesting an overlap between stimulant use and psychiatric illness [9,10,12].

Study Limitations

This study has several limitations. In addition to being a retrospective, single-center analysis with limited generalizability, the quality and completeness of the available data may vary. Some variables included self-reported information, which may have certain limitations in terms of detail or completeness. Clinical decisions regarding hospitalization or discharge were not standardized and may differ among physicians, contributing to variability in outcomes. Additionally, not all substances are detectable by

standard urine screening panels, and the 1-month follow-up period limits the assessment of long-term outcomes. Psychiatric comorbidities were identified based on historical medical records, without differentiating between acute psychiatric presentations and chronic conditions, which may influence the interpretation of the findings. Future research should aim to address these limitations through multicenter, prospective designs with larger sample sizes, expanded toxicology panels, and longer follow-up periods.

Conclusion

In conclusion, this study highlights the multifactorial nature of substance use in emergency settings and emphasizes the need for integrated psychiatric evaluation and management. Psychiatric comorbidities are common among substance-using adults and are associated with increased hospitalization rates. Furthermore, different substances appear to influence the length of hospital stay and clinical outcomes. These findings support the implementation of routine biochemical screening and mental health assessment in EDs and underscore the need for public health strategies that address both substance use and co-occurring psychiatric conditions.

Ethics

Ethics Committee Approval: Ethical approval was obtained from Ankara Bilkent City Hospital, No. 2 Clinical Research Ethics Committee (approval number: E2-23-5864, date: 06.12.2023).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: M.G., H.S.Ö., Concept: M.G., H.S.Ö., Design: M.G., H.S.Ö., Data Collection or Processing: M.G., H.S.Ö., Analysis or Interpretation: M.G., H.S.Ö., Literature Search: M.G., H.S.Ö., Writing: M.G., H.S.Ö.

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ORIGINAL RESEARCH

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Association Between Pulmonary Artery Diameter on Computed Tomography and Pulmonary Artery Pressure in Lung Transplant Recipients

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Abstract

Objective: This study aims to evaluate the correlation between pulmonary artery diameter (PAD) measured by computed tomography (CT) and pulmonary artery systolic pressure (PASP) measured by right heart catheterization (RHC) in patients undergoing lung transplantation.

Materials and Methods: This retrospective study included 88 patients who underwent lung transplantation at a tertiary hospital in İstanbul between 2013 and 2021. Patients with available data on PASP measured by RHC and PAD measured by CT were included in the analysis. Data obtained from both the preoperative and postoperative periods were analyzed using the Pearson correlation test.

Results: The mean age of the 88 patients included in the study was 44.5±13.5 years, and 78.4% were male. The mean PASP measured by RHC was 43.44±14.17 mmHg, while the value measured by echocardiography was 38.08±12.71 mmHg. The mean main PAD value measured by preoperative CT was 3.17±0.52 cm. A higher correlation was observed between PAD and PASP in the preoperative period ($r=0.773$; $p<0.001$), while a lower correlation was found in the postoperative period ($r=0.575$; $p<0.001$).

Conclusion: This study demonstrated a strong correlation between PAD measured by CT and pulmonary arterial pressure measured by RHC, particularly in the preoperative period, in patients undergoing lung transplantation. This finding represents a significant advancement in clinical practice, as it may help reduce complication risks and improve patient comfort.

Keywords: Pulmonary artery, catheterization, lung transplantation, computed tomography

Introduction

Lung transplantation is regarded as one of the most effective treatment options for patients with end-stage lung diseases. Accurate assessment of hemodynamic parameters in both the preoperative and postoperative periods is essential for ensuring optimal patient management. Among these parameters, pulmonary artery systolic pressure (PASP) serves as a key indicator for evaluating pulmonary vascular resistance and the risk of right heart failure. Traditionally, PASP is measured through right heart catheterization (RHC), an invasive but highly reliable method that enables quantitative assessment of pressure, flow, and vascular resistance [1]. Despite its accuracy, RHC carries a risk of complications and may not be feasible for frequent evaluations in all patients [1].

Echocardiography, a non-invasive technique, is frequently used as a screening tool for pulmonary hypertension (PH) [2,3]. However, factors such as obesity, postoperative anatomical changes, and pulmonary parenchymal hyperinflation may limit the accuracy of echocardiographic measurements, thereby necessitating alternative non-invasive assessment methods [4].

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Computed tomography (CT) and magnetic resonance imaging (MRI) offer significant advantages in overcoming these challenges due to their high-resolution, cross-sectional imaging capabilities. An MRI study involving patients with primary pulmonary hypertension (PPH) demonstrated a strong correlation (r=0.7, p<0.01) between mean PASP and the ratio of the pulmonary artery diameter (PAD) to the descending thoracic aorta diameter [5]. However, this ratio becomes less reliable in cases where the aorta is dilated. Moreover, MRI is time-consuming, costly, and less accessible, making CT a more practical alternative. CT also offers the added benefit of lung parenchyma simultaneously.

Recently, CT-based measurements of PAD have been proposed as a non-invasive method for assessing PH [6]. Several studies have reported a significant correlation between CT-derived PAD and PASP values [7,8]. However, research directly comparing CT and RHC measurements in lung transplant patients, both preoperatively and postoperatively, remains limited [9].

This study aims to investigate the correlation between PASP values measured by RHC and PADs obtained from CT in lung transplant recipients.

Materials and Methods

Study Design and Population

This retrospective observational study was conducted on patients who underwent lung transplantation at University of Health Sciences Türkiye, Kartal Koşuyolu High Specialization Education and Research Hospital between January 1, 2013, and November 1, 2021. The study was carried out after receiving approval from the Ethics Committee of the relevant institution (decision number: 2021/14/540, date: 19.10.2021). Patient confidentiality was maintained, and the study was conducted in accordance with the Declaration of Helsinki. Written informed consent forms were obtained from all patients.

Patient Selection and Inclusion Criteria

Patients who underwent lung transplantation during the study period and for whom PASP data measured by RHC were available were included. In addition, patients whose PAD was measured via thoracic CT during the same period were also enrolled. Patients with missing data, those who did not undergo thoracic CT, or those for whom the PAD could not be evaluated due to technical limitations were excluded.

Data Collection

Demographic data (age, gender) and the date of surgery were collected retrospectively from the hospital records. PASP values measured by RHC, tricuspid annular plane systolic excursion, pulmonary vascular pressure, and preoperative echocardiographically measured pulmonary arterial pressure (PAP) values were retrospectively obtained from the hospital data system. Additionally, the aortic and PAD measurements obtained from CT images of the same patients were recorded. The PAD measurements were evaluated based on the main PAD both preoperatively and postoperatively.

Statistical Analysis

The data utilized in the study were analyzed using the SPSS 25.0 for Windows® statistical software package (IBM Inc., Chicago, IL, USA). For continuous variables, the mean ± standard deviation and the 25th-75th interquartile ranges were calculated. Pearson correlation analysis was performed to evaluate the relationship between the PASP values measured by RHC and the PAD measurements obtained from CT. A p-value of <0.05 was considered statistically significant.

Results

A total of 88 patients were included in the study. The mean age was 44.5±13.5 years (minimum: 14, maximum: 64). Sixty-nine patients (78.4%) were male. The mean age of female patients was lower than that of male patients (36.5±13.9 vs. 46.7±12.6; p=0.008). Among the patients, 31 (35.2%) had interstitial lung disease, 25 (28.4%) had bronchiectasis, and 21 (23.9%) had chronic obstructive pulmonary disease (Table 1).

The highest number of lung transplants occurred in 2017 (n=26, 29.5%), followed by 2018 (n=25, 28.4%) and 2019 (n=15, 17.0%). A significant decrease was observed after 2020 (Figure 1).

The mean values of PASP measurements obtained via catheterization in the study cohort were 43.44±14.17 mmHg. The mean PASP values measured by echocardiography before the operation were 38.08±12.71 mmHg (Table 2).

Pearson correlation tests were performed between the pulmonary artery measurements taken from thoracic CT images of the patients pre-operation and post-operation and the PASP values obtained by echocardiography and catheterization. A positive correlation was found between the preoperative PAD measurements and both preoperative echocardiographic PASP (C: 0.747, p<0.001) and catheter-

Table 1. Distribution of lung transplant patients by etiology

Diagnosis	Frequency, n	Percent, %
Interstitial lung disease	31	35.2
COPD	21	23.9
Pulmonary vascular diseases	3	3.4
Sarcoidosis	3	3.4
Occupational diseases	4	4.5
Bronchiectasis	25	28.5
Other	1	1.1
Total	**88**	**100.0**

COPD: Chronic obstructive pulmonary disease

measured PASP (C: 0.773, p<0.001). Similarly, positive correlations were found between the postoperative PAD measurements and both preoperative echocardiographic PASP (C: 0.513, p<0.001) and catheter-measured PASP (C: 0.575, p<0.001) (Table 3, Figure 2).

Discussion

Pulmonary arterial hypertension (PAH) is defined as a mean PAP exceeding 25 mmHg at rest, a pulmonary capillary wedge pressure of 15 mmHg or less, and a pulmonary vascular resistance greater than 3 Wood units [10]. PAH was first hemodynamically described by Dresdale et al. [11] in 1951, and for decades it remained a disease without an effective treatment. Although significant advances have been made in the medical management of PAH, not all patients respond equally well to pharmacotherapy. For patients who do not respond to optimal vasodilator treatment, lung transplantation is recommended [12]. Improvements in the prognosis of PAH patients have been observed following lung transplantation. Prior to the transplantation era, the survival probability for patients with PH was very low, with an average survival duration of only 2.8 years [13]. However, in high-risk surgical procedures such as lung transplantation, monitoring PAP in both the preoperative and postoperative periods is of great importance.

Traditionally, invasive catheter angiography (ICA) is considered the gold standard for the diagnosis of PAH because it is the only technique that directly measures PASP [1]. Although ICA provides highly accurate results, it is an invasive procedure that carries a risk of complications-such as pneumothorax, bleeding, or infection-in approximately 1% to 5% of cases, making repeating the procedure impractical in every patient [14]. On the other hand, echocardiography, a non-invasive method, serves as a valuable screening tool for the presence of PH, however, it only provides an estimate of the right ventricular systolic pressure. In individual patients, this estimation may be close to the actual pulmonary arterial systolic pressure, or it may be either an overestimation or an underestimation [2,3]. For these reasons, there is a need for alternative non-invasive methods capable of estimating PASP [4].

CT and MR imaging offer significant advantages in addressing these issues due to their cross-sectional and thin-slice imaging capabilities. An MRI study conducted on eight patients with PPH demonstrated that the mean PASP was significantly

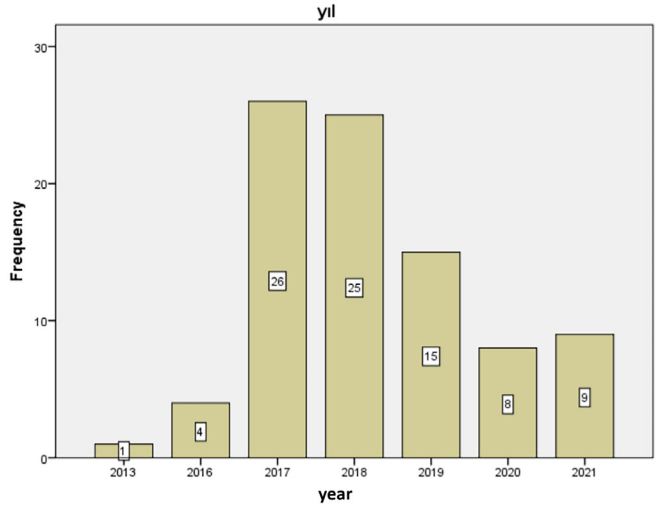

Figure 1. Distribution of lung transplants by year

Table 2. Mean measurements of patients included in the study

Measurement	Mean ± SD	IQR (25th-75th)
Aortic diameter, cm	3.08±0.52	2.70-3.60
Preoperative main pulmonary artery diameter, cm	3.17±0.52	2.70-3.57
Postoperative main pulmonary artery diameter, cm	2.86±0.45	2.70-3.27
PASP measured by echocardiography, mmHg	38.08±12.71	29.25-45.00
PASP measured by catheterization, mmHg	43.44±14.74	34.25-50.75
Tricuspid annular plane systolic excursion	2.38±0.93	1.65-2.80
Pulmonary artery vascular resistance, wood units	2.73±1.60	1.50-3.41

PASP: Pulmonary artery systolic pressure, SD: Standard deviation, IQR: Interquartile range

Table 3. Correlation of preoperative and postoperative pulmonary artery diameter with PASP measurements

	Preoperative main pulmonary artery diameter, cm		Postoperative main pulmonary artery diameter, cm	
	r	p	r	p
PASP measured by echocardiography, mmHg	0.747	<0.001	0.513	<0.001
PASP measured by catheterization, mmHg	0.773	<0.001	0.575	<0.001

r: correlation coefficient (Pearson).

PASP: Pulmonary artery systolic pressure

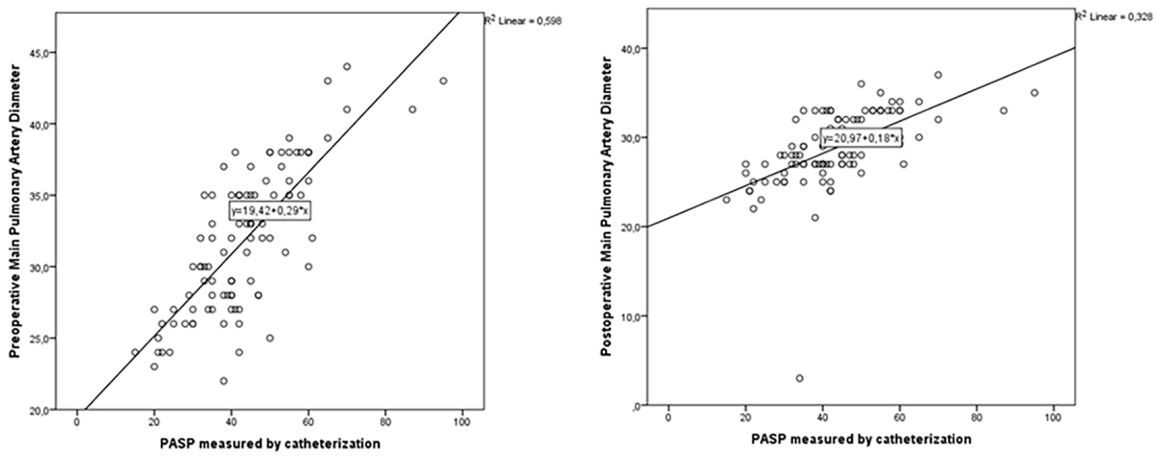

Figure 2. Correlation graph of pre- and postoperative pulmonary artery diameter with PASP measurements

PASP: Pulmonary artery systolic pressure

correlated with the ratio of the mean PAD to the descending thoracic aorta diameter (r=0.7, p<0.01) [5]. However, in cases where the descending thoracic aorta is dilated, this ratio may lose its reliability. Moreover, MRI is more time-consuming, more expensive, and less accessible, making it a less favorable option than CT for this purpose. In addition, the ability of CT to simultaneously evaluate the lung parenchyma is an important advantage [15].

In this study, we aimed to determine whether CT is a reliable method for assessing PAP in patients undergoing lung transplantation. To this end, we evaluated the correlation between the PAD and PASP values measured by ICA and echocardiography.

Our findings indicate that in lung transplant recipients, the measurements of the PAD show a significant correlation with PASP as determined by both invasive and non-invasive methods. Specifically, a strong positive correlation was detected between the main PAD measured in the preoperative period and the PASP measurements obtained via both catheterization and echocardiography (r=0.773 and r=0.747; p<0.001). These results suggest that CT-based measurements may be a reliable method for evaluating PH in the preoperative period.

It has been reported that PAD measurements obtained by CT correlate with certain threshold values for the diagnosis of PH. In long-standing PH, vascular wall calcifications, vascular tortuosity (bending), and the pruning of peripheral branches may be observed. Both tortuosity and fractal dimension have been found to be associated with the severity of PH [16]. Our findings are consistent with previous studies that emphasize the predictive value of PAD derived from CT in the diagnosis of PH.

According to the 2015 European Society of Cardiology/ European Respiratory Society Guidelines for the Diagnosis and Treatment of Pulmonary Hypertension, the presence of a PAD of ≥2.9 cm or a pulmonary artery to ascending aorta diameter ratio of ≥1.0 on CT imaging may increase the suspicion of PH in symptomatic patients [17]. In our study, the mean preoperative PAD was found to be 3.17±0.53 cm, and this value yielded results consistent with PASP measurements. A common feature of PH is the dilation of the central pulmonary arteries. In the study by Tan et al. [18] a main pulmonary artery (MPA) diameter of ≥29 mm was associated with a specificity of 89% and a positive predictive value of 97% in the diagnosis of PH [5]. However, a diameter below this threshold does not completely exclude PH because of the low negative predictive value. When the threshold is raised to 3.2 cm, specificity increases to 93% and the negative predictive value to 90%, although sensitivity drops to 47% [16].

Furthermore, CT provides a comprehensive anatomical evaluation, allowing for the simultaneous assessment of lung parenchymal changes, graft integrity, and post-transplant complications such as bronchial anastomotic stenosis or infection. This comprehensive evaluative capability enhances its clinical utility beyond mere hemodynamic assessment.

In the postoperative period, a significant, yet lower level of correlation between PAD and PASP measurements was observed (r=0.575, p<0.001). The somewhat lower correlation observed in the postoperative period may be attributed to several factors. Postoperative hemodynamic changes-including alterations in vascular compliance, pulmonary vascular remodeling, and graft-related complications-may affect PADs independently of the actual pressure changes. Additionally, immunosuppressive therapy, infections, and other postoperative complications may contribute to vascular changes that do not directly reflect PASP.

The interpretation of an enlarged MPA should be performed with consideration of factors such as interstitial lung disease,

lung fibrosis, and mechanical disruption following lung transplantation. In these patients, traction-related dilation of the MPA may be observed, even in the absence of PAH, and similar dilations can also occur in post-lung transplantation patients [19].

Study Limitations

This study has several limitations. First, it is retrospective in design, with a limited sample size. Additionally, the observation that the correlation values in the postoperative period are lower than those in the preoperative period suggests that the effects of postoperative hemodynamic changes may not be fully elucidated. Therefore, further large-scale prospective studies are warranted.

Conclusion

This study demonstrated that in patients undergoing lung transplantation, the main PAD measured by CT exhibited a significant correlation with PASP measured by invasive catheterization. In particular, CT measurements taken in the preoperative period can be regarded as a reliable non-invasive method for evaluating PAH. This finding represents an important advancement in clinical practice, as it may reduce procedural risks and enhance patient comfort.

Ethics

Ethics Committee Approval: University of Health Sciences Türkiye, Kartal Koşuyolu High Specialization Education and Research Hospital between January 1, 2013, and November 1, 2021. The study was carried out after receiving approval from the Ethics Committee of the relevant institution (decision number: 2021/14/540, date: 19.10.2021).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: N.H., M.E.Ç., Concept: N.H., M.E.Ç., Design: N.H., M.E.Ç., Data Collection or Processing: N.H., M.E.Ç., Analysis or Interpretation: N.H., M.E.Ç., Literature Search: N.H., M.E.Ç., Writing: N.H., M.E.Ç.

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