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RESEARCH ARTICLE

Relationship Between Risk Scores and Acute Kidney Injury in Patients Undergoing Transcatheter Aortic Valve Replacement

Nijad Bakhshaliyev[1*], Gokhan Ertas[2], Tolga Sinan Guvenç[2], Mehmet Eren[2]

[1]*Ege Hospital, Baku, Azerbaijan.*
[2]*Koc University Hospital, Istanbul, Turkey.*

Corresponding Author: *Nijad Bakhshaliyev, Email: nbakhshaliyev@gmail.com*

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Abstract

Introduction: Acute kidney injury (AKI) is a major predictor of mortality in patients undergoing transcatheter aortic valve replacement (TAVR). This study aimed to evaluate the relationship between the EuroSCORE II and STS scores, and the occurrence of AKI in patients undergoing TAVR.

Methods: A retrospective review was conducted on 105 patients who underwent TAVR for severe aortic stenosis at our clinic. Data on demographics, laboratory results, echocardiography, and procedural details were collected. AKI was defined according to the Valve Academic Research Consortium-2 (VARC-2) criteria.

Results: Among the 105 patients, 65 (61.9%) were female, with a mean age of 77 ± 4.88 years. AKI developed in 31.4% of the patients. The mean STS score for the entire cohort was 8.03 ± 2.30, while the mean EuroSCORE II was 10.93 ± 7.53. In patients who developed AKI, the mean STS score was 14.35 ± 7.66 and the mean EuroSCORE II was 22.34 ± 6.07, while in patients without AKI, these scores were 5.26 ± 2.41 and 4.88 ± 3.07, respectively. The predictive value of EuroSCORE II and STS was assessed using the area under the ROC curve. A EuroSCORE II cut-off of 6.16 demonstrated 91% sensitivity and 68% specificity, while an STS score cut-off of 6.30 showed 84% sensitivity and 75% specificity for predicting AKI following TAVR.

Conclusion: Both the STS score and EuroSCORE II, originally developed to predict postoperative mortality, may also serve as predictors of AKI in patients undergoing TAVR.

Keywords: Aortic Stenosis, TAVR, Cardiac Surgery, Kidney Injury.

Introduction

Transcatheter aortic valve replacement (TAVR) has emerged as a promising alternative treatment, not only for high-risk or inoperable patients, but also for those classified as intermediate or low-risk (1-3). However, a dedicated scoring system to predict long-term outcomes following TAVR remains absent. The logistic EuroSCORE, for instance, failed to predict post-TAVR outcomes in the SOURCE registry (4). In contrast, the STS score has been shown to outperform the logistic EuroSCORE in predicting adverse events after TAVR, according to a two-center registry (5). Acute kidney injury (AKI) is a critical predictor of mortality in TAVR patients, but the relationship between preoperative risk assessment scores, such as EuroSCORE II and STS, and the development of AKI has not yet been investigated. Therefore, the aim of this study was to explore the association between EuroSCORE II, STS score, and AKI in TAVR patients.

Materials and Methods

Patient Population

A retrospective review was conducted on 110 patients who underwent transcatheter aortic valve replacement (TAVR) at our center. Five patients were excluded from the study: one patient was disqualified due to the transapical approach, two patients died during or immediately after the procedure, and two patients were on prior permanent hemodialysis. The remaining patients underwent the transfemoral procedure. TAVR was indicated for all patients with symptomatic severe aortic stenosis. Severe aortic stenosis was defined as an aortic valve effective orifice area (EOA) <1.0 cm^2 or indexed EOA ≤0.6 cm^2/m^2, and a mean gradient ≥40 mmHg, as determined by echocardiography, or a combination of an EOA ≤1.0 cm^2 or ≤0.6 cm^2/m^2 indexed to body surface area, low mean transvalvular gradient (<40 mmHg), and a low left ventricular

ejection fraction (LVEF ≤40%), resulting in a low flow (LF) state. All patients were evaluated by a "Heart Team" consisting of an interventional and non-interventional cardiologist, cardiovascular surgeon, radiologist, and anesthesiologist, and were found to be eligible for TAVR. Indications for TAVR included high STS and EuroSCORE II, high risk for reoperation, fragility/poor mobilization, severe pulmonary hypertension, serious pulmonary disease, and the presence of a porcelain aorta. Exclusion criteria included patients not approved by the "Heart Team," those with an estimated life expectancy of less than one year, serious organ dysfunction, unsuitable annulus size (<18 mm and >29 mm), left ventricular thrombus, active endocarditis, increased risk of coronary ostium obstruction (e.g., asymmetric valve calcification, short distance between the annulus and coronary ostium, small aortic sinus), plaques with mobile thrombi in the ascending aorta or arch, bicuspid or non-calcified valve, hemodynamic instability, and LVEF <15%.

Acute Kidney Injury (AKI) Definition

AKI was defined according to the Valve Academic Research Consortium-2 (VARC-2) criteria as an absolute decrease in kidney function occurring within 7 days, characterized by one of the following: (1) an increase in serum creatinine of ≥0.3 mg/dL (≥26.4 μmol/L) from baseline, (2) a percentage increase in serum creatinine of ≥50% (1.5-fold increase from baseline), or (3) urine output <0.5 mL/kg/h for more than 6 hours. AKI severity was classified into three stages:

Stage I

Serum creatinine increase of 150–199% or an increase of ≥0.3 mg/dL (≥26.4 μmol/L), or urine output <0.5 mL/kg/h for >6 but <12 hours.

Stage II

Serum creatinine increase of 200–299% (2.0–2.99-fold increase from baseline), or urine output <0.5 mL/kg/h for >12 but <24 hours.

Stage III

Serum creatinine increase ≥300% (3-fold increase from baseline) or serum creatinine ≥4.0 mg/dL (≥354 μmol/L) with an acute increase of ≥0.5 mg/dL (44 μmol/L), or urine output <0.3 mL/kg/h for ≥24 hours or anuria for ≥12 hours. Patients requiring renal replacement therapy were considered to meet Stage III criteria, regardless of other factors.

Pre-Procedural Assessment

Pre-procedural evaluations included electrocardiography (ECG), transthoracic echocardiography (TTE), transesophageal echocardiography (TEE), coronary and peripheral angiography, and multi-detector computed tomography (MDCT) when necessary. Aortic annulus diameter was measured using both TEE and MDCT for optimal accuracy. STS score and EuroSCORE II were calculated using the online calculators available at [STS Risk Calculator](http://riskcalc.sts.org/stswebriskcalc/calculate) and [EuroSCORE II](http://www.euroscore.org/calc.html), respectively.

Valve Implantation

The valve implantation procedures were performed under monoplane fluoroscopy with the assistance of combined local and systemic analgesia. All patients received clopidogrel (300 mg), acetylsalicylic acid (300 mg), and cefazolin (2 g) prior to the procedure. Both balloon-expandable and self-expanding valves were used, with rapid ventricular pacing applied in selected patients. Balloon pre-dilatation was utilized in cases of severe calcifications, and balloon post-dilatation was performed when the valve was deemed inadequately expanded.

Laboratory Methods

Renal function was monitored preoperatively and at 1 hour, 12 hours, 1 day, 2 days, and 3 days post-procedure, as well as at the time of discharge. The estimated glomerular filtration rate (eGFR) was calculated using the simplified MDRD (Modification of Diet in Renal Disease Study Equation) formula. Acute kidney injury (AKI) was defined according to the VARC-2 criteria. Electrocardiograms (ECGs) of the patients were retrospectively reviewed by a cardiologist. The indication for permanent pacemaker implantation following the procedure was based on the 2013 ESC guidelines for cardiac pacing and resynchronization therapy.

Statistical Analysis

Statistical analyses were performed using SPSS 22.0 (IBM Inc., USA). Continuous variables were expressed as means ± SD, while categorical variables were presented as percentages. Data homogeneity was tested using the one-way Kolmogorov-Smirnov test and visual inspection of histograms. The equality of variances was assessed using the Levene test. For homogeneous variables, Student's t-test was used, while the Mann-Whitney U test was preferred when the dataset was non-homogeneous or when a subgroup contained fewer than ten subjects. For categorical variables, the χ^2 or Fisher's exact test was used, depending on the expected cell count.

Renal damage was considered present if the patient was classified as Grade I or higher according to the AKIN classification. Predictors of renal damage were identified using univariate analysis, and parameters with a p-value of ≤0.1 were included in binary logistic regression analysis. The forward likelihood method was employed for logistic regression. The fit of the model was assessed using the Hosmer-Lemeshow goodness-of-fit test. A receiver operating characteristic (ROC) curve was generated, and the sensitivity and specificity of EuroSCORE II and STS score values for predicting AKI were determined. Parameters with

a p-value of <0.05 were considered independent predictors of renal damage following TAVR.

A p-value of <0.05 was considered statistically significant for all analyses, and 95% confidence intervals were used for all relevant calculations.

Results

A total of 105 patients with severe aortic stenosis were enrolled in the study (mean age 77.00 ± 4.88 years, 61.9% female). Among these, 22.9% had a history of previous cardiac surgery. Hypertension was present in 71.4% of patients, diabetes mellitus in 37.1%, and 59% had a history of coronary artery disease (Table 1). Laboratory parameters for both the AKI and non-AKI groups are detailed in Table 1. The overall mean STS score was 8.03 ± 2.3, and the mean EuroSCORE II was 10.93 ± 7.53.

TAVR was performed transfemorally in all patients, with those undergoing a transapical approach excluded due to patient intake limitations. Various valve types were used during the procedures.

AKI developed in 31.4% of the patients who underwent TAVR. According to the AKIN classification, 18.1% had Stage I AKI, 5.7% had Stage II, and 7.6% had Stage III AKI (Figure 1). Four patients required temporary renal replacement therapy, and two needed permanent dialysis. Baseline serum creatinine was significantly higher in the AKI group compared to the non-AKI group (1.33 ± 1.17 vs. 0.97 ± 0.34, p = 0.02). However, multivariate analysis showed that baseline serum creatinine was not an independent predictor of AKI (odds ratio \[OR]: 1.04; 95% CI: 0.30–3.59; p = 0.95). Pre- and post-procedure hemoglobin or hematocrit levels did not correlate with nephropathy development. Similarly, factors such as high pulmonary pressure, mitral regurgitation, aortic regurgitation, aortic valve area, and gradient were not statistically significant in relation to AKI. However, a significant association was observed between AKI and

Table 1: Baseline and postprocedural features of the study population.

Variables	*Overall population*	*Acute kidney injury*		*p-value*
		Without (n = 72)	*With (n = 33)*	
Age ,years, mean ± SD	77.00 ± 4.88	77.48 ± 4.65	75.91 ± 5.28	0.13
Female , n (%)	65 (61.9)	46 (63)	19 (59.4)	0.73
Hypertension, n (%)	75 (71.4)	49 (67.1)	26 (81.3)	0.17
Diabetes mellitus, n (%)	39 (37.1)	24 (32.9)	15 (46.9)	0.14
Smoking , n (%)	16 (15.2)	11 (15.1)	5 (15.6)	0.94
CAD , n (%)	62 (59.0)	39 (53.4)	23 (71.9)	0.08
Previous CABG , n (%)	24 (22.9)	13(17.8)	11(34.4)	0.06
COPD , n (%)	37 (35.2)	27(37)	10(31.3)	0.57
BMI, mean ± SD	25.78 ± 3.48	26.23 ± 3.63	24.71 ± 2.98	0.23
STS score, mean ± SD	8.03 ± 2.3	5.26 ± 2.41	14.35 ± 7.66	<0.001
EuroSCORE II, mean ± SD	10.93 ± 7.53	4.88 ± 3.07	22.34 ± 6.07	<0.001
Contrast volume, (ml), mean ± SD	206 ± 30	202 ± 25	215 ± 36	0.07
Serum Creatinine (mg/dL), mean ± SD	0.82 ± 0.24	0.97 ± 0.34	1.33 ± 1.17	0.02
Hematocrit (%),mean ± SD	33.23 ± 4.97	34.29 ± 5.06	34.76 ± 4.81	0.67
Platelet, (x10^3 /µL), mean ± SD	201.08 ± 63.72	217.53 ± 69.04	224.27 ± 78.42	0.67
Left Ventricular EF, %, mean ± SD	51.16 ± 10.96	53.30 ± 9.01	46.28 ± 13.39	0.007
AVA, cm^2, mean ± SD	0.74 ± 0.14	0.74 ± 1.13	0.66 ± 0.16	0.21
Mean Gradient, mmHg, mean ± SD	48.95 ± 12.77	49.02 ± 13.33	48.69 ± 10.89	0.94
SPAP, mmHg, mean ± SD	44.87 ± 13.22	44.30 ± 13.47	36.82 ± 12.95	0.65
Atrial fibrillaion, %	22.9	24.2	18.8	0.51
Postprocedural features				
Serum creatinine, (md/dL)	1.11 ± 0.43	1.00 ± 0.34	2.45 ± 2.07	<0.001
Hematocrit, (%)	28,45 ± 4.94	29.04 ± 5.14	27.12 ± 4.37	0.29
RBC transfusion, n (%)	53 (50.5)	33(45.2)	20(62.5)	0.10
Prosthetic valve size, mm, mean ± SD	25.73 ± 2.49	25.18 ± 2.11	25.19 ± 2.09	0.98

Values in bold are statistically significant

AVA- aortic valve area, BMI- body mass index, CABG- coronary artery bypass grafting, CAD- coronary artery disease, COPD- chronic obstructive pulmonary disease, RBC- red blood cell, SPAP- systolic pulmonary artery pressure

Table 2: Predictors of acute kidney injury : Univariate and Multivariate analysis.

Parameters	*Univariate analysis*		*Multivariate analysis*	
	Odds ratio (95% Confidence Interval)	*p-value*	*Odds ratio (95% Confidence Interval)*	*p-value*
Hypertension	0.47 (0.17-1.30)	0.15		
DM	0.56 (0.24-1.30)	0.17		
Contrast exposure in last 5 days	2.82 (0.83-9.58)	0.96		
LVEF	0.94 (0.91-0.98)	0.005	0.98 (0.91-1.05)	0.54
Baseline serum creatinine	1.7 (0.99-7.5)	0.051	1.04 (0.30-3.59)	0.95
Contrast volume	1.01 (1.00-1.03)	0.07	1.01 (0.99-1.03)	0.35
STS score	1.62 (1.32-1.98)	<0.001	1.30 (1.04-1.62)	0.02
EuroSCORE	1.29 (1.16-1.43)	<0.001	1.26 (1.10-1.44)	0.001

Values in bold are statistically significant
DM-diabetes mellitus, LVEF- left ventricle ejection fraction

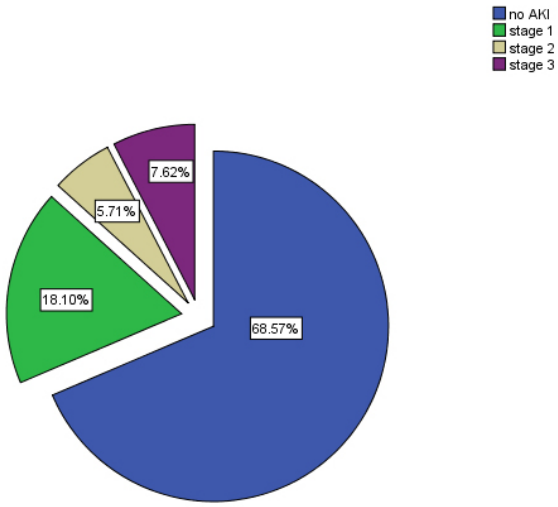

Figure 1: Distrubion of AKI patients pie chart

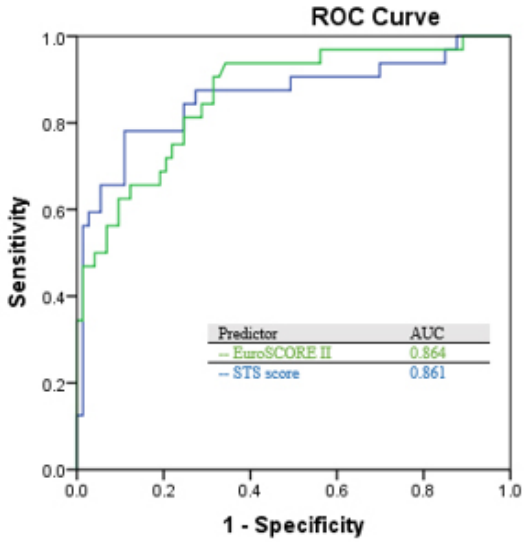

Figure 2: ROC curve

mitral stenosis (p = 0.01). Patients with AKI had a lower LVEF compared to those without AKI (46.28 ± 13.39 vs. 53.30 ± 9.01, p = 0.007). Although LVEF was correlated with AKI in univariate analysis (OR: 0.94; 95% CI: 0.91–0.98; p = 0.005), it did not remain a significant independent predictor in multivariate analysis (OR: 0.98; 95% CI: 0.91–1.05; p = 0.54) (Table 2).

Multivariate analysis identified STS (OR: 1.30; 95% CI: 1.04–1.62; p = 0.02) and EuroSCORE II (OR: 1.26; 95% CI: 1.10–1.44; p = 0.001) as independent predictors of AKI. The Hosmer-Lemeshow goodness-of-fit test (p = 0.88) indicated an adequate model fit.

Receiver operating characteristic (ROC) curve analysis showed that both STS and EuroSCORE II were strongly associated with the development of AKI \[STS score: AUC 0.86 (0.77–0.95), p < 0.001; EuroSCORE II: AUC 0.86 (0.79–0.94), p < 0.001] (Figure 2). A STS score cut-off ≥6.30 was associated with an 84% sensitivity and 75% specificity for AKI, while a EuroSCORE II cut-off ≥6.16 showed 91% sensitivity and 68% specificity.

Discussion

AKI developed in 31.4% of patients after TAVR, a rate consistent with findings from Khawaja et al (8). Renal replacement therapy was required in 5.7% of these patients. This study demonstrated a significant relationship between AKI and both the STS and EuroSCORE II scores, suggesting that these scores can predict AKI risk in TAVR patients. EuroSCORE and STS scores aggregate multiple patient-related factors, reflecting the overall impact on kidney function.

While previous studies did not evaluate STS and EuroSCORE II as predictors of TAVR-induced nephropathy, our study identified these scores as significant predictors of AKI. Multivariate analysis confirmed that both EuroSCORE II and STS are independent predictors of AKI development. Similarly, Nuis et al. found logistic EuroSCORE to be a predictor of AKI after TAVR (9).

Other established AKI predictors include baseline serum creatinine, blood transfusions, the transapical route,

peripheral vascular disease, diabetes, contrast volume, and logistic EuroSCORE (8-13). In our study, although baseline serum creatinine was higher in the AKI group, it did not remain an independent predictor after multivariate analysis .

Previous studies have shown a range of AKI incidences after TAVR, from 8.3% to 57%, with a mortality rate of 15.2% in patients with AKI and 7.7% in those without AKI. In this study, the higher AKI rate may be attributed to the new VARC-2 definition of AKI, which includes renal dysfunction occurring within 7 days post-procedure(14).

The exact mechanism of AKI following TAVR remains unclear, but contrast agents are known to cause ultrastructural damage in the renal tubules and exacerbate hypoxic injury(15-17). Pre-existing conditions such as hypertension may further predispose patients to kidney injury, although no significant association was found between AKI and hypertension in our study(18-19).

Blood transfusion is also a recognized risk factor for AKI in cardiac surgery, as the storage of erythrocytes can cause structural changes, increasing pro-inflammatory responses that impair renal auto-regulation(20). However, this association was not observed in our study, likely due to the small sample size.

Conclusion

This study demonstrated a significant association between EuroSCORE II and STS scores and the risk of developing AKI after TAVR. These scores, initially designed for mortality prediction, can also serve as useful tools for predicting AKI risk. Further studies with larger patient populations are needed to confirm these findings and refine strategies to minimize AKI risk in high-risk patients.

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