Determination of Predictors of Acute Kidney Injury in Patients with Coronary Bifurcation Lesions Revascularized with the Two-Stent Strategy

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ABSTRACT

Introduction: Acute kidney injury (AKI) is an important complication that increases mortality, morbidity, hospitalization and costs after the invasive cardiac procedures. The incidence of AKI and the factors affecting the development of AKI after the revascularization of coronary bifurcation lesions with the two-stent strategy remain unclear.

Patients and Methods: We retrospectively evaluated 230 consecutive non-ST elevation myocardial infarction (NSTEMI) patients who underwent revascularization with the two-stent strategy for the true coronary artery bifurcation lesions between January 2015 and September 2020, and did not meet the exclusion criteria. AKI was defined as meeting Acute Kidney Injury Network (AKIN) group criteria with the development of creatinine changes within the first 48 hours after the procedure. ACEF (age, serum creatinine, left ventricular ejection fraction) score was calculated for all patients.

Results: AKI developed in 28 (12.2%) patients after the procedure. As a result of the multivariable analysis, hypertension, ACEF score ≥ 1.14 and contrast agent volume ≥ 252 mL were determined as independent predictors for AKI. The coronary anatomical factors and technique related factors had no effect on AKI development. ACEF score ≥ 1.14 had sensitivity of 82.1%, specificity of 60.9% and negative predictive value of 96.1% for detecting AKI development. Moreover, the rate of AKI in the group with high ACEF score was significantly higher than the group with low ACEF score (22.5% vs. 3.9%, p< 0.001).

Conclusion: The simple and extremely user-friendly ACEF score can accurately describe the risk of AKI development after the revascularization of coronary bifurcation lesions with the two-stent strategy.

Key Words: ACEF score; acute kidney injury; coronary bifurcation.

İki-Stent Stratejisi ile Revaskülarize Edilen Koroner Bifurkasyon Lezyona Sahip Hastalarda Akut Böbrek Hasarı Prediktörlerinin Belirlenmesi

ÖZ

Giriş: Akut böbrek hasarı (ABH) kardiyak invaziv girişimler sonrası mortalite, morbidite, hastanede kalış süresi ve maliyeti arttıran önemli bir komplikasyondur. İki-stent stratejisi ile revaskülarize edilen koroner bifurkasyon lezyonları sonrası görülme sıklığı ve ABH gelişimini etkileyen faktörler belirsizliğini korumaktadır.

Hastalar ve Yöntem: Çalışmada Ocak 2015-Eylül 2020 tarihleri arasında kurumumuzda gerçek koroner arter bifurkasyon lezyonlarına iki-stent stratejisi ile revaskülarizasyon uygulanan ve dışlama kriterlerini karşılamayan 230 ardışık non-ST elevasyonlu miyokart infarktüsü (NSTEMI) hastası retrospektif olarak incelenmiştir. ABH, işlem sonrası ilk 48 saat içinde kreatinin değişikliklerinin ortaya çıkması ile "Acute Kidney Injury Network (AKIN)" grubu kriterlerinin karşılanması olarak tanımlanmıştır. Tüm hastalar için ACEF (yaş, serum kreatinin, sol ventrikül ejeksiyon fraksiyonu) skoru hesaplanmıştır.

Bulgular: İşlem sonrası hastaların 28 (%12.2)'inde ABH gelişmiştir. Yapılan çok değişkenli analiz sonucunda hipertansiyon, ACEF skoru ≥ 1.14 ve kontrast volümü ≥ 252 mL ABH için bağımsız prediktörler olarak saptanmıştır. Koroner anatomiye dair faktörlerin ve teknik ile ilişkili faktörlerin ise ABH üzerine herhangi bir etkisi bulunamamıştır. ACEF skoru 1.14 değerinin üstünde %82.1 duyarlılık, %60.9 özgüllük ve %96.1 negatif prediktif değeri ile ABH gelişimini tespit etmiştir. Ayrıca yüksek ACEF skoru olan grupta ABH oranı, düşük ACEF skoru olan gruba göre anlamlı düzeyde daha yüksek bulunmuştur (%22.5'e karşın %3.9, p< 0.001).

Sonuç: Basit ve son derece kullanıcı dostu ACEF skoru, iki-stent stratejisi ile revaskülarize edilen koroner bifurkasyon lezyonları sonrası ABH gelişme riskini doğru bir şekilde tanımlayabilir.

Anahtar Kelimeler: ACEF skoru; akut böbrek hasarı; koroner bifurkasyon.

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INTRODUCTION

Acute kidney injury (AKI) which commonly occurs after the percutaneous coronary intervention (PCI), is the third leading cause of hospital-acquired renal failure[1,2]. AKI has been associated with important adverse effects such as longer hospitalization, permanent renal failure, need for dialysis, increased risk of mortality, and recurrent ischemic events[3-5]. It is important to predict the patients who may develop AKI, in terms of taking necessary precautions.

Coronary bifurcation lesions represent a particularly challenging lesion subgroup for PCI. Although the current recommendation is a temporary side branch stenting strategy, a number of coronary bifurcation lesions require treatment of both the side branch and the main branch[6-9]. The two-stent strategy applied to the coronary bifurcation lesion leads longer operation durations and higher contrast agent volume when compared to the standard PCI procedure. Although it is assumed that this situation will increase the risk of AKI development, the incidence of AKI after the procedure and the factors affecting the development of AKI in patients with bifurcation lesions treated with the two-stent strategy still remain unclear.

This study aimed to investigate the effect of anatomical factors, technique-related factors and ACEF (age, serum creatinine, left ventricular ejection fraction) score on AKI development in patients with non-ST elevation myocardial infarction (NSTEMI) who underwent revascularization with two-stent strategy to true coronary artery bifurcation lesions.

PATIENTS and METHODS

Study Population

In this retrospective study, all consecutive NSTEMI patients who underwent revascularization with a two-stent strategy for true coronary artery bifurcation lesions at our institution between January 2015 and September 2020 and did not meet the exclusion criteria, were included. A true coronary bifurcation lesion was described as stenosis of > 50% in both the main branch and the ostium of the side branch according to Medina classification (1,1,1; 1,0,1; 0,1,1)[10]. Patients on dialysis, patients with ST elevation in the last 48 hours, cardiogenic shock, Killip 3-4, intense thrombus burden, and patients with missing data that would interfere with ACEF score calculation and AKI detection were excluded from the study. After exclusion, a total of 230 patients (179 males, 51 females; mean age 59.3 ± 10.8 years) were accepted as the study population. The study was approved by the local ethics committee (date: January 26 2021; decision no: 2021/01) and was conducted in accordance with the requirements of the Declaration of Helsinki.

Stent Implantation Procedure

The coronary procedures were performed from femoral approach by using 6-Fr or 7-Fr diagnostic and guiding catheters. All patients received loading doses of acetylsalicylic acid (300 mg) and clopidogrel (300 to 600 mg) or ticagrelor (180 mg) before or during the procedure. Dual antiplatelet therapy was given for at least 12 months (acetylsalicylic acid: 100 mg once daily and clopidogrel: 75 mg once daily or ticagrelor: 90 mg twice daily). Glycoprotein IIb/IIIa inhibitors (GPI) were used according to the the operator's decision. Unfractionated heparin was administered as an intravenous bolus at a dose of 50-70 U/kg with GPI and 70-100 U/kg without GPI. All the technical choices during the stenting procedure were decided by the operator. Intravascular ultrasound was not used routinely. Angiographic success was defined as achieving Thrombolysis In Myocardial Infarction (TIMI) 3 flow with < 30% final residual stenosis for the main branch and < 50% for the side branch.

Data Collection and Definitions

Patients' intensive care and inpatient clinic follow-up files and digital records in the hospital information system were retrospectively examined. Age, gender, co-morbidities, smoking status, pre- and post-procedural laboratory results, echocardiographic parameters, procedure date, procedure duration, stenting technique, length and size of the stents, and the amount of contrast agent were recorded. In addition, the SYNTAX score and ACEF score: Age/Left ventricular ejection fraction (%) + 1 (if serum creatinine ≥ 2.0 mg/dL) based on the original study conducted by Ranucci et al. were calculated for all patients[11].

Co-morbidities were defined as follows: Diabetes mellitus (DM) as a recent use of insulin or antidiabetic drugs, fasting blood glucose value ≥ 126 mg/dL and/or HbA1c 6.5%, hypertension (HT) as a recent use of antihypertensive drugs, systolic blood pressure 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg, hyperlipidemia (HL) as a recent use of cholesterol-lowering drugs and/or low-density lipoprotein cholesterol (LDL-C) value 140 mg/dL, peripheral artery disease as a previous peripheral artery revascularization, presence of lower extremity claudication with arterial disease detected on doppler ultrasound, cerebrovascular disease (CVA) ischemic stroke or history of transient ischemic attack.

End-point

The primary end-point of the study was the development of AKI after contrast agent administration, without any other possible etiology. The definition of AKI was a raise of 0.3 mg/dL or 50% in post-procedure (24-72 h) creatinine compared to baseline, proposed by the Acute Kidney Injury Network (AKIN) as a standardized definition of AKI[12].

Statistical Analysis

Data was analyzed using the Statistical Package for the Social Sciences, version 24.0 (SPSS Inc., Chicago, Illinois, USA). Whether the variables show normal distribution; visual (histograms, probability curves) and analytical methods (Kolmogorov-Smirnov or Shapiro-Wilk) were evaluated. Numerical variables showing normal distribution were mean ± standard deviation (SD), numerical variables not showing normal distribution were expressed as median (interquartile range) and categorical variables as percentage (%). Numerical variables were evaluated using Student t-tests and the Mann-Whitney U test between the two groups. Chi-quare or Fisher exact test were used to compare categorical variables. In order to determine the independent predictors of AKI, univariate logistic regression analysis was performed which was followed by a multivariate logistic regression analysis with the parameters found to be significant in univariate analysis. Receiver operating characteristic (ROC) curves and Youden index [max (sensitivity + selectivity-1)] were used to determine the cut-off values of parameters such as ACEF score, and the area under the ROC curve > 0.5 and p value < 0.05 were considered as statistically significant.

RESULTS

A total of 230 patients' mean age was 59.3 ± 10.8 years. 179 (77.8%) of the patients were male and 51 (22.2%) were female. Ninety-two (40.0%) patients were revascularized by T-stenting, 57 (24.8%) patients by culotte stenting, and 81 (35.2%) patients by crush stenting technique. AKI developed in 28 (12.2%) patients after the procedure. The comparison of patient groups with and without AKI in terms of basic characteristics was presented in Table 1. Patients in the AKI (+) group were older, and the rates of DM and HT were higher in the AKI (+) group. Left ventricular ejection fractions (LVEF) were lower and fluoroscopy durations were higher. In addition, contrast agent volume usage during the procedure was higher in these patients compared to patients in the AKI (-) group. On the other hand, ACEF score median values were also found to be significantly higher in the AKI (+) group (Figure 1). In Figure 2, patients were grouped according to stent strategies, and there was no significant difference between T-stenting, culotte stenting and crush stenting techniques (p= 0.872).

First, univariate logistic regression analysis was performed to determine the parameters predicting the development of AKI after the procedure in patients with coronary bifurcation lesions revascularized with the two-stent strategy (Table 2). In this analysis, age (p= 0.003), DM (p= 0.036), HT (p= 0.002), LVEF (p< 0.001), hematocrit level (p= 0.045), creatinine level (p= 0.023), contrast agent volume (p= 0.001) and ACEF score (p< 0.001) were determined as possible risk factors for the development of AKI. Among these parameters, age, LVEF and creatinine level were not included in the multivariate analysis since they were the components of the ACEF score. On the other hand, the cut-off values for the numerical data such as ACEF score, hematocrit level and contrast agent volume were determined using ROC curves and Youden index, and these data were categorized. As a result of the multivariate logistic regression analysis, HT (OR: 2.778, 95% CI: 1.065-7.244, p= 0.037), ACEF score ≥ 1.14 (OR: 4.949, 95% CI: 1.735-14.122, p= 0.003) and contrast agent volume ≥ 252 mL (OR: 2.637, 95% CI: 1.072-6.486, p= 0.035) remained significant and were found to be independent predictors of AKI development (Table 3).

Figure 3 showed the ROC curve of ACEF score for the development of AKI. ACEF score ≥ 1.14 can detect AKI development with 82.1% sensitivity, 60.9% specificity and 96.1% negative predictive value (AUC: 0.775, 95% CI: 0.685-0.865, p< 0.001). On the other hand, when the patients were divided into two groups according to this cut-off value, the rate of AKI development in the group with ACEF score ≥ 1.14 was significantly higher than the group with ACEF score < 1.14 (22.5% vs. 3.9%, p< 0.001).

DISCUSSION

In this study, we investigated the predictors of AKI development in NSTEMI patients who underwent revascularization with two-stent strategy for the true coronary artery bifurcation lesions. AKI developed in 12.2% of the patients after the procedure. As a result of the multivariate analysis, HT, ACEF score ≥ 1.14 and contrast agent volume ≥ 252 mL were determined as independent predictors for AKI. The coronary anatomical factors and technique related factors had no effect on AKI. The ACEF score ≥ 1.14 could detect the development of AKI with 82.1% sensitivity, 60.9% specificity and 96.1% negative predictive value.

Nowadays, transcatheter interventions have become the preferred treatment choice for a growing number of heart diseases. One of the most common complications after these interventions is the contrast-induced AKI, which is defined as an acute decrease in kidney function after iodinated contrast agent administration. The pathophysiology of AKI includes

Table 1. Comparison of characteristics of study patients with and without acute kidney injury

	All patients (n= 230)	AKI (-) (n= 202)	AKI (+) (n= 28)	p value
Age, years	59.3 ± 10.8	58.5 ± 10.5	65.2 ± 11.0	0.002
Male	179 (77.8%)	160 (79.2%)	19 (67.9%)	0.175
Current smoking	114 (49.6%)	98 (48.5%)	16 (57.1%)	0.392
Comorbidities				
Diabetes mellitus	89 (38.7%)	73 (36.1%)	16 (57.1%)	0.032
Hypertension	107 (46.5%)	86 (42.6%)	21 (75.0%)	0.001
Hyperlipidemia	100 (43.5%)	86 (42.6%)	14 (50.0%)	0.458
Prior PCI	71 (30.9%)	65 (32.2%)	6 (21.4%)	0.249
Prior CABG	13 (5.7%)	12 (5.9%)	1 (3.6%)	1.0
Peripheral artery disease	16 (7.0%)	15 (7.4%)	1 (3.6%)	0.700
Cerebrovascular disease	1 (0.4%)	0 (0.0%)	1 (3.6%)	0.122
Atrial fibrillation	8 (3.5%)	7 (3.5%)	1 (3.6%)	1.0
LVEF (%)	52.9 ± 10.0	54.0 ± 9.4	45.5 ± 11.2	< 0.001
Laboratory data				
Hematocrit (%)	40.6 ± 5.3	40.9 ± 5.1	38.7 ± 6.3	0.043
White blood cells (10^3/uL)	9.56 ± 2.90	9.49 ± 2.76	10.06 ± 3.79	0.335
Platelet (10^3/uL)	259 ± 62	257 ± 60	273 ± 74	0.204
Creatinine (mg/dL)	0.86 (0.72-0.96)	0.86 (0.72-0.95)	0.90 (0.78-1.14)	0.165
Total cholesterol (mg/dL)	188 ± 49	188 ± 49	193 ± 53	0.636
LDL-C (mg/dL)	107 (84-132)	107 (84-131)	109 (81-142)	0.435
HDL-C (mg/dL)	43.0 ± 10.7	43.7 ± 10.7	46.2 ± 10.9	0.254
Triglyceride (mg/dL)	152 (100-229)	152 (102-235)	161 (94-183)	0.448
ACEF score	1.07 (0.90-1.37)	1.06 (0.88-1.28)	1.45 (1.17-2.09)	< 0.001
SYNTAX score	15.7 ± 4.6	15.5 ± 4.4	17.0 ± 5.6	0.105
Bifurcation location				0.714
LAD-LCx	15 (6.5%)	12 (5.9%)	3 (10.7%)	
LAD-Diagonal	133 (57.8%)	119 (58.9%)	14 (50.0%)	
LCx-OM	73 (31.7%)	63 (31.2%)	10 (35.7%)	
PDA-PLA	9 (3.9%)	8 (4.0%)	1 (3.6%)	
Bifurcation angle > 70°	90 (39.1%)	80 (39.6%)	10 (35.7%)	0.693
Procedural data				
Stenting strategy				0.872
T-stenting	92 (40.0%)	81 (40.1%)	11 (39.3%)	
Culotte stenting	57 (24.8%)	49 (24.3%)	8 (28.6%)	
Crush stenting	81 (35.2%)	72 (35.6%)	9 (32.1%)	

Table 1. Comparison of characteristics of study patients with and without acute kidney injury (continues)

	All patients (n= 230)	AKI (-) (n= 202)	AKI (+) (n= 28)	p value
Main branch stent length (mm)	25.3 ± 6.5	25.2 ± 6.6	25.9 ± 5.9	0.607
Side branch stent length (mm)	19.3 ± 5.0	19.2 ± 5.0	19.7 ± 5.2	0.635
Main branch stent size (mm)	2.88 ± 0.29	2.88 ± 0.29	2.83 ± 0.25	0.372
Side branch stent size (mm)	2.61 ± 0.23	2.62 ± 0.23	2.58 ± 0.23	0.482
Predilation	185 (80.4%)	162 (80.2%)	23 (82.1%)	0.808
POT	195 (84.8%)	173 (85.6%)	22 (78.6%)	0.397
Final kissing	223 (97.0%)	197 (97.5%)	26 (92.9%)	0.204
Procedural time (min)	70 (55-92)	68 (54-90)	84 (61-110)	0.138
Fluoroscopy time (min)	23 (18-35)	23 (17-34)	29 (22-44)	0.044
Contrast volume (mL)	239 ± 67	234 ± 65	281 ± 70	< 0.001

Data are presented as percentage, mean ± standard deviation or median (interquartile range). AKI: Acute kidney injury, PCI: Percutaneous coronary intervention, CABG: Coronary artery bypass graft, LVEF: Left ventricular ejection fraction, LDL-C: Low-density lipoprotein cholesterol, HDL-C: High-density lipoprotein cholesterol, LAD: Left anterior descending artery, LCx: Left circumflex artery, OM: Obtuse marginal artery, PDA: Posterior descending artery, PLA: Posterolateral artery, POT: Proximal optimisation technique.

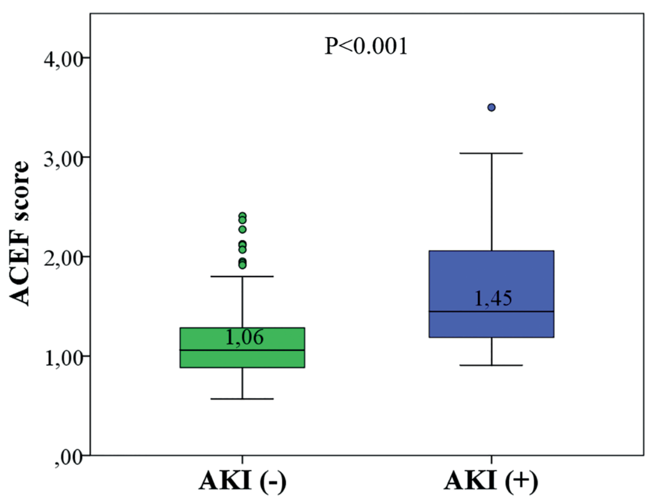


Figure 1. ACEF score box plot graph according to the presence of acute kidney injury.

AKI: Acute kidney injury.

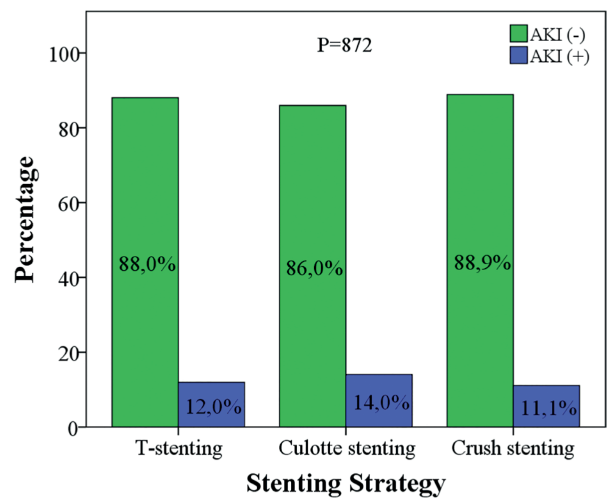


Figure 2. Comparison of acute kidney injury rates according to stenting strategy.

AKI: Acute kidney injury.

several mechanisms. First, the contrast agent shifts the balance between vasodilator and vasoconstrictive factors towards vasoconstriction, leading to cortical and medullary renal ischemia and consequently a decrease in GFR(13). Second, the contrast agent exerts a direct cytotoxic effect and disrupts various functions of tubular epithelial cells. Third, the contrast agent increases blood viscosity, leading to further reduction of microcirculatory flow and changes in blood osmolality, resulting in impaired renal function(14).

It has been reported that patients who underwent PCI with a diagnosis of acute coronary syndrome and developed AKI after the procedure had significantly higher rates of 30-day mortality, recurrent myocardial infarction (MI), target lesion revascularization, target vessel revascularization, and major bleeding compared to patients without AKI(15). In addition to increase in major adverse cardiovascular events rates, since we lack effective treatments for AKI, the detection of factors that can predict the development of AKI will be effective in taking necessary precautions to prevent AKI. Many studies

Table 2. Univariable logistic regression analysis for the development of acute kidney injury

	Univariable analysis		
	OR	**95% CI**	**p value**
Age	1.060	1.020-1.101	0.003
Male	0.554	0.234-1.313	0.180
Current smoking	1.415	0.637-3.142	0.394
Diabetes mellitus	2.356	1.057-5.252	0.036
Hypertension	4.047	1.646-9.950	0.002
Hyperlipidemia	1.349	0.611-2.977	0.459
Prior PCI	0.575	0.222-1.486	0.253
Prior CABG	0.586	0.073-4.691	0.615
Peripheral artery disease	0.462	0.059-3.637	0.463
Atrial fibrillation	1.032	0.122-8.713	0.977
LVEF	0.926	0.891-0.962	< 0.001
ACEF score	9.244	3.763-12.704	< 0.001
SYNTAX score	1.066	0.986-1.153	0.108
Hematocrit	0.928	0.863-0.998	0.045
White blood cells	1.065	0.937-1.211	0.335
Platelet	1.004	0.998-1.010	0.205
Creatinine	5.883	1.276-27.119	0.023
Bifurcation location			0.722
LAD-Diagonal*	0.471	0.118-1.872	0.285
LCx-OM*	0.635	0.152-2.654	0.534
PDA-PLA*	0.500	0.044-5.700	0.577
Bifurcation angle > 70°	0.847	0.372-1.929	0.693
Stenting strategy			0.872
Culotte stenting[#]	1.202	0.452-3.195	0.712
Crush stenting[#]	0.920	0.361-2.348	0.862
Main branch stent length	1.016	0.957-1.078	0.605
Side branch stent length	1.019	0.944-1.099	0.633
Main branch stent size	0.495	0.107-2.298	0.369
Side branch stent size	0.521	0.085-3.163	0.480
Predilation	1.136	0.407-3.172	0.808
POT	0.615	0.230-1.645	0.333
Final kissing	0.330	0.061-1.788	0.198
Procedural time	1.003	0.994-1.013	0.478
Fluoroscopy time	1.015	0.994-1.038	0.169
Contrast volume	1.010	1.004-1.016	0.001

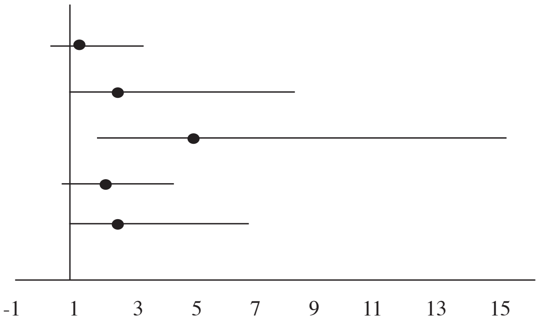
OR: Odds ratio, CI: Confidence interval, PCI: Percutaneous coronary intervention, CABG: Coronary artery bypass graft, LVEF: Left ventricular ejection fraction, LAD: Left anterior descending artery, LCx: Left circumflex artery, OM: Obtuse marginal artery, PDA: Posterior descending artery, PLA: Posterolateral artery, POT: Proximal optimisation technique.

* Compared to LAD-LCx.

[#] Compared to T-stenting.

Table 3. Multivariable logistic regression analysis for the development of acute kidney injury

	Multivariable analysis		
	OR	95% CI	p value
Diabetes mellitus	1.524	0.629-3.693	0.351
Hypertension	2.778	1.065-7.244	0.037
ACEF score ≥ 1.14	4.949	1.735-14.122	0.003
Hematocrit ≤ 37.1%	2.140	0.873-5.246	0.096
Contrast volume ≥ 252 mL	2.637	1.072-6.486	0.035



OR: Odds ratio, CI: Confidence interval.

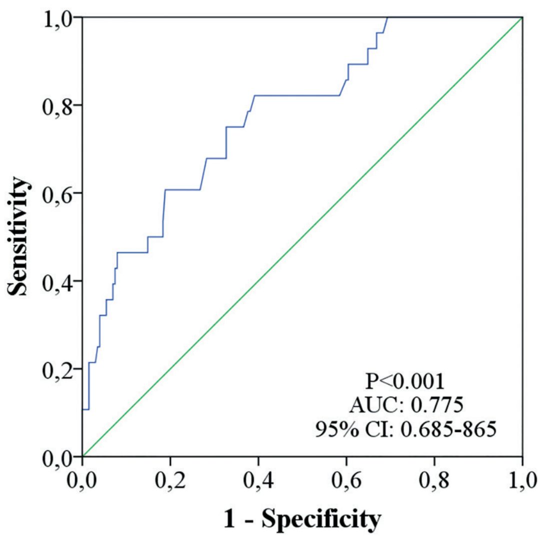


Figure 3. ACEF score ROC curve for the development of acute kidney injury.

AUC: Area under curves, CI: Confidence interval.

searching a prediction model for AKI have been conducted to help identifying the high-risk patients who can benefit from pre-procedural strategies and preserve kidney or improve pre-intervention counseling[16-23]. To the best of our knowledge, there is no study conducted for this purpose in a specific patient subgroup such as patients with PCI to the bifurcation lesion.

Challenging coronary bifurcation disease composes 15-20% of the lesions treated with PCI[24]. PCI for bifurcation is associated with a higher incidence of procedural complications, a higher rate of restenosis, and worse clinical outcomes when compared to non-bifurcation PCI[25-27]. Drug-eluting stents contributed to a significant reduction in the incidence of restenosis and target vessel revascularization. There might be several problems during bifurcation PCI due to the anatomical structure: plaque shift, carina shift, jail of side branch, the protruded stent strut in the lumen, and so on[24,28]. Therefore, many interventional techniques for bifurcation lesions have been developed and used[24]. These techniques are mainly categorized, according to the strategy for the side branch, into one-stent versus two-stent strategy. To date, no study showed clear advantages on one strategy. Mainly simpler techniques are slightly favored in the randomized trials[29,30]. Previous studies demonstrated that one-stent strategy could be recommended as the routine bifurcation stenting technique[29-31]. Based on these study results, the strategy of stenting main vessel with provisional side branch stenting is currently favored by most interventional cardiologists. However, we occasionally use two-stent strategy with various reasons, expecting more favorable side branch outcomes. For example, we could perform side branch stenting in advance, if side branch is so stenotic and large that we might be concerned with the jail of that vessel during main vessel stenting. Although the complications such as short and long-term mortality, recurrent MI, target lesion revascularization, target vessel revascularization have been well established in patients undergoing the two-stent strategy, the incidence and the predictors of AKI after the procedure are not clear.

Previous studies have reported different incidence rates ranging from 0.7% to 19% for AKI after PCI[16,19,32,33]. However, most of these studies were single-center studies and were conducted more than a decade ago, and many used different definitions of AKI. Historically, different cut-off levels have been adopted to define AKI; the most recent definition includes any of the following: increase in serum creatinine by 0.3 mg/dL within 48 hr; or increase in serum creatinine to 1.5 times baseline within the prior 7 days; or urine volume < 0.5 mL/kg/hr for 6 hr following contrast media administration. In our study, we defined AKI as the development of creatinine changes within the first 48 hours after the procedure and meeting the AKIN group criteria, and we detected AKI in 12.2% of the patients[12]. Although our rate was high, it was not contrary to the literature. In Azzalini et al. study comparing patients with complex PCI with other patients for the development of AKI, they found the AKI rate in the complex PCI group as 12.1%, very similar to our rate[34]. The higher rates in these patient groups are likely to be explained by the longer operation durations and the higher amount of contrast agent compared to standard procedures.

In our study, we concluded that the factors of coronary anatomy and the technical differences used while revascularization of bifurcation lesions with the two-stent strategy did not affect the development of AKI. This result may relax the clinicians while deciding the treatment strategy for bifurcation lesions. We determined that HT, contrast agent volume and ACEF score were the predictors of AKI. In previous studies, ACEF score has been proven to be a predictor of AKI in patients who underwent transcatheter aortic valve implantation (TAVI), mitral repair, coronary artery bypass grafting (CABG), and PCI[23,35-37]. The ACEF score combines three important clinical variables; age, serum creatinine (renal failure) and LVEF. These three preoperative clinical variables are well known independent risk factors for postoperative AKI in patients undergoing PCI. Therefore, the ACEF scoring system can be a useful and feasible risk model for predicting postoperative AKI. It is also more suitable for non-elective PCI, as it uses clinical variables that can be obtained easily and quickly. A recent study showed that the ACEF score can identify patients at the risk of early fatal or non-fatal complications and long-term mortality who underwent PCI due to coronary bifurcation lesions[38]. In another study, Ando et al. showed that ACEF score can be used as a predictor of AKI in patients who underwent primary PCI[23].

According to recent guidelines on myocardial revascularization, treatment of patients at high risk for AKI includes saline hydration and avoidance of excessive contrast agent usage[39]. In our study, we found a negative predictive value of 96.1%. This means that an operator can get more projection to get a good angiographic result in patients with low ACEF scores. In another scenario, over-hydration can be avoided in the patients at risk of pulmonary edema with a low ACEF score.

There were some limitations in our study. First of all, it was a small-sized, single-center, retrospective observational study. The only end-point was AKI development. The inclusion of different end-points would diversify the results of the study. The reduction in urine output wasn't included in the definition of AKI, which may lead to an underestimation of the incidence of AKI. For AKI estimation, we did not make a comparison with other risk models because we didn't have the data of some variables necessary for their calculations. Finally, the cut-off value of each parameter used in this study was initially developed by using ROC curves. Therefore, our results must be interpreted carefully until they will be confirmed in subsequent studies.

The ACEF score is a practical and simple user-friendly tool that independently predicts AKI in patients with coronary bifurcation lesions revascularized with the two-stent strategy. Moreover, a low ACEF score has an excellent negative predictive value for AKI, which might be clinically significant. On the other hand, the development of AKI is not affected by the anatomical location of the lesion and the technical differences used for revascularization of coronary bifurcation lesions.

Ethics Committee Approval: The study was approved by the Istanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital Clinical Research Ethics Committee (Date: 26.01.2021; Decision No: 2021/01).

Informed Consent: Informed consent was obtained.

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