Rev Nefrol Dial Traspl. 2021;41(3):192-201

Role of ankle brachial index measured by simple automatic sphygmomanometers in predicting postoperative kidney function in patients undergoing major cardiac surgery

El papel del índice tobillo-brazo medido mediante un esfigmomanómetro automático para pronosticar la función renal posoperatoria en pacientes que se sometieron a una cirugía cardíaca mayor

Abdullah Sumnu[1], Savas Ozturk[2], Eyup Cavdar[3], Fatma Tuba İlal Mert[4], Egemen Cebeci[2], Zeynep Karaali[3], Mazlum Sahin[4]

1) Istanbul Medipol University, Medical Faculty, Department of Nephrology, Istanbul, Turquía
2) Haseki Training and Research Hospital, Deparment of Nephrology, Istanbul, Turquía
3) Haseki Training and Research Hospital, Deparment of Internal Medicine, Istanbul, Turquía
4) Haseki Training and Research Hospital, Deparment of Cardiovascular Surgery, Istanbul, Turquía

Correspondencia:
Dr. Abdullah Sumnu
ORCID: 0000-0003-1185-97372
abdullahsumnu@yahoo.com

Conflict of interest:
No conflict of interest.

Recibido: 01-09-2020
Corregido: 15-10-2020
Aceptación: 03-12-2020

ABSTRACT

Introduction: Ankle-brachial pressure index is an objective, noninvasive test for predicting subclinical atherosclerotic diseases. We investigated the role of ankle-brachial pressure index measured with automated sphygmomanometer devices in the prediction of the development of acute kidney injury in patients undergoing major cardiac surgery. **Methods:** This single-centered, cross-sectional, and observational study was performed on 80 (66 males and 14 females, 58 ± 10 years) patients undergone cardiac surgery. Complete anamnesis, laboratory tests, intravenous fluids, medications, blood products, and all perioperative procedures were recorded in all patients before the surgery. Two automated sphygmomanometer devices giving equivalent results were used for measuring Ankle-brachial pressure index. The data in the first two days after the surgery were used for analysis. The criteria of AKIN were used in the diagnosis of acute kidney injury. **Results:** Twenty-one (23%) patients developed acute kidney injury in the postoperative period. None of the patients needed renal replacement therapy or died. There was no significant difference between mean ankle-brachial pressure index levels of patients with and without acute kidney injury (1.04 ± 0.17 and 1.06 ± 0.19, respectively, p=0.554). The mean ankle-brachial pressure index was significantly lower in patients with perioperative complications that cause hemodynamic instability (1.07 ± 0.14, 0.96 ± 0.13, p=0.016). On the multivariate analysis model, only perioperative hemodynamic complication development was found to be related to postoperative acute kidney injury. **Conclusion:** Ankle-brachial pressure index may have a role in predicting perioperative hemodynamic complications, which may cause acute kidney injury in patients undergoing major surgery. Simple automatic blood pressure devices can be used in daily practice for ankle-brachial pressure index measurement instead of complex and expensive doppler devices.

KEYWORDS: ankle-brachial index; acute kidney injury; automated sphygmomanometer devices; cardiovascular surgery; coronary artery bypass grafting; perioperative renal functions; postoperative renal function

RESUMEN

Introducción: El índice tobillo-brazo es una prueba objetiva y no invasiva para diagnosticar la aterosclerosis asintomática. Investigamos el papel del índice tobillo-brazo medido a través de esfigmomanómetros automáticos para pronosticar el desarrollo de

ISSN 0326-3428

insuficiencia renal aguda en pacientes que se sometieron a una cirugía cardíaca mayor. **Material y métodos:** En este estudio observacional, transversal y unicéntrico, se incluyó a 80 pacientes (66 hombres y 14 mujeres de 58 ± 10 años) que se sometieron a una cirugía cardíaca. Se registraron los siguientes datos de todos los pacientes antes de la cirugía: anamnesis completa, análisis clínicos, líquidos intravenosos, medicamentos, productos hemoderivados e intervenciones perioperatorias. Para medir el índice tobillo-brazo, se utilizaron dos esfigmomanómetros automáticos que arrojaron resultados similares. Se analizaron los datos recogidos los primeros dos días luego de la cirugía. Se siguieron los criterios de la AKIN para diagnosticar la insuficiencia renal aguda. **Resultados:** Veintiún pacientes (23 %) sufrieron insuficiencia renal aguda en el postoperatorio. Ninguno de los pacientes necesitó tratamiento renal sustitutivo ni falleció. No hubo diferencias significativas entre los valores medios del índice tobillo-brazo en pacientes con insuficiencia renal aguda y sin ella (1,04 ± 0,17 y 1,06 ± 0,19, respectivamente; p = 0,554). El valor medio del índice tobillo-brazo fue significativamente menor en pacientes con complicaciones perioperatorias que causan inestabilidad hemodinámica (1,07 ± 0,14; 0,96 ± 0,13; p = 0,016). En el modelo de análisis multivariado, solo se encontró que la aparición de complicaciones hemodinámicas perioperatorias estaba relacionada con la insuficiencia renal aguda luego de la operación quirúrgica. **Conclusión:** Es posible que el índice tobillo-brazo desempeñe un papel en la predicción de complicaciones hemodinámicas perioperatorias, que pueden causar insuficiencia renal aguda en pacientes sometidos a cirugía mayor. En la práctica diaria, pueden utilizarse dispositivos automáticos simples que calculan la tensión arterial para medir el índice tobillo-brazo, en lugar de dispositivos Doppler complejos y costosos.

PALABRAS CLAVE: índice tobillo-brazo; lesión renal aguda; dispositivos de esfigmomanómetro automatizados; cirugía cardiovascular; cirugía de revascularización coronaria; funciones renales perioperatorias; función renal posoperatoria

BACKGROUND

Acute kidney injury (AKI) is a life-threatening complication that increases perioperative mortality and morbidity. Although those who do not have preoperative renal dysfunction may not have a high risk, those who have renal dysfunction before the operation are at higher risk.[1-2] In cardiovascular surgery, AKI is more common than other surgeries because AKI can develop in cardiac surgery with its hemodynamically specific pathophysiological mechanisms in addition to other procedural risks.[3] In the evaluation, based on current AKI definitions, stage I or more advanced AKI is seen in approximately 17-49% of patients who have undergone cardiac surgery, and about 2-6% of them require hemodialysis.[4-5]

There are lots of clinical risk factors: older age, female gender, preexisting chronic kidney disease (CKD), diabetes mellitus (DM), or hypertension (HT) for developing AKI.[6] The combination of these clinical risk factors with novel biomarkers (IL-18, KIM-1, etc.) may not only help to the early identification of AKI patients but also may aid in predicting the development of AKI preoperatively.[7] On the other hand, several risk scoring systems and treatment protocols have been developed to prevent AKI.

Although some pharmacological and non-pharmacological methods have been tried to avoid the development of AKI, a definitive strategy to prevent AKI has not been developed after coronary bypass grafting (CABG) and cardiac surgery. Therefore, predicting the development of AKI in patients undergoing cardiac surgery and evaluating it with a simple method may be an appropriate approach. On the other hand, the presence of atherosclerotic disease in any part of the body within the vascular bed also increases the frequency and likelihood of symptomatic and asymptomatic disease in another region. Peripheral artery disease (PAD) is a vascular pathology resulting from progressive atherosclerotic stenosis or complete blockage of the vascular lumen[8] This disease is the peripheral effect of systemic atherosclerosis. PAD covers all vascular areas, including carotid, vertebral, upper limb, mesentery, kidney, and lower limb vessels.

The ankle-brachial index (ABI) is the ratio of the highest ankle systolic blood pressure (BP) to the highest brachial systolic BP. ABI has many features for use in vascular disease screening programs. It is a reliable noninvasive diagnostic tool that has high validity and repeatability.[9-10] The gold standard application of ABI is to make these measurements with the Doppler instruments. Generally, ABI lower than 0.9 values indicate a decrease in distal blood flow, and it is considered a risk factor for cardiovascular disease (CVD) in both uremic and non-uremic populations.(10-13)

Therefore, it helps to detect PAD early and strongly predicts advanced ischemic cardiac and cerebral events. For these reasons, current guidelines suggest the ABI measurement for PAD management in all patients over 65 years of age and > 50 years of age who have HT, DM, and/or currently smoking and the patients who have clinical PAD symptoms.(14) On the other hand, measurements with automatic BP measurement devices have been shown to be like measures with Doppler applications. The sensitivity and specificity of an automated device for detection of PAD, as defined by Doppler ABI ‹0.9, was 98% and 75%, respectively in a study including 308 with risk factors for CVD.(15) Although some studies have shown that ABI can predict the development of complications in the postoperative period in both cardiac and noncardiac surgery patients, the role of ABI in predicting the development of AKI in the early postoperative period has not been investigated in patients undergoing major cardiac surgery.

Therefore, in this study, we investigated the role of preoperative ABI values measured by automatic BP measurements in predicting postoperative AKI development in patients undergoing cardiovascular surgery with low risk for postoperative AKI development.

MATERIALS AND METHODS

Design of the study

This single-centered, cross-sectional, and observational study was performed on patients whose underwent cardiac surgery (CABG, aortic or valvular) operation was planned in our cardiovascular surgery clinic. The patients who were used cardiac pumps during the operation were included in the study, and those off-pump were excluded. During surgery, patients were typically cooled to temperature 32º C. Exclusion criteria: Patients with known acute or CKD, patients with low ejection fraction (<40%), off-pump performed cardiac surgery patients, patients those BP measurements cannot be measured due to upper or lower limb amputation, open wound or amputation, patients undergoing hemodynamic instability, advanced malignancy, or systemic patients with the disease. The Study Ethics Committee approval was received from the Health Sciences University Haseki Training and Research Hospital Ethics Committee Unit. The purpose and brief information of the research was presented to the volunteers with a disclosure form, and approval was obtained.

Preoperative evaluation

In addition to the demographic data of the patients such as age, gender, occupation, weight, height, body mass index values were recorded on the patient follow-up form. Chronic diseases of the patients, medications, family history of chronic illness, and whether they had undergone any previous surgery were questioned and recorded. All clinical and laboratory data we used in our study were obtained from the routine hospital data of our patients.

ABI measurement method and evaluation of the validity of the technique

Two Omron (M2 Basic) automatic sphygmomanometry devices were used for arm and leg BP measurements. Firstly, it was tested whether these devices gave equivalent results in BP measurement. For this purpose, brachial systolic BPs were measured on 27 healthy individuals with both instruments. There was no difference between these measurements above 2-3 mmHg. And then, we simultaneously measured BPs of the individuals with a vascular type of Doppler (Maquet brand hand type), which was accepted as the gold standard noninvasive method to evaluate ABI, together with our automatic sphygmomanometry device. The Doppler device was placed on the same artery with the cuff of the automatic sphingomanometry. During the cuff was deflated, the data obtained from automatic sphygmomanometry and the Doppler device were recorded. Correlation between ABI measured by this hand Doppler and ABI measured by automatic sphingomanometry was quite high (ABI right: 1.1 ± 0.17, Doppler: 1.06 ± 0.22, r=0.907, p<0.001; ABI left: 1.06 ± 0.14, Doppler: 1.05 ± 0.24, r=0.885, p<0.001).

The patients included in our study were visited in the patient rooms the day before the operation. They were asked to rest in a supine position for 10 minutes in a quiet environment (they did not smoke, or drink tea or coffee in the last 30 minutes). Then, simultaneous right arm and right leg systolic BPs, left arm and leg systolic

BPs were measured and recorded, respectively. All measurements were repeated until there was less than 5 mmHg difference between them. Average systolic BP values were calculated from the last two measurements

Postoperative evaluation

Perioperative and postoperative first and second-day laboratory values (including urea, creatinine, electrolyte, albumin, and complete blood count) were recorded. The patients were reassessed after the planned operation. The type of surgery, duration of the procedure, the amount and the type of the fluid therapy, and perioperative complications were recorded. Emergency operations were excluded from our study. Laboratory values of the patients on postoperative first and second days were also examined by recording the laboratory values requested in the service follow-ups. AKIN criteria were used in the diagnosis and staging of AKI.[16] All data obtained from the study were recorded in a form prepared for this study.

Statistical Method

SPSS 17.0 for Windows program was used for statistical analysis. In descriptive statistics, number and percentage were given for categorical variables, mean, standard deviation, minimum and maximum for numerical variables. Comparisons between the two independent groups were performed using the Student t-test when the numerical variables met the normal distribution condition and the Mann Whitney U test when the normal distribution condition was not met. A comparison of rates in independent groups was made with Chi-Square analysis. Multivariate analysis of parameters associated with the development of ABH was investigated using the logistic regression analysis (with the enter method). The statistical alpha significance level was accepted as p<0.05.

RESULTS

A total of 80 patients (mean age 58.0 ± 10.0 years, 66 men, 14 women) were included in the study. Demographic and clinical data, drugs they use, and their preoperative tests are presented in **Table 1**. None of the patients died in the perioperative and postoperative period. Intraaortic balloon pump was used only in 2 of the patients. In the last three months, the rate of patients using angiotensin-converting enzyme (ACE) inhibitors or angiotensin receptor blocker (ARB) was 30%, while those using aspirin was 36.3%. The rate of preoperative contrast exposure (all given during coronary angiography) was 58.8%. **(Table 1)**

CABG was performed in 69 (86.2%) patients and different cardiac operations were performed in 11 (13.8%) cases **(Table 2)**. AKI development rate was not significantly different according to the type of surgery.

AKI was diagnosed in 21 (26.2%) patients according to AKIN criteria in the follow-up (stage 1: 17 patients, stage 2: 3 patients, stage 3: 1 patient). None of the patients needed renal replacement therapy. Comparison data of patients with and without AKI are presented in **Table 3**. No statistically significant difference was found in the general characteristics of patients with AKI. There was also no statistically significant difference in the mean ABI levels of the patients developing AKI and who did not **(Table 3)**. The rate of development of AKI in those with normal ABI values (0.9-1.3) was not different from those with abnormal values.

Perioperative BPs (mmHg), BPs in the pump, duration of the operation, crossing clamp time, hematocrit value in cardiopulmonary bypass (CPB), and the amount of fluids given were not significantly different between the groups **(Table 3)**. An intraaortic balloon pump was used one patient in each group. Drugs used by patients were also not different between the groups.

There were nine patients who developed major preoperative complications (major vascular incisional hemorrhages, shock, major organ injury, etc.) leading to perioperative hemodynamic instability. In these patients, the rate of development of AKI (7 patients, 77.8%) was more significant than the rate of AKI (14 of 71 patients, 19.7%) of patients without complications (p=0.001). In addition, the mean ABI was significantly lower in patients with perioperative complications (1.07 ± 0.14, 0.96 ± 0.13, p=0.016).

Our multivariate analysis model created for the analysis of factors determining AKI development was created **(Table 4)**. ABI value (abnormal: <0.9 or normal ≥0.9) was also added to this model. In this model, only perioperative complication development was found to be related to postoperative AKI. ABI value was not significant.

Table 1. General characteristics of patients participating in the study

n=80	Mean ± SD	Min - Max
Age (year)	58.0 ± 10.0	19-78
Weight (kg)	78.4 ± 12.7	53-119
Height (cm)	166.5 ± 7.3	150-184
BMI (kg/m^2)	28.3 ± 4.5	19.8-42.5
Glucose (mg/dl)	144 ± 72	69- 367
Urea (mg/dl)	34.9 ± 11.2	17-102
Creatinine (mg/dl)	0.8 ± 0. 2	0.5-2,7
Hemoglobin (g/dl)	13.4 ± 2.0	9 -17
Hematocrite (%)	41.6 ± 6.1	26-54
Albumin (g/dl)	4.0 ± 0.5	2.4-4.9
Gender (Female/male), n (%)	14 / 66 (18-82)	
Comorbidities	**n**	**(%)**
Diabetes mellitus	30	37.5
Hypertension	30	37.5
Chronic kidney disease	3	3.8
Others	15	18.8
Preoperative medications	**n**	**(%)**
Statin	8	10.0
Fibrates	6	7.6
Aspirin	29	36.3
ACEI-ARB	24	30.0
NSAID	1	1.3
Others	23	28.8
IV contrast *	47	58.8
Diuretics	1	1.2

ACEI: Angiotensin-converting enzyme inhibitor; **ARB:** Angiotensin receptor blocker; **BMI:** Body mass index; **NSAID:** Non-steroidal anti-inflammatory drug; **IV:** intravenous
* All contrast agents have given during coronary angiography

Table 2. The types of cardiac surgery

	No AKI		**AKI**		**p**
	n	**%**	**n**	**%**	
CABG	69	86.2	19	23.7	0.51
Non-CABG	11	13.8	2	2.5	
ASD repair	1	1.25	0	0	
AVR	4	5.0	1	1.25	
Bentall procedure	2	2.5	1	1.25	
MVR	4	5.0	0	0	

AVR: Aortic valve replacement; **ASD:** Atrial septal defect; **CABG:** coronary artery by-pass grafting; **MVR:** Mitral valve replacement

Table 3. The data of the patients according to the development of AKI

		No AKI n=59		**AKI n=21**		
		Mean	**SD**	**Mean**	**SD**	**p**
Age		57.2	9.3	60.2	11.4	0.240
Weight (kg)		78.8	13.7	76.3	8.4	0.474
Height (cm)		167.3	7.1	163.8	7.6	0.090
BMI (kg/m^2)		28.2	4.5	28.6	4.5	0.762
		n	**%**	**n**	**%**	**p**
Gender	Male/Female	49/10	83/17	17/4	81/19	1.000
Comorbidities	DM	21	35.6	9	42.9	0.555
	HT	22	37.3	8	38.1	1.000
	CKD	1	1.7	2	9.5	0.167
	Others	11	18.6	4	19.0	1.000
Preoperative	Glucose (mg/dl)	137.4	69.6	156.8	83.6	0.436
	Urea (mg/dl)	34.4	12.6	36.5	4.9	0.280
	Creatinine (mg/dl)	0.95	0.86	0.90	0.26	0.165
	Hb (g/dl)	13.6	2.0	13.0	2.0	0.314
	Htc (%)	42.4	6.3	40.0	5.3	0.100
	Albumin (g/dl)	4.00	0.57	4.06	0.48	0.714
ABI		**Mean**	**SD**	**Mean**	**SD**	**p**
Left		1.06	0.19	1.06	0.13	0.577
Right		1.06	0.19	1.04	0.17	0.554
ABI		**n**	**%**	**n**	**%**	p
Right <= 1.0 or left <= 1.0		20	29.4	10	47.6	0.123
Right <= 0.9 or left <= 0.9		8	11.8	6	28.6	0.087
Perioperative data		**Mean**	**SD**	**Mean**	**SD**	**p**
Perioperative BP (mmHg)	Systolic BP	116.1	12.9	110.6	14.7	0.135
	Diastolic BP	64.2	9.5	58.8	10.6	0.030
BP in pump (mmHg)	Systolic BP	65.3	8.3	64.1	7.1	0.588
	Diastolic BP	57.3	7.9	52.9	10.6	0.263
CPB time (minutes)		93.3	39.3	107.7	33.1	0.064
Crossing clamp time (minutes)		51.7	28.9	55.6	25.7	0.375
Htc value in CPB (%)		25.1	3.6	26.4	15.8	0.054
Amount and choice of fluids given (ml)	Isotonic	2258.1	929.3	2601.6	844.6	0.087

	No AKI n=59		AKI n=21			
Mean		SD	Mean		SD	p
	Isolex	175.9	713.7	95.2	436.4	0.590
	5%dx 0.45%NaCl	38.6	296.8	0.0	0.0	0.551
	Ringer lactate	30.5	234.3	0.0	0.0	0.551
	Colloid	228	696	100	307	0.427
	Other liquid	310.3	484.8	508.1	970.6	0.687
Blood products transfusions (ml)	FFP	264.7	282.5	457.1	410.6	0.051
	Platelets	19.0	101.7	100.0	234.5	0.024

ABI: Ankle-brachial index; **AKI:** Acue kidney injury; **BMI:** Body mass index; **BP:** Blood pressure; **CKD:** Chronic kidney disease; **CPB:** Cardiopulmonary bypass; **DM:** Diabetes mellitus; **FFP:** Fresh frozen plasma; **Hb:** Hemoglobin; **HT:** Hypertension; **Htc:** Hematocrit; **SD:** standard deviation

Table 4. Multivariate analysis of parameters associated with the development of AKI (Logistic regression analysis with enter method)

	B	Sig.	OR	95% CI	
				Lower	Upper
Constant	-0.268	0.913	0.765		
Age	0.012	0.724	1.012	0.945	1.084
Presence of DM	-0.121	0.862	0.886	0.227	3.458
Presence of HT	-0.894	0.408	0.409	0.049	3.402
Preoperative ACEI and/or ARB usage	1.113	0.309	3.043	0.356	26.032
Preoperative contrast agents usage	1.372	0.078	3.943	0.859	18.099
Mean BP in pump (mmHg)	-0.039	0.231	0.962	0.903	1.025
ABI (<0.9)	0.152	0.827	1.164	0.298	4.541
Peroperative hemodynamic complications	3.759	0.010	42.908	2.439	754.88
Amount of perioperative transfusion of thrombocyte	0.000	0.843	1.000	0.996	1.003

ABI: Ankle-brachial index; **ACEI:** Angiotensin-converting enzyme inhibitor; **ARB:** Angiotensin receptor blocker; **BP:** Blood pressure; **CI:** Confidence interval; **DM:** Diabetes mellitus; **HT:** Hypertension; **OR:** Odds ratio

DISCUSSION

As far as we know, this is the first study researching the role of ABI in predicting the development of AKI after major cardiac surgery. The study was performed on patients who underwent major cardiovascular surgery (CABG, aortic, and valve disease repairs). The patients with previously known PAD, whose ABI measurements are usually expected to be abnormal, were not included in the study. However, those with diseases such as DM, HT, CKD, which increase the risk of postoperative AKI, were not excluded **(Table 1)**. This has strengthened the data we obtained to reflect the routine daily situation of the patients. To test the reliability of our method, first of all, on 27 individuals, ABI was measured with both automated sphygmomanometer and Doppler ultrasonography. It was found that there was a strong correlation between both methods (right Doppler: 1.06 ± 0.22, ABI right: 1.1 ± 0.17, r=0.907, p<0.001; left Doppler: 1.05 ± 0.24, ABI left: 1.06 ± 0.14, r=0.885, p<0.001). These results showed that the data obtained with automated devices are methodologically reliable and acceptable.

AKI developed in 21 (26.2%) of our patients according to AKIN criteria. The ABI value had no relationship with AKI development in both numerical and categorical (below 0.9 or 1.0) univariate analyses **(Tables 3 and 4)**. It also did not show any significant relationship in logistic regression analysis of the AKI related factors. On the other hand, the rate of development of AKI (7 patients, 77.8%) was significantly higher in the patients with perioperative procedural complications that causing hemodynamic instability than the rate of AKI (14 of 71 patients, 19.7%) of patients without complications (p=0.001). Importantly, the mean ABI was significantly lower in patients with perioperative complications (1.07 ± 0.14, 0.96 ± 0.13, p=0.016). The presence of renal dysfunction before surgery and renal hypoperfusion due to hypotension during the perioperative period, as in our cases, is the main cause of AKI after cardiac surgery.[1-2, 17-18] In the retrospective examination of patients who developed AKI in 108 patients undergoing cardiac surgery, perioperative hypotension (46.3%, 50/108) was among the most important etiologies responsible for the development of AKI.[20] It is known that, in cardiac surgery patients, a decrease in cardiac output or the development of hypotensive attack in the perioperative period, lasting for prolonged periods of time causes a reduction in glomerular filtration rate and cause AKI,[21] as in our cases. This process may be accompanied by renal tubular epithelial cell disruption and structural tubular injury resulting in oxidative damage and inflammatory events.[22] However, it is hard to find out why ABI was related to the development of AKI. In the literature, we could not find any study or data presenting the role of ABI on this issue. We know that the kidney has very efficient autoregulation in a wide pressure range.[23] This autoregulation occurs in preglomerular microcirculation, the faster way, and myogenic mechanism and slower tubuloglomerular feedback.[23] This range of autoregulation may be altered by some factors, including chronic HT, acute ischemia, and arteriosclerosis.[24] Therefore, it may be thought that arterial BP and renal hemodynamic autoregulation may be problematic in patients with subclinical atherosclerosis (those have lower ABI levels), and this may lead to a tendency to hypotensive attacks and the development of renal dysfunction.

We did not find a relationship between preoperative BP values and BP values in the pump with the development of postoperative AKI. It was found that the mean arterial BP during CPB did not differ between patients with and without postoperative AKI.[3, 25] For this reason, in recently published European guidelines for monitoring standards in adults undergoing CABG, it is suggested that the mean arterial blood pressure during the pump is sufficient between 50-80 mmHg,[26] which is similar to our BPs on the pump **(Table 3)**.

Although the risk of AKI is higher in patients who underwent complex cardiac surgery (valve replacement or valve repair, combined and aortic surgery, etc.), this was not seen in our study **(Table 2)**.[27] It cannot be conclusive because of the small size of non-CABG patients involved in the study.

There were some limitations in this study: Firstly, the number of the patients is relatively low. There was not any other biomarker rather than serum creatinine for the earlier diagnosis and confirmation of AKI. And we did not suggest any ABI value cut-off for prediction of risk of hypotensive attack during cardiac surgery. However, these shortcomings do not limit our results from being satisfactory and acceptable. Since our study is a pilot study on its topic, which is designed to reflect routine daily practice.

More comprehensive and complex studies about our study can make valuable contributions. Our study also provides some critical contributions to the literature: the BP devices used in our research are uncomplicated devices that are easily accessible and easy to use in routine practice. We have shown that these devices can make measurements comparable to Doppler devices in ABI measurement. In our study, moreover, PAD patients whose ABI value was already impaired were excluded, thereby adding a broader perspective to the use of ABI.

In conclusion, ABI may have a role in predicting perioperative hemodynamic complications, which may cause AKI in patients undergoing major surgery. More detailed studies are needed in this regard. On the other hand, simple automatic BP devices can be used in daily practice for ABI measurement instead of complicated and expensive Doppler devices.

BIBLIOGRAFÍA

1) Thakar CV, Arrigain S, Worley S, Yared JP, Paganini EP. A clinical score to predict acute renal failure after cardiac surgery. *J Am Soc Nephrol*. 2005;16(1):162-8. doi: 10.1681/ASN.2004040331.

2) Wijeysundera DN, Karkouti K, Beattie WS, Rao V, Ivanov J. Improving the identification of patients at risk of postoperative renal failure after cardiac surgery. *Anesthesiology*. 2006;104(1):65-72. doi: 10.1097/00000542-200601000-00012.

3) Haase M, Bellomo R, Story D, Letis A, Klemz K, Matalanis G, *et al*. Effect of mean arterial pressure, haemoglobin and blood transfusion during cardiopulmonary bypass on post-operative acute kidney injury. *Nephrol Dial Transplant*. 2012;27(1):153-60. doi: 10.1093/ndt/gfr275.

4) Thiele RH, Isbell JM, Rosner MH. AKI associated with cardiac surgery. *Clin J Am Soc Nephrol*. 2015;10(3):500-14. doi: 10.2215/CJN.07830814.

5) Haase M, Bellomo R, Matalanis G, Calzavacca P, Dragun D, Haase-Fielitz A. A comparison of the RIFLE and Acute Kidney Injury Network classifications for cardiac surgery-associated acute kidney injury: a prospective cohort study. *J Thorac Cardiovasc Surg*. 2009;138(6):1370-6. doi: 10.1016/j.jtcvs.2009.07.007.

6) Coleman MD, Shaefi S, Sladen RN. Preventing acute kidney injury after cardiac surgery. *Curr Opin Anaesthesiol*. 2011;24(1):70-6. doi: 10.1097/ACO.0b013e3283422ebc.

7) Coca SG, Garg AX, Thiessen-Philbrook H, Koyner JL, Patel UD, Krumholz HM, *et al*.; TRIBE-AKI Consortium. Urinary biomarkers of AKI and mortality 3 years after cardiac surgery. *J Am Soc Nephrol*. 2014;25(5):1063-71. doi: 10.1681/ASN.2013070742.

8) Creager MA, White CJ, Hiatt WR, Criqui MH, Josephs SC, Alberts MJ, *et al*.; American Heart Association. Atherosclerotic Peripheral Vascular Disease Symposium II: executive summary. *Circulation*. 2008;118(25):2811-25. doi: 10.1161/CIRCULATIONAHA.108.191170.

9) Khan NA, Rahim SA, Anand SS, Simel DL, Panju A. Does the clinical examination predict lower extremity peripheral arterial disease? *JAMA*. 2006;295(5):536-46. doi: 10.1001/jama.295.5.536.

10) Mourad JJ, Cacoub P, Collet JP, Becker F, Pinel JF, Huet D, *et al*.; ELLIPSE scientific committee and study investigators. Screening of unrecognized peripheral arterial disease (PAD) using ankle-brachial index in high cardiovascular risk patients free from symptomatic PAD. *J Vasc Surg*. 2009;50(3):572-80. doi: 10.1016/j.jvs.2009.04.055.

11) Gronewold J, Hermann DM, Lehmann N, Kröger K, Lauterbach K, Berger K, *et al*.; Heinz Nixdorf Recall Study Investigative Group. Ankle-brachial index predicts stroke in the general population in addition to classical risk factors. *Atherosclerosis*. 2014;233(2):545-50. doi: 10.1016/j.atherosclerosis.2014.01.044.

12) Matsushita K, Sang Y, Ballew SH, Shlipak M, Katz R, Rosas SE, *et al*. Subclinical atherosclerosis measures for cardiovascular prediction in CKD. *J Am Soc Nephrol*. 2015;26(2):439-47. doi: 10.1681/ASN.2014020173.

13) Leng GC, Fowkes FG, Lee AJ, Dunbar J, Housley E, Ruckley CV. Use of ankle brachial pressure index to predict cardiovascular events and death: a cohort study. *BMJ*. 1996;313(7070):1440-4. doi: 10.1136/bmj.313.7070.1440.

14) 2011 Writing Group Members; 2005 Writing Committee Members; ACCF/AHA Task Force Members. 2011 ACCF/AHA Focused Update of the Guideline for the Management of patients with peripheral artery disease (Updating the 2005 Guideline): a report of the American College of Cardiology Foundation/American Heart Association Task Force on practice guidelines. *Circulation*. 2011;124(18):2020-45. doi: 10.1161/CIR.0b013e31822e80c3.

15) Davies JH, Williams EM. Automated plethysmographic measurement of the ankle-brachial index: a comparison with the doppler ultrasound method. *Hypertens Res*. 2016;39(2):100-6. doi: 10.1038/hr.2015.124.

16) Mehta RL, Kellum JA, Shah SV, Molitoris BA, Ronco C, Warnock DG, *et al*.; Acute Kidney Injury Network. Acute Kidney Injury Network: report of an initiative to improve outcomes in acute kidney injury. *Crit Care*. 2007;11(2):R31. doi: 10.1186/cc5713.

17) Yang J, Lu C, Yan L, Tang X, Li W, Yang Y, Hu D. The association between atherosclerotic renal artery stenosis and acute kidney injury in patients undergoing cardiac surgery. *PLoS One*. 2013;8(5):e64104. doi: 10.1371/journal.pone.0064104.

18) Conlon PJ, Stafford-Smith M, White WD, Newman MF, King S, Winn MP, *et al*. Acute renal failure following cardiac surgery. *Nephrol Dial Transplant*. 1999;14(5):1158-62. doi: 10.1093/ndt/14.5.1158.

19) Mehta RL. Acute renal failure and cardiac surgery: marching in place or moving ahead? *J Am Soc Nephrol*.

2005;16(1):12-4. doi: 10.1681/ASN.2004110954.
20) Han GF, Zhang JY, Lu S, Li YZ. Etiological and prognostic factors in patients with acute renal failure after cardiac surgery. *Chin J Blood Purific*. 2005;4(6):302-5.
21) Wang Y, Bellomo R. Cardiac surgery-associated acute kidney injury: risk factors, pathophysiology and treatment. *Nat Rev Nephrol*. 2017;13(11):697-711. doi: 10.1038/nrneph.2017.119.
22) Sutton TA, Fisher CJ, Molitoris BA. Microvascular endothelial injury and dysfunction during ischemic acute renal failure. *Kidney Int*. 2002;62(5):1539-49. doi: 10.1046/j.1523-1755.2002.00631.x.
23) Cupples WA, Braam B. Assessment of renal autoregulation. *Am J Physiol Renal Physiol*. 2007;292(4):F1105-23. doi: 10.1152/ajprenal.00194.2006.
24) Weir MR, Aronson S, Avery EG, Pollack CV Jr. Acute kidney injury following cardiac surgery: role of perioperative blood pressure control. *Am J Nephrol*. 2011;33(5):438-52. doi: 10.1159/000327601.
25) Kanji HD, Schulze CJ, Hervas-Malo M, Wang P, Ross DB, Zibdawi M, *et al*. Difference between pre-operative and cardiopulmonary bypass mean arterial pressure is independently associated with early cardiac surgery-associated acute kidney injury. *J Cardiothorac Surg*. 2010;5:71. doi: 10.1186/1749-8090-5-71.
26) Wahba A, Milojevic M, Boer C, De Somer FMJJ, Gudbjartsson T, van den Goor J, *et al*.; EACTS/EACTA/EBCP Committee Reviewers. 2019 EACTS/EACTA/EBCP guidelines on cardiopulmonary bypass in adult cardiac surgery. *Eur J Cardiothorac Surg*. 2020;57(2):210-51. doi: 10.1093/ejcts/ezz267.
27) Bellomo R, Auriemma S, Fabbri A, D'Onofrio A, Katz N, McCullough PA, *et al*. The pathophysiology of cardiac surgery-associated acute kidney injury (CSA-AKI). Int *J Artif Organs*. 2008;31(2):166-78. doi: 10.1177/039139880803100210.