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The Prognostic Nutritional Index in prediction of two-year mortality in patients undergoing Transcatheter Aortic Valve Replacement

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ABSTRACT

Objective: Transcatheter aortic valve replacement (TAVR) is a minimally invasive procedure employed to treat aortic valve disease in patients who are ineligible for open-heart surgery. Undergoing TAVR patients generally include the elderly and frail. Malnutrition is associated with high morbidity and mortality in patients with undergoing TAVR. The aim of this study was to investigate the prognostic value of the prognostic nutritional index (PNI) for two-year survival after TAVR.

Material and Methods: A cohort of 213 consecutive patients with severe aortic stenosis who underwent transcatheter aortic valve replacement between March 2019 and July 2021. The study population was divided into two groups according to the cut-off PNI level in a receiver operator characteristic (ROC) curve analysis. The two-year follow-up results of the patients were recorded retrospectively. PNI was defined according to the following formula: PNI = (10 x serum albumin [g/dl]) + (0.005 x total lymphocyte counts [1000/mcL]).

Results: Mean age of the patients was 76.15, and 93 (43.7%) of them were males. Patients with low PNI (group 1) were significantly older. The mean PNI of group 1 was 43.17 ± 4.04 and the mean PNI of group 2 was 54.23 ± 4.30. Mortality at two-year was 32.6% in low PNI group and 10.7% in high PNI group. Hypertension and PNI were independent predictors of mortality after TAVR. In ROC curve analysis, PNI at a cut off value of 48.325 predicted the mortality after TAVR with 63.5% sensitivity and 70.1% specificity. Kaplan-Meier curves for two-year mortality between low and high PNI groups showed worse outcomes in patients with low PNI.

Conclusion: PNI is a practical and useful nutritional index that predicts two-year mortality after TAVR.

Keywords: mortality, prognostic nutritional index, transcatheter aortic valve replacement

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INTRODUCTION

Aortic stenosis is the most common valvular disease in developed countries and its prevalence is rapidly increasing due to the ageing population (1). Transcatheter aortic valve replacement (TAVR) is a minimally invasive procedure employed for the treatment of aortic valve disease in patients who are considered ineligible or high-risk for traditional open-heart surgery (1, 2).

Therefore, this group of patients undergoing TAVR generally includes elderly and frail patients. In addition to more comorbid risk factors in elderly patients, malnutrition and cognitive dysfunction also contribute to perioperative morbidity and mortality risk. This patient population has a high risk of morbidity and mortality. The increased risk of perioperative complications in elderly patients needs to be considered.

Early prediction of mortality risk in this group with elderly patients allows to reduce the mortality risk by taking protective and preventive precautions against this risk. Surgical risk scores have been used to predict mortality in various patient groups for many years. They are not sufficient to predict mortality and morbidity after TAVR. Other scores need to be developed for better risk prediction in these patients.

Malnutrition is a common condition in the elderly patient population (3). It is especially common in patients with cardiovascular disease and hospitalized patients (4,5). Previous studies have shown that patients with malnutrition have higher mortality rates after cardiovascular diseases and interventional procedures (6,7,8). Several parameters have been used to assess nutritional status in patients undergoing TAVR, but none of these parameters are yet used in clinical routine except the well-known Body Mass Index (BMI) (9). Some of these scores include the Geriatric Nutritional Risk Index (GNRI), body surface area (BSA) and the Controlling Nutritional Status (CONUT) scale (10,11,12). Malnutrition is associated with high morbidity and mortality in patients with severe aortic stenosis undergoing TAVR (3,13,14).

The Prognostic Nutrition Index (PNI) definition was first used by Buzby et al. in gastrointestinal surgery patients (15). PNI includes both lymphocyte count and albumin level. It was analyzed in cancer patients and showed that lower PNI values were associated with worse outcomes (16,17). Recently, the prognostic value of the PNI score has also been examined in various cardiovascular diseases, including heart failure and patients with acute coronary syndrome (18,19,20). Studies are showing that low PNI value is also an indicator of poor prognosis in patients with advanced heart failure (21). The aim of this study was to investigate the prognostic value of PNI for two-year survival following TAVR.

MATERIAL and METHODs

This study was planned as a single-center retrospective study. The study population consisted of 213 consecutive patients with severe aortic stenosis who underwent transcatheter aortic valve replacement between March 2019 and July 2021. The implanted valves included two types of delivery systems available: self-expandable and balloon-expandable. Patients with acute infection, hematological diseases, chronic kidney disease, chronic liver disease, systemic inflammatory and autoimmune diseases, patients who received blood and blood product or albumin replacement in the last three months, and malignancy were excluded. All decisions regarding the performance of TAVR were made by a heart council following a thorough evaluation that included clinical, echocardiographic, and computed tomography assessments. The study protocol received approval from the Institutional Ethics Committee.

Patients' medical records were used to obtain data about medical history, including demographic parameters and cardiovascular risk factors. Venous blood samples were obtained at admission. Patients without crucial nutritional data or with severe malnutrition were excluded. Therefore, the patients included in the study had no significant malnutrition. Albumin levels and lymphocyte count were measured to allow PNI estimation. Albumin and lymphocyte counts were determined at the first venous blood test after hospitalization. The 24-month follow-up results of the patients were recorded retrospectively. Survival was prospectively assessed based on outpatient visits or national medical records system. The primary endpoint in our study was overall two-year mortality. PNI was defined according to following formula: PNI = (10 x serum albumin [g/dl]) + (0.005 x total lymphocyte counts [1000/mcL]) (22).

Statistical analysis:

Statistical analyses were performed using SPSS Statistics version 21.0 for Windows (SPSS Inc, Chicago, IL). The distribution pattern was tested with the Kolmogorov-Smirnov method. Continuous variables were presented as mean, standard deviation, or median and interquartile range. The student's t-test was used to compare data with normal distribution, and Mann-Whitney U test was applied to compare the data without normal distribution.

Categorical variables were presented as numbers and proportions and compared with the chi square test. Receiver-operating characteristics (ROC) curve analysis was used to determine the optimum cutoff value for PNI to predict mortality. Subsequently, the study population was divided into two groups: those with low PNI and those with high PNI, based on the cut-off value determined through ROC curve analysis. Cox regression analysis was used to assess the effect of different variables on clinical outcomes.

The variables for which the unadjusted P value was < 0.25 in univariate Cox regression analysis were included in the multivariable Cox regression model. The survival curves for PNI were analyzed using the Kaplan-Meier method, and statistical assessment was performed using the log-rank test. A p value < 0.05 was considered statistically significant for all analyses.

RESULTs

A total of 213 patients were included in the study. Patients were divided into two groups as low PNI (group 1) and high PNI (group 2) according to the threshold value on the receiver operating characteristic (ROC) curve. Mean age of the patients was 76.15 and 93 (43.7%) of them were males. Baseline demographics, clinical, and laboratory parameters are presented in **Table 1**.

There is no significant difference in terms of gender between both groups. Patients with low PNI (group 1) were significantly older (78.34 ± 7.69 vs 74.48 ± 8.73 years; p<0.001). CT-calcium score and systolic pulmonary artery pressure were higher in group 1. The mean PNI of group 1 was 43.17 ± 4.04, and the mean PNI of group 2 was 54.23 ± 4.30. Left ventricular ejection fraction, albumin, hemoglobin, white blood cell, lymphocyte and e-GFR were significantly higher in group 2. Mortality at 2 years was 32.6% in low PNI group and 10.7% in high PNI group(p<0.001).

A multivariate Cox-regression analysis revealed that hypertension and PNI were independent predictors of mortality after TAVR (**Table 2**). In receiver operating characteristic (ROC) curve analysis, PNI at a cut off value of 48.325 predicted the mortality after TAVR with 63.5% sensitivity and 70.1% specificity. (AUC=0.751; 95% CI = 0.67 - 0.83; p < 0.001) (**Figure 1**). In addition, Kaplan-Meier curves between low and high PNI groups for 2-year mortality showed worse outcomes in patients with low PNI (p = 0.001) (**Figure 2**).

Table 1. Comparison of groups according to the baseline demographics, clinical and laboratory characteristic

	Group 1 – Low PNI (n=92)	Group 2 – High PNI (n=121)	p value
Age	78.34 ± 7.69	74.48 ± 8.73	<0.001
Male Gender, n (%)	44 (47.8)	49 (40.5)	0.285
Hypertension, n (%)	72 (78.3)	103 (85.1)	0.113
Diabetes Mellitus, n (%)	37 (40.2)	54 (44.6)	0.461
CAD, n (%)	54 (58.7)	78 (64.5)	0.365
BMI	28.68 ± 6.95	30.24 ± 5.79	0.343
AVA (cm2)	0.71 ± 0.14	0.68 ± 0.15	0.287
Mean aortic gradient (mmHg)	48.83 ± 11.99	48.30 ± 10.96	0.744
CT, calcium score	3167.6 ± 1729.3	2568.4 ± 1409.8	**0.010**
PNI	43.17 ± 4.04	54.23 ± 4.30	**<0.001**
LVEF (%)	49.09 ± 13.76	53.54 ± 11.00	**0.011**
SPAP (mmHg)	44.11 ± 14.50	38.44 ± 11.28	**0.002**
Albumin (g/L)	37.14 ± 3.53	43.41 ± 3.31	**<0.001**
Total cholesterol (mg/dl)	155.0 ± 41.2	152.4 ± 55.3	0.543
LDL (mg/dl)	90.13 ± 32.3	91.95 ± 48.5	0.492
HDL (mg/dl)	41.32 ± 10.41	41.64 ± 11.92	0.872
Hemoglobin (g/dl)	11.68 ± 1.69	12.60 ± 1.62	**0.001**
Platelet (10^9/L)	233.28 ± 86.01	267.89 ± 83.32	0.874
WBC (10^9/L)	7.23 ± 2.90	8.23 ± 2.27	**0.008**
Neutrophil (10^9/L)	5.13 ± 2.92	5.16 ± 1.98	0.910
Lymphocyte (10^9/L)	1.26 ± 0.46	2.16 ± 0.67	**<0.001**
CRP (mg/dL)	0.15 ± 0.18	0.12 ± 0.15	0.517
e-GFR (%)	60.93 ± 24.38	69.24 ± 21.47	**0.010**
Death, n (%)	30 (32.6)	13 (10.7)	**<0.001**

Continuous data are presented as mean ± standard deviation, or median ± interquartile range

CAD: coronary artery disease, BMI: body mass index, AVA: aortic valve area, CT: computed tomography, PNI: prognostic nutritional index, LVEF: Left ventricular ejection fraction, SPAP: systolic pulmonary arterial pressure, LDL-C: low density lipoprotein cholesterol, HDL-C: high density lipoprotein cholesterol, WBC: white blood cell, CRP: C-reactive protein, e-GFR: estimated-glomerular filtration rate.

Table 2. Cox-regression analysis for prediction of two-year mortality

	Univariable		Multivariable	
Factor	95% CI)	p value	95% CI)	p value
Age			1.006 (0.961-1.053)	0.795
Male gender	1.081 (0.873-1.276)	0.687	-	-
Hypertension	2.123 (1.045-5.356)	0.012	2.309 (1.098-4.853)	**0.027**
CT Valve score	1.123 (1.024-1.253)	0.04	1.001 (0.999-1.002)	0.778
LVEF	0.873 (0.789-0.981)	0.003	0.993 (0.967-1.019)	0.583
SPAP	0.993 (0.987-0.999)	0.05	0.994 (0.970-1.018)	0.620
PNI	0.832 (0.798-0.911)	<0.001	0.877 (0.823-0.934)	**<0.001**
Hemoglobin	0.932 (0.723 -1.012)	0.122	0.945(0.755-1.184)	0.626
e-GFR	0.964 (0.932-1.002)	0.083	0.987 (0.973-1.001)	0.074

CT: computed tomography, LVEF: Left ventricular ejection fraction, SPAP: systolic pulmonary arterial pressure, PNI: prognostic nutritional index, e-GFR: estimated-glomerular filtration rate.

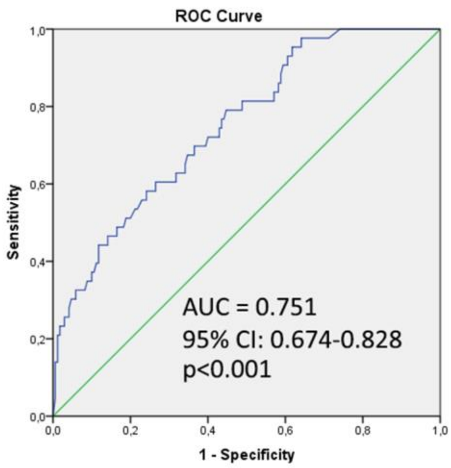

Figure 1. Receiver operating characteristics curve analysis of PNI in predicting two-year mortality after TAVR.

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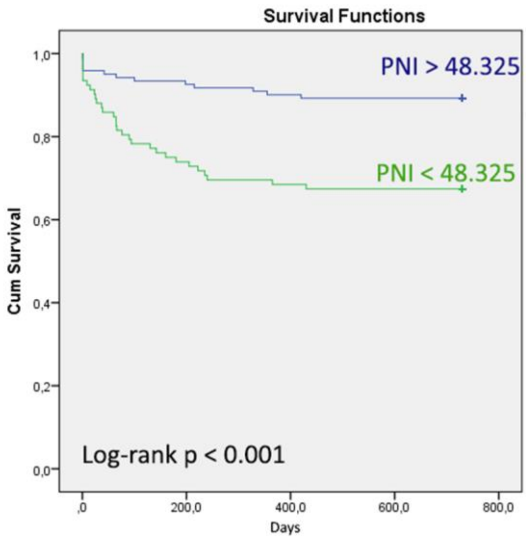

Figure 2. Kaplan-Meier survival curve

DISCUSSION

This study investigated the effect of PNI value on two-year mortality in patients who underwent TAVR for severe aortic stenosis. This study showed that a low PNI value was a strong independent predictor of two-year mortality.

PNI is a formula that combines serum albumin levels and lymphocyte counts, providing insight into a patient's nutritional status.This is easy to assess. Both albumin levels and lymphocyte counts are commonly available parameters in routine blood tests. Therefore, it can be a very practical method to assess nutritional status before TAVR. By combining basic laboratory parameters, PNI may allow a rapid risk stratification before TAVR and better selection of suitable patients.

Experts have suggested that studies may benefit from including frailty markers related to risk stratification in TAVR. However, no studies have assessed the effect of all these markers on 2-year outcomes (23,24). Several studies have focused on the effect of specific frailty markers on predicting 1-year outcomes after TAVR. In another study, a scoring system was designed to predict mortality after TAVR (24). Albumin level was also included in this scoring system. Similarly, some studies used low serum albumin level to indicate frailty (25).

Both hypoalbuminemia and low lymphocyte count have been suggested to predict mortality after TAVR (26,27). Low albumin levels reflect malnutrition, whereas low lymphocyte counts reflect immunosuppression. Thus, PNI provides a combined evaluation of nutritional and immune status in patients with cardiovascular diseases. Several studies have shown that serum albumin levels decrease in the presence of inflammation (20,22). This situation also indicates catabolism. Therefore, the association between low albumin levels and mortality can be predicted. In our study, low lymphocyte and albumin levels were associated with mortality.

According to our study, PNI seems to be a useful tool for risk stratification before TAVR; a low PNI value before TAVR is associated with high mortality in the first year after TAVR. These results agree with some previous studies (28,29). In another study, the mean age of the patients was 82.20 years, and 59.7% of the patients were male, whereas in our study, the mean age was 76.15 years, and the male sex ratio was 43.7% (28). Median PNI values differ in patients with different cardiovascular diseases or undergoing different treatment modalities. A specific cut-off value for the prognostic use of PNI may be required for each disease or treatment. In some studies, patients were categorized according to the median value, whereas in our study, patients were categorized according to the threshold value obtained from the ROC curve (28). Therefore, we think that our classification is statistically more significant.

Other objective nutritional indices have also been analyzed in TAVR populations. The GNRI has been shown to predict outcomes after TAVR in previous series (10,28,30). Although GNRI seems to be a good index for risk stratification in this population, our study suggests that PNI may be a better indicator. Although PNI seems to be easier and more feasible than other nutritional indexes, more studies are needed to evaluate the predictive ability of PNI. In another study, an assessment questionnaire called mini nutritional assessment (MNA) was applied to the TAVR population. This questionnaire was associated with one-year mortality after TAVR (31). However, this subjective assessment tool may not be appropriate in this geriatric population. This population may not be able to report the questions with absolute accuracy.

Study Limitations

This study has several limitations. First, it has a retrospective and single-center design which may limit the generalizability of its results. This value needs to be validated in a larger population, although a cut-off value of PNI has been suggested for the TAVR population. In this study, we presented two-year mortality findings.

However, longer follow-up is needed to assess the association of PNI with longer-term outcomes. Finally, in-hospital mortality could not be statistically evaluated due to sample size. It is crucial to conduct studies with larger patient populations to determine the prognostic role of PNI in in-hospital mortality.

CONCLUSION

Our study demonstrates that PNI is a practical and valuable nutritional index for predicting 2-year mortality following TAVR. Serum albumin and lymphocyte count serve as indicators of a patient's nutritional and inflammatory status before TAVR and significantly influence prognosis.

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Author Contributions: MOÖ, SKA; contributed to the conception of the work, execution of the study, revision of the draft, approval of the final manuscript version, and concur with all aspects of the work. All authors have reviewed the manuscript, and affirm that they fulfill the ICMJE criteria for authorship.

Ethical approval: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and/or with the Helsinki Declaration of 1964 and later versions.

REFERENCES

1. Vahanian A, Beyersdorf F, Praz F, Milojevic M, Baldus S, Bauersachs J, et al. 2021 ESC/EACTS Guidelines for the management of valvular heart disease. European heart journal. 2022;43(7):561-632.
2. Nishimura RA, Otto CM, Bonow RO, Carabello BA, Erwin JP, 3rd, Guyton RA, et al. 2014 AHA/ACC guideline for the management of patients with valvular heart disease: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Journal of the American College of Cardiology. 2014;63(22):2438-88.
3. Stortecky S, Schoenenberger AW, Moser A, Kalesan B, Jüni P, Carrel T, et al. Evaluation of multidimensional geriatric assessment as a predictor of mortality and cardiovascular events after transcatheter aortic valve implantation. JACC Cardiovascular interventions. 2012;5(5):489-96.
4. Bonilla-Palomas JL, Gámez-López AL, Anguita-Sánchez MP, Castillo-Domínguez JC, García-Fuertes D, Crespin-Crespin M, et al. [Impact of malnutrition on long-term mortality in hospitalized patients with heart failure]. Revista espanola de cardiologia. 2011;64(9):752-8.
5. Agra Bermejo RM, González Ferreiro R, Varela Román A, Gómez Otero I, Kreidieh O, Conde Sabarís P, et al. Nutritional status is related to heart failure severity and hospital readmissions in acute heart failure. International journal of cardiology. 2017; 230: 108-14.
6. Barge-Caballero E, García-López F, Marzoa-Rivas R, Barge-Caballero G, Couto-Mallón D, Paniagua-Martín MJ, et al. Prognostic Value of the Nutritional Risk Index in Heart Transplant Recipients. Revista espanola de cardiologia (English ed). 2017;70(8):639-45.
7. Wada H, Dohi T, Miyauchi K, Doi S, Naito R, Konishi H, et al. Prognostic Impact of the Geriatric Nutritional Risk Index on Long-Term Outcomes in Patients Who Underwent Percutaneous Coronary Intervention. The American journal of cardiology. 2017;119(11):1740-5.
8. Eichler S, Salzwedel A, Harnath A, Butter C, Wegscheider K, Chiorean M, et al. Nutrition and mobility predict all-cause mortality in patients 12 months after transcatheter aortic valve implantation. Clinical research in cardiology : official journal of the German Cardiac Society. 2018;107(4):304-11.
9. Sannino A, Schiattarella GG, Toscano E, Gargiulo G, Giugliano G, Galderisi M, et al. Meta-Analysis of Effect of Body Mass Index on Outcomes After Transcatheter Aortic Valve Implantation. The American journal of cardiology. 2017;119(2):308-16.
10. González Ferreiro R, Muñoz-García AJ, López Otero D, Avanzas P, Pascual I, Alonso-Briales JH, et al. Nutritional risk index predicts survival in patients undergoing transcatheter aortic valve replacement. International journal of cardiology. 2019; 276: 66-71.
11. Arsalan M, Filardo G, Kim WK, Squiers JJ, Pollock B, Liebetrau C, et al. Prognostic value of body mass index and body surface area on clinical outcomes after transcatheter aortic valve implantation. Clinical research in cardiology : official journal of the German Cardiac Society. 2016;105(12):1042-8.
12. Honda Y, Yamawaki M, Shigemitsu S, Kenji M, Tokuda T, Tsutumi M, et al. Prognostic value of objective nutritional status after transcatheter aortic valve replacement. Journal of cardiology. 2019;73(5):401-7.
13. Lindman BR, Alexander KP, O'Gara PT, Afilalo J. Futility, benefit, and transcatheter aortic valve replacement. JACC Cardiovascular interventions. 2014;7(7):707-16.
14. Green P, Woglom AE, Genereux P, Daneault B, Paradis JM, Schnell S, et al. The impact of frailty status on survival after transcatheter aortic valve replacement in older adults with severe aortic stenosis: a single-center experience. JACC Cardiovascular interventions. 2012;5(9):974-81.
15. Buzby GP, Mullen JL, Matthews DC, Hobbs CL, Rosato EF. Prognostic nutritional index in gastrointestinal surgery. American journal of surgery. 1980;139(1):160-7.
16. Nozoe T, Kohno M, Iguchi T, Mori E, Maeda T, Matsukuma A, et al. The prognostic nutritional index can be a prognostic indicator in colorectal carcinoma. Surgery today. 2012;42(6):532-5.
17. Okada S, Shimada J, Kato D, Tsunezuka H, Teramukai S, Inoue M. Clinical Significance of Prognostic Nutritional Index After Surgical Treatment in Lung Cancer. The Annals of thoracic surgery. 2017;104(1):296-302.
18. Zencirkiran Agus H, Kahraman S. Prognostic nutritional index predicts one-year outcome in heart failure with preserved ejection fraction. Acta cardiologica. 2020;75(5):450-5.
19. Cheng YL, Sung SH, Cheng HM, Hsu PF, Guo CY, Yu WC, et al. Prognostic Nutritional Index and the Risk of Mortality in Patients With Acute Heart Failure. Journal of the American Heart Association. 2017;6(6).
20. Chen QJ, Qu HJ, Li DZ, Li XM, Zhu JJ, Xiang Y, et al. Prognostic nutritional index predicts clinical outcome in patients with acute ST-segment elevation myocardial infarction undergoing primary percutaneous coronary intervention. Scientific reports. 2017;7(1):3285.
21. Yost G, Tatooles A, Bhat G. Preoperative Nutritional Assessment with the Prognostic Nutrition Index in Patients Undergoing Left Ventricular Assist Device Implantation. ASAIO journal (American Society for Artificial Internal Organs : 1992). 2018;64(1):52-5.
22. Onodera T, Goseki N, Kosaki G. [Prognostic nutritional index in gastrointestinal surgery of malnourished cancer patients]. Nihon Geka Gakkai zasshi. 1984;85(9):1001-5.
23. Edwards FH, Cohen DJ, O'Brien SM, Peterson ED, Mack MJ, Shahian DM, et al. Development and Validation of a Risk Prediction Model for In-Hospital Mortality After Transcatheter Aortic Valve Replacement. JAMA cardiology. 2016;1(1):46-52.
24. Hermiller JB, Jr., Yakubov SJ, Reardon MJ, Deeb GM, Adams DH, Afilalo J, et al. Predicting Early and Late Mortality After Transcatheter Aortic Valve Replacement. Journal of the American College of Cardiology. 2016;68(4):343-52.

25. Forcillo J, Condado JF, Ko YA, Yuan M, Binongo JN, Ndubisi NM, et al. Assessment of Commonly Used Frailty Markers for High- and Extreme-Risk Patients Undergoing Transcatheter Aortic Valve Replacement. The Annals of thoracic surgery. 2017;104(6):1939-46.

26. Hebeler KR, Baumgarten H, Squiers JJ, Wooley J, Pollock BD, Mahoney C, et al. Albumin Is Predictive of 1-Year Mortality After Transcatheter Aortic Valve Replacement. The Annals of thoracic surgery. 2018;106(5):1302-7.

27. Condado JF, Junpaparp P, Binongo JN, Lasanajak Y, Witzke-Sanz CF, Devireddy C, et al. Neutrophil-lymphocyte ratio (NLR) and platelet-lymphocyte ratio (PLR) can risk stratify patients in transcatheter aortic-valve replacement (TAVR). International journal of cardiology. 2016; 223: 444-9.

28. Mas-Peiro S, Hoffmann J, Seppelt PC, De Rosa R, Murray MI, Walther T, et al. Value of prognostic nutritional index for survival prediction in trans-catheter aortic valve replacement compared to other common nutritional indexes. Acta cardiologica. 2021;76(6):615-22.

29. Okuno T, Koseki K, Nakanishi T, Sato K, Ninomiya K, Tomii D, et al. Evaluation of objective nutritional indexes as predictors of one-year outcomes after transcatheter aortic valve implantation. Journal of cardiology. 2019;74(1):34-9.

30. Shibata K, Yamamoto M, Kano S, Koyama Y, Shimura T, Kagase A, et al. Importance of Geriatric Nutritional Risk Index assessment in patients undergoing transcatheter aortic valve replacement. American heart journal. 2018; 202: 68-75.

31. Goldfarb M, Lauck S, Webb JG, Asgar AW, Perrault LP, Piazza N, et al. Malnutrition and Mortality in Frail and Non-Frail Older Adults Undergoing Aortic Valve Replacement. Circulation. 2018; 138(20): 2202-11.