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Research Article

Impact of Right Ventricular Function on Mortality and Reoperation Rates in Cardiovascular Surgery

Muhammet Fethi Sağlam[1]*, Emrah Uğuz[1], Kemal Eşref Erdoğan[1], Hüseyin Ünsal Erçelik[2], Murat Yücel[2], Mete Hıdıroğlu[1], Erol Şener[1]

[1] Ankara Yıldırım Beyazıt University Faculty of Medicine, Department of Cardiovascular Surgery, Ankara, Türkiye
dr.m.fethisaglam@gmail.com
emrahuguz@gmail.com
kemal_esref@hotmail.com.tr
metetaha@hotmail.com
rerolsener@gmail.com

[2] Ankara Bilkent City Hospital, Ankara, Türkiye
unsalercelik@gmail.com
dr_yucelmurat@hotmail.com

* Corresponding Author

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Objective: This study aimed to investigate the impact of preoperative right ventricular (RV) function on postoperative outcomes such as mortality, reoperation rates, valve size, and other clinical variables in patients undergoing tricuspid valve surgery.

Methods: This retrospective study included 100 patients who underwent tricuspid valve surgery. Patients were categorized into four groups based on preoperative RV function: normal, mildly depressed, moderately depressed, and severely depressed. RV function was assessed using echocardiographic parameters, including tricuspid annular plane systolic excursion (TAPSE), tissue Doppler imaging (TDI), mean pulmonary artery pressure (MPAB), and valve size. Postoperative outcomes, including mortality and reoperation rates, were analyzed.

Results: Patients with severely depressed RV function had significantly higher mortality rates (p=0.035). Reoperation rates also increased as RV function worsened (p=0.006). No significant difference was found between groups regarding valve size (p>0.05) or the type of surgery (sternotomy or thoracotomy) (p=0.714).

Conclusion: Right ventricular dysfunction significantly increases postoperative mortality and reoperation rates in patients undergoing tricuspid valve surgery. Careful preoperative evaluation of RV function, including valve size, is critical for improving surgical outcomes.

Keywords: Right ventricular dysfunction, Tricuspid valve surgery, Mortality, Reoperation

1. INTRODUCTION

Right ventricular (RV) function is a critical determinant in the prognosis of patients undergoing cardiovascular surgery, particularly in those involving tricuspid valve surgery.[1,2] The right ventricle, which pumps blood to the lungs, plays a fundamental role in maintaining pulmonary circulation, and its dysfunction can have profound implications on overall cardiovascular outcomes. Cardiovascular surgeries, especially those requiring tricuspid valve interventions, impose unique challenges on the RV.[3] This is primarily due to the anatomical and physiological burden placed on the right heart during and after surgery.[4]

Tricuspid valve surgery, commonly performed to address tricuspid regurgitation or stenosis, increases the RV's workload by altering hemodynamics and increasing the afterload.[5,6] The surgery often involves the placement of a prosthetic valve, either bioprosthetic or mechanical, which, while restoring valve competence, can exacerbate existing RV dysfunction. This is particularly concerning in patients with pre-existing RV impairment, where postoperative RV failure becomes a significant risk factor for adverse outcomes such as increased mortality, prolonged intensive care unit (ICU) stays, and higher reoperation rates.[7,8]

Preoperative RV dysfunction has been identified as a major prognostic factor in several studies.[3,9]

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It is known to correlate with higher morbidity and mortality rates, especially in patients undergoing valve surgeries that involve the right heart. In the context of tricuspid valve surgery, RV dysfunction can compromise surgical outcomes by impairing the heart's ability to adapt to the increased hemodynamic stress post-surgery.[10] This dysfunction may manifest as reduced right ventricular ejection fraction, increased right atrial pressures, and decreased right ventricular longitudinal strain, all of which are associated with poor clinical outcomes.[11,12]

Despite the growing awareness of RV dysfunction's role in surgical outcomes, there remains limited consensus regarding its exact prognostic value, particularly in tricuspid valve surgery. Previous research has predominantly focused on left ventricular dysfunction, often overshadowing the importance of RV function.[13,14] However, with advances in echocardiography and tissue Doppler imaging, it has become easier to assess RV parameters preoperatively, allowing for a more precise risk stratification of patients. Metrics such as tricuspid annular plane systolic excursion (TAPSE), RV fractional area change, and RV strain provide valuable insights into the extent of RV dysfunction and its potential impact on surgical outcomes.[15]

Tricuspid valve surgery is a less frequently addressed and often neglected area compared to other valve surgeries. However, surgical intervention before deterioration of right ventricular function is one of the most important priorities of tricuspid valve surgery. The timing of surgery plays a decisive role in the long-term prognosis of patients.

The present study aims to investigate the specific effects of varying degrees of right ventricular dysfunction, ranging from mild to severe, on postoperative outcomes in patients undergoing cardiovascular surgery, particularly in tricuspid valve surgery. RV function was assessed using echocardiographic parameters, including TAPSE, tissue Doppler imaging (TDI), mean pulmonary artery pressure (MPAB), and valve size. Our hypothesis is that patients with severe RV dysfunction will exhibit higher mortality and reoperation rates compared to those with normal RV function. By analyzing a cohort of patients with differing levels of RV function, this study seeks to provide a clearer understanding of how RV impairment, as measured by these echocardiographic parameters and valve size, influences post-surgical prognosis and contributes to the growing body of literature highlighting the importance of RV function in cardiovascular surgeries.

2. MATERIAL AND METHODS

2.1. Study design and population

This study was a retrospective cohort analysis aimed at investigating the impact of right ventricular (RV) dysfunction on postoperative mortality and reoperation rates in patients undergoing tricuspid valve surgery. The study included 100 patients who underwent tricuspid valve replacement. Of these patients, 82 underwent sternotomy, and 18 underwent thoracotomy. Ethical approval was obtained from the 1nd Clinical Research Ethics Committee of Ankara Bilkent City Hospital on 07.06.2023, with decision number TABED-1-24-529. This study adhered to the principles outlined in the Declaration of Helsinki. All patient data were anonymized, and informed consent was obtained from all participants.

2.2. Patient selection

Patients included in this study were selected based on specific inclusion and exclusion criteria. All patients who had undergone tricuspid valve replacement and had complete preoperative echocardiographic data available to assess RV function were included. Postoperative outcomes, such as mortality and reoperation rates, were documented. Patients with incomplete preoperative echocardiographic assessments or those who underwent surgeries unrelated to the tricuspid valve were excluded. Additionally, patients with severe left ventricular dysfunction that could interfere with the independent evaluation of RV performance were excluded from the study.

2.3. Assessment of right ventricular function

Preoperative right ventricular function was evaluated using echocardiography and classified based on three key parameters: mean pulmonary artery pressure, tricuspid annular plane systolic excursion, and tissue Doppler imaging, along with ventricular and atrial size. MPAP primarily indicates the afterload imposed on the right ventricle and does not directly measure RV function, but persistently elevated MPAP values can lead to long-term functional impairment of the RV. TAPSE is a critical marker of RV systolic function and measures the systolic motion of the tricuspid annulus. TAPSE values were used to classify RV function into four categories: normal (≥17 mm), mildly depressed (13-16 mm), moderately depressed (9-12 mm), and severely depressed (<9 mm). TDI provides a quantitative measure of myocardial velocities and was used to assess systolic and diastolic function of the RV. TDI values below 10 cm/s were considered indicative of RV dysfunction in this study. The size of the right ventricle and right atrium was also measured to evaluate ventricular and atrial enlargement, providing additional context for surgical decision-making. Based on these parameters, patients were stratified into normal, mildly depressed, moderately depressed, and severely depressed RV function groups.

2.4. Surgical procedures

All patients underwent standard tricuspid valve replacement, with the choice between bioprosthetic or mechanical valves determined by the operating surgeon based on individual patient factors. All surgeries were performed using cardiopulmonary bypass (CPB). Two distinct approaches were employed during CPB: either on a beating heart, where the heart continued to beat without cross-clamping, or on an arrested heart, where the heart was temporarily stopped using cross-clamp and myocardial protection strategies.

The choice of approach (beating heart or arrested heart) was made by the operating surgeon, considering patient-specific clinical conditions and surgical factors. In cases where an arrested heart approach was used, myocardial protection was ensured through standard techniques such as cold blood cardioplegia or intermittent cross-clamp release to minimize ischemic injury. The beating heart approach, where CPB was initiated without cardioplegia, was utilized in select cases to maintain continuous coronary perfusion. While these procedural variations were applied to accommodate individual surgical needs, they were not analyzed as separate variables in this study. Instead, this information was included to describe the technical variability inherent in tricuspid valve surgeries

2.5. Postoperative outcomes

The primary outcomes of the study were postoperative mortality and reoperation rates. Mortality was defined as any death occurring during the hospital stay or within 30 days post-surgery. Reoperations were defined as any subsequent surgical intervention required due to valve dysfunction, prosthesis failure, or other complications. Secondary outcomes included length of stay in the intensive care unit, the need for inotropic support, and the incidence of postoperative right ventricular failure.

2.6. Statistical analysis

The data obtained from the study were transferred to the computer and organized using Microsoft Excel, and then analyzed using SPSS (Statistical Package for Social Sciences) version 29.0. Categorical data were presented with frequency and percentage values, while numerical data were expressed as means and standard deviations. The Chi-Square test was used for categorical data analysis. Since the sample size for numerical data was below 30, and the depressed levels consisted of four categories, the Kruskal-Wallis H Test, a non-parametric test, was employed for comparison of numerical variables across groups. In cases where the expected count in the Chi-Square test was below 5, Fisher's Exact Test was used. For multiple comparisons following the Kruskal-Wallis H Test, the Bonferroni post-hoc test was performed to determine which groups showed significant differences. The level of statistical significance for all tests was set at $p<0.05$.

3. RESULTS

Table 1.

Comparison of demographic, clinical characteristics, and surgical outcomes according to preoperative right ventricular function

	Normal		Mildly Depressed		Moderately Depressed		Seriously Depressed			
	$\bar{x}$±SD **Median (min-max)**		$\bar{x}$±SD **Median (min-max)**				$\bar{x}$±SD **Median (min-max)**			
Age (years)	49.11±15.36 54 (18-69)		57.54±8.65 57 (39-70)		57.13±9.98 59 (33-76)		53.45±9.41 55 (31-68)		H=5.507	0.138
	n	%	n	%	n	%	n	%	χ^2	p
Gender										
Male	6	31.6	2	15.4	12	26.7	9	45.0	3.733	0.292
Female	13	68.4	11	84.6	33	73.3	11	55.0		
Surgery Type										
Sternotomy	16	84.2	9	69.2	33	73.3	14	70.0	1.365	0.714
Thoracotomy	3	15.8	4	30.8	12	26.7	6	30.0		
Reoperation										
No	10	36.8	7	38.5	12	15.6	0	0.0	12.451	**0.006**
Yes	9	63.2	6	61.5	33	84.4	20	100.0		
Expoloration										
Re-sternotomy	9	47.4	5	38.5	19	42.2	12	60.0	5.881	0.752
Sternotomy	7	36.8	4	30.8	14	31.1	2	10.0		
Thoracotomy	2	10.5	3	23.1	8	17.8	5	25.0		
Thoracotomy (minimal)	1	5.3	1	7.7	4	8.9	1	5.0		
Valve Type										
Bioprosthesis	5	26.3	5	38.5	17	37.8	8	40.0	1.007	0.800
Metallic	14	73.7	8	61.5	28	62.2	12	60.0		

Tricuspid Regurgitation										
1TR	0	0.0	0	0.0	0	0.0	1	5.0	9.770	0.369
2TR	0	0.0	1	7.7	3	6.7	0	0.0		
3TR	3	15.8	1	7.7	9	20.0	1	5.0		
4TR	16	84.2	11	84.6	33	73.3	18	90.0		
Mortality										
Ex	0	0.0	0	0.0	10	22.2	6	30.0	8.573	**0.035**
Alive	19	100.0	13	100.0	35	77.8	14	70.0		
Need for Pace										
Yes	1	5.3	2	15.4	9	20.0	2	10.0	2.751	0.432
No	18	94.7	11	84.6	36	80.0	18	90.0		

H=Kruskal-Wallis H Test, χ^2=Chi-Square Test, p<0.05, $\bar{x}$=mean, SD=standard deviation,*Fisher Exact value was used in cases where the observation value was below 5., TR=Tricuspid regurgitation

In Table 1, the Chi-Square test was employed to assess the relationships between demographic, clinical characteristics, and surgical outcomes in relation to preoperative right ventricular function. While no statistically significant relationships were found for most variables, including age, gender, surgery type, exploration, valve type, tricuspid regurgitation, and pace requirement (p>0.05), significant differences were observed for both reoperation and mortality.

Reoperation rates differed significantly among the groups (p=0.006), with higher rates in the moderately and seriously depressed groups, where 84.4% and 100% of patients underwent reoperation, respectively. In contrast, the normal and mildly depressed groups had lower reoperation rates of 63.2% and 61.5%. Additionally, a significant difference in mortality was found between the groups (p=0.035). Mortality was observed in 22.2% of patients in the moderately depressed group and 30.0% in the seriously depressed group, while no deaths occurred in the normal and mildly depressed groups. These findings highlight the greater risk of reoperation and mortality in patients with moderate to severe right ventricular dysfunction compared to those with normal or mildly depressed function.

Table 2.

Post-hoc analysis of mortality data

Comparison Groups	p-value
Normal vs. Mildly Depressed	-
Normal vs. Moderately Depressed	0.032
Normal vs. Seriously Depressed	0.028
Mildly Depressed vs. Moderately Depressed	0.041
Mildly Depressed vs. Seriously Depressed	0.035
Moderately Depressed vs. Seriously Depressed	0.849

p<0.05

In table 2, the results of the Bonferroni post-hoc analysis are presented to compare the mortality rates among the different preoperative right ventricular function groups. The analysis revealed significant differences between the normal and moderately depressed groups (p=0.032), as well as between the normal and seriously depressed groups (p=0.028). Similarly, there was a significant difference between the mildly depressed group and both the moderately depressed (p=0.041) and seriously depressed (p=0.035) groups. However, no significant difference was found between the moderately depressed and seriously depressed groups (p=0.849). These results highlight that mortality rates are significantly higher in the moderately and seriously depressed groups compared to the normal and mildly depressed groups, while the mortality rates between the moderately and seriously depressed groups remain statistically similar.

Table 3.

Comparison of preoperative right ventricular function parameters (MPAB, TDI, TAPSE) and valve size measurements

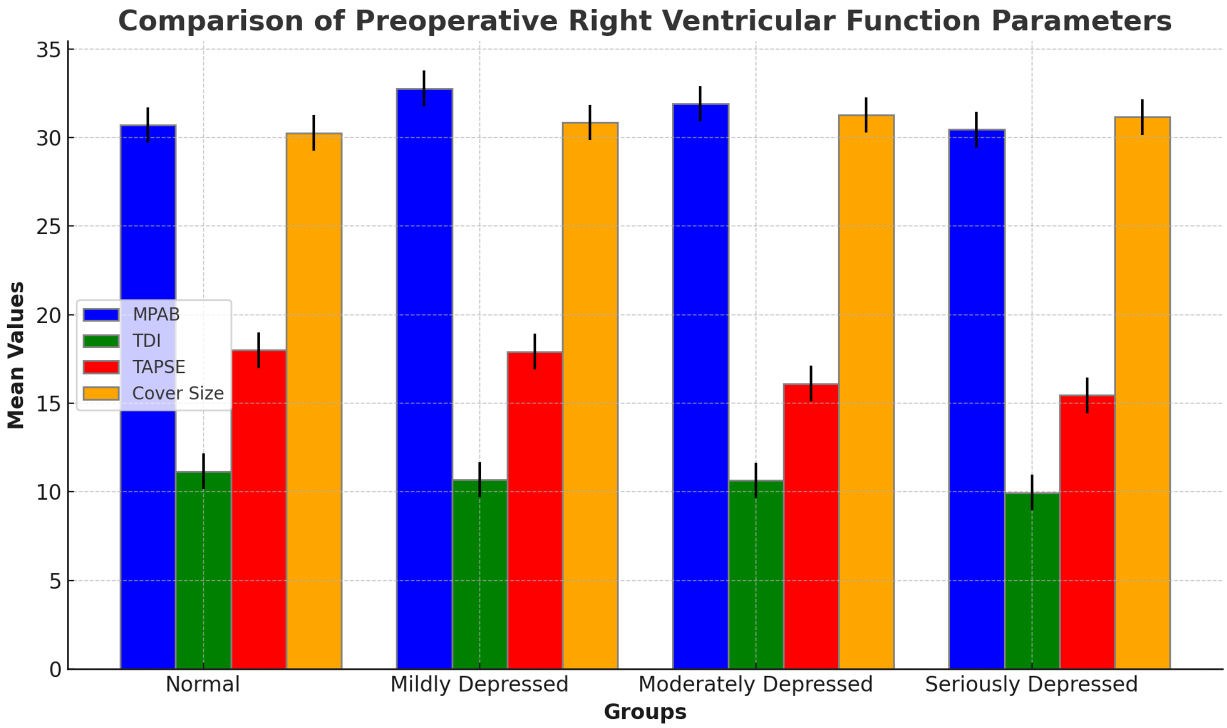
	Normal		Mildly Depressed		Moderately Depressed		Seriously Depressed			
	$\bar{x}$±SD	Median (Lover-Upper)	$\bar{x}$±SD	Median (Lover-Upper)	$\bar{x}$±SD	Median (Lover-Upper)	$\bar{x}$±SD	Median (Lover-Upper)	H	p
Preoperative MPAB	30.79±10.93	30 (14-55)	32.77±10.65	30 (20-55)	31.91±9.32	30 (15-53)	30.45±8.78	29.5 (20-44)	0.526	0.913
Preoperative TDI	11.16±3.10	11 (6-18)	10.68±2.45	11 (7-16)	10.65±2.35	10 (6.5-16)	9.96±2.04	9.65 (7.5-16)	2.496	0.476
Preoperative TAPSE	18.00±4.52	16 (14-29)	17.92±3.52	17 (13-24)	16.11±2.05	16 (13-23)	15.45±3.09	16 (10-25)	6.141	0.105
Cover size	30.26±2.02	31 (27-33)	30.85±2.23	31 (27-33)	31.27±1.51	31 (27-33)	31.15±1.39	31 (29-33)	3.601	0.308

Kruskal-Wallis H Test, p<0,05.,$\bar{x}$=mean, SD=standard deviation., Preoperative mean pulmonary artery pressure (MPAP), Tissue Doppler imaging (TDI), Tricuspid annular plane systolic excursion (TAPSE)

According to Table 3, the Kruskal-Wallis H test was used to evaluate whether there was a statistically significant difference between preoperative mean pulmonary artery pressure (MPAP), tissue Doppler imaging (TDI), tricuspid annular plane systolic excursion (TAPSE), and valve size measurements based on preoperative right ventricular function. The mean preoperative MPAP in patients with normal right ventricular function was 30.79±10.93, in mildly depressed patients it was 32.77±10.65, in moderately depressed patients it was 31.91±9.32, and in severely depressed patients it was 30.45±8.78. No statistically significant differences were observed between right ventricular function and preoperative MPAP values (p>0.05). Similarly, no significant relationships were found between preoperative TDI, TAPSE, valve size, and right ventricular function (p>0.05).

Figure 1.

Comparison of preoperative right ventricular function parameters (MPAB, TDI, TAPSE, and Valve Size) across different levels of ventricular function



The bar chart illustrates the comparison of preoperative right ventricular function parameters across four groups: Normal, Mildly Depressed, Moderately Depressed, and Seriously Depressed. The parameters include Preoperative Mean Pulmonary Artery Pressure (MPAB), Tissue Doppler Imaging (TDI), Tricuspid Annular Plane Systolic Excursion (TAPSE), and Valve Size (Cover Size). Each group is represented by distinct colored bars with error bars indicating standard deviations. The mean values for each parameter are displayed, showing no significant differences between the groups for these preoperative measurements.

The findings of this study highlight the crucial impact of right ventricular dysfunction on postoperative outcomes in patients undergoing tricuspid valve surgery. Prior research has predominantly focused on the role of left ventricular function in cardiovascular surgeries, often underestimating the significance of RV function.[13,16] However, this study confirms that RV dysfunction, particularly in its severe form, is a strong predictor of increased mortality and reoperation rates, emphasizing the need for comprehensive RV evaluation in preoperative assessments.[17,18]

Several studies in the literature support these findings.[19,20] For instance, research by Sanchez et al. demonstrated that RV dysfunction, as measured by parameters like tricuspid annular plane systolic excursion (TAPSE) and right ventricular fractional area change (RVFAC), significantly correlates with poorer postoperative outcomes, including higher mortality rates.[21] These parameters, widely used in clinical practice, are reliable indicators of RV systolic function and were similarly applied in this study to categorize patients based on their level of RV dysfunction. Our results align with this previous research, showing that patients with severely depressed RV function had the worst postoperative outcomes, highlighting the prognostic value of RV assessment.

The pathophysiology of RV dysfunction during cardiovascular surgery, particularly when cardiopulmonary bypass is involved, has been extensively studied.[22] As reported by Mattei et al., the RV is more susceptible to ischemia-reperfusion injury due to its thinner wall and increased dependence on low afterload in the pulmonary circulation.[23] The stress placed on the RV during cardiopulmonary bypass can lead to acute dysfunction, increasing the risk of postoperative complications such as RV failure.[24] In our study, patients with preoperative RV dysfunction were more likely to experience hemodynamic instability, prolonged intensive care unit stays, and a greater need for inotropic support findings consistent with other studies that link RV dysfunction to poor postoperative recovery.[25]

Moreover, the relationship between RV dysfunction and reoperation rates is an important aspect of this study. Studies like those by Merlo et al. have found that patients with impaired RV function are more likely to require reoperation after valve surgery.[26] Our results similarly demonstrated that patients with severe RV dysfunction had significantly higher reoperation rates, indicating that RV impairment complicates the postoperative course and increases the likelihood of subsequent surgical interventions.

In addition to its effects on mortality and reoperation, RV dysfunction also influences long-term outcomes by contributing to prolonged recovery periods and increased hospital resource utilization. As noted by Scudiero et al., RV dysfunction not only affects immediate postoperative stability but can also have long-term repercussions on patient quality of life and survival. This study did not include long-term follow-up, but future research should aim to explore how RV dysfunction impacts patients beyond the initial postoperative period.[27]

This study's use of echocardiographic parameters, including TAPSE and mean pulmonary artery pressure (MPAP), provided an objective and clinically meaningful assessment of RV function. These measures are widely accepted in the literature as key indicators of RV performance, and their application in this study allowed for a clear stratification of patients into functional categories. The consistency of these parameters across studies strengthens their role in preoperative risk assessment, especially in complex cardiovascular surgeries like tricuspid valve replacement or repair.

Limitations

There are several limitations to this study that must be acknowledged. First, the retrospective nature of the study may have introduced selection bias, and the reliance on medical records may have resulted in incomplete data for some patients. Furthermore, while echocardiography is a widely used tool for assessing RV function, the addition of more advanced imaging techniques, such as cardiac MRI or 3D echocardiography, could provide a more comprehensive evaluation of RV mechanics. Finally, the lack of long-term follow-up limits our understanding of how RV dysfunction affects survival and reoperation rates beyond the immediate postoperative period. Future studies should focus on longitudinal outcomes to better understand the extended impact of RV dysfunction on patient prognosis.

4. CONCLUSION

In conclusion, this study highlights the pivotal role of right ventricular function in predicting postoperative outcomes for patients undergoing tricuspid valve surgery. RV dysfunction was found to significantly increase the risk of mortality and reoperation, especially in patients with severely depressed RV function. These findings emphasize the importance of timely surgical intervention before significant RV dysfunction develops, aligning with existing literature that underscores the prognostic value of RV function in cardiovascular surgeries. Careful preoperative evaluation, including the use of echocardiographic parameters such as TAPSE, TDI, and MPAP, is essential for optimizing patient outcomes. As RV dysfunction remains a critical determinant of postoperative success, further research is needed to investigate advanced diagnostic tools and long-term outcomes to enhance patient care and refine surgical strategies.

Declarations

Funding:

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Competing Interests:

The authors declare no competing interests.

Authors Contributions:

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Muhammet Fethi Sağlam, Emrah Uguz, Kemal Eşref Erdoğan, Hüseyin Ünsal Erçelik, Murat Yücel, Mete Hıdıroğlu, and Erol Şener. The first draft of the manuscript was written by Muhammet Fethi Sağlam, Emrah Uguz, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethics Approval:

This study received ethical approval from the 1nd Clinical Research Ethics Committee of Ankara Bilkent City Hospital on 07.06.2023, with decision number TABED-1-24-529. The study, was reviewed and unanimously approved in terms of ethical considerations.

Consent to Participate:

Informed consent was obtained from all individual participants included in the study.

Availability of Data and Materials:

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

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